“No hay reino que no sea newtoniano”: José Celestino Mutis and the appropriation of Newton’s *experimental physics* in New Granada (1762-1804)

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by

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Table of contents

List of Illustrations

Abbreviations

AGNC	*Archivo General de la Nación de Colombia*
RJB	*Archivo del Real Jardín Botánico de Madrid*

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Introduction. Newtonianism as a historiographical category

The label *Newtonianism* is one of the historiographical categories subject to the most revisionism in the so-called *Newton industry*.[1] Used extensively during the first half of the last century for describing, in a general manner, 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*. As the period of institutionalization of Newtonianism in Europe also corresponded to the period of development and consolidation of the physico-mathematical sciences, by studying Newtonianism, several historians of science tried to understand it as the consolidation of the mathematical approach to nature that had been emerging since the sixteenth century. In the light of these considerations, several eighteenth-century authors of different fields – especially mathematics, natural philosophy, physics, medicine, and theology – from the Netherlands, France, Switzerland, Germany, and Italy have been characterized as *Newtonians* or followers of Newton, with little regard for the particular conditions in which they knew and used Newton's methodological and theoretical principles.[2]

Nevertheless, since the 1970s, because more detailed and specific research studies about these "Newtonian" authors have been refined, the classical image of Newtonianism as a single,

[1] The progressive publication since the 1960s of Newton's manuscripts on theology, chronology of ancients, biblical exegesis, and alchemy has influenced in a decisive way the new approaches to Newton's works and the development of Newtonianism in the eighteenth century. A compendium of studies on the transformations of the label *Newtonianism* in historiography is in Force & Hutton (Eds.) (2004); Domski (2012).

[2] *Cf.* Ducheyne & Besouw (2017).

uniform set of methodological and conceptual principles has been modified. As historians like Simon Schaffer, Steffen Ducheyne, and Jip van Besouw have argued, what we understand as *Newtonianism* is a problematic, general historiographical category in the sense that it does not account for the particularities of the appropriation of Newton's methodological and theoretical elements in the different places to which it was attributed during the eighteenth and nineteenth centuries.[3] Thus, by using Newton's tenets and concepts, as well as his methodology for natural philosophy, in such diverse fields as physics, medicine, chemistry, theology, geology, or zoology, they were modified to the point where it was impossible to distinguish the Newtonian features in these disciplines without considering them combined with the different traditions and worldviews of each specific field. Furthermore, Newton's theoretical and methodological principles were combined with local traditions, resulting in the emergence of different *Newtonianisms* in which the 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. Mostly, studies about the appropriation of Newton's tenets and concepts have focused on the reception of Newtonianism in the Netherlands, France, and Germany, and have led to questioning the real value of the general category of *Newtonianism* for the historiography of science.[4] Likewise, recent studies on the reception of Newtonianism in Spain, Portugal, and Greece have given rise to a more detailed panorama of the reception of Newton's theories and methodology in Europe; a panorama which, interestingly, has reconfigured our general conception of science and the role

[3] *Cf.* Schaffer (2009), Ducheyne & Besouw (2017). A good compendium of studies on the historical reception of Newton's physics in different European contexts is in Boran & Feingold (Eds.) (2017).
[4] On the reception of Newton's physics in the Netherlands, Ducheyne & Besouw (2017); in France, Shank (2008). In Germany, Ahnert (2004).

that the appropriation of scientific practices and theories has for modeling a worldview in a specific period of time.[5]

In this revisionist context, efforts have been concentrated on the study of the appropriation of Newton's tenets and concepts in the traditionally-considered centers of production of knowledge in Europe. Indeed, the most well-known attempt to break this tendency was I. Bernard Cohen's *Franklin and Newton, an inquiry into speculative Newtonian experimental science and Franklin's work in electricity as an example thereof* (1957). However, Cohen's work is centered on the description of the appropriation of Newton's experimental philosophy by Franklin, rather than on a description of the context in which such an appropriation took place. As a result, there is a historiographical gap concerning the diffusion and appropriation of Newton's methodology and theories outside Europe in the eighteenth century. A gap which is particularly troublesome, considering that it was in this period that European colonialism in the New World led to the diffusion of modern science there and, with it, to the consolidation of Newtonianism overseas. Therefore, by focusing on José Celestino Mutis' pedagogical enterprises in the Viceroyalty of New Granada, this dissertation attempts to make the first steps to fill this gap, establishing some general considerations about the appropriation of Newton's methodology and theories in the particular region of New Granada and their impact upon its late colonial period.

In this sense, rather than being anchored to a general concept of Newtonianism, I intend to study the specific way in which Mutis appropriated Newtonianism and to analyse his own

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[5] The particular study on the reception of Newton's physics in Spain, Portugal, and Russia – countries that have been not considered traditionally as centers of knowledge production – has configured a completely new field of historiographical studies: studies on reception. They aim to avoid the center-periphery model for reconstructing the appropriation and variations that scientific theories suffer in the process of taking it out of the contexts they were initially ideated. *Cf.* Patiniotis & Gavroglu (2012).

definition of what it is to be a "Newtonian". In his inaugural lectures for the courses of mathematics and physics at the Dominican *Colegio del Rosario* of Santafé de Bogotá, in 1762 and 1764, Mutis declared on multiple occasions to be a "Newtonian" and he defined *la física experimental de Newton* [*Newton's experimental physics*] in the frame of his defence of the enlightened useful sciences and the utility of mathematics for studying nature.[6] Thus, Mutis' appropriation of Newton's experimental philosophy, and his own self-definition as a Newtonian, may constitute a considerably important case study for considering the impact of local contexts on the appropriation of Newtonianism. As it encompassed the discussions about the theoretical and methodological aspects of Newton's theories and the struggles of some individuals to establish them in a highly scholastic academic milieu – such as the one present in Santafé in the 1760s –, Mutis' diffusion of Newtonianism depicts the strategies he adopted for making Newton's experimental physics acceptable and attractive to his audience.

In general, studies about the reception of Newton's tenets and concepts in the Viceroyalty of New Granada have been developed as a part of the historiographical studies on science in Colombia by Colombian scholars who have been interested in highlighting the role of the enlightened ideas in the process of independence of Spain.[7] This tendency has been broken by Colombian historians like Luis Carlos Arboleda and Víctor S. Albis, who, using Mutis' manuscripts in the archives of the *Real Jardín Botánico* of Madrid and the *Archivo Histórico de la Nación de Colombia*, have focused on Mutis' appropriation of Newton's methodology, rather than on its importance for the configuration of a scientific community in the Colombian colonial

[6] *Cf.* Mutis (1982), pp. 43-68.
[7] See, for instance, Wilhite (1976), Wilhite (1980), Martínez Chavanz (1993), Arboleda (1993), Marquínez Argote (1994), Restrepo Forero (1998), Soto (2005b), Díaz Piedrahita (2005).

time.[8] Certainly, the most interesting result of their studies has been the discovery of an unpublished translation of Newton's *Principia* that Mutis made in the 1780s and which is the first Spanish translation ever identified of Newton's *magnum opus*. By studying Mutis' published and unpublished manuscripts, these historians have arrived at the conclusion that he was what Ducheyne has called a "methodological Newtonian".[9] According to them, in discussing Newton's principles in his lectures at the *Colegio del Rosario*, Mutis focused on the characterization of Newton's methodology, thus highlighting the roles that experimenting and mathematizing had for the study of nature. Undoubtedly, Mutis' published works support their conclusions in which it is possible to see that Mutis not only praised and recommended the use of Newton's methodology as it is presented in the *Opticks*, but that he did so in such a way that allowed him to criticize the method proposed in the scholastic cloisters of New Granada's universities.[10] However, as I shall argue in Chapter 4, such a characterization of Mutis' works fails to account with any precision for the entire scope of his lectures in New Granada and it is based upon a lack of awareness of the unpublished manuscript sources in which it emerges clearly that Mutis also dealt with several theoretical aspects of Newton's physics. Conversely, by using the unpublished manuscripts in the *Real Jardín Botánico* of Madrid, I shall demonstrate that Mutis was not only aware of Newton's physics, but that he actively taught it in New Granada during the 1760s and 1770s, and that he was particularly interested in the mathematical explanation of the motion of bodies in conic sections.

Therefore, this dissertation intends to answer some questions concerning the introduction of Newtonianism in the Viceroyalty of New Granada in the eighteenth century, and

[8] *Cf.* Albis & Arboleda (1988). Arboleda has been especially dedicated to study Mutis' interpretation of "Newton's experimental physics" by studying Mutis' translation of Newton's *Principia* – a translation that Arboleda discovered in 1984. I shall study in detail Arboleda's interpretation in Chapter 4.
[9] *Cf.* Ducheyne (2014).
[10] *Cf.* Mutis (1982), pp. 43-68.

namely, how did Mutis introduce what he understood by Newtonianism in New Granada in the eighteenth century? What were his objectives? What were the sources of Mutis' Newtonianism? What were the consequences for him and for the Viceroyalty after the introduction of a worldview that competed with New Granada's intellectual, social, and academic traditions? How was the audiences' reception and understanding of Mutis' lectures? One of the most interesting aspects of Mutis' Newtonianism that emerges in answering these questions is his pronounced eclecticism. Influenced by the French and Dutch experimentalists – and probably because of the lack of the material conditions necessary for performing experiments and observations –, Mutis combined a highly experimental approach to nature with a basic mathematical foundation in which the works of experimentalists like 's Gravesande, Musschenbroek, and Nollet met with the mathematical mechanics of Wolff and Descartes. This occurred precisely during a period in which the theoretical physico-mathematical scientists and the experimentalists were distancing themselves and defining their own subjects and the boundaries of their fields.[11] Such eclecticism, I shall argue, was reflected in the textbooks Mutis used – and translated – for his lectures.

Interestingly, in general, the study of Mutis' conception of Newtonianism and its diffusion in New Granada also helps to understand two other important aspects of the diffusion of science and its social uses in the eighteenth century. On one hand, it sheds light on the problem of the ways in which science is diffused and appropriated in the periphery. By studying the specific context in which Mutis was educated and the strategies he used for making Newton's experimental physics acceptable in New Granada, it is possible to see the importance of both academic and non-academic milieus for the institutionalization of Newtonianism in the eighteenth century. Likewise, as Mutis lectured in the context of emergence of Charles III's

[11] *Cf.* Ducheyne and Besouw (2017).

enlightened reformism, by studying this case study, it is possible to shed light on the role of Newtonianism for consolidating a worldview in non-academic environments; thus supporting different royal policies and leading to the positioning of individuals and beliefs in different political and social contexts – a kind of study which, as regards the *Newton industry*, has been developed mostly for the cases of post-revolutionary England and the rejection of the atheistic consequences of Spinozism in the Netherlands.[12] On the other hand, it also sheds light on the limitations and problems of the so-called center-periphery model for understanding the diffusion of modern science. Developed by George Basalla in 1976, this model assumes that science is a production of centers of knowledge, which is somehow not connected to the local circumstances in which it is created. From these centers, science is uniformly diffused to the peripheries – nations that were only providers of raw-materials for the centers of production of knowledge – where it is used for colonizing and, finally, is made part of the local traditions.[13] Such a model, inspired by the model center-periphery of the political economy of the 1950s, has recently been reevaluated by historians such as Manolis Patiniotis, Kostas Gavroglu, José R. Bertomeu Sánchez, among others.[14] By considering the particular circumstances of Mutis' appropriation of Newtonianism as well as his struggles for introducing it in New Granada, I hope to shed light on the complex process of the diffusion of Newton's natural-philosophical tenets and concepts in the periphery that the Europe-centered historiography of the Newton industry has left aside.

In order to understand the process of introduction of Newtonianism in the Viceroyalty of New Granada I have divided this dissertation into three parts. In the first part – chapters 1 and 2 –, I study the general context in which Mutis' lectures took place and his earliest training

[12] For the development of Newtonianism in England in the post-revolutionary context of the early-eighteenth century, see Shapin (1981), Guerrini (1986), Schaffer (1989), Friesen (2003). For its acceptance in the context of the anti-Spinozism developed in the Netherlands in the early-eighteenth century, see Knoeff (2002).
[13] *Cf.* Basalla (1967).
[14] *Cf.* Bertomeu Sánchez et al. (2006), Patiniotis & Gavroglu (2012).

in Spain. In Chapter 1, specifically, I analyse the historical development of Colombia before independence so as to present some general features of its politics, economy, and cultural environment. In so doing, I intend to characterize the context of Mutis' lectures and his intention of making out a botanical expedition to New Granada. My analysis of Colombia's colonial time is mostly based upon Anthony McFarlane's *Colombia before independence* (1993) and Francisco Eisa-Barroso's *The Spanish Monarchy and the creation of the Viceroyalty of New Granada (1717-1739)* (2016). More specifically, I use their idea that changes occurring in New Granada, leading to the creation of a viceroyalty there and to the process of independence, were the results of the failure of Spanish policies to control the territory rather than the struggle of local movements, which, in any case, were more concerned about their own interests than the consolidation of the local economy or the local traditions. Certainly, such a position is disputable; however, as it deals with the history of colonialism rather than the history of science, I shall not discuss it in this dissertation. Here, it is also important to point out that, like McFarlane, when I mention the territory of New Granada in this dissertation – irrespective of whether *Audiencia* of New Granada or the Viceroyalty of New Granada – I am concerned with the modern-day territory of Colombia exclusively.[15] I understand that the *Audiencia* and, moreover, the Viceroyalty, encompassed the modern-day territories of Ecuador, Venezuela, Brazil, Peru, and Panama as well. However, in focusing on the figure of Mutis I shall only deal with the reception of Newtonianism in present-day Colombia.

Chapter 2, on the other hand, deals with the education of Mutis in Cadiz during the 1950s. In this chapter I study the reception of Newtonianism in Spain during the mid-eighteenth century, arguing that it was the result of the struggles of some individuals whose training, outside

[15] *Cf.* McFarlane (1993), p. 6.

the scholastic Spanish universities, was centered on the appraisement of modern science and, especially, of its experimentalism and its tendency to mathematize nature. In this sense, I focus on Pere Virgili and Jorge Juan as the two most important influences for the training of Mutis during the period of 1749-1755. By studying them, I argue that the reception of Newtonianism in Spain was connected to its multiple applications for navigation, the study of fluid mechanics, and physiology. Consequently, I conclude that Mutis' interests in introducing and defending the useful enlightened sciences, as he presented them in his lectures, was the result of his education in Cadiz rather than the effect of the Bourbon modernizing policies of Charles III – as has been explained traditionally.

The core of the dissertation is in part two – chapters 3, 4, and 5. Thanks to a study of Mutis' published and unpublished works, in this part, I analyse in detail his characterization of Newton's experimental physics, his interpretation of Newton's methodology as it is discussed in the *Opticks* and the *rules* of the *Principia*, as well as the presentation of the mathematical analysis of the motion of bodies moving in conic sections attracted by a centripetal force. In Chapter 3, I study Mutis' lectures on mathematics and present the manuscripts containing Mutis' lectures on mathematics at the *Colegio del Rosario*, arguing that they are translations of Wolff's *Elementa matheseos universae* (1710) and Descartes' *Géométrie* (1637). The discovery of these translations constitutes one of the novelties discovered from the research for this dissertation and it reveals the importance that translating had in Mutis' pedagogical enterprises. Because of the lack of books for his teachings, he was forced to make translations of these works and use them for his *dictados* – a practice for which he had no particular appreciation, consisting of a dictation of the books that should be memorized by students.[16] More importantly, by studying his manuscripts

[16] *Cf.* Rivas Sacconi (1993), pp. 64-65.

on mathematics, I argue that Mutis taught calculus of fluxions in New Granada, thus presenting some elements of Newton's mathematics which could lead him to teach the basic principles of Newton's physics to his students.

More specifically, in Chapter 4, I study Mutis' manuscripts dealing with Newton's physics, analysing Mutis' pronouncements about Newton's methodology such as it is presented in the *Opticks* and the *rules* of the *Principia*. In studying such pronouncements, I explain that they are based upon the interpretation of 's Gravesande's *Physices elementa mathematica, experimentis confirmata* (1742); a work of which Mutis translated the first chapters for his lectures. As in the case of his translations of Wolff's and Descartes' works, this translation of 's Gravesande's textbook is an original discovery of this research. Interestingly, in commenting 's Gravesande's interpretation of Newton's rules, Mutis deployed an anti-Cartesian approach to them that I study in detail. Despite the importance of these findings, the central part of this Chapter is the analysis of Mutis' study of the motion of bodies in conic sections that are accelerated by a centripetal force. By his application to these problems, it is possible to conclude that, unlike what was believed by historians of science in Colombia concerning Mutis' lectures, he not only taught Newton's methodology but also some theoretical aspects of Newton's physics. Furthermore, as I shall argue, he did so in such a way that it reflects his conviction of the power of mathematizing nature for accounting natural phenomena.

Finally, Chapter 5 deals with the last pedagogical enterprise to which Mutis was committed to during his life. The construction of a study plan for the course of Medicine at the *Colegio del Rosario*. This plan, which Mutis created between 1799 and 1804 – and that was used after his death for guiding the teaching of medicine in the first universities of Colombia after its independence –, was based upon the conviction of the importance of mechanics and mathematics in the physiological study of the functions of the body. An idea that Mutis adopted from Herman Boerhaave, revealed in the fact that he recommended his works as textbooks for the course of Medicine. By adopting Boerhaave's works as a reference, and its pretension of studying physiological functions from a mechanical point of view, I shall argue that Mutis also embraced some ideas of the so-called Newtonian medicine. I conclude by explaining that the introduction of Newtonianism in New Granada was not confined to Mutis' lectures on physics and mathematics, but that its scope was larger than it had previously been considered, also encompassing the theoretical training of students in the course of Medicine at the *Colegio del Rosario*.

In the last part – Chapter 6 –, I study the aftermath of Mutis' introduction of Newtonianism in New Granada and focus on one of the most interesting episodes of Mutis' life: his debate with the Dominicans on the Copernican system. Due to several statements in the invitation sent to Mutis for an academic event in which the Copernican system would be under criticism by some Dominican friars, the protagonists of the debate extended it to encompass a wider discussion about the control of the monopoly of education in New Granada after the expulsion of the Jesuits in 1767. In this chapter, I evaluate Mutis' arguments in favor of the Copernican system, explaining that he used well-known argumentative strategies common to the seventeenth and eighteenth centuries for defending the teaching of the Copernican system. More importantly, I argue that, in defending the Copernican system, Mutis used an argumentation that recalls Galileo's physical arguments in *Dialogo sopra i due massimi sistemi del mondo* (1632). This depicts Mutis' intellectual background which is valuable for understanding his appropriation of Newton's experimental physics. In general, in this Chapter I argue that Mutis' debates with the Dominicans were used as a strategy for consolidating his own position in the reforming environment that the reign of Charles III promoted as well as the definitive construction of his image as the *oracle of the kingdom*.

Chapter 1. A historical context for the introduction of "Newton's experimental physics" in New Granada

Foundation and historical development of New Granada

According to historians like Anthony McFarlane, Carl Ortwin Sauer, and Francisco A. Eisa-Barroso, the process of conquest and colonization of America by the Spanish Crown exhibits some patterns that depict the Spanish monarchical traditions and the intricacies of the relationship between Church and State in Spain between the sixteenth and eighteenth centuries.[17] Focused on the exploitation of America's natural resources – and its natives –, the Spaniards arrived in *Tierra Firme* at the beginning of the sixteenth century. They usually departed from Spain on private adventures sponsored by bankers and merchants in Seville and received the royal authorization to go to the Indies with the responsibility of creating multiple Spanish settlements in the territories they visited.[18] In so doing, the Spanish Crown tried to assure the existence of the material conditions for carrying out the second stage of the colonization process: establishing its own institutions to rule and control the territory and more importantly, to rule over its new subjects, the Indians.[19]

[17] *Cf.* Sauer (1966), pp. 147-177; McFarlane (1993), pp. 7-28; Eisa-Barroso (2016), pp.

[18] In his survey concerning the new exploration of *Tierra Firme*, Sauer studies the royal *cédulas* in which the creation of settlements in the territories to be discover were authorized. Interestingly, as Sauer points out, the conquerors were also considered as *gobernadores* of the settlements they established, which gave rise to multiple debates concerning the authority of Columbus as viceroy of the Indies in the early sixteenth century. *Cf.* Sauer (1966), pp. 104-119.

[19] The importance of the administration of justice with the Indians as a function of the Spanish Crown has been studied in detail in Bosch García (1990); Bushnell (1993), pp. 1-24; Eisa-Barroso (2016), pp. 28-31.

In establishing its own governmental institutions in America, the Spanish Crown had three purposes in mind. Firstly, that of satisfying the compulsory presence of the king in the territory he ruled through a representative figure, who would do everything as the king would do if he were there. Such a requirement was part of the traditions of the Crown of Aragon which explains, for instance, the use of the figure of the viceroy for ruling the newly discovered Indies.[20] Secondly, the presence of a king-like authority made it possible to have more control over the territory and its inhabitants of which it was assumed the appointed ruler had first-hand knowledge. Lastly, by assuring the presence of a representative of the king who had comparable authority to his own and who physically represented him, the Spanish Crown ensured the administration of justice which was, in essence, the ultimate purpose of the king as a representative figure of the divine authority on Earth.[21] Such an administration of justice was twofold. On one hand, it consisted of acting as a judge in the issues between conquerors – which were highly frequent, mostly, in the first half of the sixteenth century –, whilst on the other, it was also focused on the protection of the new subjects of the king, the Indians.

In this context, in order to ensure protection of the Indians and the "good government" of the Spanish overseas territories, during third stage of the colonization process, the Spanish Crown authorized the arrival of some religious orders to the New World. It must be borne that as regards the discovery of America, through the Alexandrine Bulls of 1493, the Spanish King was appointed as the vicar of the Pope in the Indies, which turned him into a ruler of both

[20] As Eisa-Barroso explains, since the constitution of the Crown of Aragon, the continual presence of the king in the territory was a compulsory requirement. Thus, on various occasions on which this was not possible, the king appointed lieutenants who acted as their physical representatives. A good example of this is in Lalinde Abadía (1960).

[21] For the idea of the essential functions of the king and the Spanish image of the king as an administrator of justice, see MacLachlan (1991); Cañeque (2004), pp. 1-50.

temporal and spiritual issues.[22] In this sense, with their emphasis on education, the religious orders – especially the Dominicans and Jesuits – were able to guarantee not only correct government of souls but, more importantly, the creation of a ruling class, educated according to the traditions of Spanish scholasticism. Therefore, along with the creation of archbishoprics, bishoprics, and the education of the local Spanish, Creole, and Indiand communities, the Church was connected directly with the government of the Indies since the ruling class of the generation following the conquerors was educated by the religious orders which, in the second half of the sixteenth century, had already created the first colleges and universities of America.[23]

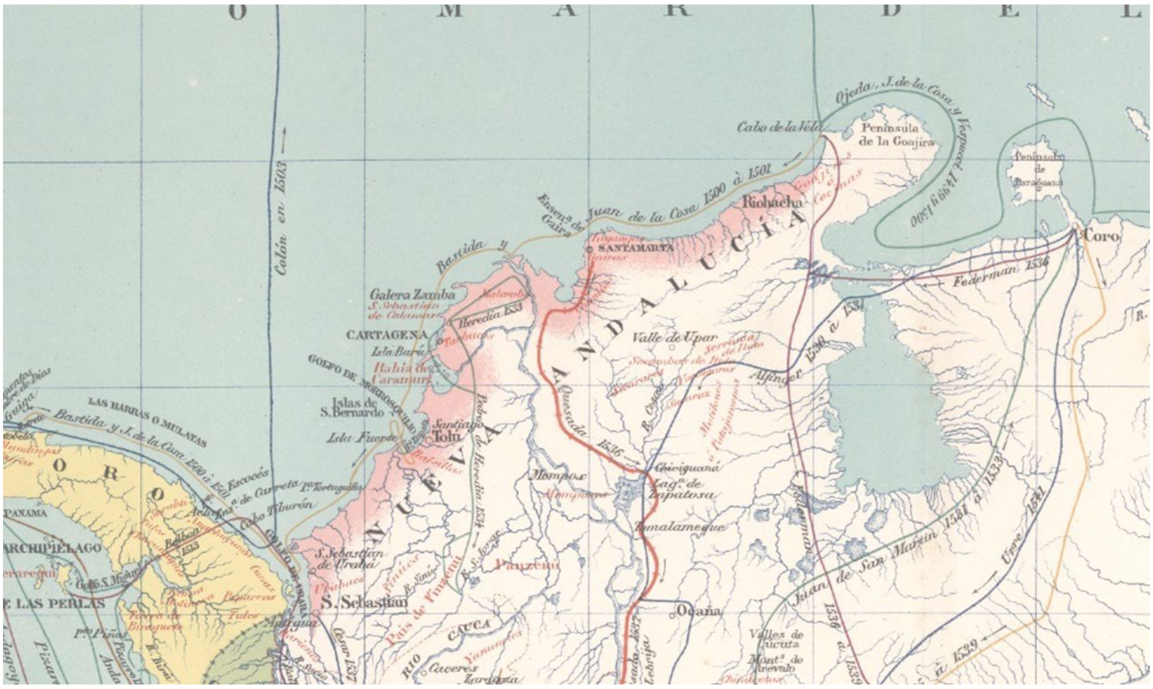

Figure 1. Routes of the Spanish conquerors and explorers of Colombia (Codazzi et al., 1890).

22 The role of the relationship between Church and State in the Spanish colonization of America has been one of the most widely studied issues in the historiography about colonialism. Several interesting studies on the specific importance of the Alexandrine Bulls and the role of the King's power over spiritual issues in America can be found in Weckman (1949); Shiels (2011); López Guédez (1971); Rivera (1992), 23-41.

23 Probably one of the most complete works concerning the history of Latin American universities is Rodríguez Cruz (1973).

The colonization of the modern-day territory of Colombia was not alien to these patterns. Visited by Alonso de Ojeda, Juan de la Cosa, and Amerigo Vespucci for the first time around 1499-1500 – just before they became aware of the fact that it was indeed a new continent – the first Spanish colonial settlements in Colombia's territory (and in *Tierra Firme*) begun in 1502 along the northern shores of the Colombian Caribbean coast (Fig. 1). However, they were just small, temporary constructions that served the Spaniards well as centers from which it was possible to trade with the gold and pearls of the local tribes, rather than definitive settlements from which they could begin the colonization of the inlands. The belligerent character of the natives of the *Guajira* territory as well as their poisoned darts and arrows, forced the Spaniards to move westward, where they founded the first well-established Spanish stronghold in *Tierra Firme*, Santa María del Darién. This stronghold had an extremely important impact on the Spanish colonization and ruling of the new continent.[24] Situated in the Isthmus of Panama, it was the first settlement from which it was possible to deploy the colonization of *Tierra Firme*, as was revealed when Francisco Pizarro departed from there and colonized the Inca's territory. Likewise, the territories under the jurisdiction of Santa María del Darién – the Gulf of Urabá – became the boundary for the creation of the first Spanish *gobernaciones* in *Tierra Firme.* Alonso de Ojeda was appointed *gobernador* of *Nueva Andalucía*, the name given to the territory from the Gulf of Urabá as far as the Cabo de la Vela.[25] Along the coast, the Spaniards founded multiple settlements and *gobernaciones*, including Cartagena de Indias (founded in 1533) and Santa Marta

[24] Details concerning the process of conquest and colonization of the modern-day territory of Colombia are in Sauer (1966), pp. 104-119, 161-177; Góngora (1962), pp. 14-38; McFarlane (1993), pp. 7-16; Bushnell (1993), pp. 7-24.

[25] *Tierra Firme* or *Castilla del Oro*, as it was called by the Spaniards who visited it for the first time in 1499, was a large region on the Caribbean coast, reaching from Cabo Gracias a Dios, in modern-day Honduras, as far as the frontier with Potugal's territories in America. In 1508, it was divided in two, using the Gulf of Urabá as the frontier, thus forming the *Gobernación* of Veragua to the west, and the *Gobernación* of Nueva Andalucia, on the modern-day Caribbean coast of Colombia. A detailed description of the political division of this region and the constitution of the first *gobernaciones* in *Tierra Firme* can be found in Sauer (1966), pp. 161-177.

(founded in 1525). In fact, together with Portobelo, the former was to turn into the most important Spanish port on the Caribbean coast for both commercial and military purposes.[26]

Figure 2. First colonial divisions of Colombia, Ecuador and Venezuela, 1538 (Codazzi et al., 1890)

In conquering the Caribbean coast of modern-day Colombia, the Spaniards were conviced that *Tierra Firme* was a territory rich in mineralogical resources, especially gold. Such a conviction was generated by the looting of gold of the natives and their tombs, thus leading to the first expeditions to the inlands.[27] Consequently, moved by the possibility of looting more gold and

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[26] On the importance of Cartagena for the commerce between Spain and the New World, see McFarlane (1993), pp. 40-48.

[27] It is a well-known fact that the colonization of the inlands of modern-day Colombia, which led to the discovery of the lands of the *Chibchas* and the foundation of Santafé de Bogotá, occurred through three different routes with a common interest in the gold of the Indians, guided by local natives who spread the legend of *El Dorado* among the Spaniards. On the importance of the looting of gold and the legend of *El Dorado* in the colonization of Colombia, see Silverberg (1967).

reaching the territories that Pizarro had conquest in Peru, Gonzalo Jiménez de Quesada departed from Santa Marta on a route that led him to the discovery of the lands of the *Chibchas*, in the highlands of the Colombian Andes. After conquering the territories of the *Chibchas*, Jiménez de Quesada founded the city of Santafé de Bogotá in 1539 (Fig. 2). It is interesting to note that just after the arrival of Jiménez de Quesada in Santafé, he met up with the expeditions led by Sebastián de Belalcazar – who had helped Pizarro in the conquest of the Inca's territory in 1532 – and Nikolaus Federmann – who worked for the Welser, a German family of bankers to whom the Spanish Crown had granted the administration of the Province of Venezuela.[28] As these latter expeditions were also motivated by the interest in gold, it reveals how thet Spaniards had arrived in the highlands of the modern-day territory of Colombia because of their mineralogical resources. It is not surprising that the legend of *El Dorado* emerged precisely in relation to the conquest of this region. Once the early settlements had been built, the Spaniards set up the first political institutions to allow them to control the region as well as establishing the presence of the king through a representive. I will now describe the process of institutionalization of the Spanish monarchical tradition in New Granada in order to understand how it turned into an important Spanish center in the Indies.

The creation of the *Audiencia del Nuevo Reino de Granada* and its religious educative system

As the highlands of Santafé and its neighboring villages had a considerably larger population than the dispersed cities along the Caribbean coast and a more benevolent climate, the Spaniards soon turned it into the most important center for commercializing gold and the agricultural

[28] Studies on Belalcazar can be found in Ramos Gómez (1988), Avellaneda Navas (1992). Details about Federman's actions in New Granada are in Avellaneda Navas (1995).

products of the inlands.[29] Consequently, in 1550, Santafé was designated capital of the newly created *Audiencia del Nuevo Reino de Granada*, which encompassed the *gobernaciones* of Popayán, Santafé, Cartagena, and Santa Marta and was subordinated to the Viceroyalty of Peru. As McFarlane and Eisa-Barroso argued, rather than being created because of the economical benefits for the Spanish Crown reported by the *gobernaciones* it encompassed, the *Audiencia del Nuevo Reino de Granada* was created because of the Spanish necessity to control the problems of the region which gave rise to the segregation of the *gobernaciones* and the lack of royal authority over them.[30] Likewise, the creation of the *Audiencia* coincided with the modification of the methods for exploiting gold by the Spaniards in New Granada. Rather than the looting of gold that had characterized the first half of the sixteenth century, during the second half there was a consolidation of mining through the creation of mining districts, especially in the regions of Chocó and Antioquia, belonging to the *Gobernación de Popayán*.[31]

In this sense, as the *Audiencia* became economically independent from the Viceroyalty of Peru during the second half of the sixteenth century, Santafé was consolidated as an important center of power for Spanish America. As a result, in 1580, through the Bull *Romanus Pontifex*, Pope Gregory XIII authorized the creation of a university in the convent of *El Rosario* directed by the Dominicans. As Diana Soto and José Manuel Rivas Sacconi commented, the Dominicans in Santafé had adopted the idea of creating a college or university since their arrival there in the 1540s, but only in 1571 were Arts and Theology studies established in the convent of *El Rosario*, designed for the training of clergymen in New Granada. Soto also points out that the training was based on the teaching of Aristotle's works as commented by Thomas Aquinas and using

[29] *Cf.* McFarlane (1993), pp. 48-60.
[30] *Cf.* Eisa-Barroso (2016), pp. 1-22.
[31] See, McFarlane (1993), pp. 10-23. A detailed survey concerning the role of mining in the colonization of America is in Tandeter et al. (2008). On the role of mining in Colombia during the colony, see Colmenares (1978), pp. 246-356; West (1987)

Goudin's works as textbooks.[32] The model of teaching that the Dominicans adopted for their academy in Santafé was the one implemented in the University of Salamanca, strongly rooted in the Spanish scholastic traditions. A feature that, as we shall see in Chapter 6, constituted one of the most important subjects of discord between Mutis and the New Granada's university milieu that the Dominicans represented. It is also noteworthy that despite the papal authorization to create a university, the Dominicans only received the royal approval in 1630. Rivas Sacconi describes the details of the delay in creating the university: after overcoming several economical issues related to the foundation of the university, it was decided that the university would not be founded in the cloister of *El Rosario* but instead at the Dominican *Colegio de Santo Tomás* – a transfer of university privileges that was approved by Pope Paul V's Bull *Cathedram militantis* in 1612:

> Pero el propósito dominicano no pudo llevarse a la práctica, por mandato real, que ordenó la erección del colegio sin que se hiciera universidad, y por el pleito surgido posteriormente con la Compañía de Jesús sobre la fundación de Núñez.[33] Terminado el litigio (1630) y cumplidas las formalidades de reconocimiento de la bula de Paulo V, se hizo en la capital del Nuevo Reino solemne publicación de ella (1639) y quedó inaugurada la Real Pontificia Universidad de Santo Tomás de Santa Fe, llamada comúnmente Tomista o Tomística (Rivas Sacconi, 1993: 46-47).

Indeed, as Rivas Sacconi comments, the official creation of the *Universidad de Santo Tomás* occurred after the Jesuits had been authorized to establish their own college and university, the

[32] *Cf.* Rivas Sacconi (1993), pp. 41-65; Soto (2005b).
[33] Rivas Sacconi refers here to Don Gaspar Nuñez, a wealthy Spanish settler, who in 1608, left his properties to the Dominicans to found their university. *Cf.* Rivas Sacconi (1993), pp. 46-47.

Universidad de San Francisco Javier, also known as *Universidad Javeriana*. The second university created in Santafé was the result of the works of Archbishop Bartolomé Lobo Guerrero, who set the foundations for the arrival in Santafé of the Jesuits. Having arrived in Santafé in 1599 as its new Archbishop (the Archbishopric of Santafé was created in 1562), Lobo Guerrero planned the reconstruction of the *Seminario de San Luis*, which belonged to the Archbishopric, for the purpose of turning it into a educational center of both clergy and laymen. To this end, Lobo Guerrero suggested taking the Jesuits to Santafé and appointing them to direct the intended college. They arrived in 1604 and in 1605 the *Colegio de San Bartolomé* was established which began to work as *Colegio Máximo* in 1608.[34] In 1621, through Gregory XV's Brief *In Supereminenti*, the Jesuits received the papal authorization to create a university for graduate students in Santafé; an authorization that was ratified in 1622 by the Spanish Crown. As the Dominicans had asked for permission to create the university way back in 1580, which they received from the Pope, though with several problems in respect of the royal authorization, the authorization for the Jesuits to graduate students and create a university gave rise to disputes between these religious orders concerning the control of New Granada's educational system.[35] Arguably, these disputes in the seventeenth century should be considered an antecedent to the debates between the Dominicans and the supporters of the modernization of New Granada's education, generated by the reforms promoted by Moreno Escandón, Mutis, and Caballero y Góngora during the 1770s and 1780s. In both cases, as we shall see in Chapter 6, the core of the discussion was the control of the monopoly of the education in New Granada. An objective which in the end was to entail the control of the members of the vice regal court.

[34] Soto has explained the differences between the *Colegio de San Bartolomé* and the *Colegio Máximo* as well as their scopes and privileges. *Cf.* Soto (2005b).

[35] *Cf.* Rivas Sacconi (1993), pp. 41-65; Soto (2005b).

Unlike, the *Salmantinas* sources of the *Universidad de Santo Tomás*, education at the Jesuit *Colegio de San Bartolomé* was founded upon the principles established in the 1599 version of the *Ratio Studiorum* of the Jesuits.[36] This difference led to the implementation of different sources for teaching in the Jesuits colleges and universities. In this sense, it is possible to understand the reasons why, in 1755, it was at the Jesuit *Colegio de San Bartolomé* that the Copernican system was presented in a positive way for the first time in New Granada.[37] Other religious orders, such as the Discalced Augustinians and Franciscans, created different colleges in Santafé as well,[38] but their influence in New Granada's society was never as high as that of the Dominicans and Jesuits because the administrative elite of New Granada was formed precisely in the cloisters of these religious orders.

In general, the *Audiencia de Nueva Granada* of the seventeenth century witnessed the consolidation of the Spanish institutions installed there for controlling and ruling its territory. Along with the creation of colleges and universities, during the seventeenth century, the *audiencia* gained political, economical, and religious independence from the Viceroyalty of Peru. Nonetheless, despite the efforts of the Spanish Crown, the establishment of the Spanish institutions for controlling New Granada's colonial society did not translate into a more effective royal ruling over the territory. Instead, the difficulties for creating effective communication between Santafé and the other *gobernaciones* of the *Audiencia* caused by the geographical conditions of its territory and the different origins in their foundations, the creation of local elites especially in Popayán, Santafé, and Cartagena, and the development of a Transtlantic network of

[36] On the implementation of the Jesuit's *Ratio Studiorum* in New Granada, see Fajardo (1999).
[37] The first extended discussion on the Copernican system was presented in 1755, in the work *Physica specialis et curiosa* by Professor of Philosophy of the *Colegio de San Bartolomé*, Francisco Javier Trías. Analysis of the content of this work, as well as its discussion on the Copernican system, can be found in Martínez Chavanz (1993), pp. 60-72; Marquínez Argote (2005).
[38] The history of these other institutions has been presented in Rivas Sacconi (1993).

contraband in Cartagena, depicted a panorama of a fragmented *Audiencia*, in which local interests were more powerful than the royal authority.[39] In this context, and as part of the reforms enforced by the Bourbon House on ascending to the Spanish Throne in the eighteenth century, it was decided to create a viceroyalty in the jurisdiction of the *Audiencia*, the first viceroyalty to be created since the installment of the viceroyalties of Peru and New Spain in the sixteenth century. In the next section, I shall describe the historical circumstances concerning the creation of the Viceroyalty of New Granada in 1719, its abolishment in 1723, and its restoration in 1739. In so doing, I intend to outline the conditions for understanding the particular context surrounding the arrival of Mutis in New Granada in 1761 and the development of the different enterprises he was committed to until his death in 1808.

Creation and development of the Viceroyalty of New Granada

As Eisa-Barroso has commented, due to the idea that the "king had to be seen as a temporary manifestation of a divine and compassionate ruler located at the apex of a social hierarchy that replicated God's celestial court" (2017: 28-29), in the sixteenth century Spain it was considered that the essential function of the king was the administration of justice. In this sense, the main reasons for creating the *Audiencia de Nueva Granada* were that of providing settlers with access to justice as well as protecting the Indians. To this end, the Council of Indies considered it necessary to centralize the power in the capital, Santafé, in the figure of a president of the *audiencia* and his *oidores*; a figure that was a direct representative of the king in the territories under its jurisdiction.[40] Nevertheless, as I have described above, the authority of the president, and by extension, that

[39] *Cf.* Eisa-Barroso (2016), pp. 76-77.
[40] Until now, the most specialized study of the *Audiencia* of New Granada, focused on its government and the underlying Spanish politics is Ones (2000). For the government of New Granada and its administrative structure, see, specifically, pp. 18-38.

of the king, was under great discussion in New Granada, especially in the early-eighteenth century. The constitution of local elites accentuated the fragmentation of the *audiencia* – initially caused by the difficulties imposed by the geographical conditions of the territory – and each of its *gobernaciones* had good reasons to defend their own position. Santafé, which had been declared the capital of the *audiencia*, since its foundation, was not only the residence of the president of the *audiencia* and the *oidores*, but it also had the largest population in the viceroyalty, the Archbishopric, the Mint – which had been established in 1621 –,[41] and the universities and colleges where the administrative elite of the *audiencia* was educated. On the other hand, the City of Cartagena de Indias was the most important port of the *audiencia* – and one of the most important Spanish ports of the Caribbean coast –, in addition to which was the stronghold for the defence against the attacks from the other European Transatlantic empires, like the French and the British.[42] As a port city, Cartagena was the connection with the European market and consequently it was also the place where smuggling took place. In fact, as McFarlane has pointed out, contraband in Cartagena was the main and most profitable commercial activity of the port and of the *audiencia* itself.[43] Finally, the case of the *Gobernación* of Popayán is very unusual. Founded in 1537 by Sebastián de Belalcazar, who came from the land of the Incas in the south, Popayán's political, ecclesiastical, and economical development was rarely connected to Santafé and it frequently worked as an almost independent province, more connected culturally, politically, and economically to Quito than to the capital of the *Audiencia de Nueva Granada* – in fact, only in 1564 it was definitely established as a *gobernación* of the *Audiencia de Nueva Granada*.

[41] On the foundation of the Mint and silver coinage in Santafé, see Friede (1963), Barriga Villalba (1969).
[42] An interesting study on the earlier years of Cartagena de Indias as well as its military strategic functions is in Gómez Pérez (1984).
[43] In his study about the economy in New Granada McFarlane constantly makes reference to the role of contraband in the different stages of the historical development of the *audiencia* and the viceroyalty. *Cf.* McFarlane (1993), pp. 99-185. A specific study concerning the creation of a commercial elite because of contraband commerce can be found in McFarlane (1993), pp. 164-185.

Likewise, it had the most important gold-mining districts in New Granada – Antioquia and Chocó – and as a result, Popayán developed a wealthy local elite that created direct routes of commerce with Cartagena and Quito. In Cartagena, Popayán's elites purchased goods coming from Europe; whilst in Quito they bought clothes produced in Peru and Ecuador. Thus, they enjoyed a certain independence from the administrative decisions made in Santafé. Indeed, as McFarlane points out, it seems that during the seventeenth century there were some attempts to make of Popayán an independent *audiencia*.[44]

For the smuggling in New Granada, it was essential for the gold dust to pass directly from the mining districts of Popayán to the port of Cartagena, thereby avoiding the payment of the *quinto* and the various taxes for coining gold in Santafé's mint.[45] For this reason, during the seventeenth century, a strong contraband economy was created in New Granada which frequently involved the participation of official authorities of both Popayán and Cartagena. Undoubtedly, it led to a weakening of the authority of the president of the *audiencia*, his *oidores*, and the royal authority they represented – not to mention the economical problems that it generated. As McFarlane comments,

> An idea of the scale of foreign contraband was given by a Spanish resident of Cartagena in 1712; he estimated that illicit trade was probably worth about 2 million pesos a year, paid for in New Granadan gold[46] (…) In economic terms,

[44] My analysis of the situation of the *Gobernación* of Popayán is founded on McFarlane's study in McFarlane (1993), pp. 61-70. However, the most extensive and general studies about the *Gobernación* of Popayán are Colmenares (1975) and Colmenares (1997).
[45] As Barriga Villalba explained in detail, the artisanal gold-mining in New Granada was an arduous labor which implied the work of numerous men in the mines and the use of primitive technology. Thus, by avoiding melting the gold dust to make ingots in the mint, the miners not only avoided taxes but also payment of more workers and the acquisition of new technical instruments. A description of the machinery and techniques for melting gold in Santafé's Mint can be found in Barriga Villalba (1969), Vol. 2, pp. 65-67.
[46] A scandalous quantity, considering that between 1703 and 1706, that is, during the first years of the War of the Spanish Succession, the total amount of gold reaching Spain from Cartagena was 4 million pesos. *Cf.* McFarlane (1993), p. 104.

> the colony had become almost completely detached from Spain, neither relying on the metropolis for the greater part of its imports, nor returning more than a relatively small proportion of its gold production (1993: 104).

Consequently, during the seventeenth century and the first decade of the eighteenth century, different *visitadores* to the *audiencia* as well as some of its presidents, asked the king to turn the *audiencia* into a viceroyalty. They argued that by appointing a viceroy in the territory who was a physical representation of the king – with more decision power –, it would be possible for him to overcome the lack of royal authority, thus reinforcing the economic dependence on legal commerce with Spain. Such a measure would have solved the problems deriving from the lack of power of the president of the *audiencia* over the different *gobernadores* – especially that of Cartagena. Nonetheless, the recommendations of *visitadores* fell on deaf ears in Madrid.[47]

As Eisa-Barroso has argued, in order to create the Viceroyalty of New Granada a combination of various factors involving different circumstances was necessary on both sides of the Atlantic. According to him, the change of dynasty in the Spanish throne led to a modification in Spain of the ideas concerning the role of the king as well as to a reconfiguration of the distribution of power in the Spanish institutions. In Eisa-Barroso's words,

> As the king stated in 1714, his reforms aimed at improving and expediting the processes through which the monarchy was governed. To this end, he intended to be informed, in person, of the most important matters in government and to 'take himself the determinations on everything, deserving the greatest accuracy for the greatest benefit of his subjects' (2016: 94).

[47] Particularly important were the recommendations of *Visitador General* Carlos Alcedo y Sotomayor, who was in New Granada between 1712 and 1718. Details about Alcedo y Sotomayor *visita* are in Garrido Conde (1965), pp. 1-19.

In general, after the accession of the Bourbon House to the Spanish throne, a set of transformations was established in Spain founded upon a different conception of the monarchical authority. As Eisa-Barroso and Pablo Fernández Albaladejo have argued, the idea of the king as an administrator of justice, whose source of authority had divine origins, was extended to include the administration of the well-being of his subjects. In this sense, for the Bourbon House, the origin of the power of the king and his functions was more material than divine, giving rise to a progressive reconsideration of relations between Church and State.[48] In the center of these transformations there was the idea promoted by Philip V, probably following the recommendations of his grandfather Louis XIV, of creating a cabinet of ministers, who acted as his counselors, thus allowing him to rule without the inherent problems of relying on the various institutions that the Hapsburg House had created. Amongst these ministers, Abbot Giulio Alberoni, the confessor of the king and *de facto* prime minister, was the most influential in the King's decision-making process and he played a fundamental role in the creation of the Viceroyalty of New Granada.[49]

Nevertheless, while circumstances in Madrid's court were changing in the early-eighteenth century, on the other side of the Atlantic, the situation was not particularly easy. Since 1697 there had been a series of events leading to the convulsions that ended in the establishment of the viceroyalty. In 1697, the French admiral and privateer, Bernard Desjeans, Baron de Pointis, led the Raid of Cartagena with a sound victory. On May 6th, after only twenty days of siege, Pointis and his men entered the city of Cartagena, raiding it for almost twenty days and looting between ten and twenty million pesos. They abandoned it on May 24th, when Pointis left

[48] *Cf.* Albaladejo (1994), pp. 375-409; Eisa-Barroso (2016), pp. 94-111.
[49] I shall deal with several issues of the transformations developed by the Bourbon House in the Spanish society during the eighteenth century in the chapter on Mutis' education. My analysis is based on Sánchez Blanco (1999), Pérez Estevez (2002), Domínguez (2005), Sanchis (2014), and describes the general reconstructions of the transformations after the enthronization of the Bourbon House in Spain in 1700.

behind the filibusters he hired for the enterprise.[50] News on the humiliating defeat in Cartagena soon arrived at the Court of Madrid which opened an investigation on the performance of the civil authorities of Cartagena in the defence of the port. The shock in Madrid over the defeat was caused by two reasons: first, the Council of Indies found out about the plans of the French Navy and suggested that the *gobernador* of Cartagena, Diego de los Ríos, took measures to ward off the attack. Secondly, for this reason the *audiencia* had authorized resources for reinforcing the defensive infrastructure of the port and purchasing new armaments. Likewise, once the news about the attack arrived in Santafé, a reinforcement of men was sent to defend the city, but they arrived when it had already been besieged by Pointis. As it was known that the city had provisions for resisting at least two months of siege, doubts about De los Ríos' actions emerged, and in the end it was demonstrated that the Gobernor had received around two million pesos from the French for the capitulation.[51]

For the investigation, the *Council of Indies* sent as *Visitador General*, Carlos Alcedo y Sotomayor, who had been in Santafé since 1695 investigating the "reports of 'the disorder which exists in that Kingdom in the treatment of the Indians and the collection of tributes', of the virtual enslavement of the Indians by encomenderos in the province of Popayán, and of the prevalence of fraudulent practices in the registration and exportation of gold" (McFarlane, 1994: 24-25). The purpose of the *visita* reveals the concerns in Madrid regarding the state of corruption of the *audiencia* and their worries about contraband. However, as McFarlane and Eisa-Barroso comment, the *visita* was not successful. Deflected from his initial task, the *visitador* was sent to Cartagena only to find out that *Gobernador* de los Ríos refused his entry into the city, arguing that

[50] John Lynn has explained several details of Pointis' *Raid on Cartagena* in the context of the Nine Years War which saw France up against the so-called *League of Augsburg*. See, Lynn (2013), pp. 261-263. Details about the raid and its aftermaths can be found in Rodríguez Caso (1979); Eisa-Barroso (2016), pp. 61-67.
[51] *Cf.* Eisa-Barroso (2016), pp. 61-67.

neither the *visitador* nor the *audiencia* had any jurisdiction over Cartagena and its military issues. In fact, de los Ríos arrested the *visitador* and deported him to Cuba where he was freed by *Gobernador* Diego Córdoba Lasso de la Vega, and sent back to Madrid where he was able to hand in his reports.[52]

As McFarlane suggests, although Alcedo y Sotomayor's reports fail to provide a detailed account of the social, political, and economical context of New Granada, they do depict a general panorama of the problems emerging from the lack of royal authority in the *audiencia*; especially regarding the problems of contraband and enslavement. In McFarlane's words:

> In his investigations, Alcedo found few areas in which royal authority was not openly flouted. In the two major provinces of Popayán and Santafé, Indian labor was exploited without regard of the law, and revenues from tributes bore no relation to Indian numbers. The crown was also defrauded of income by widespread evasion of taxes and duties on the products of the colony's single richest resource, its gold mines (1994: 25).

Therefore, the lack of royal authority was not only perceived in the disobedience of the local *gobernadores*, who failed to recognize the authority of the president of the *audiencia* and his *oidores* but, equally important, it was visible in the daily activities of the local elites. By directly taking the gold dust from the gold-mining districts of Chocó and Antioquia to the port of Cartagena, wealthy families of the *gobernaciones* of Popayán and Cartagena evaded the various taxes and supplied a currency for contraband goods. Likewise, the illegal enslavement of the Indies

[52] *Cf.* McFarlane (1993), pp. 188-189; Eisa-Barroso (2016), pp. 61-67.

provided evidence that the administration of justice, the essential activity of the Spanish Crown, was not performed satisfactorily in the capital, Santafé.[53]

Along with the problems of contraband and the conflicts between the elites of the *gobernaciones* of Cartagena and Santafé, the coup d'etat of 1715 against President Francisco Meneses Bravo de Saravia, by *oidores* Vicente Aramburu and Mateo Yepes, and the prosecutor Manuel Zapata, reveals the power that local interests had acquired and the lack of royal authority to counteract them. As McFarlane and Eisa-Barroso explain, in order to be appointed president of the *Audiencia de Nueva Granada*, Meneses was indebted to the French *asiento* company and, consequently, since his arrival in Santafé, in 1711, he began to favor the actions of the French *asiento* in the port of Cartagena, thus also facilitating the income of contraband coming from France. Problems arose for Meneses when a wealthy and influential family of Santafé, the Flórez, whose business involving commerce and contraband with the British ports in the Caribbean had been considerably affected since the arrival of Meneses, moved their influences to the *oidores*. Thus, in September 1715, arguing that Meneses had created a kind of state police, Aramburu, Yepes, and Zapata arrested him, seized his goods, and imprisoned him in San Luis de Bocachica, Cartagena.[54] As Eisa-Barroso comments:

> The coup d'etat against the president demonstrated clearly both the importance of contraband trade networks for local politics and the power that the local interests had acquired within the *audiencia*; moreover, it signaled strongly that local interests believed they could do as they pleased when it came to the internal affairs

[53] *Cf.* Colmenares (1978), pp. 246-356; Eisa-Barroso (2016), pp. 77-85.
[54] *Cf.* McFarlane (1993), pp. 188-189; Eisa-Barroso (2016), pp. 67-77.

> and government of the kingdom. Perhaps they were not entirely mistaken (2016: 76-77).

In the aim of clarifying the facts surrounding the coup d'etat against Meneses, the Council of Indies sent a commission to Santafé which, in 1718, determined the innocence of Meneses and condemned the *oidores*. Meneses should have been rehabilitated to occupy his position as president of the *audiencia*. Nevertheless, since 1717, as a part of the reforms implemented by the Bourbon King, Philip V, following the suggestions of his confessor Giulio Alberoni, and without notifying the Council of Indies – the Spanish authority for issues related to America –, the king had decided to create a new viceroyalty for replacing the *Audiencia de Nueva Granada*.[55] Thus, as Eisa-Barroso concludes:

> It would seem fair to say then that the creation of the viceroyalty was primarily motivated by the need to strengthen royal authority in the northern region of South America. This measure would both subordinate local conflicts and vendettas between local officials, and increase the crown's capacity to extract revenue through better control of royal finances and treasuries (2017: 138).

Empowered with the authority of the viceroy, Don Antonio de la Pedrosa y Guerrero arrived in New Granada in mid-1718 for the purpose of preparing the *audiencia* for the transition to a viceroyalty. He created new measures for enforcing the payment of the already existing taxes, especially those related to the importing of black slaves and the effective payment of *quintos* – a 5% tax that the Spanish Crown charged for the extraction of gold.[56] Therefore, in 1719, Don

[55] As Eisa-Barroso suggests, the decision of the King and Giulio Alberoniis influence meant the new regalism of the Bourbon House was faced with the traditions of the institutions that the Hapsburgs created for managing the affairs of the Indies, like the *Casa de la Contratación* or the Council of Indies. Hiwever, these internal debates in the Spanish Court are outside the boundaries of this dissertation. *Cf.* Eisa-Barroso (2016), pp. 86-139.

[56] Pedrosa y Guerrero's reforming actions played an important role in revealing to the Spanish Crown the degree of corruption in New Granada as in only one year he increased the revenues for the Crown coming from the *quinto*.

Jorge de Villalonga arrived in New Granada as the first viceroy of the newly created Viceroyalty (Fig. 3).[57] After arriving, Villalonga's main purpose was to create effective measures for controlling contraband in Cartagena and in order to do so he moved to the port in 1720. Nevertheless, as McFarlane comments, his measures were not completely effective and he was actually accused of complicity with contraband.[58] However, after analysing the reports of revenues during the rule of Villalonga, Eisa-Barroso argues that such an accusation should be revised, as there was a considerable increase in the revenues from taxes. He claims that the cause of the accusations against Villalonga were rooted in the reconfiguration of the institutional powers in the Spanish court as Alberoni left his position and the Council of Indies regained control over the issues related to the Spanish overseas territories.[59] In any case, the conflicts during Villalonga's rule proved that far from being solved, the problems that caused the creation of the viceroyalty remained and furthermore, they encompassed some spheres of the Court of Madrid as well. As a consequence of the problems related to Villalonga's regency of the Viceroyalty of New Granada, in 1723 the Crown, this time at the advice of the Council of Indies, suppressed the viceroyalty and reestablished the *audiencia*, arguing that the cost of maintaining a viceregal court in Santafé was higher than the expected benefits.

In addition, the incompatibility between his and Villalonga's policies also reflected the different approaches to governing in the Spanish Court in the early eighteenth century. *Cf.* McFarlane (1993), pp. 189-192.

[57] Perceived as an ostentatious and extravagant viceroy, Villalonga's ceremonies and rituals, have been advanced as one of the possible causes for the abolition of the viceroyalty in 1723. *Cf.* McFarlane (1993), pp. 191-192; Maqueda Abreu (2007), p. 165. Contrarily, Eisa-Barroso has argued that such ceremonies and rituals were part of the traditions of the Spanish Crown and a manifestation of the power of the sovereign. *Cf.* Eisa-Barroso (2016), pp. 140-191.

[58] *Cf.* McFarlane (1993), pp. 191-192.

[59] *Cf.* Eisa-Barroso (2016), pp. 140-191.

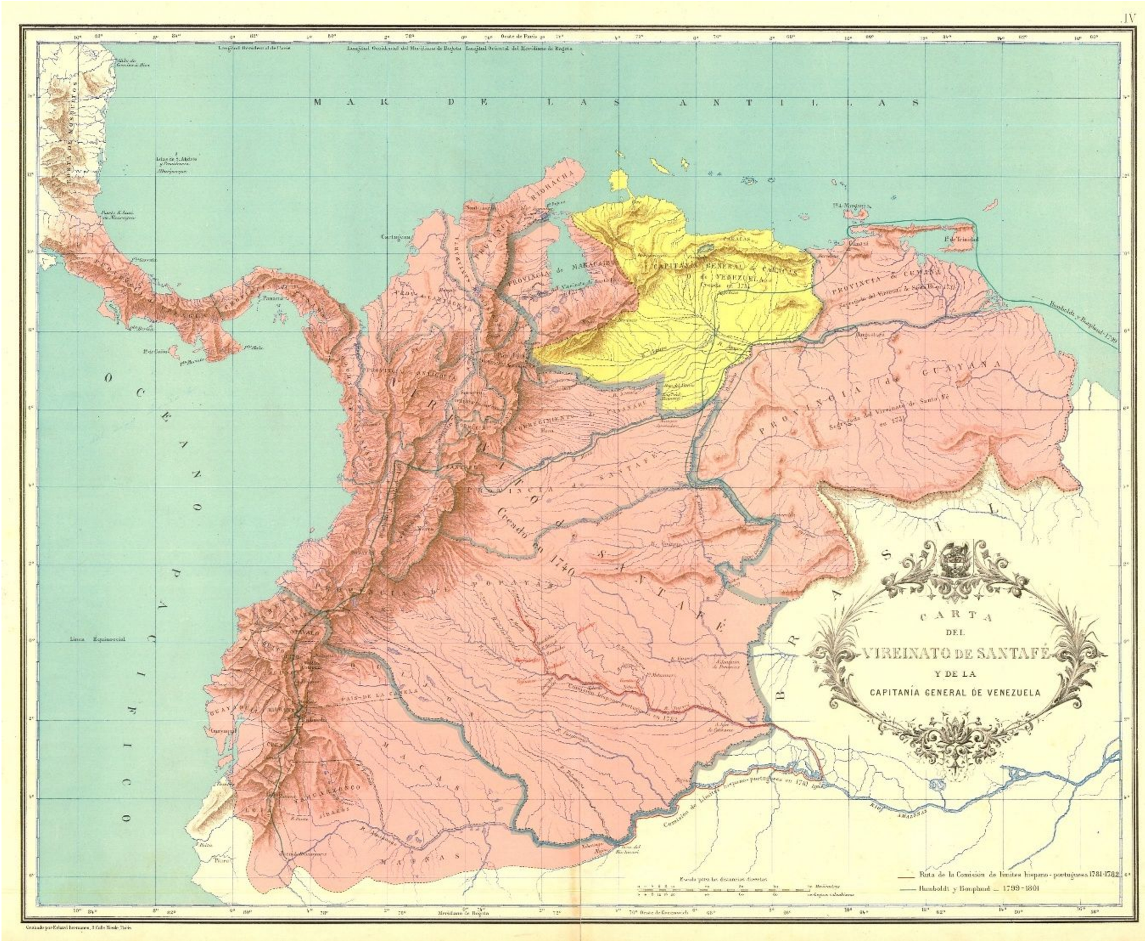

Figure 3. Viceroyalty of Santafe and Captaincy General of Venezuela, 1742 (Codazzi et al., 1890)

After the suppression of the viceroyalty, there were no changes to situation in the *audiencia* compared to before its first creation: conflicts between local elites, contraband, and lack of royal authority remained its essential panorama.[60] In this context, Antonio Manso, president of the *audiencia* between 1724 and 1729, asked for the reestablishment of the viceroyalty, arguing that the policies he tried to implement were not carried out because of the lack of authority that the figure of the president had in his jurisdiction. Along with Manso's appeal, the Council of Indies also received several requests from different sectors of the local elites in New Granada in which

[60] *Cf.* Eisa-Barroso (2016), pp. 204-246.

the need to reinforce the authority of the king in the *audiencia* was emphasized through the reestablishment of the viceroyalty.[61] However, during the 1730s, the necessity of reinforcing the royal authority in New Granada was accentuated by two facts. On one hand, gold-mining, the single important economical activity of New Granada in the eyes of the Spanish Court, had increased considerably since the 1720s – along with the production of other raw materials, and agricultural goods. In this sense, as Eisa-Barroso has commented, unlike the first reforms that led to the first creation of the Viceroyalty of New Granada – which was exclusively focused on the promotion of the royal authority in northern South America –, on this occasion the "reformers also gave extensive consideration to the specific ways in which establishing a viceroyalty would encourage the economic development of northern South America" (2016: 224). On the other hand, the anxiety for the imminent war with Britain, and the possibility of turning the Spanish Caribbean ports into scenarios for international conflict, forced the Spaniards to devise strategies for reinforcing their defences in the overseas territories.[62] The reestablishment of the viceroyalty seemed a good solution for both issues.

The road to reestablishing the viceroyalty began in 1734, when José Patiño asked Bartolome van Craywinckel – a member of a Dutch family working for the Spanish Crown, who Hispanized his name to Bartolomé Tienda de Cuervo –, for a report on the resources and necessities of New Granada of which he had gained first-hand knowledge while serving as an official in Cartagena during the first viceroyalty. In Tienda de Cuervo's report, he emphasized the economic potential of the territory, claiming that its main resources had not been exploited yet, as the Spanish merchants had focused almost exclusively on its gold. In his report, as McFarlane explains, Tienda de Cuervo concluded that the best way to seize such resources was

[61] A description of the appeals to the Spanish Court for re-establishing the Viceroyalty of New Granada is in McFarlane (1993), pp. 194-197.
[62] *Cf.* Eisa-Barroso (2016), p. 224.

to increase the sovereign's authority in the territory.[63] Interestingly, Tienda de Cuervo's report antecedes by almost thirty years the Mutis' and Viceroy Messia de la Cerda' appeal to Charles III to create a botanical expedition to produce a natural history of New Granada's territory capable of fostering appropriate exploitation of its natural resources – thus modifying the gold-dependence of the commerce between Spain and New Granada. It reveals how by the time Mutis arrived in New Granada, the idea of the need for a more detailed exploration and exploitation of New Granada's territory and its natural resources was circulating among the administrative spheres of the Court of Madrid.

Though Patiño died in 1736, the report reached King Philip V who, after consulting with a committee created for the occasion and at the suggestion of the Council of Indies, decided to reestablish the Viceroyalty of New Granada in 1739. As Eisa-Barroso suggests, the importance of both military and administrative issues in the second creation of the viceroyalty is evident in the election of the second viceroy, Sebastián de Eslava y Lesaga who was not only a consummated lieutenant-general of the Spanish army, but had accompanied Alberoni to the re-conquest of Sicily in 1718 and also had administrative experience as he had worked in the Viceroyalty of Peru. This profile demonstrates the changing mentality concerning the idea of what a "good government" consists of in Bourbon Spain in the mid-eighteenth century.[64] As Eisa-Barroso comments, in considering Colin MacLachlan's analysis of the transformation of the idea of monarchy under the Bourbon reign in Spain in the eighteenth century:

> As Colin McLachlan has argued, coinciding with the accession of the Bourbon to the Spanish throne, a major change within the ideological justification of

[63] A transcription of Tienda de Cuervo's report is in Becker & Groot (1921), pp. 203-230. Tienda de Cuervo's report is historically significant as it constitutes the earliest evidence of Spanish attempt at exploiting New Granada's natural resources as a way of promoting its economy and gaining better control of the territory.
[64] *Cf.* Eisa-Barroso (2016), pp. 255-261.

monarchical government took place. Although the fundamental principle of the King's benevolent intent was not abandoned, its impulse shifted 'from a remote divine source to a definite material foundation'. This new articulation was based upon "an economic justification […] that linked the state to the prosperityand [material] well-being of the individual". In this regard, Tienda de Cuervo's report and the Council's adoption of it represent perhaps the culmination of this transformation (2016: 214-242).

The Spanish fears of war with the British as well as the appropriate election of Eslava y Lesaga as viceroy of New Granada materialized in 1739, when a new episode of the long-term conflict between the Spanish and British empires was declared. As a part of the War of Jenkins' Ear, the purpose of the British Navy was to attack various strategic Spanish ports along the Caribbean coast. The offensive, which initially only intended to weaken the Spanish strongholds in the region, ultimately attempted to expand the territories controlled by the British Empire in America. Thus, in 1739 Officer Edward Vernon attacked and (easily) captured the Spanish port of Portobelo. Motivated by his triumph, and with the land support of General Thomas Wentworth's troops, he attacked Cartagena in 1741, only to encounter one of the major defeats of the British Navy.[65] Since his arrival in the port in 1740, Eslava y Lesaga, who had learnt about the British attacks to Portobelo whilst he was in Spain, established his residence in Cartagena where he took care of reconstructing the defensive infrastructure of the city – an operation during which he collaborated with *gobernador* Blas de Lezo. Consequently, in 1741, the viceroy had a sound victory that justified the reestablishment of the viceroyalty and its underlying military reasons.[66]

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[65] Details of the episodes of the War of Jenkins' Ear in the Caribbean are in Pares (1963) and Woodfine (1998).
[66] For Eslava y Lesaga's actions in the defence of Cartagena, see Rivas Ibáñez (2013).

The polemic circumstances surrounding the creation of the Viceroyalty of New Grannada and its place among the Bourbon policies for the Indies have undergone extensive historiographical debates.[67] However, as my purpose here is to merely present a general panorama of the historical context Mutis found on his arrival, I believe it is sufficient to highlight how the creation of the viceroyalty was a measure designed to increase royal authority in New Granada, framed by the royalism of the Bourbon House and the transformation of the idea of "good government" that it entailed. For the Bourbon House, the essence of royal government was not only to administer justice – as it had been since the times of the conquest – but also, along with the administration of justice, to provide the best economic and social conditions for its subjects. Such a reformism implied the modification of the image of the kingdom, which was no longer considered as an ecclesia in which the highest position of the hierarchy was in the hands of the king – a reformism that ended with the secularization of power promoted by Charles III during the second half of the eighteenth century. However, unlike Spain, in the case of New Granada such a reformism of the state entailed neither a secularization of the state nor a reconfiguration of the social spheres in which the power was concentrated. By contrast, as the administrative elites of New Granada were educated by the religious orders, during the eighteenth century the Church gained considerable influence at the vice regal court of Santafé which was reflected in the creation of measures for consolidating their dominion in the educative system of the viceroyalty. In this context, the apparition of Mutis, and his interest in promoting the enlightened useful sciences according to his own interpretation of "Newton's experimental physics", represented a breakthrough for the panorama of education in New Granada. As I shall argue, for the first time, it established a direct opposition to the Church's authority over New

[67] A reconstruction of these debates is in Eisa-Barroso (2016), pp. 224-242.

Granada's society and its academic milieu. Such an opposition, as we shall see later, was emphasized during the debates about Copernicanism after the expulsion of the Jesuits in 1767.

Chapter 2. Newtonianism in mid-eighteenth-century Spain: the context of Mutis' education

The reception of Newtonianism in Cadiz in the 1750s and the modernization of Spain

One of the most striking features of the process of introduction of Newton's theories and Newtonianism in New Granada is the period of time when it saw the greatest development. Mutis made explicit references to his particular interpretation of "Newton's experimental physics" since the beginning of his lectures on mathematics and physics in 1762 – being its most algid point in the early 1770s. The specific feature of this period was that it preceded all Spanish royal policies developed during the reign of Charles III in relation to the introduction of experimental physics in university education, both in Spain and overseas; that is usually considered the breaking point for the modernization of Spain's education. As historians like Laurence Brockliss, Antonio Ten, Antonio Dominguez, and Jean-Pierre Amalric have pointed out, the reformation and modernization process of the Spanish universities was mostly established by the actions of Charles III's ministers, the Earl of Campomanes and the Earl of Aranda. Thus, during the late 1760s and early 1770s, in order to emphasize the Spanish royalism, they tried to remove the influence of the Church in diverse spheres of Spanish culture and education, which they achieved in the latter case by introducing modern science in the university curriculum.[68] As Ten argues:

[68] *Cf.* Ten (1983) and (1993); Amalric & Domergue (2001), pp.100-152; Brockliss (2003), pp. 61-62; Dominguez (2005), pp. 160-180.

> La Nueva Filosofía Natural, la Ciencia "Newtoniana", se introduce oficialmente en la Universidad Española con un considerable retraso respecto a la europea. Si ya en 1716 's Gravesande la enseña en Leyden y en la segunda mitad del siglo se introduce en la cartesiana Universidad francesa, no es sino con los planes de estudios promovidos por los ministros de Carlos III, cuando se intent oficialmente en las principales Universidades la renovación de los estudios y la superación de la vieja Filosofía Aristotélica. (1983: 166).

However, as Mariano Peset and Brockliss have shown, the policies developed during the reign of Charles III for reforming education in Spain and America only had a tangible impact on the Spanish colonies during the 1780s, as reflected in the creation of university programs based on different interpretations of Newton's experimental approach to nature.[69]

In the light of these considerations, I shall argue that the sources of Mutis' appropriation of Newton's experimental physics and his teaching of it at the *Colegio del Rosario* are part of a Spanish pre-enlightened current that emerged before the royal patronage of Charles III and which can be identified as a precedent of the same. Indeed, historians such as Antoni Malet, the Peset brothers, Rosa Maria Pérez Estévez, Olga Quiroz Martínez, and López Piñero, have studied in detail the emergence and development of a "pre-Enlightened" current of thought in Spain during the reigns of Philip V and Ferdinand VI. Such a current is characterized by its interest in underscoring the retrograde state of the Spanish intellectual and academic milieus, and by its partial, but progressive, adoption by the Spanish Crown.[70] The members of this current, who were ironically called *novatores* by their detractors, were committed to various forms

[69] *Cf.* Ten (1987); Peset, M. (1988); Brockliss (2003), pp. 61-62.
[70] See Quiroz Martínez (1949), López Piñero (1979), Peset, M. (1988), Peset, M. & Peset J. L. (1992), Pérez Estévez (2002), Peset, J. L. (2006). For the historiography polemics concerning the introduction of modern science in Spain, see Lafuente (1982), Lafuente & Peset, J. L. (1988), Pagden (1988).

of experimentalism and rationalization of nature that linked them to diverse traditions: Baconian experimentalism, Gassendian atomism, and Cartesian mechanical philosophy were articulated in the aim of criticizing the scholastic approach to nature developed in the Spanish university context. As a result, during the first half of the eighteenth century, one of the main features of eighteenth-century Spanish modern thought emerged: its eclectic character. In order to criticize the scholastic tradition of the universities, the *novatores* implemented different traditions, presenting them as a single tradition – which they generically called "modern science" – as opposed to the university Aristotelianism. Interestingly, the Bourbon House, which had held the Spanish Crown since the year 1700, supported the *novatores*, as they were conceived as agents for reducing the power and control of the Church over different aspects of Spanish cultural and intellectual life. It is a well-known fact that such a control was part of a Bourbon policy, created for the purpose of increasing the royal power over its territories. Therefore, in the early-eighteenth century, the institutionalization of experimentalism in Spain began out of the university milieu, which happened to be considered a stronghold of scholasticism.[71]

In this context, during the 1750s, Cadiz was one of the most important points of reference for the introduction of modern science in Spain, and particularly of Newton's physics. Being the port connecting Spain with the New World, the commerce and the permanent presence of foreigners had turned the port city into a "metropolis" in which several cultures and traditions converged. As Juan J. Rodríguez Ballesteros comments: "La nueva dinastía borbónica y sus ministros ilustrados focalizaron en dicha ciudad las instituciones con que dotaron a la Marina española iniciándose una estratégica renovación institucional e intelectual de gran calado que convertiría al puerto gaditano en uno de los más importantes del momento" (2004: 476). As

[71] *Cf.* Pagden (1988), pp. 131-132.

one of the main Spanish port of the eighteenth century, Cadiz was both a city of commerce and a military center where Spanish marines were trained and educated. In this sense, the modernization of the city entailed a modernization of the Spanish navy as well. The Marquis of La Ensenada, the most influential minister of Kings Philip V and Ferdinand VI, decided the naval academy of the city was the most appropriate place for applying the policies he had devised for reforming education. Within the context of the War of Jenkins' Ear, La Ensenada believed that the British Navy had the advantage because of their modernized infrastructure and being an advocate of the use of force and the need to strengthen the relationship with France in the war against the British Empire, he proposed a set of reforms to Cadiz's naval academy in order to achieve its modernization.[72]

These reforms not only consisted in the modernization of the material conditions of the Spanish Navy through the construction of new, modern ships. For La Ensenada, the modernization of the navy also entailed the reformations of the study plan of the naval academy. Thereby, he promoted the use of Pedro Padilla's *Curso militar de mathematicas* (1753-1756) in Cadiz – it was originally created for training students at the *Academia de Matemáticas* of the *Guardias de Corps* in Madrid.[73] Such reformism was based upon the promotion of the technical knowledge concerning shipbuilding and navigation, founded on the mathematical principles of modern science. In order to accomplish his plan, La Ensenada appointed as directors of the *Real Colegio de Guardiasmarinas* and the *Real Colegio de Cirugía* of Cadiz to Jorge Juan (1752) and Pedro Virgili (1748), respectively. Under their supervision, the Cadiz's colleges were modernized under the

[72] *Cf.* Pérez Estévez (2002), pp. 52-53.

[73] Padilla's *Curso militar de mathematicas* is a voluminous work encompassing different technical aspects of mathematics as they were connected to military engineering. In his *Curso*, Padilla deals with several mathematical branches of mathematics, such as geometry, algebra, trigonometry, starting from their very first principles. Particularly important is his *Tratado 5* as it is the first work dedicated to teaching differential and integral calculus and the method of fluxions in Spain. Padilla's work on calculus is in Padilla (1756). An interesting survey on Padilla's pedagogical work on calculus is in Blanco Abellán (2011).

influence of diverse interpretations of Newton's mathematical approach to nature. Whereas Juan was deeply committed to a mathematization of nature and the application of Newtonian fluid mechanics for shipbuilding and navigation, Virgili was influenced by the tradition of Newtonian medicine developed since the early-eighteenth century. As a result, and as I shall argue in this chapter, by being educated in the context of these reforms in education, which were part of the modernization of the Spanish navy,[74] and the progressive acceptance of diverse Newtonian traditions, Mutis appropriated Newton's experimental physics.

Figure 4. José Celestino Mutis. Real Academia Nacional de Medicina, Madrid.

[74] For the role of military academies in the introduction of modern science in Spain, see Lafuente & Peset J. L. (1982) and Lafuente (1985).

Mutis studied Surgery at the *Real Colegio de cirugía* of Cadiz as of 1749. There, he was educated under the precepts of the modernization of the field established by Virgili, founded on the idea that surgeons, who in Spain were considered almost as butchers, should also have theoretical knowledge of anatomy and animal economy.[75] Mutis studied mathematics, physics, and mechanics there,[76] and we can find the first traces of his personal conception of the role of Newton's physics in explaining physiological phenomena. Likewise, we also have manuscripts showing how during the years 1757-1760 he performed experiments on, and vivisections of, animals – particularly dogs –, in order to verify the conclusions achieved by Albrecht von Haller in his *Elementa physiologiæ corporis humani* (1747-1766), in which he argues that the irritability of the muscles is related to the presence of nerves.[77] It proves the up-to-date state of Mutis' knowledge of physiology and medicine.[78] Since 1750 he also studied Medicine in Seville, another center that introduced early modern science in Spain, thanks to the influence of the *novatores* and the creation of the *Regia Sociedad de Medicina* by King Charles II in 1700.[79] In 1753, after obtaining the title of Physician, Mutis returned to Cadiz until 1755. Though we do not have evidence that he participated in Juan's recently created *Asamblea amistosa literaria*, it is likely that he attended its weekly meetings or that, at least, he was aware of the topics that were discussed in them. In the *Asamblea*, as González de Posada has explained, several subjects of the modern science were dealt with, including the application of Newton's physics to medicine and navigation.[80]

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[75] *Cf.* Rodriguez Ballesteros (2004), Rueda Pérez (2013). It is interesting to highlight here that such a consideration of surgeons was also held in Santafé by the time Mutis created his *General Plan* for the medical study in 1804. I shall address this issue in Chapter 5.

[76] There are some discussions concerning the stages of Mutis' training in Spain during the 1750s focused particularly on his mathematical education. See, for example Quevedo (1984); Arboleda (1993), pp. 39.

[77] *Cf.* RJB III, 11, 1, 1, ff. 2r-10r. This manuscript has been published in Mutis (1983a), pp. 105-114.

[78] This is also evident in Mutis' idea of writing a compendium of medicine and creating a small medical academy. For these projects, see Bernal Villegas & Gómez Gutierrez (2008), Gómez Gutierrez et al. (2011).

[79] *Novatores*' influence in Seville was considerably important because of the effectiveness of their treatments and the private support they received. It gave rise to the royal patronage as of the last decade of the seventeenth century. *Cf.* Pagden (1988).

[80] *Cf.* Gónzalez de Posada (2005).

As we can see, by being educated in Cadiz during this period, Mutis benefited from the progressive institutionalization process of Newtonianism in Spain during the mid-eighteenth century. I shall argue how in said process it is possible to identify three stages, two of which had a direct influence on Mutis' appropriation of Newton's experimental physics. The first stage corresponds to the initial introduction by Benito Feijoo during the 1730s, which merely presented several general features of Newton's methodology related to the British experimental tradition inaugurated by Bacon's works. Feijoo only discussed a few methodological elements of Newton's experimentalism, as presented by 's Gravesande. Likewise, this stage was also characterized by the notorious absence of any mathematical or technical aspects of Newton's natural philosophy. The second stage developed after the arrival in Spain of Juan, who introduced these technical and mathematical aspects as they are applied to fluid mechanics, shipbuilding, and navigation. As we shall see, during this stage the idea that mathematics can be a source of explanations for natural phenomena was also introduced, and we can also find the figure of Pedro Virgili, who had a direct influence on Mutis' education on the consolidation of the application of mathematics and physics to the medical field at the Cadiz naval academy. Finally, the third stage, developed during the 1770s and 1780s was characterized by the creation of Newtonian works applied to local requirements. The most important work of this period is Juan's *Examen maritimo theórico práctico* (1771), which is the ultimate example of the application of Newton's mechanics to the solution of problems related to navigation and shipbuilding. However, as this work was published posthumously in 1771, when Mutis was already in New Granada, I shall only consider it briefly.

Therefore, in this chapter, I intend to study the introduction of Newtonianism in Spain, with special focus on its reception in Cadiz through the works of Juan and Virgili in order to determine the origins of Mutis' Newtonianism resulting from the intellectual milieu in which he was educated in Cadiz in the early 1750s. By doing so, I shall argue that the reasons motivating him to introduce Newtonianism in New Granada were not connected to the enlightened projects of the Bourbon House. Conversely, I can claim that it was a personal endeavour, deriving from his training in Cadiz and the influence of Juan and Virgili.

Feijoo and the early Spanish Newtonianism

Since the publication of Olga Quiroz's *La introducción de la filosofía moderna en España* (1949) the process of introducing modern science in Spain has been reconsidered. As I explained in the previous section, it has been classically assumed that such a process was produced under the aegis of Charles III, and his enlightened ministers who created policies for reforming education in the aim of modernizing the Spanish university milieu. Certainly, these policies intended to reorganize the social structure, in an attempt to diminish the influence of the Church on diverse spheres of Spanish society and culture. However, under the influence of Quiroz Martínez's argument, historians such as López Piñero, the Peset brothers, Mestre, and Sánchez Blanco, have explained how the introduction of early modern science in Spain was produced before the beginning of the eighteenth century, with the works of the *novatores*. These works had a considerable impact on the Spanish university and cultural milieu as they promoted the image that, by being a stronghold of Aristotelianism, Spanish universities had slowed-down the modernization process in Spain. Furthermore, as we shall see, these works helped to develop the eclecticism that characterized the reception of modern science in Spain during the eighteenth century.[81]

[81] *Cf.* Quiroz Martínez (1949), López Piñero (1979), Pagden (1988), Mestre (1996), Sánchez Blanco (1999)

The so-called *novatores* consisted of a group of individuals, most of whom physicians, concentrated in Seville, Madrid, and Valencia. They were committed to strong criticism of the sectarianism of the Spanish universities and the introduction of multiple modern ideas for overcoming it. Led by figures such as the physicians Juan de Cabriada and Diego Mateo Zapata, the *novatores* concentrated mainly on criticizing the Galenic system defended in the Spanish universities, arguing in favor of several ideas inherited from Cartesian iatromechanics and from Wallis' iatrochemistry, and all of them purported a solid defence of a Baconian experimentalism.[82] As a result, they had a twofold impact on the introduction and development of modern science in Spain. On one hand, they insistently pointed out the retrograde state of the Spanish university milieu, claiming it to be sectarianist by emphasizing its Aristotelianism in natural philosophy and, especially, the Galenism of its medicine. For instance, Zapata claimed that the Spanish universities suffered an "ictericia aristotélica" (Aristotelian jaundice) as they only perceived nature in the colours Aristotle had painted it.[83] On the other, they promoted different forms of iatromechanics and iatrochemistry founded on their commitment with a kind of Baconian experimentalism.[84] Juan de Cabriada's *Carta filosofica medico-chymica* (1687) is a clear example of this eclectic approach to medicine. The very title of the work – *Carta filosofica, medico-Chymica. En que se demuestra, que de los tiempos y experiencias se han aprendido los Mejores Remedios contra las Enfermedades* [*Medico-chemical philosophical letter. In which it is demonstrated that time and experience teach the best remedies for diseases*] –, is indicative of how Cabriada explores the consequences of an

[82] Certainly, the most influential *novator* works were Cabriada's *Carta filosofica, medico-chymica* and Zapata's *Ocaso de las formas aristotélicas*. The former constituted the first steps in the introduction of experimentalism in Spain in the late-seventeenth century. It contains what we can consider a manifesto for Spanish experimentalism in medicine, framed in the description of treatment for the king and the role of anatomical experiments in medicine. *Cf.* Cabriada (1687), pp. 11-23. The best study on Cabriada's *Carta* and its influence in Spanish medicine is López Piñero (1965).
[83] *Cf.* Zapata (1745), p. 13.
[84] The most influential works on the criticism against Aristotelianism of the Spanish universities and the Galenism of medicine, as well as for the reception of iatromechanics and iatrochemistry in Spain were Cabriada (1687), Martínez (1722-1725), and Zapata (1745). It is noteworthy that Zapata's *Ocaso de las formas aristotélicas* was written, ostensibly, in the last decade of the seventeenth century, but was published posthumously because of the author's fear of being condemned during the Inquisition – a condemnation that inevitably arrived in 1721.

experimental approach to medicine, in which iatrochemistry and Harvey's doctrine of the circulation of blood are at the center of the treatments of diseases.[85]

The *novatores*, such as Cabriada or Zapata, did not perceive any differences in the explanations of natural phenomena – and their applications to medicine –, as proposed by Gassendi, Descartes, Bacon, and Wallis. For these *novatores*, they all represented a form of rationalization of nature which had the particularity of being a rejection of the scholastic system. Therefore, as the *novatores* embraced these different medical approaches as though part of a single tradition, they combined their methods, theoretical tenets and concepts, and worldviews in order to apply them to the different fields they were interested in. As a result, one of the main features of the early Spanish reception of modern science was the eclecticism rooted in the rejection of the sectarianism of the universities and the embracing of a strong conviction in the explicative power of an experimental approach to nature. Such eclecticism has been explained by historians like Anthony Pagden and Pérez Estévez as a consequence of its reception in the field of medicine. In Pagden's words:

> Descartes' views on causation, his experiments in sensation, his writings on psychology all had far-reaching medical implications. Doctors could also find patrons outside the university system and, if they were successful, those patrons were likely to protect them whatever their views. The Spanish nobility, like the nobility everywhere, wished to be cured of its diseases. If a doctor could achieve that, or apparently do so, then he could be confident of finding some measure of

[85] For Cabriada's influential work, see López Piñero (1969); López Piñero (1973); Rodríguez Sánchez (1998); Pérez Magallón (2002), pp. 57-185; Fernández-Medina (2015), pp. 93-206.

support in his struggle both with the theologians and with the academic doctors who could cure no-one (1988: 131).

In Pagden's characterization we also find two main features of the early reception of modern science in Spain which are important to consider in detail. First, since the very beginning of its introduction in the Spanish territories in the 1680s, modern science was perceived as an opposition to the Church's teaching in the universities. Therefore, many *novator* works were considered as heretics and were attacked by the ecclesiastic authorities in the universities. Thus, for instance, Diego Zapata himself was accused by the Spanish Inquisition and his work *Ocaso de las formas aristotélicas*, though written in the 1690s, was published posthumously in 1745 (Fig. 5).[86] The second feature that Pagden highlights in his characterization of the *novatores* is the royal support of their ideas. As medicine was in essence a practical discipline, the noblemen were mostly interested in the effectiveness of the treatments more than in their theoretical or metaphysical foundations. Accordingly, as long as a physician could treat a disease, he would receive royal support, which consisted not only of economic support but, more importantly, of his defence against the attacks coming from the university authorities because of the theological or religious implications of his position. This royal support translated in the creation of institutions that supported the early diffusion of modern ideas in Spain which constitute an anticipation of the Bourbon policies of the eighteenth century.[87]

Both the eclecticism and the royal support characterizing the reception of modern science in Spain by the *novatores* proved to be fundamental for the early reception of Newton's

[86] Details of Zapata's trial by the Inquisition are in Pardo Tomás (2004).
[87] These kinds of arguments have led different historians to conclude that royal patronage of modern science was a feature of the last Hapsburg kings in Spain rather than a novelty of the Bourbon House. For these historians, by contrast, the idea of the Bourbon House as the promoter of the modernization of Spain was self-propaganda by the Bourbon House itself. *Cf.* Pagden (1988) and Pérez Estévez (2002).

concepts and tenets, as well in the works of the Benedictine friar Benito Jerónimo Feijoo in the 1730s. Unlike the *novatores*, who concentrated mostly on the medical implications of diverse modern authors, Feijoo's *Teatro Crítico Universal* (1726-1740) and *Cartas Eruditas* (1742-1760) reveal his interest in presenting the implications and scope of a Baconian experimentalism when it is used to study nature. According to Feijoo, the basic problem of the philosophical systems taught in the Spanish universities was that they developed a kind of "sectarianism", which led to explanations of nature founded on the principles established by doctrines rather than by an experimental study of natural phenomena. Consequently, unlike the *novatores*, Feijoo also neglected the Cartesian mechanics, due to his criticism of any system based on the use of a hypothetical-deductive method.[88]

Figure 5. Benito Feijoo. Juan Bernabé Palomino (1781), Biblioteca Nacional of Madrid.

[88] Evident in his *Teatro crítico universal* is Feijoo's criticism of Descartes' system, see for example, in his nineth Discourse, Volume V, entitled *Nuevas Paradoxas physicas*, and, in particular, paradox XIV. *Cf.* Feijoo (1773a, V), pp. 225-232.

In general, in his *Teatro crtíco universal*, Feijoo argues that philosophical systems lead men to account for natural phenomena based on imaginary principles which are taken as assumptions, rather than on experiments and observations. Furthermore, for him, the reasons for doubting the explicative power of the assumptions of the philosophical sects were that by attempting to reduce every phenomenon to its basic assumptions, they attempt to reduce God's actions on nature to those they can account for. As a result, Feijoo developed a theologically-founded, moderate skepticism concerning the philosophical systems, founded on the impossibility of knowing God's providence. Yet, unlike the *novatores*, he applied his skepticism not only to the systems promoted in the university context – Aristotelianism, Galenism, etc. –, but also to the Cartesian system which, in his opinion faced the same problems. For him:

> El asombro del efecto se aumenta con la obscuridad de la causa. ¿Quién impele, o descoge los resortes del aire dividido en tan menudas partículas? Misterio es éste sepultado en densísimas tinieblas. Todas las *cualidades* de Aristóteles, todos los *Átomos* de Epicuro, toda la *Materia Etherea* de Descartes, son trastos inútiles para penetrar en esta profundidad. Acabemos ya de desengañarnos de la vanidad de los sistemas, y conozcamos que aquel Artífice Omnipotentísimo, y Sapientísimo, que formó esta grande máquina, juega en ella con unos instrumentos superiores a toda especulación humana (1773a, V: 228).

Feijoo accentuates this position in the *Discurso XI* of the Volume V of his *Teatro Crítico*, entitled *El gran magisterio de la experiencia* by claiming:

> Así sucede frecuentemente, que los hombres piensan de un modo, y Dios obra de otro. Suponen los hombres, y suponen bien, que Dios obra siempre con orden, y proporción; pero aunque suponen bien, discurren mal, porque piensan, que no

> hay otro orden, y proporción; que la que a ellos se representa como tal. Obra Dios con proporción; pero una proporción altísima, y muy superior a todas nuestras reglas (1773a, V: 264).

For Feijoo, the impossibility of knowing God's providence entails a rejection of any form of philosophical system because it hypothesizes a reduction of God's capacity to act on our capacity to understand his actions. In this sense, he developed a form of skepticism which he characterized as "prudent caution": as it is impossible to know how God acts upon his creation, the best we can do is suspend any judgment concerning natural phenomena. With Feijoo, the eclectic tradition of the *novatores* suffered a modification, as it also encompassed some features of a moderate skepticism regarding the scope of any explanation of nature. Such a modification, as Pérez Estévez and Mestre have argued, was related to the influence of the physician Martín Martínez and the polemics that Feijoo had with several Valencian intellectuals like Mayans and Martí.[89]

However, by establishing a theological foundation to his skepticism, Feijoo also distrusted the capacity of a strict experimental approach to nature. For him, "No bastan, pues, los sentidos solos para el buen uso de los experimentos: es menester advertencia, reflexión, juicio, y discurso, y a veces tanto, que apenas bastan todos los esfuerzos del ingenio humano para examinar cabalmente los fenómenos" (1773a, V: 271). Thus, he postulated the need to explain nature through a judicious analysis of the findings arising from experiments and observations. In his opinion, this conception of a rational experimentalism had been developed by Newton in both the *Principia* and the *Opticks*. In these works, as Feijoo presented them, Newton explained natural phenomena through the postulation of principles discovered by the

[89] *Cf.* Mestre (1976), pp. 34-53; Pérez Estévez (2002), pp. 89-92.

application of a geometrical analysis to the observed phenomena.[90] As a consequence, according to Feijoo, Newton's approach to nature is legitimized by the use of a method in which the principles are not accepted as basic assumptions of a system since they are derived from observation of and experimentation. As Feijoo stressed in Letter XXIII of Volume II of his *Cartas eruditas*:

> Parece que niega V. E. a la doctrina Newtoniana la cualidad sistemática, porque prescinde de los principios (…) Si por sistema se quiere entender un complejo, o un todo de doctrina, cuyas partes están ligadas, o como contenidas debajo de alguna razón genérica y común a todas, sistema es el de Newton, pues cuantos fenómenos hay en la naturaleza, reduce a la recíproca pesantez de los cuerpos (1773b, II: 287).

A similar characterization is evident in his consideration of the principles of the refraction of light, as Newton proposed them in his *Opticks*.[91] As we can see, in the 1730s and 1740s, Feijoo introduced a conception of Newton's experimentalism in Spain as it was presented in the *Opticks*; he also appraised Newton's mathematical approach of the *Principia* as a good method for rationalizing the naked experience that we have of nature. He did this as a way to escape the epistemological problems entailed in his skepticism concerning the explicative power of philosophical systems and the impossibility of knowing God's action upon his creation. In this context, he discussed multiple Newtonian ideas, such as attractive forces, the composed constitution of white light, and the ratio of centripetal force, as paradigmatic examples of the

[90] One of the longest and clearest references to Newton's works in Feijoo's *Teatro crítico universal* is in the fifth volume, in the discourse entitled *El gran magisterio de la experiencia*. *Cf.* Feijoo (1773a, V), pp. 271-272. References to Newton in Feijoo's *Cartas eruditas* can be found in Feijoo (1773b, II), pp. 282-302.

[91] Feijoo's reference to Newton's treatment of the refrangibility of light and the composition of white light is in Feijoo (1773a, V), pp. 271-272. Interestingly, he used Newton's experiments as evidence for supporting the inapprehensive character of nature thus accentuating his scepticism.

results that can be achieved by carefully analyzing the information gathered from experiments and observations.

Nevertheless, it is important to highlight how Feijoo's account of Newton's method and his theoretical achievements was characterized more by its explicative gaps than by a well-formed understanding of them. For instance, in Volume V of his *Teatro crítico*, in which he presented the most complete explanations of these issues, he only included a general characterization of some of their features, avoiding any reference to the technical or mathematical aspects of Newton's demonstrations. That is the case, for instance, of his explanation of the heaviness of air, the action of attractive forces as causes of the acceleration of bodies, and the mutual interaction between the moon and the ocean waves, where Feijoo did not make any explicit reference to Newton's works.[92]

It is probable that the problems related to Feijoo's understanding of Newton's principles as they are presented in his works derive from the fact that, as Feijoo himself confessed, he did not know Newton's works directly, but only through 's Gravesande's reference. But, more importantly, it is likely that Feijoo did not have the intellectual capacity or adequate mathematical background for understanding Newton's mathematical explanation of natural phenomena.[93] The first of these difficulties is evident when Feijoo considers the reasons why he has not introduced Newton's theories in his *Teatro crítico*. According to him,

> La primera consiste en la dificultad, o mejor diré imposibilidad, que hallo en explicar al público español, ni aun superficialmente, el sistema newtoniano. Yo no tengo de Newton sino las Instituciones de su filosofía, que compiló 's

[92] *Cf.* Feijoo (1773a, V), pp. 271-272. For Feijoo's pronouncements on the interaction between the moon and sea waves, pp. 261-263.
[93] For Feijoo's lack of capacity for science and the controversies originating due to that condition, see Mestre (1976), pp. 48-53.

> Gravesande, el cual se abstiene de entrar en aquellos enredosos laberintos del cálculo, que es menester para la aplicación del sistema a los diferentes fenómenos, y en que no puede dar un paso quien no esté muy instruido en la más sutil, y profunda geometría (1773a, II: 291).

Feijoo's lack of familiarity with Newton's works is visible in different passages of his major works where he refers to Newton's theories and methods. In general, he only presented some general insights of his methodology, by making reference to the principle of simplicity for explaining natural phenomena, which derives from 's Gravesande's interpretation of Newton's rules in his *Physices elementa mathematica*.[94] One of the most suggestive consequences of this particular fact is that this work also played a fundamental role in Mutis' appropriation of Newton's physics. But I shall explain this further on.

Likewise, it is also interesting to consider the other two reasons Feijoo advanced when arguing why he did not explain in detail Newton's system in his works. After explaining the difficulties in understanding Newton's *Principia* – which do not refer exclusively to *his* personal struggles but to a general characterization of the possibility of understanding it in Spain –, he argued that "La segunda razón es, que aun cuando las entienda, no se halla aun España en disposición para admitir unas novedades para ella tan extrañas" (1773a, II: 291). In this passage, Feijoo discussed his own perception of the Spanish intellectual and academic milieus, describing them in an evident negative fashion. He underlined the retrograde state of the Spanish universities as well in his *Teatro crítico universal*.[95] On the other hand, Feijoo argues that "La tercera razón, y la más fuerte, es, que el sistema newtoniano envuelve, o supone necesariamente el

[94] I am going to adress 's Gravesande's interpretation in the chapter about Mutis' lectures on physics.
[95] *Cf.* Feijoo (1773a, VII), pp. 313-314. In this discourse, interestingly, Feijoo also explained his own strategy for reforming education in Spain as well as different plans study for different careers.

copernicano de la constitución del mundo" (1773a, II: 293). In diverse passages of his *Teatro crítico*, he contended that the Copernican system should only be considered as a hypothesis, claiming that it is untenable as a thesis as it contradicts the Holy Scriptures.[96] As I shall explain in Chapter 6, the importance of this characterization of Newton's natural-philosophical system, as a system that presupposes the Copernican system, as well as the problems related to its acceptance because of its heretic character, demonstrate how the appropriation of Newton's physics in the Spanish World was related to its connection with Copernicanism. Besides, such a consideration also sheds light on our understanding of the polemics between Mutis and the Dominicans in the 1770s.

In general, it is possible to conclude that this first stage of the introduction of Newton's theories, method, and natural philosophy, presented in Feijoo's works, is characterized by a partial and general presentation of some features of Newtonianism as they were derived from a problematic interpretation of 's Gravesande's *Physices elementa mathematica*. However, these features reveal some important characteristics not only of the early reception of Newtonianism and modern science in Spain, but also of the constitution of the Spanish intellectual milieu prior to the period of Mutis' education in Cadiz. In the first place, we can observe how the reception of Newtonianism during the 1730s and 1740s was reduced to a general characterization of several features related to the optics and application of mathematics as complementary of a Baconian experimental approach for explaining natural phenomena. In this context, Feijoo introduced some ideas regarding the composition of white light and the forces of attraction as

[96] *Cf.* Feijoo (1773a, II), pp. 21-22; Feijoo (1773a, II), pp. 292-295. His considerations on the relationship between the Copernican system and Newton's natural-philosophical system are in *Carta XXI* of the fourth volume of *Cartas eruditas*, *Progresos del Sistema filosófico de Newton, en que es incluido el astronómico de Copérnico*. *Cf.* Feijoo (1773b, IV), pp. 294-308.

causes of motion.[97] However, as I have argued, he only did this in a very general way, without presenting either the technical details or the mathematical demonstrations of Newton's works, because his purpose was just to illustrate his idea of the advantages of applying Baconian experimentalism under the precepts of a judicious, mathematical, analysis of the collected experimental and observational information.

This particular manner of understanding Newton's works is considerably important for Mutis, because it established not only the acceptance of experimentalism and the implications of a mathematical analysis of the study of nature in Spain, but also and above all because it set the foundations for a royal patronage. As Arboleda claims:

> La ponderada influencia sobre Mutis de un autor como Feijoo fue ciertamente decisiva porque moldeó su cultura en un "Nuevo espíritu científico" de crítica al escolasticismo, de reforma de instituciones, de gusto por la investigación científica (…) En esencia, es el planteamiento cultural de Feijoo, que a fines de la década de 1750 ha sido ampliamente reconocido y adoptado como aquel que mejor interpreta los intereses de la nueva dinastía borbónica (1993: 38-41).

As we shall see later in more detail, by emphasizing the role of experimentalism and introducing the general features of Newton's methodological approach to nature, in which experiments and mathematical demonstrations are combined, Feijoo established the basis for an easier acceptance of Newtonianism in Spain in the 1750s. This is evident from the fact that when the controversy regarding Feijoo's views on experimentalism arose, he received royal support because, Kings Philip V and Ferdinand VI, helped by their ministers José Patiño and Marquis of La Ensenada,

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[97] Feijoo introduced Newton's considerations about light in the context of his explanation of the virtues of an experimental approach to nature in Volume V, *Discurso* XI of his *Teatro Crítico Universal*. *Cf.* Feijoo (1773a, V), pp. 271-272. A reference to attraction and the 'secret' actions of nature can be found in the *Discurso* II, Volume III. *Cf.* Feijoo (1773a, III), pp. 32-33.

saw in this new experimentalism a way to increment the royal power over the Catholic Church and to modernize the Spanish state.

Jorge Juan and the application of Newton's mechanics for shipbuilding and navigation

In the previous section, I have argued that the early reception of Newton's concepts and tenets in Spain in the 1730s and 1740s through Feijoo's interpretation of 's Gravesande, only consisted of a superficial presentation of some general features of Newton's theories. As Arboleda has argued, it reveals the important role of the Dutch and French experimentalists in the reception of Newton's theories in the peripheries, as they made the basic principles of Newton's physics apprehensible for a public which, in most cases, was not qualified to understand the complex mathematical demonstrations and methods proposed in the *Principia* nor did it have material conditions for repeating the experiments of the *Opticks*.[98] However, the first stage of the introduction of Newtonianism in Spain, which was characterized by the absence of the explanations of the mathematical and technical elements of Newton's works, finished with the emergence of Jorge Juan y Santacilia in the end of the 1740s. As we shall see, Juan's appropriation of Newton's physics was the result of his interaction with La Condamine and Bouguer in the French geodesic expedition between 1739 and 1742.

One of the more interesting and suggestive debates of mid-eighteenth-century physics involved Newton's and Cassini's conception of the shape of the earth as determined by the mathematical consequences of their works.[99] Whilst Newton had argued in Proposition XIX of the Book III of the *Principia* in favor of the earth's oblate shape because of the effects of

[98] *Cf.* Arboleda (1989).
[99] The most detailed account of the theoretical foundations of the debates concerning the shape of earth in the eighteenth century is in Greenberg (1995).

gravitational and centrifugal forces on rotating fluid bodies, Cassini, in *Discours de la cause de la pesanteur* (1690), claimed that the earth's prolate shape was a by-product of the measures made for mapping France since the 1680s – and of several measures made by Jean Richer in an expedition made to the French Guiana.[100] Certainly, the debate involved different mathematical and experimental approaches and constituted a scenario for the direct confrontation of two opposed conceptions of nature. Yet, interest in this debate was not strictly scientific. A correct determination of the form of the earth would lead to a better understanding of the correct position of the meridians and the circles of latitude. The application of which would, for instance, entail multiple consequences for the correct establishing of the limits of the empires and the correct positioning of ships in the sea. Because of this, following Maupertius' advice, in 1735 the *Academie* of Paris created a special commission for solving the debate regarding the earth's shape, consisting of two expeditions, one sent to Lapland (Sápmi) and the other sent to Quito, for the purpose of measuring the arc of the meridian at the height of the equator and the pole. Thus, the French geodesic expeditions aimed at determining, by triangulation, the longitude of an arc of the meridian and the extremes of that arc. The names of those sent on the expeditions reveal its importance for the *Academie*: Maupertuis, Clairaut, Camus, Lemmonier, Outhier, and Celsius went to Lapland. Whereas, the expedition sent to Quito consisted of Godin, La Condamine, Jussieu, Hugot, Morainville, and Bouguer.[101]

As the workplace of the expedition was a Spanish overseas territory, it was necessary for Louis XV, King of France, to ask to his cousin Philip V, King of Spain, royal authorization to set up the commission. Authorization was given on the condition that the expedition group

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[100] *Cf.* Terral (2006), pp. 685.
[101] Several accounts of the French geodesic expeditions can be found in Lafuente & Delgado (1984); Lafuente & Estrella (1985); Lafuente & Mazuecos (1987); Terral (2006); Ferreiro (2011), pp. 1-30.

should include two Spanish marines and two young ensigns, Jorge Juan and Antonio de Ulloa, were chosen and promoted to lieutenants for the comission.

Figure 6. Jorge Juan de Santacilia. Rafael Tejeo (1828), Museo Naval de Madrid.

In the context of the geodesic expedition to Quito, both Juan and Ulloa were trained by the French members of the expedition on the mathematical elements of Newton's physics, as well as in how to create their own experiments and produce precise measurements.[102] However, when they returned to Spain in 1746 the social and political situation had changed dramatically. Philip V, who had promoted them for the expedition, had died in 1745 in addition to which it was

[102] In the prologue to his *Observaciones astronómicas*, Juan himself describes the techniques they learnt with the French expeditionaries. Such techniques were not limited to the measurement of an arc of the meridian, but also included the measurement of altitudes of mountains, a fundamental point for measuring the arc in the mountainous regions of Ecuador. *Cf.* Juan & Ulloa (1748), pp. 117-131.

more than ten years since they have sailed away from Spain, and they had been almost completely forgotten on the Spanish intellectual panorama. This situation changed due to the support of the Marquis of La Ensenada, Minister of Kings Philip V and his son Ferdinand VI.[103] Since the early 1740s, convinced of the need to strengthen the military sector in order to deal with the conflicts with the British Empire, La Ensenada had been implanting policies tending towards the modernization of the Spanish army. He was convinced of the need to apply a twofold strategy: firstly, by modernizing the intellectual conditions of the Spanish naval academies, to equilibrate the naval power of the British army which, in his opinion provided the enemy with an advantage over the Spanish naval force. Secondly, during the 1750s, La Ensenada promoted a strong policy of improvement of the Spanish ships, focused on the application of the British construction model.[104] In this twofold strategy Juan played a fundamental role. On his return from the expedition, La Ensenada acknowledged his training in mathematics and physics, and created the necessary conditions for him to publish his *Observaciones astronomicas, y physicas hechas de orden de S. Mag. en los reynos del Peru* (1748), containing the results of the expedition. In this book, as I shall address further on, Juan also discussed several concepts and tenets of Newton's natural philosophy, thus representing, as far as I know, the first discussion of some of the technical and mathematical elements of Newton's *Principia* in Spain. Likewise, La Ensenada appointed Juan as Director of the *Colegio de Guardiasmarinas* of Cadiz, turning him into the vehicle of the modernization of the Spanish army. Juan's importance for La Ensenada's military projects, as well as his trust in the intellectual capacities of the former, were confirmed in 1752, when he was commissioned to carry out several espionage missions in London, to study the British shipbuilding techniques and hire the most capable shipbuilders for the Spanish navy.[105] As we

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[103] *Cf.* Martínez Ruiz (2013), Alberola Romá & Die Maculet (2013).
[104] *Cf.* Pérez Estévez (2002), pp. 53-55.
[105] For Juan's espionage missions, see Juan y Ferragut (2013).

can see, the context of the second stage of the introduction of Newton's ideas in Spain was characterized by an interest in modernizing the Spanish navy through the improvement of both its material and intellectual conditions. Juan used Newton's physics, and specifically his fluid mechanics, as the foundation for establishing the theoretical shipbuilding and navigation conditions.[106] I shall study in detail Juan's adopting of Newton's mechanics and its application to shipbuilding, but, first, let us see the general aspects of his characterization of Newton's method as he considered the application of mathematics (*theorica*) to the study of nature in his *Observaciones*.

In the prologue of *Observaciones*, Juan describes some general features of the geodesic expedition, focusing on the royal patronage and the possible applications of its results. He explains the breakdown of the work, stating how the first part, written by Ulloa, contains a description of the trip and their findings in the Peruvian territories.[107] However, the most interesting point of the prologue appears after Juan's description of the structure of the work, when he claims that it deals with geodesic problems in a geometrical way and, because of that, he assumes as given the principles upon which the theoretical explanations are based. According to Juan:

> Advierto últimamente, que siendo muchas de las cosas, que se tocan en esta obra de muy sublime geometría, he procurado explicarme del modo más claro, y perceptible, para que me entiendan aun los no muy versados en sus abstrusas especulaciones (…) Con el que ningunos tuviese [knowledge on geometry], no

[106] For the role of military academies in the appropriation of Newton's physics in Spain and the importance of Juan in that process, see Lafuente & Peset (1982).

[107] It must be recalled that Juan and Ulloa presented the report of the results of the geodesic expeditions in two different works. Thus, if we follow Juan's description in the *Prologue* of the *Observaciones*, the part corresponding to Ulloa was the one entitled *Relacion historica del viage hecho a la America meridional hecho por orden de S. Mag*., published in 1748. Because of Juan's commentaries, I shall assume him to be the individual author of the *Observaciones*.

> puede hablar una obra, en que no se dan estos, sino que se suponen; pues para darlos todos, fueran sin duda necesarios otros volúmenes, y aun acaso no se darían con ellos por satisfechos (1748: Prologue).

As we can see, even in the Prologue, Juan emphasizes the mathematical character of his work, arguing that the explanations of the problems he dealt with are based on geometrical principles. In so doing, he introduced the idea in Spain that there is a relationship between mathematics and physics in which the former provides explanations for the phenomena studied by the latter, both being considered abstract mathematical (geometrical) entities. As Juan underscores how this conception of the role of mathematics in physics was developed by Newton in his *Principia*, it is possible to conclude that in his *Observaciones* Juan introduced Newton's mathematical principles in Spain as the basis for accounting for natural phenomena from a strictly mathematical point of view. Unlike Feijoo, who referred to Newton's mathematization of nature only from a methodological point of view and with second-hand knowledge of his work, in Juan's *Observaciones*, we can see the results of the use of mathematics for analysing natural phenomena, founded on a direct interpretation of Newton's *magnum opus*.[108] This consideration is clearer in the Introduction, in which Juan presented the discussion justifying the geodesic expedition he was part of, and the important role of mathematics, that he calls *theorica*, in determining the earth's shape.[109]

In the introduction Juan discusses the historical development of geodesy claiming that one of the central problems in this field since ancient times has been how to determine both the

[108] Juan's references to Newton's *Principia* are frequent. See, for instance, Juan (1748), p. XIII, 90, 333. I cannot be certain whether Juan knew the *Principia* before the geodesic expedition, however there is evidence that he had knowledge of some theoretical aspects of Newton's works when he studied in the *Academia de Guardias Marinas* in 1729. *Cf.* Martínez Ruíz (2013), p. 19.
[109] *Cf.* Juan (1748), pp. XII-XVIII, XXII-XXIII.

exact measurement and the shape of the earth. Thus, he evaluates the historical development of the solutions to these problems, stating that although the problem of earth's measurement has been solved satisfactorily; that is not the case for its shape. After describing several solutions to this problem, he argues that in the late-seventeenth century the idea that the earth was a spheroid emerged.[110] He therefore introduces the discussions between Newton and Huyghens who have advanced mathematical demonstrations from which it was deduced that the earth was an oblate spheroid, and Cassini and the Cartesians, who defended the idea that the earth was a prolate spheroid. The way in which Juan presents the issues of the discussion is rather interesting as he focused on the methodological discussion rather than on Newton's and Cassini's results – which, by the way, were the core of the discussion in *Observaciones* and the foundation of the entire enterprise of the geodesic expedition. By focusing on the methodological aspects of the discussion, he made some general considerations about the scope of mathematics in the study of nature which which led him to accept Newton's mathematical approach to nature rather than Cassini's observational practices. In so doing, it made it possible for him to introduce Newton's physics in the naval academy of Cadiz. Let us see in detail such an articulation.

As Juan presents it, Newton's and Huyghens' argument for earth's oblate shape is based on the principles of statics. According to them, the earth's centrifugal force is greater at the equator than at the poles. Such interaction of forces explains why pendulums, with the same mass and extension of strings, have faster periods of oscillation when they are closer to the equator than when they are closer to the poles.[111] In this sense, they founded their mathematical approach on the empirical evidence provided by the experiments with pendulums – Newton

[110] *Cf.* Juan (1748), pp. XII.
[111] *Cf.* Juan (1748), p. XVIII.

specifically used observations made by Jean Richer in Cayenne between 1672 and 1673.[112] Newton and Huyghens deduced that in a rotating fluid body – like the earth –, the centrifugal force is stronger at the equator than at the poles. Thus, they accounted for the different periods of oscillations of pendulums at different latitudes as an effect of the action of the different magnitudes of the force caused by the increment of the distance to the center of the earth. In this sense, in order to balance the interaction of the forces, the rotating fluid body takes on an oblate shape in which there is more mass at the equator to produce a greater centripetal force that can be in equilibrium with the centrifugal one. In Juan's words:

> Para que se conserve pues el equilibrio es preciso, que haya más porción de masa hacia el ecuador, para que la pesadez, correspondiente a la mayor cantidad, contrabalancee el peso mayor, que en menor cantidad tengan las porciones hacia los polos; y es bien fácil de ver, que en esta suposición la Tierra estará más elevada hacia el ecuador, que hacia los polos y que así su figura será no una esfera o bola perfectamente redonda, sino es una esferoide plana, o una bola chata hacia los polos, o por decirlo así, tendrá figura de una naranja (1748: XVI).

Interestingly, Juan highlighted how Newton's and Huyghen's determination of the earth's shape was founded upon the principles of their *theorica*. For Juan, it meant that they constructed a description of nature based on the mathematical deductions of the principles established. In other words, he argues that Newton's and Huyghen's approach to nature presupposes a complex relationship between mathematics and experiments in which the former discipline provides not only explanations, but also the principles upon which the experiments are performed. He

[112] *Cf.* Juan (1748), pp. XIV-XV. Newton's pronouncements on the earth's shape are in the Book III, Prop. XX of his *Principia*. Interestingly, in this Proposition, Newton also used astronomical evidence from Flamsteed and Cassini for supporting his considerations on the earth's oblate shape. A detailed survey on Newton's mathematical analysis of earth's shape is in Greenberg (1996).

illustrates this by considering the application of Newton's laws of motion to the case of the motion of pendulums.[113] As the results of both geodesic expeditions revealed that Newton's description of the earth's shape was correct, Juan became an advocate of Newton's mathematical approach to nature in which mathematics not only provided explanations of experiments and observations but, more importantly, it also provided a language that worked for describing with precision natural phenomena of any kind. As I shall argue, Juan's discovery of Newton's fluid mechanics in the context of the geodesic expedition was important not only in the sense that it allowed him to develop this branch of physics in an unprecedented way, but it also represented the first steps in the appropriation of Newton's physics and its conception of the mathematization of nature in the Spanish world. This feature of Juan's appropriation of Newton's physics is evident in diverse passages of his *Observaciones*, but one of the most interesting is when he uses integral calculus for determining the measurements of latitude and longitude of the earth in the conclusions,[114] and in which, before applying the calculus, he stresses:

> Para hallar la periferia de los meridianos, es necesario valerse de la rectificación de la elipse. Esta la traen varios autores, que tratan de geometría sublime, y de los cálculos diferencial, e integral; pero las fórmulas, que dan para ello, solo pueden servir, cuando se buscan arcos pequeños de la curva (…) Con esto me ha parecido, que pueden los geómetras gustar de ver el método, que yo he seguido de rectificar, o hallar la periferia de la elipse de la Tierra; pues en él se evita el inconveniente que padecen los demás (1748: 336).

[113] *Cf.* Juan (1748), pp. XIII. In this passage, Juan makes reference to Newton's laws of motion as they are mathematically founded. For a more detailed characterization of Juan's understanding of these laws, see Juan (1771), pp. 6-9.
[114] *Cf.* Juan (1748), pp. 313-345.

By using differential and integral calculi, Juan solved the problem of "Rectificar la elipse de los meridianos de la Tierra, o hallar la periferia de estos" (Juan, 1748: 337), concluding that "La Tierra pues rodeada Norte Sur, tendrá menos, que rodeada por encima del ecuador 38690 toesas, 90103 varas castellanas" (1748: 343).[115] Therefore, observations and the application of the differential and integral calculi not only indicated to Juan that Newton's *theorica* was correct; moreover, it showed him how Newton's mathematical approach to nature had the power to explain nature from the postulation of some basic mathematical principles. Certainly, it created the conviction in the young mathematician about the explicative virtue of mathematics when it was applied, along with solid experimentalism, in the study of nature. A conviction that was to be confirmed with his major work, the *Examen maritimo*, where he applied the tools of differential and integral calculi, and his long-life experience as a sailor for shipbuilding and navigation. Juan's *Examen maritimo* was to become the epitome of Spanish physics and mechanics – especially the mechanics of fluids – of the eighteenth century, and it is the greatest result of the appropriation of Newton's physics in Spain during that period. Nevertheless, though it was published in 1783 and, therefore, it cannot be considered in our study of the context in which Mutis was educated, it represented the conviction of the explicative power of mathematics that Juan achieved during the geodesic expedition. In this sense, a brief analysis of this can shed light on the role of Newton's concepts and tenets in the other enterprises to which he was dedicated.[116]

Undoubtedly, Juan's conviction of the explicative power of Newton's physics permeated his diffusion of Newton's mechanics in Cadiz in the context of the reforms of the study plans of the *Real Colegio de Guardiasmarinas* and the constitution of his *Asamblea amistosa literaria* – a small

[115] A *vara castellana* corresponds to 0,835905 m. The *toesa* is an old French measure corresponding to 1949 m.
[116] Regretfully, since it is not within the scope of my dissertation I cannot present a detailed study of Juan's very interesting *Examen maritimo*. For this work and its impact on navigation, fluid mechanics, and shipbuilding in the eighteenth and nineteenth centuries, see Calero (2001); González González (2006); Calero (2008), pp. 182-184, Fauque (2010).

academy that he set up in 1755 and the meeting of which were held in his home. Newton's physics were studied in Juan's *Asamblea amistosa literaria*, framed by the development of a mechanical conception of physiology and medicine, and the problems inherent to navigation.[117] We should keep in mind that Cadiz was one of the most important Spanish ports, connecting the New World with Europe. Consequently, Juan's pronouncements on navigation and shipbuilding, based on his appropriation of Newton's physics had a considerable impact on the city during the 1750s. In the case of the *Real Colegio de Guardiasmarinas* of Cadiz, Juan introduced the theoretical and practical matters of navigation in the training of his students, as can be observed in his *Compendio de navegación para el uso de cavalleros guardias-marinas* (1757). Thus, in the first sections of the work, he established the mathematical principles of navigation, leaving the practical issues for the end of the book.[118] Nevertheless, it is important to clarify that the *Compendio* is an elementary textbook, designed by Juan to introduce the basic mathematical aspects of navigation at the *Real Colegio de Guardiasmarinas*. In this sense, there are no theoretical elements of Newton's mechanics and physics in this work, but only a general characterization of the application of mathematics to the practical issues of navigation.

On the other hand, the *Asamblea amistosa literaria*, set up by Juan in 1755, was a small academy at the weekly meetings of which different issues of modern science were discussed, focusing on medicine and Newton's physics. It is likely that the young Mutis attended some of the meetings of the *Asamblea*, in which Pedro Virgili, his tutor and director of the *Real colegio de cirugía* took an active part ever since its foundation.

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[117] Details on the topics dealt with by the members of Juan's *Asamblea amistosa literaria* are in González de Posada (2005).

[118] The description of the general structure of the *Compendio* is in Juan's dedicatory *A los cavalleros guardias-marinas*.

All in all, Juan played a fundamental role in the diffusion of Newton's physical theories and mathematics in Spain as he presented, discussed, and made effective use of the mathematical principles that Newton established in his *Principia*. It must be pointed out that Juan's greatest impact was observed after the publication of his *Examen maritimo*, which was later translated into various languages – including French and English – and which played an important role in the development of fluid mechanics in the early nineteenth century.[119] Nevertheless, as I have argued in this section, since arriving in Spain after the geodesic expedition, Juan demonstrated his commitment to the diffusion of Newton's mathematical principles and its multiple applications in the field of fluid mechanics, including navigation and shipbuilding. In this sense, the Marquis of La Ensenada found in Juan's knowledge of Newton's physics a cornerstone upon which to develop the reformation to the military education that he had been planning since the early 1740s. Such a reformation, as we shall see in the next section, also entailed the modernization of Spanish surgery, through the creation of several institutions in which it would be possible to educate a new generation of Spanish surgeons, with a sound training in physiology and medicine. Pedro Virgili was appointed to lead this project, allowing Mutis to be educated in the tradition of Newtonian medicine through Boerhaave's works.

Pedro Virgili, iatromechanics, and his influence on Mutis

In 1617, thanks to the *Pragmatica de El Pardo* of November 7th, royal policies were established in Spain dealing with the study program, evaluations, and the conditions required for obtaining the title as Surgeon. The *Pragmatica* officialized the kinds of surgeons studying in the universities: the

[119] *Cf.* Calero (2001), Calero (2008).

Cirujanos Latinos and the *Cirujanos Romancistas*.[120] Thus, whereas the former had to study the Galenic and Hippocratic medical systems for four years and practice surgery under the supervision of a physician for two more years; the latter only had a superficial training in the art of surgery, with almost no education in anatomy. The division, which was aimed at improving of the training of surgeons in the Spanish universities, actually produced a deterioration of their social conditions and the decomposition of this field in Spain.[121] As Diego Velasco describes in his inaugural discourse in the *Real colegio de cirugía* of Madrid in 1764:

> Es evidente, que el estudio de dicha Pragmática exigía a los Cirujanos Latinos, para ser recibidos, era mucho más extenso, que el que por la misma se pedía a los Médicos, supuesto que debían ser examinados en todas las materias médicas, quirúgicas, y anatómicas, que debían oir en los cuatro años de teórica, y además de las enfermedades de los huesos, que debían aprender durante los dos años de práctica (1764: XIX-XX).

As a result, this kind of surgeons "para evitar el demasiado estudio, de que les hacían riguroso examen" (Velasco, 1764: XX), opted for studying medicine which involved not only greater social acknowledgment, but also a greater economic benefit. As Juan Manuel Rueda Pérez has explained, this consideration was founded on the assumption that, until the mid-eighteenth century, wealthy Spanish families preferred that their sons studied a profession with a high social recognition, in the major faculties of the universities, instead of Surgery that was one of the

120 The complete set of laws regarding medical studies in Spain – Medicine, Surgery, and pharmacy – set up during the seventeenth and eighteenth centuries can be found in the Book VIII of the *Novísima recopilación de las leyes de España*, *Títulos* VIII-XII. Laws specifically concerning surgery can be found in *Título* XII. *Cf. Novísima recopilacion de las leyes de España* (1805), pp. 89-106. It is interesting to note that these policies contain the regulations for the course of medicine manifesting the ancillary character of surgery – and pharmacy – in seventeenth-century Spain. My analysis of these policies is based on Rueda Pérez (2013).

121 *Cf.* Velasco (1764), Rueda Pérez (2013).

lowest careers and had no place amongst the university milieu.[122] Therefore, as the training as a *Cirujano Latino* implied a greater intellectual effort and no economic or practical benefits, the profession of Surgeon in Spain was soon broken down, both in its practice and its social recognition. As their education was extremely superficial, the *Cirujanos romancistas* or *barbero*, were seen almost as butchers.[123]

This panorama was radically changed by the reforming actions of Pedro Virgili at the *Real Colegio de cirugía* of Cadiz. Promoted by La Ensenada as part of his policies for modernizing of the Spanish Navy, royal colleges of surgery were thought of as centers of education for surgeons for the navy, under the precepts of early modern medicine. In order to set up these colleges, desired initially by the French Jean La Combe, Major Surgeon of the Spanish Army, La Ensenada appointed Virgili as their Director. Virgili was educated in Tarragona (Spain) as *Cirujano Romancista* by Gabriel Riera and in Paris by the French obstetrician André Levret under whom he probably learned the obstetrical techniques that Virgili mentioned in the *Compendio del arte de partear* (1765). He also had a solid training as a surgeon on ships – a position that he occupied in his three trips to America in the late 1730s. As I shall argue, he introduced the precepts of modern surgery in Cadiz, through the creation of a study plan founded on the principles of Boerhaave's appropriation of Newton's physics for medicine.[124]

[122] *Cf.* Rueda Pérez (2013), p. 114.

[123] This panorama of the Spanish surgery did not imply that there were exceptional cases, such as anatomist Martín Martínez who as a *novator*, besides highlighting the retrograde state of Spanish surgery, also embraced different anatomical traditions, most of which founded on Cartesian mechanics. See, for instance, his *Medicina sceptica y cirugia moderna* (1722).

[124] Despite of the historical importance of Virgili's work in the institutionalization of enlightened ideas on medicine and surgery in Spain, it is hard to find judicious studies on his works. Some details about his life and education are described in Comenge (1893), Albiol Molnè (1993), Rueda Pérez (2013)

Figure 7. Pedro Virgili. Francisco Galofré Oller (1895), Galería de Catalanes Ilustres del Ayuntamiento de Barcelona.

The foundation of the *Real Colegio de cirugía* of Cadiz met the military necessities of Spain during the belligerent period of the 1740s-1750s. After the War of Jenkins' Ear (1739-1748), which officially ended with the *Treatise of Aix-La-Chapelle* (1748), leaving the relationship between Spain and Great Britain in a delicate state, the Marquis of La Ensenada had discovered that one of the basic problems of the Spanish Navy concerned the training of its surgeons, who were either Spanish *Cirujanos Romancistas* or poorly-trained foreigners. In this context, the creation of the *Real Colegio de Cirugía* attempted to solve these problems through the consolidation of a solid study plan based on in-depth study of the anatomy, as initially desired by La Combe.[125] However, after being appointed Director, not only was Virgili concerned about education on anatomy for students who were obliged to attend dissections in the amphitheater of the Hospital of Cadiz, but he was also keenly interested in educating his students in the traditions of European medicine, by then well-rooted in Boerhaave's works. As a consequence, he created a study plan according to which, in addition to courses on anatomy with a theoretical-practical content, students also had to attend courses on mathematics, mechanics, and experimental philosophy, which constituted a precedent and a guide not only for Juan's study plan for the *Real Colegio de guardiasmarinas* but also for Mutis' reforms of medical studies in New Granada in the early-nineteenth century. In so doing, Virgili introduced in Spain the principles for modernizing Surgery as a field founded on the application of chemistry, physics, and mathematics, thus producing a reevaluation of the social position of Surgeons in Spain.

In order to accomplish his reforming plan of the *Real Colegio de Cirugía*, as Rueda Pérez contends, Virgili sent some students to be educated in the most important faculties of medicine of Europe – Paris, Bologna, Leiden, and London – where they were to learn the principles of Boerhaave's approach to medicine and physiology.[126] Rodríguez Ballesteros has presented Virgili's strategy in a more detailed fashion, claiming that it was part of a modernization process of the Spanish academic military institutions centered in Cadiz. For him,

> La física en España hasta entonces, entre gassendistas y cartesianos, quedaba por debajo del listón de la síntesis newtoniana; pero en Cádiz, además de contar con la presencia de J. Juan y L. Godin (1704-1760), los maestros y alumnos del Colegio

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[125] Historical details on the creation of the *Colegio de Cirugía* of Cadiz and its relation to the Spanish Army are in Ferrer (1983).
[126] *Cf.* Rueda Pérez (2013), p. 115.

> de Cirugía viajaron pensionados a las más prestigiosas universidades europeas. Los que permanecieron en Leiden de 1751 a 1753 entraron en contacto con la escuela de Boerhaave a través del físico newtoniano, inventor de la botella de Leiden, Musschenbroek y el ginebrino Allamand (2004: 480).

Interestingly, as Rodríguez Ballesteros claims, Cadiz turned into a center of appropriation of Newton's physics not only because of the presence of Juan and Goudin, whose works I have characterized in the last section. Virgili's efforts for modernizing Spanish Surgery through the consolidation of a strong program for the *Colegio de Cirugía*, based on the influence of Newtonian medicine developed in the early-eighteenth century, also played a fundamental role in this process. In general, we can see that they helped to institutionalize a Newtonian approach to different disciplines in Cadiz, in which mathematics and a Newtonian theory of matter allowed students to study nature and apply such understanding in solving practical problems related to animal economy. It is interesting to highlight as well that Mutis was supposed to be part of this group of students being educated in Europe, as he himself explains it in his *Diary of observations* [*Diario de observaciones*], written before he travelled to New Granada – a position that he dismissed in order to travel there as physician and surgeon of Pedro Messia de la Cerda.

As a result of Virgili's reformism, as Juan Riera explains, the *Real Colegio de Cirugía* of Cadiz, turned into "el centro quirúrgico español que mantuvo mayor contacto con la cirugía europea" (1976: 156). Furthermore, Virgili consolidated the integral education of students by creating a botanical garden, where they could be trained in natural history and its application to pharmacopeia. Thus, by introducing Boerhaave's medicine in Spain through his own study plan at the *Real Colegio de Cirugía* of Cadiz and by promoting the training of students in different European faculties of medicine, Virgili became a disseminating agent of Newton's physics in

Spain. In other words, unlike Juan, Virgili did not promote Newtonianism through the diffusion of Newtonian works in his specific field of study. Instead, he made the institutionalization of Newtonianism possible in Cadiz through the creation of a study plan that encouraged the learning of different university traditions which encouraged the application of Newton's theories to medicine, physiology, and chemistry ever since the early-eighteenth century. He did this in a specific manner by encouraging the study of Boerhaave's works at the *Real Colegio de Cirugía de Cadiz*. As I shall explain later, Boerhaave's conception of medicine and physiology was influenced by the so-called Newtonian medicine, developed by Pitcairne, Cheyne, and James Keill during the early eighteenth century. This approach to medicine was not only based on the application of a strict mathematical mechanization of the animal economy, which historians like Anita Guerrini and Theodore Brown have denominated iatromathematics, but also on the explanation of several physiological and chemical phenomena in terms of attractive forces, which are similar to Newton's characterization of gravity. In this sense, by considering the implications and consequences of Newton's mathematical approach to nature and the Newtonian theory of matter for the medical field, Virgili extended the scope of Spanish Newtonianism which I have analysed in this chapter: Feijoo introduced the need to apply mathematics to account for experiments, thus consolidating the experimental tradition in Spain; Juan presented Newton's mechanics and physics, as well as the application of mathematics to explain natural phenomena; finally, we complete this panorama with Virgili, thanks to whom the introduction was possible of the application of Newton's physics and mechanics to the explanation of physiological and chemical phenomena.

As we can see, by considering the context of Mutis' education in Cadiz it is possible to explain his interest in Newton's works and the formation of his particular Newtonianism. Educated during the era of the modernizing reforms that La Ensenada promoted in Cadiz's naval academies which were implemented by Juan and Virgili, Mutis found a rich intellectual environment, diametrically different to that of the Spanish universities in which the scholastic Aristotelianism in physics and the Galenic tradition in medicine still dominated. In other words, Mutis' education as a surgeon and physician is framed by the tradition of Newtonianism introduced by Juan and Virgili in Cadiz and institutionalized through the royal patronage of La Ensenada and several particular intellectual societies, like Juan's *Asamblea amistosa literaria*.

Chapter 3. Newtonianism in Mutis' lectures on mathematics: utility and the mathematical study of nature

Unawareness and myth in the studies on Mutis' lectures

As historians such as Arboleda and Olga Restrepo Forero argued, Mutis' lectures on mathematics have been frequently presented covered by the fog of the myth. As of Mutis' times, his lectures were perceived by his students, local authorities, and visitors as the establishment of the Enlightenment in New Granada.[127] These historians have supported such characterization by using the image of Mutis constructed by important figures who directly knew him, such as Caldas or Humboldt, whose descriptions depict the important role of Mutis' pedagogical enterprise in the construction of an intellectual milieu opposed to the environment of the universities. However, as Clara Helena Sánchez and Víctor Álbis commented, "Poco sabemos de los contenidos de la cátedra de matemáticas, salvo el Discurso Preliminar y la Primera Lección" (2012: 110). In this sense, we can argue that Mutis' mythical figure emerged as a result of the positive appraisement of his pupils and acquaintances rather than on a certain knowledge of the content of his lectures on mathematics and physics.

The problem of identifying the content of Mutis' lectures has been tackled by historians such as Arboleda, Restrepo Forero, and Álbis, who have studied Mutis' published manuscripts

[127] See, for instance, Viceroy Pedro Mendinueta y Múzquiz's commentaries on Mutis' role in New Granada's educational reform in Mendinueta y Múzquiz (1869), pp. 482-490. Although Francisco José de Caldas' relationship with Mutis varied from a naïve admiration to a clear contempt, his first letters to Mutis reveal the general consideration on the importance of the latter in the consolidation of New Granada's educational reforms. *Cf.* Caldas (2016b), pp. 113-116.

in the different editions made by Guillermo Hernández de Alba.[128] Likewise, Arboleda and Álbis have studied several unpublished manuscripts, in which they discovered that Mutis also translated Newton's *Principia* for his lectures. A new image of Mutis' figure and his lectures at the *Colegio Mayor de Nuestra Señora del Rosario* have emerged as a result of the study of the manuscript sources, characterized, as Arboleda suggests, by the influence of Newton's physics, Wolff's mathematics, and several features of Descartes' mathematical approach to natural philosophy.[129]

However, by studying the unpublished manuscript sources that are in the archives of the *Real Jardín Botánico* of Madrid, unknown aspects of Mutis' lectures on mathematics can be identified. The purpose of this chapter is to shed light on the contents of Mutis' lectures by studying in detail these manuscripts sources. In this way, I intend to explain the content and scope of said lectures, in which Mutis dealt with issues of arithmetic – and particularly logarithms – and geometry and their relationship with the study of nature. Consequently, it should allow me to explain what Mutis understood as "Newton's experimental physics" and its theological implications. In this context, I shall show that Mutis used Wolff's *Elementa matheseos* and Descartes' *Géométrie* as textbooks for his lectures, using translated versions into Spanish that he himself made, probably with the purpose of dictating them to his students.[130] These manuscripts have not been considered as translations so far and they constitute one of the most interesting findings of this research. I shall argue that, in using these works as references, Mutis presented a particular notion of mathematics and its application to the study of nature influenced by a

[128] Several of Mutis' manuscripts have been published in Mutis (1982) and Mutis (1983a). Likewise, several excerpts have been published in Gredilla (1911).
[129] *Cf.* Arboleda (1993).
[130] As Rivas Sacconi has explained, because of the lack of printed textbooks, one of the most common practices among university professors in New Granada was to dictate to their students the content of their respective subjects. According to him, because of the lack of books and the difficulty to purchase them, the professors were forced to dictate the content of their courses – the result of which was called *mamotretos*. *Cf.* Rivas Sacconi (1993), pp. 64-65.

mechanical idea of the production of curves, close to the notions of the *geometria organica*. Likewise, by emphasizing the role of logarithms in the study of the motion of bodies, Mutis established the foundations for presenting the utility of calculus in the study of the motion of bodies in conic sections. A fundamental feature for his lectures on physics during the 1770s in which he discussed Newton's physics and its mathematical explanations of natural phenomena.

I divide this chapter in three parts. Firstly, in sections one and two, I study Mutis' general considerations on the utility of mathematics and its applications to different disciplines as he discussed it in the *Preliminary discourse for the inauguration of the course of mathematics* [*Discurso preliminar pronunciado en la apertura del curso de matemáticas*]for the lectures on mathematics of 1762 and the manuscript entitled *Mathematical method* [*Método matemático*]. In these sections, I explain that Mutis' description of the relationship between mathematics and natural philosophy is produced in the light of his particular interpretation of "Newton's experimental physics" and, as a result, it constitutes the first Newtonian element that Mutis discussed in New Granada. I also argue that Mutis' works on mathematics are actually translations of some passages of Wolff's *Elementa matheseos* and Descartes' *Géométrie*. Secondly, in sections three and four, I study Mutis' textbooks on arithmetic and geometry. In these sections I explore his translations, presenting them as the *mamotretos* that Mutis used to dictate to his students at the *Colegio del Rosario*. It allows to understand the role of these lectures in the introduction of Newton's physics in New Granada in the 1760s and 1770s. In section five, I study Mutis' manuscripts on calculus. As these manuscripts are too vague and probably incomplete, I only present here some suggestions on the extent of Mutis' understanding of calculus, his presentation of it, and its application to the study of the motion of bodies. Lastly, I conclude that Mutis' lectures on mathematics should be understood as the result of his struggle for presenting mathematics as the foundation of any study of nature, which constitutes the establishment of the basis for his students to understand his own conception of Newton's experimental physics.

The utility of mathematics: Mutis and the relationship between mathematics and physics

Mutis traveled to New Granada as physician and surgeon of the newly elected Viceroy Pedro Messía de la Cerda. By accepting such position, he neglected the possibility to continue studying medicine at Paris, Leiden, or Bologna, commissioned by the Spanish Crown – with some other outstanding young Spaniard students – and eventually a position in the Royal Court.[131] 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: "Pensaba yo desde España que a estas horas me hallaría caminando hacia Loja, con el fin de investigar la *Quina*" (Mutis, 1957 I: 104). Certainly, medicine occupied almost all of his time; however, his frustration regarding his initial plan was emphasized in 1762, when he accepted to teach mathematics at the *Colegio Mayor de Nuestra Señora del Rosario* (hereafter, *Colegio del Rosario*). Mutis accepted this endeavour as the result of a promise he made on the ship that tooked him, Viceroy Messía de la Cerda, and his vice regal court to the New World. As Mutis describes it in his *Diary*: "Yo había prometido en el navío que daría en mi casa un curso de Matemáticas a la gente joven que acompañaba a S. Ex. Sin embargo de haber pasado mucho tiempo desde nuestra llegada a Santa Fe, me hicieron los oficiales y pajes del virrey que cumpliese mi palabra" (Mutis, 1991: 201). Actually, Mutis' casual promise turned into a formal endeavour as the Director of the

[131] *Cf.* Gredilla (1911), p. 14, Amaya (1986), p. 6.

Colegio del Rosario, José Joaquín León y Herrera, asked the Viceroy to create an official course on mathematics in the cloisters of the college. The Viceroy accepted León y Herrera´s proposal and Mutis reluctantly inaugurated on March 13th of 1762 the first course on mathematics ever created in the Viceroyalty of New Granada.[132]

Mutis' lectures on mathematics had the purpose of training the students in the basic elements of arithmetic and geometry, with several introductory elements of both the differential and integral calculi. He began his lectures with the *Preliminary discourse* where he explained the utility of mathematics for the development of several fields and particularly for the study of nature and God's providence.[133] In his lecture, Mutis referred to Newton for the first by characterizing his experimental approach to nature, which Mutis called "experimental physics" [*física experimental*]. In his opinion, such approach makes it possible to relate mathematics to physics in a manner that implies the rejection of the scholastic conception of physics as it was defended in New Granada's and Spain's universities.[134] As a result, Mutis' *Preliminary discourse* not only should be understood as a defence of mathematics based on its utility for the development of different fields and the knowledge of nature, but as a rejection of the scholastic milieu characterizing New Granada's and Spain's university education.

Following some ideas promoted by the Spanish Enlightenment in the 1740s, Mutis' *Preliminary discourse* begins by assessing any discipline by its utility in daily life. In his opinion, "siendo tan manifiestas para el mundo sabio las utilidades de las matemáticas no es de extrañar

132 Mutis' reluctant acceptance was probably caused by two facts. On one hand, because he had already rejected the course on Medicine proposed by León y Herrera, which evidences his lack of desire of being related to New Granada's academic milieu – he constantly complained about the retrograde state of Viceroyalty's education. *Cf.* Palacios Sánchez (2008). Details on the creation of the course and its content are in Arboleda (1993). On the other, the lectures occupied the time he would like to use for natural history.
133 Mutis' *Preliminary discourse* has been transcribed by Hernández de Alba in Mutis (1982) and Mutis (1983a). A draft manuscript version is in RJB III, 7, 1, 1, ff. 1r-1v.
134 *Cf.* Mutis (1982), pp. 33-34.

que muchos hombres de competencia hayan rodado en esta parte por todos los siglos con mejor fortuna que en las otras ciencias" (Mutis, 1982: 33).[135] Mutis claimed that the historical emergence of this appraisement of the utility of mathematics occurred in the late-seventeenth century, arguing that it was reflected in its application to different fields, especially to the investigation of God's providence. By considering the theological implications of the mathematical investigation of nature, Mutis also analysed its religious consequences, which are reflected in the fact that knowing God's actions allow men to determine the best manner to adore him. A manner that, according to Mutis, was legitimized by the Holy Scriptures and the Church Fathers:

> Un modo de conocer en alguna manera aquel Ser Supremo, de donde dimana todo lo creado, es una cierta obligación con que debe alabar la creatura al Creador. Es un modo de adorar al verdadero Dios tan inseparable y familiar al hombre, como que se le entra por los sentidos, tan al propósito, como que es el medio más oportuno para conocer al Creador, suelen ser las creaturas y últimamente tan necesario como recomendado eficazmente por las Divinas Escrituras y Santos Padres (Mutis, 1982: 35).

As Mutis characterized it, the tradition of relating mathematics and theology comes from Newton's mathematical study of nature in the seventeenth century. For Mutis, by using mathematics, Newton discovered and explained the laws of motion that God created for ruling natural phenomena. In this sense, in his opinion, studying natural phenomena entails the possibility of reducing them to mathematical laws which, in the end, lead the men to knowing God. Mutis supports this conclusion on the assumption that God created a set of laws that can be expressed in mathematical terms and on the idea that said laws rule the behavior of

[135] It is important to point out that Mutis did not consider Spain as part of *el mundo sabio*. Conversely, he continuously criticized Spain's educational system, describing it as retrograde. *Cf.* Amaya (1986), pp. 21-23.

measurable bodies. In Mutis' words: "Cuando creó Dios al mundo, esta máquina tan maravillosa, que no acabaremos de admirar bastantemente, parece haber formado entonces el alto designio de poner en práctica las leyes matemáticas. Todo lo dispuso en número, peso y medida con un orden y establecimientos tan constantes que permanecerán hasta cierto día" (Mutis, 1982: 35). As I shall argue, Mutis' conception of the "mathematical laws" with which God controls nature is related to his own conception of "Newton's experiental physics" as he considered that mathematics not only should be used as an external frame for studying nature, but fundamentally as an explicative system of natural phenomena. Consequently, in the *Preliminary discourse*, Mutis did not only refer to "Newton's experimental physics" in general terms, but he also included a specific characterization of what he considered one of its central features: the assumption that God disposed bodies in nature in a measurable manner and their mutual interactions are ruled by mathematical laws.

Likewise, the passage also contains some hints that reveal other traditions permeating Mutis' eclectic thought. For instance, we can find there the mechanical metaphor of a machine-like universe. By considering Mutis' educational context, as I characterized it above, we can assume that he was dealing with different currents of mechanics, encompassing Cartesianism, Gassendi's atomism, and Newton's physics. Therefore, we can conclude that despite that Mutis' conception of the natural philosophy was strongly informed by Newton's mathematization of nature, his conception of the universe was the result of his eclectic interpretation of different – and not necessarily compatible – traditions where multiple mechanical systems converged.[136]

[136] As multiple historians have argued the general category "mechanical philosophy" is highly problematic when it is used for characterizing the different traditions emerging during the seventeenth century to explain the phenomena of motion. In effect, in such category have been placed the works of natural philosophers as differents as Newton, Descartes, Hobbes, Galileo, Gassendi, Leibniz, *inter alia*. Therefore, it must be borne that Mutis' use of different mechanical traditions should be understood as part of his eclecticism. An interesting study on the mechanization of natural philosophy and the different versions of mechanical philosophy of the seventeenth century is in Garber & Roux (Eds.) (2013).

After the introduction, Mutis proceeds to demonstrate the utility of mathematics in the fields of logic, physics, and medicine. In the case of logic, for instance, he argues that the mathematical method of analysis and synthesis is an application of the principles of logic in order to demonstrate the certainty of a proposition. Accordingly, when mathematics is applied to logic it should be considered as an instrument for training the mind in order to proceed demonstratively from particular propositions to the discovery of general ones.[137] Such a characterization has led to historians such as Arboleda, Mauricio Nieto Olarte, and Regino Martínez Chavanz to argue that Mutis only considered mathematics as an external frame of thought.[138] I shall argue in the next chapter that this idea is founded on the lack of awareness of the manuscript sources, where we can clearly see that by teaching Newton's mathematical principles applied to the study of the motion of bodies in conic sections, Mutis also used mathematics as a source of explanations of natural phenomena.

However, the specific point where Mutis more diligently analyses the influence of mathematics in other fields is when he comments the relationship between mathematics and physics and its theological implications. In Mutis' opinion, by studying nature with the use of mathematics it is possible to know God's mathematical laws. In this sense, for him, the utility of mathematics in physics relies on the fact that it provides evidence for arguing about God's providence. Nevertheless, the importance of the relationship that Mutis presents between these disciplines does not exclusively rely on its theological implications. For the purpose of this research, it is equally important to highlight that, in the establishment of said relationship Mutis makes an explicit reference to Newton's experimental physics and therefore it constitutes the first explicit reference to Newton's ideas in New Granada.

[137] *Cf.* Mutis (1982), pp. 35-36.
[138] Arboleda (1993); Martínez Chavanz (1993), p. 73; Nieto Olarte (2006), p. 218.

Mutis' characterization of what he considers to be Newton's experimental physics begins by presenting a brief historical description of its emergence. According to Mutis, Newton's approach to nature was originated in the seventeenth century as an opposition to two different systems of natural philosophy: the systematic Aristotelianism and the hypothetical philosophy.[139] Mutis argues that hypothetical philosophy emerged in the seventeenth century as a consequence of the opposition to the authority of Aristotle and the medieval scholasticism, which Mutis characterizes as a "philosophical sect".[140] On the other hand, although hypotheses were not the best way to explain nature, Mutis contends that the hypothetical philosophy was useful in the sense that it was an opposition to the Aristotelianism dominating the university panorama. Nevertheless, the hypothetical philosophy replaced the doctrinaire authority by a system of suppositions assumed as real representations of the world. Therefore, Mutis argues, it also failed in its attempt of explaining nature in a proper manner.[141] Despite that there is no an explicit reference to Descartes in this passage, we can assume that Mutis, being an advocate of Newton's experimental physics, was thinking on him when he referred to the philosophers that developed hypothetically-deduced systems.[142]

Conversely, experimental physics, as Mutis describes it, emerged as an approach to the study of natural phenomena opposed to these traditions. In his words: "Si todos los sabios se hubiesen destinado a no fingir, sino a buscar los movimientos de la naturaleza por la observación hubiera sido más corto el camino para hallar la verdad" (Mutis, 1982: 38). Thus, Mutis claims that the path to find the true has been opened recently by Newton and the Newtonians: "El

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[139] *Cf.* Mutis (1982), p. 37.

[140] It is worth noting that Mutis' presentation of Aristotelianism and hypothetical philosophy as "philosophical sects" resembles Feijoo's *Cosmosia*, a fable in which he depicts the historical emergence of experimentalism as a rejection of philosophical sects. *Cf.* Feijoo (1773a, V), pp. 256-260.

[141] *Cf.* Mutis (1982), pp. 37-38.

[142] Arboleda and Soto pointed out the anti-Cartesian nature of Mutis' pronouncements on natural philosophy in the different published versions of his manuscripts. *Cf.* Arboleda & Soto (1992).

camino está ya abierto en nuestros días y son imponderables los aumentos que ha recibido la física por el grande Newton y por sus esclarecidos secuaces Gravesande, Munschembroek [sic] y Mollet [sic] entre otros igualmente acreedores a las mayores alabanzas" (Mutis, 1982: 38).

In the presentation of what Mutis understood as Newton's experimental physics in his *Preliminary discourse*, we can see two features which are going to be fundamental in the process of introduction of Newtonianism in New Granada. Firstly, Mutis considered Newton's experimental physics as the only appropriate method to study nature because its propositions were demonstrated experimentally and explained mathematically. According to Mutis,

> ¿Y quién dudará que todo el aumento de la Física experimental le ha venido por las observaciones, experimentos y la justa aplicación de las matemáticas? Los matemáticos más insignes del pasado y presente siglo han ilustrado la Física con las demostraciones y varios cómputos analíticos propios a descubrir muchas verdades, que se hallaron después acordes con las experiencias. Debería yo alegar pruebas más específicas y determinadas, si todo el cuerpo de la Física Newtoniana no fuese una continuada prueba de lo mismo que llevo dicho (1982: 38).

For Mutis, as a matter of fact, Newtonian physics represented an evidence of the important role of mathematics in explaining natural phenomena as the general propositions it postulates are mathematically gathered and deduced from experiments and observations. Secondly, Mutis used as a reference the works of the Newtonian Dutch experimentalists in order to describe the scope of Newton's physical theories. As Arboleda suggests, the reception of Newton's physics in Spain was deeply influenced by its appropriation in the Netherlands and consequently it would be natural for Mutis presenting several aspects of Newton's experimental physics using the works of Dutch Newtonians as theoretical and practical references.[143] Although I have pointed above that the historical category of Newtonianism is problematic and, following Ducheyne's and van Besouw's arguments, it should be especially reconsidered in the case of the appropriation of Newton's physics in the Netherlands, by considering Mutis' statements in his *Preliminary discourse*, we can see that it was perceived as a single body of theories in Spain, disregarding the particular variations developed by each of the so-called Dutch experimentalists.

Finally, Mutis concludes his historical reconstruction of the application of mathematics to physics after Newton's works by illustrating it through the case of the determination of the weight of the air and its mechanical functions. It was a paradigmatic issue of experimental physics since the late-seventeenth century, and one of the basic topics motivating the introduction of experimental physics in Spain in the eighteenth century,[144] as it was evidenced by its constant presence in Feijoo's *Teatro Critico*.[145] It is likely that Mutis knew the mechanical functions of the air and their quantification through his study of Feijoo's works or Juan's analysis of the mechanics of fluids in his *Observaciones*, but it is important to highlight that when Mutis describes the weight of the air and its mechanical functions, he refers to the same quantities that Herman Boerhaave presented in his *Elementa chemiae* (1732), when he dealt with the physical properties of air.[146]

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143 Arboleda (1993), p. 64.

144 Since the postulation of Boyle's law, the works of Mariotte, and Torricelli's and Pascal's barometrical observations, the development of studies on atmospheric pressure led to the development of hydraulics in the eighteenth century and the problems related with the mechanical functions of the air and how to use them became in one of the central issues for natural philosophers and mathematicians such as Halley, Newton, Casssini, Euler, and Laplace. Interesting reconstructions of the development of these fields are in Cajori (1929) and Frisinger (1974).

145 Feijoo specifically refers to the problems of the weight of air in the *Discurso XI*, Volume II of his *Teatro crítico universal*. *Cf.* Feijoo (1773a, II), pp. 244-250.

146 *Cf.* Boerhaave (1753), p. 387. Boerhaave's *Elementa chemiae* was originally published in 1732 at Leiden. I am using Shaw's translated version of 1753, *A new method of chemistry*.

Mutis' implicit reference to Boerhaave should not be overlooked, because, as I explained above, his formation in surgery at the *Colegio de Cirujanos* of Cadiz under the aegis of Virgili, allowed him to embrace an iatromechanical conception of surgery and medicine which also was related to Newton's theory of matter as it was applied to medicine and physics. In addition, such connection with Boerhaave was important from an argumentative point of view because, after explaining the connection between mathematics and physics, Mutis comments the utility of mathematics in medicine. In so doing, he embraced an iatromechanical conception of medicine, in which the human body is presented as a microcosm where it is possible to perceive the action of the same laws affecting the bodies in the macrocosm.[147] In Mutis' words:

> Recorred, Señores, el dilatado campo de la naturaleza y no hallareis ante alguno que haya dado asunto más dilatado para más reflexiones que el cuerpo humano, llamado con razón mundo pequeño, en cuya fábrica se esmeró la omnipotencia del Creador. Las más de las leyes con que se hacen los movimientos en el grande mundo se observan también en el cuerpo humano, sobre otras que le son muy particulares por razón de la vida (Mutis, 1982: 39-40).

As we can see, Mutis' *Preliminary discourse* constitutes the first step in the reception of Newton's experimental physics in New Granada during the second half of the eighteenth century. In it, Mutis discussed several features of Newton's experimental physics which were recurrent in the process of its diffusion in New Granada. Firstly, Mutis emphasized and praised the mathematical character of the explanations developed in Newton's approach to physics. This mathematical

[147] As I shall comment in Chapter 5, in accounting physiological phenomena, Boerhaave articulated both the iatromechanical and the iatrochemical traditions attempting to develop the best therapies for multiple diseases. In so doing, he moves from a strict mechanical conception of medicine to a more generalized idea of medicine, in which Newton's analysis of attractive forces play a fundamental role in explaining physiological and chemical operations.

character, not only was reduced to the use of mathematics as an external frame of thought, but as a source of explanations of natural phenomena. In this sense, for Mutis, the utility of mathematics was not limited to its application to the rethoric of the demonstrations as he conversely considered it to be a fundamental aspect of natural philosophical investigations. He framed such a consideration in the idea that nature was organized following the mathematical laws that God created. Secondly, Mutis praised Newton's experimental physics, which he considered to be the ultimate source of examples of the utility of mathematics in explaining natural phenomena. Lastly, he made explicit references to Newton's achievements and to the works of Newtonians. As a result, a detailed study of Mutis' lectures on mathematics and physics provides enough evidence in order to describe the process of appropriation of Newton's experimental physics in New Granada.

The scope of Mutis' lectures on mathematics

Because of the multiple activities Mutis was involved into and different social circumstances, Mutis' lectures at the *Colegio del Rosario* took place in two different periods of time. The first period goes since the year 1762, when the lectures on mathematics were firstly established, up to 1766, when Mutis was appointed Director for the exploitation of the mines of *Real de Montuosa*.[148] In this period, Mutis was forced to combine his activities as professor of mathematics with his duties as physician of the vice regal court, which occupied almost all of his time. In addition, it should be noticed that the course was cancelled in 1763 because Mutis had to move to Cartagena with Viceroy Messía de la Cerda, who had to move his office there to

148 As part of his mining activities, it is worth noting that Mutis introduced in New Granada the method of amalgamation of silver. For Mutis' mining activities, see Pelayo (1990).

attend the problems arisen from the British invasions to the Spanish ports in the Caribbean.[149] The second period began in 1770, when Mutis moved back to Santa Fe, up to 1777, when he left the university cloisters to mining one more time as he was appointed Director of *Real de Minas de Sapo*.[150] Despite the polemics with Dominicans regarding Copernicanism, this second period was favourable for Mutis as he witnessed the promotion of his course of mathematics, through the creation and implementation of Moreno Escandon's plan for reforming New Granada's educational system. The plan was thought as the cornerstone for the creation of a public university in Santa Fe, filling the space left by the expulsion of the Jesuits from the Spanish territories in 1767.[151]

As regards the content and order of Mutis' lectures, the lack of evidence has made it difficult for historians of science in Colombia to clarify the specific subjects he dealt with and their disposition in the order of the lectures. In general, only few of Mutis' manuscripts in the archives of both the *Real Jardín Botánico* of Madrid and the *Archivo General de la Nación* of Bogotá are dated. Therefore, although it is a remarkable fact to have the manuscripts containing his lectures on mathematics and the different issues he taught at the *Colegio del Rosario*, it is difficult to establish the precise order in which he presented them. However, based on the manuscript evidence, I shall argue that Mutis' lectures on mathematics dealt with four basic subjects in a specific order. Firstly, he presented an introduction to the basic concepts and tenets of mathematics as well as to its methods. In this sense, it is likely that, because of its introductory character, the manuscript entitled *Mathematical Method* [*Método Matemático*], containing the

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149 British assaults in the Caribbean in the 1750s and 1760s were part of the conflicts of the Seven Years' War. As Cartagena had been an important target for British Navy since the War of Jenkin's Ear, Messia de la Cerda had to move his office there to defend it from a possible attack. An analysis of the strategic role of Cartagena de Indias in the Seven Years' War is in Harding (2012), pp. 297-300.

150 Mutis' biographical references are mostly extracted from Gredilla (1911).

151 Polemics about reforms to education in New Granada during the 1770s and especially Moreno Escandón's plan have been studied in detail in Hernández de Alba (1961), Soto (2011). I shall study them in Chapter 6.

elements of the method of analysis and synthesis and the definition of several basic mathematical concepts, followed his *Preliminary discourse*. Secondly, the manuscript evidence suggests that the following topic that Mutis dealt with in his lectures was arithmetic, as he himself placed it after the *Preliminary discourse*. In the beginning of his manuscript on arithmetic, called *Elements of arithmetic* [*Elementos de arismetica* [sic.]] Mutis claims: "En el discurso preliminar manifesté a Vmos. en compendio la utilidad de las matemáticas para las otras ciencias" (RJB, III, 7, 1, 5, f. 436r). Ostensibly, the third topic Mutis taught was geometry and his manuscripts on this topic deal with the so-called *geometría plana*, the Euclidean geometry, also containing several elements of trigonometry. Finally, we also find among Mutis' manuscripts several lectures on Newton' calculus of fluxions and integral calculus. However, these manuscripts are really vague as they only contain introductory concepts of differential calculus rather than any characterization of the integral calculus. It seems that Mutis' manuscript entitled *Elements of integral calculus* [*Elementos del cálculo integral*], which is in the archives of the *Real Jardín Botánico* of Madrid, is an incomplete version of a longer treatise in which both differential and integral calculi were accounted for. Therefore, in order to find Mutis' explanation and use of Newton's calculus of fluxions, it is necessary to refer to other manuscripts where Mutis studied the motion of bodies in conic sections, determining areas under curves.[152] However, in general, it is difficult to determine whether Mutis included them in his lectures or if they were taught only for the most advanced students, a practice that Mutis used to apply as it is revealed in his plans for the medical and mathematical studies.[153]

[152] In this context Mutis' manuscript *Conocimientos para la inteligencia los fenómenos* reveals Mutis' application of calculus for the problems of the motion of bodies in conic sections. *Cf.* RJB, II, 7, 1, 5, ff. 325r-328r. I will study this treatise in detail in Chapter 4.

[153] In his plans Mutis claimed that professors needed to include lectures aimed to most advanced students in order to avoid slowing down their training. *Cf.* RJB, VII, 1, 17, ff. 1r-5v; Mutis (1983a), pp. 63-96.

Likewise, evidence for supporting that this was actually the order of Mutis' lectures is founded in his *Provisional plan for teaching mathematics at the Colegio del Rosario* [*Plan provisional para la enseñanza de las matemáticas en el Colegio del Rosario*] (1787), in which he commented that his lectures at the *Colegio del Rosario* were planned following Wolff's works.[154] Hence, it is likely that he also followed Wolff's specific order of presentation of the topics. Although Mutis did not specify the work of Wolff he used, by studying in detail his manuscripts on arithmetic, it is possible to conclude that he used Wolff's *Elementa Matheseos Universae* (1713) as textbook in a translated version that Mutis himself prepared for his lectures. Said translation, as far as I know, had not been identified as such by any historian working on Mutis' manuscripts and it is the only translation into Spanish of any of Wolff's mathematical works.[155] For example, Arboleda pointed out that some passages of the manuscript on the mathematical method "resembles" [recuerdan] Wolff's *Discours préliminaire sur la méthode dont on se sert pour traiter les mathématiques* (1757), which is the French version to the introductory chapter on the method in Wolff's *Elementa*. As a result, Arboleda concludes that, rather than Newtonian, Mutis is a Wolffian mathematician, who went back and forth between that position and a methodological Cartesianism.[156] However, although Arboleda's interpretation seems to be consistent with the evidence, I believe that his characterization of Mutis as a Wolffian mathematician should be nuanced as it only depicts a partial image of the scope of Mutis' lectures on mathematics. Thus, I shall argue that more than a "resemblance" of Wolff's *Elementa matheseos*, Mutis' manuscripts on arithmetic are literal translations of several passages of it. In this sense, I shall conclude that Mutis only used Wolff's

[154] The study plan was commissioned by Viceroy Caballero y Góngora, who asked Mutis to create a plan for the reestablishment of the course of mathematics at the *Colegio del Rosario*, which had been cancelled in 1778. *Cf.* Mutis (1982), pp. 119-120.
[155] Wolff's only work available in Spanish nowadays is his *Vernünftige Gedanken von Gott, der Welt und der Seele des Menschen, auch allen Dingen überhaupt* which was translated into Spanish as *Pensamientos racionales acerca de Dios, el mundo y el alma del hombre, así como sobre todas las cosas en general (Metafísica alemana)* by A. González Ruiz in 2000.
[156] *Cf.* Arboleda (1993), pp. 45-53.

Elementa matheseos as a *mamotreto* for his lectures, intending to make it the textbook for his students to achieve the theoretical foundations of arithmetic.

After teaching arithmetic, Mutis dealt with geometry. Suprisingly, instead of keep using Wolff's *Elementa matheseos*,[157] in the case of the lectures on geometry, Mutis used Descartes' *Géométrie* (1637) as textbook. The manuscript entitled *Commentaries to Descartes' geometry* [*Comentarios a la geometría de Descartes*] actually is an almost complete translation into Spanish of Book I of the *Géométrie* as it was published and commented by the Jesuit Claude Rabuel in 1730.[158] As in the case of Mutis' translation of Wolff's *Elementa matheseos*, the translation of Descartes' *Géométrie* had not been considered by historians as such and it constitutes one of the most interesting discoveries that the research for this dissertation produced. It also is an evidence for arguing that translating was a basic practice in Mutis' pedagogical enterprise, as the translated works constitute the foundation of his dictates at the *Colegio del Rosario*. This conclusion is particularly suggestive by considering it in the light of his translation of Newton's *Principia*, carried out in the 1770s, and his translation of 's Gravesande's *Physices elementa mathematica* that I discovered in the archive of the *Real Jardín Botánico* of Madrid and that I shall describe in detail in the next chapter. However, as I shall argue, there are some distinctive features in Mutis' enterprise of translating Newton's *Principia* which differentiate it from the translations of Wolff's *Elementa*, Descartes' *Géométrie*, and 's Gravesande's *Physices elementa mathematica*. But, before studying in detail Mutis' translations of Wolff's and Descartes' works, let us consider the lecture on the mathematical method, following his *Preliminary discourse* of 1762.

As I pointed out above, Mutis' *Preliminary discourse* deals with the utility of mathematics for the progress of different fields. In it, Mutis claimed that mathematics are useful as they are

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[157] Wolff's study on geometry, including his study on trigonometry, is in Wolff (1732), pp. 97-232.
[158] *Cf.* RJB, III, 7, 1, 5, ff. 397r-416v.

the foundation of the certainty of several fields, providing them with the demonstrative character of their explanations. In this sense, the *Preliminary discourse* is rather a general defence of mathematics based on its utility than a presentation of its method or a description of how to proceed in mathematical demonstrations. Thus, the manuscript entitled *Mathematical Method*, which I assume as the lecture following the *Preliminary discourse*, fills up this gap by presenting the basic conceptual aspects on which any mathematical demonstration is founded. In Mutis' opinion, the certainty of mathematics depends on the application of three rules which allows the mathematician to proceed from simple intuitive definitions to more complex deductions:

> La primera es, que de las ideas más sencillas y más generales se ha de subir a las más compuestas y menos generales. La segunda es, que en la definición de los términos nada quede obscuro, nada quede ambiguo. La tercera es, que todas las proposiciones, cuyas verdades no constan a primera vista por la significación y percepción de los mismos términos con que se enuncian, se hayan de probar demostrando muchas verdades, y por medio de las definiciones supuestas, los axiomas concedidos y las proposiciones ya demostradas (Mutis, 1982: 125-126).

The rules Mutis presented, as we can see, imply that the veracity of the mathematical method is founded on the simplicity of the definitions used for demonstrating the more complex propositions deduced from them. Arboleda has suggested that the intuitive character of the definitions that Mutis asked for reveals that he combined Descartes' notion of the method and the rigorousness of Wolffian mathematical procedures. For Arboleda,

> Mutis quiere empezar a hablar del rigor del "método matemático"a un nivel lo más intuitive posible, dejando para el "lugar oportuno" la explicación de las "leyes que se deben observar para que la demostración sea buena". Esta precaución se

manifiesta en diferentes lugares de la lección. Así, pues, Mutis abandona el enfoque logicista y se inclina más bien por el enfoque cartesiano del método. (1993: 51).

In this sense, Arboleda argues that despite that Mutis conceived mathematics in a Wolffian manner, which is clear in the fact that he presented the basic concepts of mathematics in a very similar manner as Wolff, his notions on the mathematical method were based on a Cartesian conception of the intuitiveness of simple ideas.[159] In Arboleda's opinion, Mutis understood the geometrical method as a process of deducing propositions from intuitive, evident ideas as revealed in the fact that he opposed the syllogistic logic of scholasticism to the mathematical foundation of modern science – specifically of Cartesianism.[160] In this sense, we can see that although Mutis considered mathematical demonstrations as exemplary case of the application of logical principles, he was not considering logic in the sense of a logical concatenation of premises as in syllogistic demonstration. Rather, for Mutis, mathematical demonstration were more solid than syllogistic demonstations because they are based on simple principles whose veracity is undeniable from an experimental point of view.[161]

In explaining the first rule of the mathematical method, Mutis followed Wolff's introduction to *Elementa Matheseos* and defined the basic concepts and tenets used in mathematics: definitions, axioms, propositions, and problems.[162] Interestingly, Mutis also claimed that the order in which these basic concepts are deployed in mathematical

[159] *Cf.* Arboleda (1993), pp. 45-53.
[160] *Cf.* Arboleda (1993), p. 51.
[161] it is important to highlight that in the final passages of Mutis' *Mathematical method*, he emphasized the fact that mathematical demonstrations are nothing but an application of logical principles and consequently that it is not possible to establish a strict disciplinary breaking between logic and mathematic. *Cf.* Mutis (1982), pp. 132-134.
[162] As Wolff's *Elementa matheseos* is written as a general treatise on mathematics, he dedicates the introduction to the definition of the basic concepts of the field and the characterization of its method. *Cf.* Wolff (1732), pp. 3-13. An interesting study on Wolff's reasoning on mathematical method in the light of his and Leibniz's responses to Newton's works is in Dunlop (2013).

demonstrations vary if the propositions are related to either mixed or pure mathematical issues. In the former case, when the mathematician is dealing with mixed mathematics, Mutis argues that there is a need to include experiences and observations before corollaries and scholia.[163] This characterization is particularly interesting as it reveals that Mutis presented in his lectures a conception of mixed mathematics in which the mathematical demonstrations are founded on experiments and observations. In this sense, by considering the experimental nature of the basic definitions in mixed mathematics, he established the basis for arguing in favour of a mathematically-founded conception of nature. In other words, in both the *Preliminary discourse* and the *Mathematical method*, Mutis presented several aspects of the connection between natural philosophy and mathematic that anteceded his lectures on physics in which he defended Newton's method for studying nature.

Mutis' lectures on arithmetic: Wolff's influence and the importance of logarithms

In the context of the reestablishment of the lectures on mathematics in New Granada by Viceroy Caballero y Góngora in the 1780s, Mutis created in 1787 its study plan.[164] In his plan, Mutis argued that the lectures on mathematics at the *Colegio del Rosario* should be based on Benito Bails' *Elementos de matemáticas* (1772-1783) which replaced Wolff's *Elementa matheseos* that he had used

[163] *Cf.* Mutis (1982), p. 126.
[164] It must be borne that, as a backlash of the Dominicans against the reformism of Moreno Escandón's plan, the course of mathematics that Mutis inaugurated in 1762 at the *Colegio del Rosario* had been cancelled in 1778. Fernando Vergara, a pupil of Mutis, had the idea of reestablishing the course of mathematics in 1786, supported by *Director de Estudios* Estanislao Joaquín de Andino and Mutis himself, who was by then Director of the botanical expedition. *Cf.* Hernández de Alba (1983), pp. 102-110. For a general characterization of the polemics concerning the reforms of New Granada's educational system in the 1770s, see Hernández de Alba (1961), Soto (2009). I shall explain in detail in Chapter 6 the causes and consequences of New Granada's educational reformism of the 1770s and its implications for Mutis' pedagogical activities.

in the 1760s.[165] In commenting the reasons for changing, Mutis claimed that – besides of being in Spanish – Bail's *Elementos* was more updated and one of the greatest achievements of Spain's mathematics in the eighteenth century. In Mutis' words:

> Por fortuna logra hoy la España en el curso más completo y en su compendio el más bien reducido, las obras más excelentes de que no puede gloriarse a competencia alguna otra nación de Europa. Se ha trabajado con el mayor esmero de orden de la Real Academia de San Fernando por su director de matemáticas D. Benito Bails; cuyo acierto lo publican los aplausos en todas las escuelas de la Península, donde se halla universalmente adoptado (Mutis, 1983c: 112).

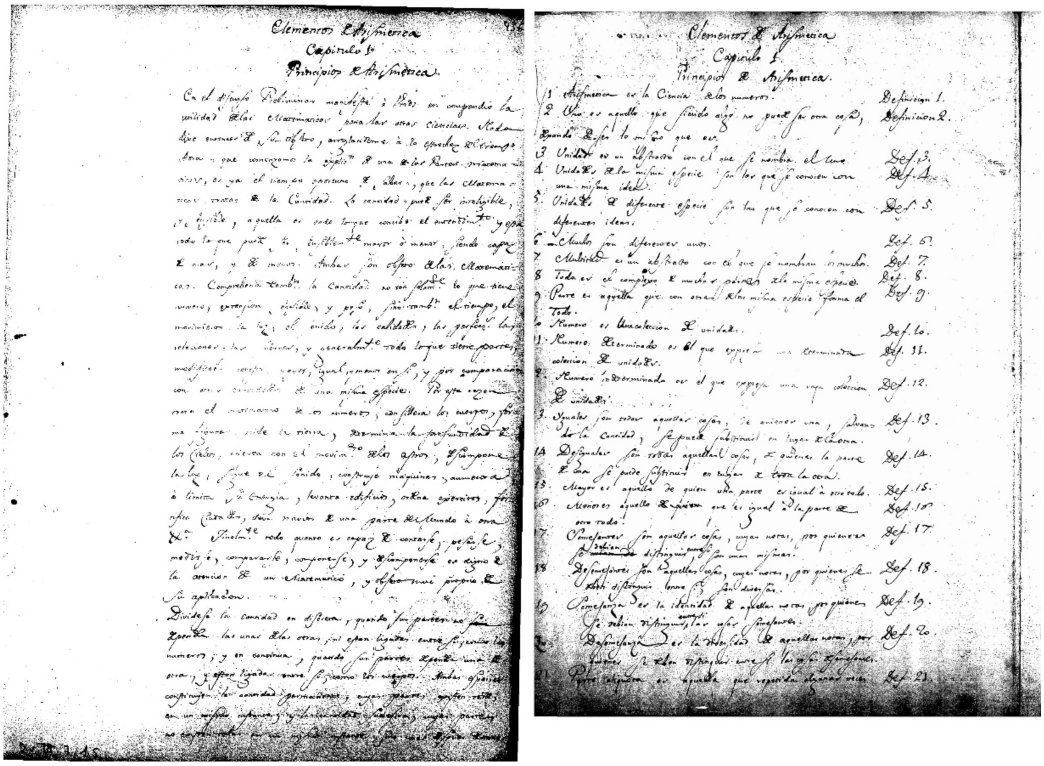

Figure 8. Front pages of the two versions of Mutis' Elementos de arismetica. The short version (left) is RJB III, 7, 1, 5, ff. 436r-458r; the large version (right) is RJB III, 7, 1, 5, ff. 460v-522r.

[165] Bails' *Elementos de matemáticas* consists of 11 volumes in which he not only explained the most basic issues of mathematics, but also problems related to infinitesimal calculus. It was one of the first works on calculus published in Spain. For an analysis of Bails' *Elementos*, see Arias de Saavedra Alias (2003).

Thus, the evidence reveals that Mutis' lectures of mathematics in the 1760s were carried out with Wolff's work *Elementa matheseos* as textbook and that he replaced it in the 1780s by Bails' *Elementos*. As I commented above, for his lectures, Mutis translated several passages of Wolff's *Elementa matheseos* as *mamotretos* for his dictates. Such passages are found in two separated manuscripts, both of them entitled *Elements of arithmetic* [*Elementos de arismetica* [sic.]] which complement each other (Fig. 8).[166] 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. Thus, for instance, in the shortest manuscript Mutis exclusively translated Chapter I of Wolff's *Elementa*, thus translating in detail the definitions of arithmetics. In this manuscript he also included Wolff's scholia and problems.[167] 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.[168] The shortest manuscript is also important because in it Mutis made a description of the historical approaches of mathematicians to the relation between physics and mathematics as it was related to the definition of quantity. As an introduction to his translations of Wolff's definition, Mutis included a prefatory commentary in which he argues that mathematics deals with quantities and that they can be considered either as intelligible or sensible. In describing sensible quantities, Mutis argues:

> Comprenden también la cantidad no tan solamente lo que tiene número, extensión sensible y peso, sino también el tiempo, el movimiento, la luz, el sonido, las calidades, las perfecciones, las relaciones, las suertes, y generalmente todo lo

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[166] 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.
[167] *Cf.* RJB III, 7, 1, 5, ff 436r-458r.
[168] *Cf.* RJB III, 7, 1, 5, ff. 460r-522r.

> que tiene partes, modificaciones, cotejos, mayor, igual y mayor en sí, y por comparación con otras cantidades de una misma especie (…) Por esta razón trata el matemático de los números, considera los cuerpos, forma figuras, mide la tierra, determina la profundidad de los cielos, acierta con el movimiento de los astros, descompone la luz, sigue el sonido, construye máquinas, aumenta o limita su energía, levanta edificios, ordena ejércitos, fortifica ciudades, lleva navíos de una parte del mundo a otra (RJB, III, 7, 1, 5, f. 436r)

In this sense, Mutis concludes that although ancient mathematicians divided mathematics in arithmetic, geometry, music, and astronomy, modern mathematicians have reconsiderd 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,[169]

> Las matemáticas puras consideran la cantidad en sí, sin considerar ella accidente alguno, ni afección sensible. Éstas son la artimética y la geometría, ambas universales (…) Las matemáticas mixtas, o no puras, consideran la cantidad vestida y acompañada con algún accidente o afección [illeg.]; *y como las afecciones sensibles pertenecen a la filosofía natural, o a la física, se llaman partes físico-matemáticas* (RJB III, 7, 1, 5, f. 436v).[170]

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 I suggested in the first section of this chapter,

169 *Cf.* RJB, III, 7, 1, 5, f. 436v.
170 My emphasis.

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 *Preliminary discourse*, Mutis presented mathematics as a theoretical and practical field, narrowly related to physics. In other words, by considering the application of mathematics to the study of nature and its theological consequences, Mutis proposed to his audience a reason for reevaluating the role of mathematics in the investigation of nature.

Notwithstanding, Mutis argued that in order to be able to study nature from a mathematical pont of view, the natural philosopher needed to know the theoretical principles underlying pure mathematics: "Antes de entrar en la doctrina de las físico-matemáticas es menester hallarse perfectamente instruidos en las puramente matemáticas" (RJB III, 7, 1, 5, f. 436v). Such a characterization of the process required to be able to study mixed mathematics reveals that Mutis thought his lectures on mathematics with an instrumental purpose as he considered them conceived as a foundation to know the theoretical elements that his students needed to be capable to study nature under the precepts of what he understood by Newton's experimental physics. This fact is particularly important as it reveals that Mutis' ultimate purpose with his lectures was connected with the enterprise that motivated him to go to New Granada in the first place: the botanical expedition. By educating young pupils in mathematics and its relation with the study of nature, Mutis intended to make up his own personal *scientific community* in which he could deploy a study of nature in the light of what he considerd to be the correct method to do it: the method of Newton's experimental physics. In other words, the lectures would provide Mutis with disciples that would help him to create adequate material conditions for his own investigations. This consequence is confirmed by the fact that Mutis continued to do it so in the cloisters of the botanical expedition in which a young generation of Granadian intellectuals were trained in botany, zoology, astronomy, chemistry, and mathematics.[171]

After pointing out the need to study the theoretical elements of mathematics, Mutis presented the basic definitions of arithmetic. As I commented above, in order to understand Mutis' translations is necessary to use both manuscripts as they complement each other. As regards to the definitions specifically, whilst in the largest manuscript, Mutis deployed the entire set of Wolff's definitions, in the shortest one, he also included scholia and problems related to several definitions as well as several equations demonstrating them. Let us take Definition II as an example to illustrate Mutis' procedure in his translation of Wolff's *Elementa*.

After defining the subject of arithmetic as the science of numbers in Definition I, in Definition II Wolff deals with the concept of "one"from both mathematical and philosophical points of view. According to him, "*Unun* est, quod ita est aliquid, ut aliud præterea idem esse nequeat. Illustris *Leibnitius* unum sic definit: Si A sit B, nec præterea D ponatur B, nisi A & D idem sint, ponetur B unum" (1732: 17). As we can see, Wolff not only defined "one" in terms of the law of non-contradiction, but he refered to Leibniz in order to clarify the concept, thus establishing a metaphysical foundation to his mathematical definition of it.[172] On the other hand, in Mutis' version of Wolff's Definition II in the largest manuscript, he only made reference to "one" in terms of the law of non-contradiction with no reference to Leibniz at all: "Uno es aquello que siendo algo no puede ser otra cosa dejando de ser lo mismo que es" (RJB III, 7, 1,

171 The pedagogical character of the botanical expedition has been studied in Amaya (2004), Soto (2005). Particular attention worths the creation of an academy of arts in the core of the botanical expedition. In the academy, Mutis taught to the young apprentices the details that should be highlighted in botanical painting. For this purpose, Salvador Rizo and especially Francisco Javier Matis played an important role. A study on the artistic matters related to the botanical expedition is in Bleichmar (2012).

172 It is a well-known fact that Leibniz considered the law of non-contradiction as it was related to his own conception of the principle of sufficient reason. In this sense, in his opinion, both of them not only constituted for Leibniz a cornerstone of logical demonstrations but the fundamental principles of his metaphysics. For the law of non-contradiction in Leibniz's works, see Rodriguez-Pereyra (2013).

5 f. 460v). He completed this definition in the shortest manuscript in which he included Wolff's reference to Leibniz and a detailed analysis of Wolff's symbolic example:

> Uno es aquello, que siendo algo no ~~dejar de ser lo mismo que~~ puede al mismo tiempo ser otra cosa dejando de ser lo mismo que es. Leibnicio [Leibniz] se explica en estos términos: supóngase por un instante que A es B, supóngase también que B no es D; supuesto esto sino se supone que A es D, vendremos en conocimiento de que A no es B, sino uno diverso del otro llamado B. Y aplicando la definición nuestra a términos más precisos, diremos, que A es uno, porque siendo A que es ser algo, no puede ser B que sería ser otra cosa, diverso de A o de aquello mismo que es (RJB III, 7, 1, 5, f. 437v).

The fact that Mutis revised and crossed out his own translation reveals his effort for capturing the essential features of Wolff's definition. Likewise, the fact that he pretended to make it as clear as possible Wolff's symbolic example is an evidence of Mutis' pedagogical interest in the work and his concerns regarding the possibility of being understood in a context where his course on mathematics was the first one ever existed.

It is worth noting as well that in the largest manuscript, Mutis also made some variations to the order of presentation of the definitions. These variations were caused by the fact that Mutis included as definition several terms that in Wolff's *Elementa* were not considered as such. For instance, Definition VII, which in Wolff's work deals with the concepts of "all" and "part", is divided by Mutis in two separated different definitions – Definitions VIII and IX – in which he separately deals with the terms *Todo* and *Partes*. This multiplication of definitions led Mutis to include 51 definitions – in Wolff's original version there are only 38.[173] This feature produced that the order of presentation of the definitions was slightly different in respect to Wolff's *Elementa*, although Mutis included all the definitions.

The second chapter, *De las operaciones de la arismetica en números enteros*, retakes Wolff's *Elementa* order, as it begins by postulating Problem II and its solution, demonstration, and scholia: "Problema II. *Numeros quotcunque datos addere*" (Wolff, 1732: 28). The problem, translated by Mutis as "Sumar cualesquiera números dados" (RJB III, 7, 1, 5, f. 466r), contains five steps in the resolution which Mutis turned into six, as he considered Wolff's example as another step. The problem also contains one demonstration, two scholia, and one corollary – although Mutis did not translate the corollary. In the rest of the chapters, encompassing different subjects of arithmetic – ratios of quantities, logarithms, potencies, and roots – Mutis repeats the same features of the translation of the first two chapters: the pretension of following the same order of presentation of the subjects as Wolff; the total omission or only partially translation of passages – this feature is most notably in the omission of several scholia –; the inclusion of several explanations to multiple passages of the text; are the main characteristic of Mutis' translation of Wolff's *Elementa*.

These features are repeated along the manuscript, except in Chapter 5, entitled *Fractions of fractions* [*Quebrados de quebrados*] which does not correspond to any section of Wolff's book on arithmetic in his *Elementa*. In this chapter, Mutis dealt with the division of fractions by fractions. In his words, "Número quebrado es el que se refiere a un quebrado como una parte menor a otra mayor" (RJB III, 7, 1, 5, f. 503r). Mutis enumerated this section beginning at 240, which in

[173] *Cf.* RJB III, 7, 1, 5, ff. 460v-461v. Wolff (1732), pp. 17-25. It is also important to point out that Mutis did not include in either the shortest or the largest manuscript Wolff's hypotheses and theorems. It is likely that he had written them as the shortest manuscript includes multiple formulae and resolution of problems derived from definitions, but further research is required to clarify this point.

Wolff's *Elementa* corresponds to the paragraphs on the multiplication of fractions.[174] Probably, the inclusion of a different chapter on this topic reveals either that Mutis was having problems in teaching the principles of division of fractions or that he wanted to emphasize that the same operations that were applied to integer numbers could be applied to fractions, thus proving the universality of mathematical operations.

In the passages of Mutis' translation that I have analysed so far we can see that in addition to multiple conceptual aspects of Wolff's *Elementa*, Mutis also introduced in his lectures on arithmetic the basic arithmetical operations as they were related to integers and fractions. Nevertheless, in Mutis' translation, there are two sections which are peculiarly interesting: the chapters on logarithms and trigonometry. The particularity of the chapter on logarithms relies on the fact that Mutis included, as a scholium, a historical description of the invention of logarithms and the construction of logarithmical tables in order to determine its suitability to be applied to the study of natural phenomena – particularly to astronomy.[175] It reveals that Mutis was particularly interested in logarithms and its application to the study of natural phenomena, as he thought that logarithms were particularly important for the study of the motion of bodies in conic sections, as it is revealed in his manuscripts on mechanics that I will study later. On the other hand, the particularity of his translation of the section on trigonometry relies on three reasons: first, Mutis only translated the section of Wolff's trigonometry related to the Euclidean geometry [*geometría plana*], thus omitting its application on the study of spheres and the potential

[174] *Cf.* Wolff (1732), p. 62. The importance of considering the precision in the order of numeration of Mutis' translation shall be highlighted when I study his translation of Newton's *Principia*. By considering the order of numeration in that translation, it is possible to determine the specific sections of Leseur's and Jacquier's commentaries to the work that Mutis included in his translation.
[175] *Cf.* RJB III, 7, 1, 5, ff. 417r-425v. Mutis' scholium on the history of logarithms is specifically in 424v-425v.

of trigonometry in astronomy and geodesy.[176] Second, Mutis focused on the application of logarithms for calculating trigonometric reasons. However, the most important particularity is that Mutis studied trigonometry with Wolff's *Elementa* instead of Descartes' *Géométrie*. Being trigonometry a part of geometry, it is worth of notice that Mutis did not choose the basic work he used for geometry to teach about it. Let us consider in detail Mutis' translation of these sections.

Wolff's chapter on logarithms in *Elementa matheseos* begins by postulating a set of three definitions in which he explains logarithms in terms of geometrical and arithmetical progressions and how they are related.[177] After these definitions there is a corollary, where Wolff explains that, in the case of arithmetic progression of natural numbers beginning by any given number, the logarithms are used to determine the distance between the numbers in proportion to the unity: "Corollarium I. Si progressio arithmetica fuerit series numerorum naturalium & a cyphra incipiat, ut in exemplo allato; logarithmi designant distantias numerorum proportionalum ab unitate" (Wolff, 1732: 82). Conversely, Mutis translated as a scholium Wolff's commentary to Definition III:

> Escolio. Supongamos que la progression geométrica es 1, 2, 4, 8, 16, 32, 64, 128, &c, y que la progression arismética que debe escribirse debajo sea esta 0, 1, 2, 3, 4, 5, 6, 7 claro está que 0 será el logaritmo de 1, 4 el logaritmo de 16, y 7 el logaritmo de 128. Stifel [Stifelius] en su arimética llama exponentes a los logaritmos: lo cual deberá tenerse presente, para no desconocer en algunos libros la voz de aquel autor. Camus entiende por logaritmo la distancia que hay en una

[176] This feature is particularly intriguing by considering the important role that spherical trigonometry played in the French geodesic expedition and the latter's impact on Mutis' formation at Cadiz in the 1750s. For a study on the development of spherical trigonometry in early modern mathematics, see Brummelen (2012), pp. 76-109.
[177] *Cf.* Wolff (1732), pp. 82-83.

progresión geométrica; entre cuyos términos se halla la unidad (RJB, III, 7, 1, 5, f. 417r).

Mutis referred to Charles Éttiene Louis Camus' *Élements d'Arithmetique* (1749). The importance of this reference should not be overlooked. In the first place, it reveals that Mutis was particularly interested in logarithms and its applications for multiple fields, as he studied it in different works. In the second place, it reveals that Mutis' formation in mathematics depended to a large extent on the influence of French works on mathematics and physics. Said influence was surely caused by the context of his education at Cadiz and the impact of the French mathematicians and natural philosophers on influential figures for Mutis during his training, such as Virgili and Juan.[178] It is possible to assume that Mutis knew Camus' *Élements* as a student at Cadiz. Likewise, the reference to Camus' work also reveals that Mutis had a partially updated formation in mathematics. Something which is also evidenced because he cited William Gardiner's *Tables of Logarithms* (1742) as well. Although, this last feature should be considered with caution, because it is also remarkable that he did not refer to Euler's *Mechanica sive motus scientia analytice exposita* (1736) or *Institutiones calculi* (1755), where logarithms are used in the study of the motion of bodies in conic sections and particularly the motion of projectiles.[179]

After this brief digression on the history of logarithms, Mutis retakes the translation of the section on logarithms of Wolff's *Elementa*, translating up to the corollary of Problema XXXVI, omitting the following problems Wolff posed. Instead, Mutis included a scholium

[178] Although Juan was recognized by his good training in mathematics, he constantly claimed that a good deal of his education was carried out during his stay in America with the French geodesic expedition. See, for instance, the prologue to his *Observaciones* where Juan comments the methods and techniques he learnt with the French expeditionaries. Likewise, Virgili's training in surgery in France played a fundamental role in his acceptance of the importance of mathematics and physics in physiological studies. *Cf.* Rueda Pérez Albiol (1993), (2013).
[179] As it is well-known, Euler's use of logarithms is associated to his project of separating analysis from geometry in the frame of his understanding of the foundations of calculus. In this context, logarithms played an important role for Euler as they allowed him to study the geometrical infinitesimal elements of any curve with nothing but the tools of analysis. For the use of logarithms in Euler's works, see Fraser (2003).

where he focused on the history of logarithmical tables and its utility for astronomy. In his historical reconstruction, Mutis describes Napier's and Briggs' works in order to explain how they imagine the project of constructing the first logarithmical tables including fourteen decimal numbers. Howe, as Mutis claimed:

> Pero como el Barón de Neper [Napier] hubiese muerto poco tiempo después de haber planteado su proyecto y de haber comenzado su empresa, quedó Briggs con todo el peso de este admirable trabajo, y public en Londres el año de 1624 unas tablas de logaritmos, que alcanzaban hasta 14 cifras decimals, y serían para todos los números enteros desde 1 hasta 20000, y desde 90000 hasta 101000, dejando un vacío considerable entre 20000 y 90000 (III, 7, 1, 5, f. 425v).

Then, Mutis says that the gap Briggs left was filled by Adrian Vlacq, who "tomó a su cargo llenar este vacío, y logró calcular todos los logaritmos de todos los números enteros desde 20000 hasta 90000, publicando en Gouda de Holanda el año de 1628 las tablas logarítmicas para todos los números enteros desde 1 hasta 100000" (RJB III, 7, 1, 5, f. 425v). After this brief history of the construction of the first logarithmical tables, Mutis explains that their value relies on the fact that they make it easier the computation of astronomical tables. For Mutis, "Finalmente como las tablas de los logaritmos se hicieron principalmente para la facilidad de los cómputos astronómicos" (RJB III, 7, 1, 5, f. 425v), they were modified to include only seven numbers instead of the fourteen with which they were firstly constructed. Mutis also highlighted the application of logarithms to astronomy in the beginning of this scholium: "Es imponderable la importancia de toda la doctrina de logaritmos en las matemáticas, pero especialmente en la trigonometría y astronomía" (RJB III, 7, 1, 5, f. 424v). As we can see, Mutis considered the application of logarithms to astronomy as it was a mathematical discipline. This consideration should be understood in the light of his defence of the modern distinction between mixed and pure mathematical sciences that posed physico-mathematical sciences as the result of the mathematical approach to nature developed in the seventeenth and eighteenth centuries.

On the other hand, the translation of the section on trigonometry in Wolff's *Elementa matheseos* is certainly the most different as regards to the original text. In this section, Mutis begins by translating the definitions, thus omitting Wolff's *Præfatio*, where he explains the application of trigonometry to astronomy.[180] An omission which is difficult to explain, considering Mutis' interest in the application of the theoretical elements of mathematics to the study of nature. In this preface, for instance, Wolff argues:

> Momenti perquam exigui tyronibus videtur Trigonometria, utilitatis prorsus nullius. Enimvero rerum athematicarum periti ore unanimi consitentur, quod, sublata trigonometria, maxima eorum pars pereat, quæ in Mathesi admiramur. Certe Stellarum magnitudinem, distantiam a Terra, motum, Eclipsum tam Solarium, quam lunarium computum, magnitudinem globi terraquei & innumera alia prorsus ignoraremus, si nobilissimæ hujus scientiæ auxilio destitueremur. Trigonometria igitur pro arte haberi debet, qua maxime abscondita & a cognitione hominum remota in apricum producuntur. Eam qui nescit, non magnos in Mathesi mixta sentiet progressus: sæpius ipsi in Philosophia naturali hærebit aqua, e. gr. iridis Phænomena ad rationes suas revocaturo aliaque meteora emphatica explicaturo (1732: 211).

180 *Cf.* Wolff (1732), pp. 211-212. It is also important to highlight that in the *Præfatio* Wolff made reference to the application of trigonometry in geodesy.

Wolff's characterization of the utility of trigonometry in astronomy implies the acceptance of the Copernican system, as trigonometry helps for measuring the orbit the Earth is traversing while it is orbiting the Sun. Likewise, he praised the value of trigonometry as an art improving the knowledge of mixed mathematical sciences. In this sense, it is strange that Mutis did not include it in his translation, as it clearly establishes a connection between the theoretical and operational character of the pure mathematics with the practical consequences of the mixed ones. By contrast, Mutis begins translating the definitions which not only are dedicated to define trigonometry by itself, but to define the trigonometric functions [*razones trigonométricas*] using common definitions taken from geometry.[181] It makes it reasonable to think that Mutis presented his lectures on trigonometry after his lectures on geometry, which made it possible for him to make it easier the transition from Wolff's *Elementa* to Descartes' *Géométrie*. Another relevant feature that Mutis included in his translation of Wolff's trigonometrical definitions is the definition of the trigonometric functions by examples. Let us consider, for instance, Definition II: "La recta *DE* mitad de la cuerda *DF* al arco *DBF* se llama seno del arco *DB*, y también del arco *DG*, los cuales son mitades del arco *DBF*, *DGF*" (RJB III, 7, 1, 5, f. 428r). In addition to the definition of *sinus* in a geometrical manner – despite that Mutis did not include any graphics in the translation –, we can see that Wolff and Mutis were postulating a kind of geometry in which the definitions of geometrical terms are made through the construction of geometrical figures. As I shall explain later, it reveals that Mutis accepted the basic assumptions of the so-called *geometria organica*.

Nevertheless, Mutis' literal translation of Wolff's section on trigonometry in his *Elementa matheseos* only encompassed the definitions and the first theorem. From this point, he changed

[181] *Cf.* RJB II, 7, 1, 5, f. 428r.

the order of the argument to present the application of logarithms to the problem of finding trigonometric functions.[182] It begins with the demonstration of Theorem I, where Mutis poses a demonstration based on the construction of a specific triangle, whereas Wolff demonstrates the theorem in general terms.[183] Then, the difference is accentuated as Wolff included a hypothesis that Mutis completely suppressed, and a scholium that Mutis also changed. In Wolff's original version, he referred to Ptolemy and Regiomontanus as they faced some problems related to trigonometric functions.[184] Conversely, in his version of the scholium, Mutis explained the origins of the tables of sinuses and tangents. Then, he included another scholium, where he argues in favour of the application of logarithms to trigonometry, making explicit references to Napier and Briggs:

> Como los senos y tangentes sean números grandes, es mucho el embarazo que causan sus multiplicaciones, y particiones. Por esta razón Juan Neper [Johannes Napier], noble escocés, y Enrique Biggs [Henry Briggs] inglés inventaron ciertos números, cuya suma equivale a la multiplicación, y su recta a la partición. Estos números se llaman logaritmos y están dispuestos en unas tablas bien copiosas, no solo para los senos y tangentes, sino también para los números comunes desde 1 hasta 10000; y más adelante. Será necesario decir aquí algo de esos logaritmos (RJB III, 7, 1, 5, f. 429r).

Mutis completed this brief description of logarithms in trigonometry by adding a definition of logarithms in terms of geometrical and arithmetical progressions. If we assume that the lectures on trigonometry took place after the lectures on arithmetic – and consequently after the lectures

[182] *Cf.* RJB III, 7, 1, 5, f. 428v.
[183] *Cf.* RJB III, 7, 1, 5, f. 428v; Wolff (1732), p. 214.
[184] *Cf.* Wolff (1732), p. 214.

on logarithms –, it is necessary to explain why Mutis considered the need to explain again this particular topic. I believe that there are two possible explanations to this strange repetition in Mutis' lectures. Firstly, it is possible to claim that Mutis perceived that the topic was especially important because of its application to different fields and, as a result, he seized the opportunity to emphasize it. Secondly, by following Mutis' idea in his study plan for the course of mathematics of 1787, it is likely that he had designed the lecture on trigonometry for those students who were studying the entire curriculum of mathematics to apply it to other fields.[185] In any case, Mutis insistence on the role of logarithms in trigonometry is revealing of several features of Mutis' lectures, as it shows one of the subjects he was more interested in and the particular applications he saw in it.

Descartes' *Géométrie* in Mutis' lectures on geometry

By following Mutis' description of the "Wolffian" order of his lectures on mathematics as it appears in his *Provisional plan for the study of mathematics* of 1787, it is likely that after teaching arithmetic the next topic he taught was geometry. Mutis' manuscripts containing his lectures on this subject follow the pattern of his lectures on arithmetic. In the last section, I pointed out that Mutis used Wolff's *Elementa matheseos* as a textbook for his lectures on arithmetic. Also, I argued that he included several commentaries, in which he posed explanations for difficult passages, and he also omitted several passages – most of them scholia. In the case of his lectures on geometry, he proceeded in a similar manner, although, in the case of geometry, he used

[185] It must be borne that Mutis' study plan of mathematics of 1787 considered two kinds of students: those who studied the entire curriculum, because they would apply it later to other fields and those who studied mathematics by itself. For the latter ones, as Mutis argues in his plan, the curriculum is limited and consequently in those lectures where both kinds of students coincide, he was forced to reintroduce some topics already studied with greater dedication by the the former ones. *Cf.* Mutis (1982), pp. 117-124.

Descartes' *Géométrie* as it appeared in Claude Rabuel's commented version, *Commentaires sur la Geometrie de M. Descartes* (1730) (Fig. 9).

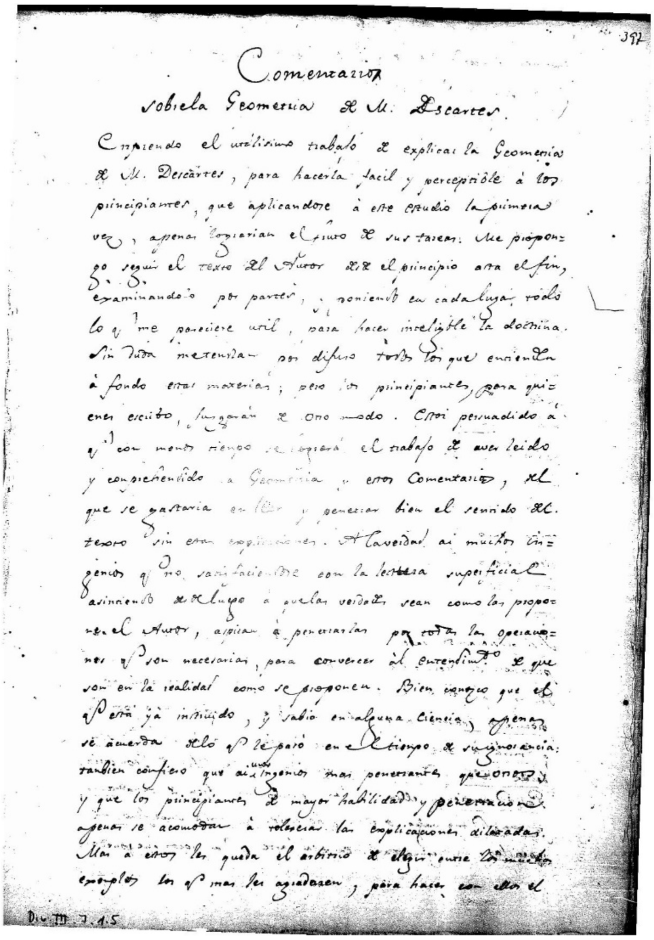
Comentarios sobre la Geometria de M. Descartes

Figure 9. Front page of Comentarios a la Geometría de Descartes, RJB III, 7, 1, 5, ff. 397r-416v.

Rabuel's *Commentaries* is a commented version in French, in which he included Descartes' entire original text illustrating it with several problems. Thus, whilst the original version published in 1637 contained just few more than one hundred pages – it must be borne that it was published as a part of a set of three works, together with *Les Météores* and *La Dioptrique*, which are the appendix to the *Discourse sur le méthode* –, Rabuel's version is more than six hundred pages, covering all the subjects treated by Descartes. He even commented the beautiful introduction

Descartes included, where he accounted for the foundation of analytical geometry.[186] In Rabuel's opinion, his *Commentaires* were published with the purpose of shedding light to Descartes' *Géométrie*, arguing that Descartes made it particularly difficult and the only available comments, published by van Schooten in 1649 and extended by he himself in 1659, were the cause of more troubles than clarifications: "M. de Schooten a voulu éclaircir le tout; mais le Commentateur semble avoir aspire luimême à la gloire d'être Commenté à son tour. Il exige en plus d'un endroit autant d'étude & d'application, qu'il en saudroit pour comprendre le texte même, qu'il pretend expliquer" (1730: Preface).[187] As a result, Rabuel argues,

> Le commentaire que nous donnous au public, s'étend sur toute la Geometrie de M. Descartes, & n'a point le défaut de l'obscurité. Le texte y est suivi article par article. Partout on truve les éclaircissemens necessaries & des exemples de tous les cas, dont M. Descartes ne dit souvent qu'un mot, & que tout autre qu'un geometre consommé ne sçauroit entrevoir (1730: Preface).

As I commented above, Rabuel's text is illustrated with a set of problems in every point that he considered obscure or rather difficult to understand. Thus, Mutis' translation of this book included both Descartes' original version and Rabuel's commentaries to the entire first part.[188] However, it is important to say that some passages of the translation are not found in the archives of the *Real Jardín Botánico* of Madrid in its proper order. Thus, for instance, the last four rules of Rabuel's commentaries to "Section IV" – which is the commentary to the last part of Descartes'

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[186] *Cf.* Rabuel (1730), pp. 3-6. Interestingly, Rabuel illustrates Descartes' introduction with four problems that attempt to explain the reduction of geometrical figures to an analytical form. I shall show that Mutis' translation also included these problems.
[187] Despite Rabuel's commentaries on van Schooten translated edition of Descartes' *Géométrie*, his commentaries came to be referents to understand Descartes' new analytical approach to geometry. A good study on van Schooten 1659 edition of Descartes' *Géométrie* can be found in Maanen (2003), pp. 42-56.
[188] *Cf.* RJB III 7, 1, 5, ff. 397r-416v.

first book – are among other mathematical manuscripts.[189] This part corresponds to the first four sectionsof the *Géométrie*, in which Descartes explains the foundations of analytical geometry before applying it to solve the problem of Pappus. The meticulousness of Mutis' translation is worth of notice as he also translated the summary that Rabuel included at the beginning of Book I:[190] "Libro I. Este libro se puede divider en tres partes. La primera será como una introducción a la geometría de M. Descartes. La segunda enseñará el modo de resolver los problemas planos. La tercera contendrá el principio del problema de Pappo [Pappus]" (RJB III, 7, 1, 5, f. 398r). Meanwhile, in Rabuel's original version we find: "On peut diviser ce Livre en trois Parties: la premiere est comme une introduction à la Geometrie de M. Descartes; la seconde enseigne la maniere de resoudre les problêmes plans; la troisiéme contient le commenecement du problême de Pappus" (1730: 2).

The literality of Mutis translation of Rabuel's *Commentaires* is clearer in the translation he made of the notes at the end of Section II:

> 1. Es necesario explicar cómo las operaciones de la arismetica, de que ha hablado nuestro autor en este lugar, se hacen como las líneas rectas. 2. Es menester manifestar la relación que estas operaciones hechas con los números tienen con las mismas operaciones hechas con las líneas rectas; hacienda ver aquí mismo, que la extracción de la raíz cuadrada es una especie de partición. 3. Es necesario traer

[189] Here it is important to say that, as regards to their proper order, there are serious difficulties to face the problem of studying Mutis' manuscripts. In the first place, several folios were found damaged, because they were used for separating seeds, fruits, and, in general, botanical specimens, in the boxes used for translating them from Santa Fe to Madrid when the Royal authorities in Madrid asked Sinforoso Mutis, José Celestino's nephew, to package and sending all the material of the botanical expedition. Apparently, it was further disordered in the 1810s, when Mariano Lagasca and Simón de Rojas Clemente were commissioned to write the *Flora de Santa Fe de Bogota*. However, the greatest detriment to the collection was caused in 1992, as they tried to organize it using archival models which made it impossible to establish a proper order to the documentation. Nowadays, the *Real Jardín Botánico* attempts to reconstruct the original order, based on the inventory of documents produced in their shipment and reception.

[190] Rabuel's summary of Descartes' *Géométrie* is in Rabuel (1730), pp. 1-2.

> algunos ejemplos, en que la unidad se puede tomar a discresión, otros en donde no se puede hacer así. 4. Finalmente es necesario explicar si introduciendo los términos del cálculo arismetico en la geometría, se hacen más perceptibles los asuntos que va a tratar nuestro autor (RJB III, 7, 1, 5 f. 403r).

Afterwards, Mutis translated the passages where Descartes explains that every geometrical problem could be reduced to arithmetical terms, by giving to line-segments the names of the letters of the alphabet. It means, where he explained the reduction of geometrical problems to arithmetical terms. Thus, it would be possible to reduce the geometrical figures to algebraic equations, articulating both mathematical fields with the purpose of establishing general conditions for solving problems in geometry.[191] As Descartes points out, in the ancient approach to geometrical problems, every problem required a new, particular insight. Thus, the *Géométrie* intended to overcome the problem of the singularity of the solutions of geometrical problems by reducing them to terms which can be understood in a general manner. In Descartes' opinion, it illustrated the application of the geometrical method of analysis and synthesis and the universality of the conclusions to which it is possible to arrive if it is used in different fields of study. Consequently, by including the translation of the introduction of the *Géométrie*, Mutis offered to his audience an argument in favour of the universal character of mathematical analysis and its potential as it is applied to the study of different problems.

Nevertheless, it is important to highlight that Mutis' translation is reduced to the presentation of the general aspects of the procedure that Descartes proposes. In fact, Mutis concentrated on translating the initial sections of the *Géométrie* and Rabuel's commentaries until

[191] It is likely that, along with his metaphysics, Descartes' foundation of analytical geometry is one of the most studied topics of his works. Interesting general studies on Descartes' *Géométrie* can be found in Bos (1981); Mancosu (1995); Bos (1998); Boyer (2004), pp. 74-102.

the point where Descartes discusses the problem of Pappus and its resolution. In so doing, Mutis focused on the translation of the rules that Rabuel included at the end of Section IV to explain how to reduce geometrical figures to algebraic equations, following Descartes' method.[192] However, he only translated eight out of the thirteen that Rabuel wrote. Ostensibly, Mutis was more interested in presenting to his students the main methodological features of Descartes' geometry than in its proper use to solve geometrical problems related to curves. This conclusion makes more sense by considering that Mutis was already aware of the problems related to the study of certain curves when they were analysed following Descartes' precepts, as it can be seen in his manuscripts on conic sections. Furthermore, this conclusion is reinforced by considering that Mutis did not include Descartes' solution to Pappus' problem, which is one of the most interesting results of Book I of the *Géométrie*. Arguably, Mutis was aware of the importance of Descartes' method for the study of curves, but he only referred to the general features of its application, in order to highlight the universality of the mathematical method. It would explain his interest in the application of logarithms to geometry, as they allow to deal with geometrical figures with large quantities – namely, the ones found in astronomy.

On the other hand, Mutis' use of his translation of Descartes' *Géométrie* as a textbook for his lectures on geometry reveals his interest in emphasizing the importance of the arithmetical knowledge to solve different mathematical problems and especially the use of logarithms. It explains, for instance, his insistence in using logarithms to solve trigonometric problems. But, more importantly, it reveals that Mutis' curriculum for his lectures on mathematics during the 1760s attempted to connect mathematical branches in a clearly discernible way, allowing the students to smoothly move from one into another. This structure, nevertheless, is not so well

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[192] *Cf.* Rabuel (1730), pp. 20-45. RJB III, 7, 1, 5, ff. 414v-416v. So far, I have not been able to determine whether Mutis translated all of them or not, further research on the manuscripts would be required to clarify it.

connected to the teaching of calculus. The difficulty to connect his lectures on calculus, as I shall argue, is founded on the impossibility of dating with precision the manuscripts regarding that subject and the evident change in the difficulty of the subject itself. Considering that the lectures on calculus constitute one of the features of Mutis' introduction of Newton's ideas in New Granada, I shall study it separately.

Calculus and Newton's method of fluxions in Mutis' lectures

Unlike the evidence found in Mutis' manuscripts on arithmetic and geometry, which supports the idea that he lectured on these subject by translating Wolff's and Descartes' works and using them as textbooks, in the case of his lectures on calculus we do not have enough evidence to determine the work on which Mutis based them. Furthermore, we do not have enough evidence to claim without hesitate the extent of these lectures during the 1760s or 1770s. Among Mutis' manuscripts in the archives of the *Real Jardín Botánico* of Madrid, we only find one folio dedicated to the specific subject of calculus entitled *Elements of integral calculus* [*Elementos del cálculo integral*].[193] However, despite what the title suggests, this folio does not deal with integral calculus at all; rather, it establishes the conceptual foundation for differential calculus. Probably, it was part of a missed, largest manuscript in which Mutis presented the elements of both differential and integral calculi.

After the title of the manuscript, Mutis introduced a headed: "Primera parte. De la integración de las diferenciales de una sola variable" and, then, he begins the first chapter, "De los principios generales del cálculo diferencial y del integral".[194] The structure of this manuscript

[193] *Cf.* RJB III, 7, 1, 20, f. 1r.
[194] *Cf.* RJB III, 7, 1, 20, f. 1r.

suggests that it follows the pattern of his lectures on arithmetic and geometry and consequently we can assume that it is the manuscript containing his lectures on calculus at the *Colegio del Rosario*. Nevertheless, I have not been able to determine so far whether it is a translation or not of any work on calculus Mutis had available in the 1760s-1770s. As the catalog of Mutis' personal library reveals, he had access to several important works on calculus during that time: Newton's *Opuscula Mathematica, philosophica, et philologica*, edited in 1744 by Johannes Castillioneus; James Hodgson's *The doctrine of fluxions founded on Sir Isaac Newton's method published by himself in his tract upon the quadrature of curves* (1758); and of course Wolff's *Elementa Matheseos Universæ*; among others.[195] As I argued in the last section that translating was a fundamental pedagogical practice for Mutis' pedagogical endeavours, the lack of evidence to relate this manuscript to any known work available for him makes it inconsistent to present it as part of his lectures. However, the existence of a manuscript directly dealing with calculus is revealing of Mutis' mathematical interests and, by including it in a largest set of manuscripts in which Mutis treated the motion of bodies in conic sections with the tools of Newton's calculus of fluxions, I shall argue that we can assume it as part of his lectures.

The single folio of this manuscript is constituted by three statements, which seems to be definitions – although Mutis did not postulate them as such – of the concepts "variable" and "constant" and how they are related. According to Mutis,

> Cuando se comparan entre sí muchas cantidades, de las cuales las unas aumentan o disminuyen continuamente, mientras que las otras perseveran siempre las

[195] *Cf.* Cañón Vega (1993). It is interesting to point out that Colombia's *Biblioteca Nacional* received the collection of Mutis' personal library and the books of the Botanical Expedition. In this sense, a detailed study of the "donation" could reveal the extent and scope of Mutis' knowledge on mathematics and physics. Likewise, the *Biblioteca Nacional* was firstly founded with the Jesuits' library confiscated after their expulsion in 1767. Thus, its section of rare books constitute an important resource to understand the configuration of New Granada's academical panorama in the eighteenth century. For the foundations of the *Biblioteca Nacional*, see Hernández de Alba (1977).

> mismas; se llaman las primeras variables, y las segundas constantes. Comúnmente se nombran las constantes con las primeras letras del alfabeto a, b, c, &c. y las variables con las últimas x, y, z, u, &c (RJB III, 7, 1, 20, f. 1r).

Mutis compared variables and constants quantities by postulating that the former are *evanescent quantities* tending to be equal to constant quantities in a determined period of time as the difference between them is reduced; it means, when their difference tends to 0. In Mutis' opinion,

> Es un principio bien evidente, que si una variable *z* se aumenta o disminuye de una cantidad cualquiera, que llamaremos *Dz;* de modo que se convierta en esta *z*±*Dz;* estas dos cantidades *z*, *z*±*Dz* se irán aproximando a ser iguales tanto más cuanto su diferencia fuere disminuyendo respecto de la cantidad *z*. Y que finalmente quedarán iguales en aquel instante en que se *desvanecerá* esta diferencia (RJB III, 7, 1, 20, f. 1r).[196]

In this characterization of the relation between a variable tending to be equal to a constant, we can see two key features of Mutis' understanding of calculus. First, he refered to the differential between a variable and a constant with the symbol *D*. It was a usual notation in the late-eighteenth century, close to Leibnizian notation of calculus.[197] Second, Mutis used the term *evanescent quantities* to define the precise moment when the difference between two quantities instantaneously tends to 0 rather than to a finite quantity. It must be borne that the notion of "evanescent quantities" was a rather confused term during the late-eighteenth century, inherited

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[196] My emphasis.
[197] For the history of calculus in the eighteenth century, see Guicciardini (1989), Edwards (1994), Guicciardini (2003), Fraser (2003).

from Newtonian conception of the calculus of fluxions.[198] In Newton's calculus of fluxions, a differential was produced when a variable, which is a fluent quantity – an *evanescent quantity* –, is matched to a constant in an instantaneous moment, or *fluxion*. In other words, the fluent quantities in a fluxion are precisely *evanescent quantities*. Nevertheless, the notion of evanescent quantities tended to be diffused in the eighteenth century, as it was soon abandoned by Newton and the Newtonians by adapting Leibnizian notation to their own mathematical studies.[199] It was also abandoned because of the impact of Berkeley's criticism against the notion of evanescent quantities which determined the development of calculus during the eighteenth century.[200] In this context, it is not clear the reasons why Mutis used the notion of evanescent quantities and the direct source for his appropriation of the term. However, by considering his eclectic articulation of the Leibnizian notation and the use of the Newtonian concept "evanescent quantities", we can see that he used different traditions to explain calculus. This eclectic approach to calculus, as I shall argue, is simplified in the study of the motion of bodies in conic sections, as Mutis – although still using Newtonian "fluxions" – decidedly used the Leibnizian notation.

Despite that Mutis' manuscript on integral calculus does not provide sufficient information regarding the specific elements of calculus that he introduced in his lectures in New Granada and how well he understood calculus, we can find evidence on these issues in other

198 Although abandoned by Newton after his invention of the method of last and first ratios – which he used to replace the infinitesimals, as the former was closer to his atomism – the notion of *evanescent quantities* played a fundamental role in Newton's early development of calculus and his rejection of Cartesian analytical methods. *Cf.* Guicciardini (1989), Guicciardini (2003).

199 For the reception of Leibnizian calculus in England, see Edwards (1994), pp. 265-268; Guicciardini (2003); Bardi (2006), pp. 169-242.

200 It must be borne that Berkeley's strong criticism against Newton's calculus of fluxions and Leibniz's infinitesimals was part of his radical agenda of criticism against the so-called "free-thinkers". As Berkeley describes them in *The Analyst: a discourse addressed to an infidel mathematician* (1734), fluxions and infinitesimals were nothing but "ghosts of departed quantities" whose rigorousness could not be superior to that of religion. Berkeley's ideas were highly supported in the early-eighteenth century, thus forcing Newtonians and Leibnizians to develop different counterarguments to them. For a study on Berkeley's critiques, see Sherry (1987); Edwards (1994), pp. 231-300; Andersen (2011).

manuscripts found in the archives of the *Real Jardín Botánico* of Madrid.[201] Especially, in his lectures on conic sections and particularly the ones on hyperbolas.[202]

Mutis' manuscript on hyperbolas begins by describing how to construct a hyperbola from the lines drawn of the intersection of the asymptotes. Then, in Theorem III, Mutis used Newton's calculus of fluxions, with a Leibnizian notation, in order to explain that the area under a hyperbola is a logarithm of the abscises:

> Digo finalmente que las áreas de la hipérbola son logaritmos de las abcisas. Desde el centro *C* tírese el eje *CA*; y desde el vértice *A* tírense las líneas *AR*, *AC* paralelas a las asimptotas. Por quedar dividido en dos partes iguales el ángulo *C*, y por las paralelas, será *CR*=*AR*. Sea pues *AR*=1, y fínjanse las ordenadas que se muevan de tal modo, que las abcisas de la una sean siempre una misma potencia de la otra. Coincidirán ciertamente en *R*; porque cualquier potencia de la unidad siempre es 1; pero caminándose *CE*=*x*, deberá ser *CF*=$x^n.x$. Luego serán *GE*$\frac{1}{x}$, y *HF*$\frac{1}{x^n}$; porque es *CE*.*CR*=*AR*.*GE* (…) La fluxión de la línea *CE* será *dx*=*Ee*, y la fluxión de la línea *CF* será $nx^{n-1}dx$=*Ff*. Por tanto la fluxión del área de *RG* será $dxX\frac{1}{x}=\frac{dx}{x}$, y la fluxión del área *RH* será $dxX\frac{1}{x^n}=\frac{ndx}{x}$ (RJB III, 7, 1, 5, f. 319r).

As we can see, despite the fact that Mutis referred to the calculus in terms of Newtonian fluxions, he explained how to calculate the area under the hyperbola by algebraic symbols. Hence, he studied here hyperbolas as conic sections produced by the motion of a geometrical point; that is to say, as a fluent magnitude. However, he solved the problems emerging from the line produced

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[201] Mutis' manuscript on conic sections is RJB III, 7, 1, 5, ff. 329r-330v.

[202] The manuscript on hyperbolas is in RIJB III, 7, 1, 5, ff. 318r-320v. Interestingly, the folios before the section on hyperbolas deal with fluxions. It is likely that, in its original order, these folios were part of the manuscript on conic sections.

by the fluent point in algebraic terms, using Leibnizian notation. I shall argue that Mutis' twofold understanding of calculus, and his apparent combination of the Newtonian approach to the nature of the production of curves with a more updated Leibnizian approach to the solution of the problems emerging from them, was fundamental in his lectures on mechanics and his mathematical explanation of multiple mechanical phenomena.

Eclecticism in Mutis' appropriation of mathematical traditions

Arboleda and Restrepo Forero have pointed out that Mutis' pedagogical role in New Granada in the 1760s and 1770s have been considered in an almost mythological manner. They have argued that the historical characterizations of Mutis' lectures have produced the image that said lectures caused a revolution in New Granada's academical milieu during the 1760s. This image, as these historians commented, was promoted by Mutis himself and it was supported by his pupils, contemporaries, and most of the historians of science in Colombia. The construction of the myth around Mutis' figure as a teacher in New Granada began with the *Representación* he wrote to Viceroy Caballero y Góngora when the Royal Botanical Expedition was about to be established. In it Mutis wrote:

> A pesar de las tareas de la medicina práctica, de donde sacaba los auxilios para la continuación de mi historia natural, procuraba destinar algunas horas para las lecciones públicas de matemáticas y filosofía newtoniana, que enseñé sin renta alguna y sin interrupción desde el 62, en que tomé posesión de la cátedra en el

> Colegio del Rosario hasta fines del 66. *Siendo esta la primera vez que se oyeron lecciones de tales ciencias en el Nuevo Reino de Granada desde su conquista* (Gredilla, 1911: 167).[203]

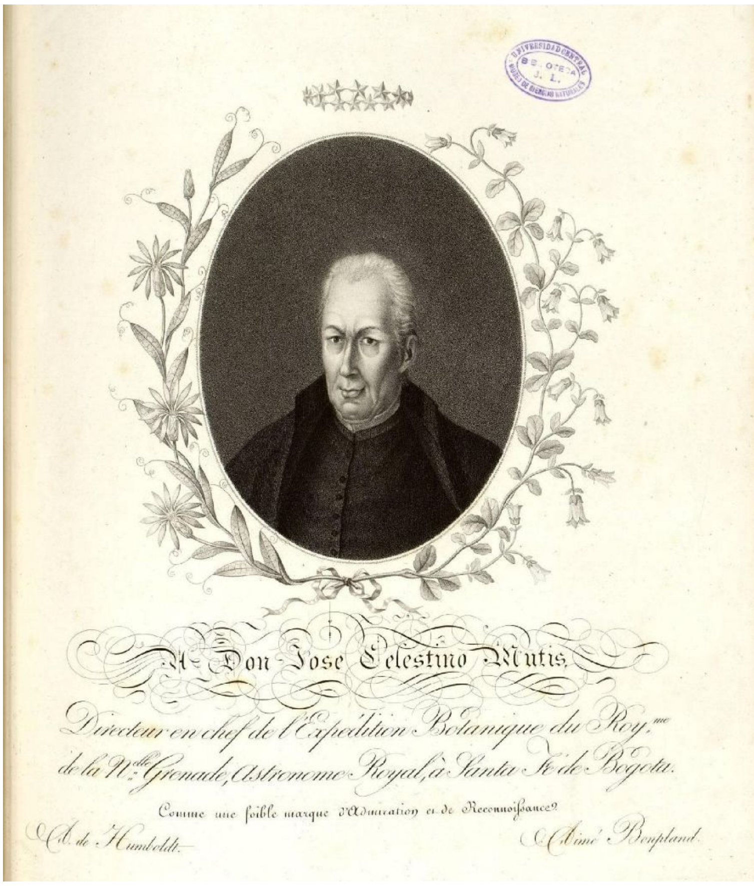

Figure 10. Dedication to Mutis in Humboldt's and Bonpland's Plantae aequinoctiales (1808).

Despite that Mutis' *Representación* was written in 1783, it is possible to find that Mutis had built this image of himself as of the early 1760s.[204] Restrepo Forero studies how this image was diffused in New Granada in the context of the late-eighteenth century and consequently it was consolidated as the traditional manner to present Mutis' lectures since then.[205] Among the individuals who presented Mutis in this way, one of the most influential probably was Alexander

203 My emphasis.
204 *Cf.* Arboleda (1993), p. 30.
205 Restrepo Forero (1998), pp. 35-39.

von Humboldt, who knew Mutis directly during his travel to Santa Fe in 1801 (Fig. 10).[206] As Humboldt described it in an entry of his diary:

> Mutis, quien ha tenido una influencia tan grande en la ilustración de esta region, fue el primero que se atrevió, en Santa Fé en 1768 a demostrar, en un programa, las ventajas de la filosofía newtoniana sobre los peripatéticos y enseñó la primera públicamente como catedrático de matemáticas del Colegio del Rosario (Humboldt, 1982: 46).

However, although the influence of Mutis' lectures on mathematics and physics in New Granada should not be overlooked, both Arboleda and Restrepo Forero have pointed out that they should be reconsidered in the light of its real impact on New Granada's context.[207] According to them, New Granada's intellectual and academic milieu during this period was not dramatically affected by Mutis' lectures, as it is evidenced by the fact that in 1801 Mutis was asked by Viceroy Pedro Mendinueta to write a defence of the Copernican system that he had defended as of the 1770s.[208] It is a proof that the apparent modernization of the education in New Granada thanks to Mutis' lectures on mathematics and physics was just apparent, as the scholastic tradition of the universities still dominated New Granada's intellectual and academic panorama.

In this chapter, I tried to avoid any consideration on the real impact of Mutis' lectures during the 1760s and 1770s. Rather, I focused on the lectures themselves, in order to determine which elements of Newton's theories Mutis presented in his lectures. Likewise, I divided the

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[206] It is worth of notice that Humboldt not only dedicated to Mutis the *Plantae aequinoctiales*, but he also dedicated him the *Essai sur la géographie des plantes* (1805).
[207] *Cf.* Arboleda (1993), Restrepo Forero (1998).
[208] As I shall argue in Chapter 6, Copernican system had caused multiple polemics in New Granada during the late-eighteenth century which had as common factor the dispute between Mutis and the Dominicans. The polemics that had been apparently settled in the end of the 1770s emerged again as a student of the Augustinian college in Santa Fé had proposed its defence in 1796. For a history of the Copernican system in Santa Fé in the eighteenth century, see Lanning (1944), Soto & Negrín Fajardo (1984).

lectures into lectures on mathematics and lectures on physics only for practical purposes. It does not mean that Mutis developed the lectures separated as lectures on physics and lectures on mathematics. In assuming such distinction, I tried to focus on Newtonian aspects of Mutis' lectures. I divide such aspects in two. First, by considering the utility of mathematics in several fields, Mutis argued that the field where it is more visible is natural philosophy, as mathematics provides it with both the external frame of the new scientific rationality and a source of explanations for natural phenomena. As a result, I argued that the traditional interpretation of Mutis' conception of the mathematization of nature, as it is defended by historians like Arboleda, Nieto Olarte, and Martínez Chavanz, should be reconsidered, as the manuscript evidence suggests that Mutis also considered mathematics as a source of explanations of natural phenomena. I shall treat in detail this conclusion in the next chapter, when I explain the content of Mutis' lectures on physics and his application of Newton's physics for the study of the motion of bodies in conic sections. Second, I showed that the other important aspect of Newton's mathematics that Mutis presented in his lectures was the calculus of fluxions. As I explained, he did so by presenting Newton's conception of the production of curves and trajectories as the result of fluent quantities whose difference tends to 0. However, by considering Mutis' use of algebraic symbols, it is possible to conclude that he developed an eclectic approach to mathematics that allowed him to combine Newton's calculus of fluxions with Leibniz infinitesimals. As we can see, Mutis' lectures on mathematics were characterized by the presence and influence of multiple authors and different currents. Wolff's arithmetic, Descartes' geometry, Newton's calculus of fluxions, and Leibniz's infinitesimals were articulated in his lectures in order to present to the students the basic issues of mathematics. By doing so, Mutis established the conditions to deploy his explanation of the mathematization of nature in the light of what he understood as Newton's experimental physics, which came to be more appropriately developed in his lectures on physics.

Chapter 4. Newton's physics in New Granada: Mutis' lectures and mathematatization of nature

Mutis' appropriation of Newton's mathematical approach to physics

As I pointed out in the last chapter, the first period of Mutis' lectures on mathematics was until 1766, being interrupted in September of 1762, as Viceroy Messia de la Cerda moved from Santa Fe to Cartagena, with the purpose of defending the port city after the British invasion to Havana.[209] It must be borne that the invasion was one of the military acts of the Seven Years' War between the British and the Spanish Crown and it evidenced Spain's weakness at the Caribbean.[210] Consequently, as viceroy's physician, Mutis had to leave unattended his recently inaugurated course of mathematics. After the *Treaty of Paris*, which formally ended the war in February 1763, Mutis returned to Santa Fe with the viceroy, thus resuming his lectures. This year and the following were decisive for Mutis because of two reasons. In the first place, he presented two *Representaciones*, to King Charles III in which he asked for royal support for his project of drawing up a botanical expedition in New Granada. Although the Viceroy supported the solicitudes, the King ignored both of them and Mutis had to witness how the purpose motivating him to go to New Granada was vanished, forcing him to dedicate himself to multiple activities – mining, teaching, and medicine – in order to fulfill the needs of a botanical expedition financed

[209] Mcfarlane described Mesia de la Cerda's military strategies in Cartagena, which mostly comprised a great investment in the city's fortification. *Cf.* Mcfarlane (1993), pp. 202-203.

[210] Before the attacks to Cartagena in 1763, the British navy also attempted to conquer it in 1641 in the so-called 'Battle of Cartagena de Indias', which occurred in the context of the War of Jenkins' ear. The British navy was defeated by the Spanish navy and it lead to the progressive end of the war. On the Battle, see Kuethe and Andrien (2014), pp. 133-167; and Eisa-Barroso (2017), pp. 224-258. On the economic consequences of the Battle in New Granada, see Mcfarlane (1993), pp.199-200.

by himself.[211] In the second place Mutis inaugurated in 1764 the lectures on physics of his course on mathematics at the *Colegio del Rosario* – hereafter, lectures on physics –, in which he discussed Newton's experimental physics more detaidly and presented – and defended – the Copernican system. Historically remarkable by themselves as they constituted New Granada's first lectures on modern science, they also played a fundamental role in Mutis' personal life because they established the conditions of his debates with the Dominicans regarding Copernicanism.

I claimed in the last chapter that Mutis' lectures on mathematics presented several Newtonian elements chiefly related to the determination of the conditions to apply the mathematics in natural philosophy. I argued that, in Mutis' opinin, the relationship between these disciplines is founded on theological basis, as knowing nature entails knowing God's providence. For that purpose, he introduced a set of methodological aspects of what he considered to be Newton's experimental physics, with which Mutis illustrated the need to explain natural phenomena by mathematical demonstrations. Thus, we can say that the first steps of the introduction of Newtonianism in New Granada consisted in the presentation of the methodological aspects of Newton's experimental physics as they were related to the articulation between mathematics and natural philosophy. Nonetheless, as I shall argue in this chapter, Mutis' introduction of Newton's experimental physics in New Granada was not limited to the presentation of Newton's methodology. Conversely, the manuscripts reveal that he was also committed to discussing several theoretical aspects of Newton's natural philosophy framed in his defence of the Copernican system. Furthermore, the manuscripts also reveal a very interesting feature of Mutis' understanding of Newton's natural philosophy: he defended the idea of forces as attractive powers of matter, as he presented it in the frame of the polemic

211 A transcription of Mutis' *Representaciones* is in Gredilla (1911), pp. 20-31.

between the Newtonians and the Cartesian mechanical philosophers concerning the ontological causality of the force.[212]

I divide my analysis of Mutis' lectures on physics in three parts. First, I study Mutis' presentation of Newton' methodology. As we shall see, he made explicit references to it in different passages of his lectures and consequently I shall concentrate on the variations he introduced in each of them. In general, I shall argue that Mutis emphasized the mathematical character of Newton's method and the simplicity it entails. Second, I analyse Newton's theoretical elements that Mutis introduced in his lectures, as they were presented in the manuscripts entitled *Knowledge required for understanding natural phenomena* [*Conocimientos para la inteligencia de los fenómenos*] and *Elements of mechanics* [*Elementos de mecánica*]. As we shall see, these manuscripts focused on Newton's study of the motion of bodies in conic sections when a centripetal force is acting upon them. Consequently, I shall argue that Mutis did not only relate mathematics to natural philosophy in the sense that the former provides the latter with a formal structure of thought. Conversely, as the manuscripts suggest, Mutis also used mathematics for the analysis of the motion of bodies in conic sections, considering the role of the force in such a motion. Likewise, I provide more evidence concerning the importance of translating as a pedagogical practice for Mutis, by showing that several of his lectures were based on his translation of 's Gravesande's *Physices elementa mathematica*. As in the case of his translations of Wolff's *Elementa matheseos* and Descartes' *Géométrie*, this manuscript had not been identified as a

[212] It is a well-known fact that one of the most criticized aspects of Newton's *Principia* during the 1690s and the early-eighteenth century was related to the lack of causal (mechanical) explanations to the force. It must be borne that Newton deduced the existence of the force by considering the consequences in nature of his mathematical explanation of the motion of bodies and consequently mechanical philosophers characterized Newton's concept of attractive force as the reintroduction of "occult qualities" to the natural philosophy. In this sense, in the *scholium generale* that Newton added to the second edition of the *Principia*, he included a brief commentary in which he replied this criticism by claiming that the existence of the force was mathematically demonstrated. It led to the highly interesting debate between Newtonians and mechanical philosophers concerning the causality of the force, whose core was the debate between Leibniz and Clarke. For the history of this debate, see Cohen (1980), pp. 96-99; Hall (1983). pp. 306-331; Henry (1994); Copenhaver (1998); Attfield (2005).

translation yet and its discovery constitutes one of the fruits of this research. As I shall show, in the manuscript, it is possible to find a translation of Chapters I through V of Book I of 's Gravesande's work. Likewise, Mutis included his own commentaries to Newton's rules for natural philosophy, as they were presented by 's Gravesande in Chapter I of his work,[213] which reveals interesting facets of Mutis' Newtonianism. Another important feature of this translation in particular is that it confirms the fact that different historians pointed out that Mutis' introduction of Newton's ideas in New Granada was informed by the "Newtonianism" of the Dutch experimentalists.[214] Third, in the context of the study of the role of Mutis' translations in his lectures on physics, I shall focus on his translation of Newton's *Principia*. I shall argue that said translation is considerably different from the others, because of both its extension and the fact that Mutis included a translation of the commentaries made by the Minim friars Le Seur and Jacquier.[215] In this part, I also study Mutis' presentation of the polemics against the attractive character of the force. This final point is particularly interesting because 1. it reveals that Mutis was a convinced and consequent Newtonian and 2. because it evidences the scope of Mutis' knowledge of Newton's physics.

Newton's methodology in Mutis' lectures on physics

Mutis' introduction of the methodological aspects Newton's experimental physics began with his inaugural lecture in 1764, entitled *Elements of natural philosophy, containing the principles of physics mathematically demonstrated and confirmed by observations and experiments: disposed for instructing the youth*

[213] *Cf.* 's Gravesande (1748), pp. 1-3. For a study on 's Gravesande's interpretation of Newton's *rules*, see Ducheyne (2014).
[214] See, for instance, Arboleda (1993).
[215] The edition by Leseur and Jacquier used by Mutis was a commented edition of the *Principia* published in Geneva between 1739 and 1742. I shall provide details of the edition in the part dedicated to Mutis' translation. An interesting study on Leseur's and Jacquier's edition can be found Guicciardini (2015).

in the doctrine of the Newtonian philosophy 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*]. However, it is necessary to claim that, contrary to what the title suggests, it does not deal with any of the physical principles of Newton's natural philosophy. In it, Mutis rather presents a historical panorama of its emergence and his application of the method of analysis and synthesis as it was described in the *Query* 31 of the *Opticks*.[216]

As in the case of the *Preliminary discourse* of 1762, Mutis began *Elements* by explaining the importance of natural philosophy by its utility. According to him, the utility of natural philosophy consists in providing the conditions to know God through his providence. Thus, the main merit of natural philosophy

> consiste, en que sirve de fundamento sólido para la religión natural, y la filosofía moral, conduciendo al hombre en modo muy agradable al alto conocimiento del autor de la naturaleza, y criador del universo. Porque estudiar la naturaleza es lo mismo que dirigirse a conocer las obras maravillosas de aquel soberano criador, que se deja conocer en parte por las cosas visibles (RJB III, 2, 4, 11, f. 5r).

This passage is really suggestive. On one hand, by arguing in favor of the theological and religious foundations of natural philosophy, it extends Mutis' characterization of this discipline as it was presented in the *Preliminary discourse*. It evidences that, for Mutis, demonstrating the compatibility of Newton's experimental physics with theological and religious matters was a permanent

[216] A transcribed version of the lecture can be found in Mutis (1982), pp. 43-68. The manuscript version of the lecture is RJB III, 2, 4, 11, ff. 2r-19v.

concern during his period as *catedrático* at the *Colegio del Rosario*. Such concern should not be overlooked, especially by considering this kind of pronouncements in the context of the polemics Mutis was involved regarding the Copernican system in the 1770s.[217] On the other hand, the passage reveals that Mutis' conception of the utility of natural philosophy is not consistent with the enlightened idea that developed in Spain during mid-eighteenth century – especially during the reign of Charles III – and consequently that it is problematic to consider Mutis' defence of modern science as a part of the enlightened projects of the Spanish Crown for its overseas territories. This interpretation has been held by historians like Arboleda, Soto, Martínez Chavanz, and Nieto Olarte, who have argued that Mutis' lectures on mathematics and physics were developed in the frame of Charles III's reforms to the university education – mostly advanced by the influential Earl of Floridablanca.[218] As I explained in the chapter on Mutis' education, these reforms were produced by some policies created with the purpose of introducing modern science into Spanish universities. However, they only had an impact on the colonies in the 1780s, which means that Mutis' lectures, and his struggle for introducing Newton's experimental physics, cannot be explained as a consequence of these reforms.[219]

For Mutis, rather than the concerning with economy and the improvement of the material conditions of Spanish territories, as the passage just quoted reveals, 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 found the principles of natural religion and moral philosophy. By considering this characterization, we discover the most interesting feature of this passage for

[217] In fact, in his polemics with the Dominicans, Mutis claimed that their critiques to the Copernican system were an indirect attack against him and his lectures. *Cf.* AGNC, Sección Colonia, Colegios: SC. 12, 2, ff. 9r-13r.
[218] Arboleda (1993), Martínez Chavanz (1993), Soto (2005), Nieto Olarte (2006).
[219] As Brockliss and Ten have commented the impact of Charles III's reforms was firstly seen in Lima universities in which Newton's physics replaced Descartes' and Gassendi' mechanical philosophies as guidelines in education. *Cf.* Ten (1987); Brockliss (2003), pp. 61-62.

the purpose of understanding the diffusion of Newton's experimental physics in New Granada: it undoubtedly recalls the final paragraph of Newton's *Query* 31 of the *Opticks*, in which he explains that by extending the limits of natural philosophy, the limits of moral should be enlarged as well.[220] Hence, by adopting Newton's redefinition of the disciplinary boundaries of both natural philosophy and theology, Mutis presented one of the most intricate features of Newton's thought in *Elements*. Certainly, as I shall argue later, the influence of this *Query* was fundamental in Mutis' arguments in this inaugural lecture on the elements of natural philosophy. First, let us analyse the historical emergence of Newtonian natural philosophy as Mutis explained it in this manuscript.

After accounting for the possibility of founding natural religion and theology on the principles of natural philosophy, Mutis argued that the problem of this position is that a wrong natural philosophy could lead men to atheism and skepticism.[221] In Mutis' opinion, it entails the need to find a correct method to study nature which allows men to know God's providence. We can shed light on this idea presented in *Elements* by using Mutis' reference to Newton's experimental physics in *Preliminary discourse*. In the latter, as I commented above, Mutis compared Aristotelian sectarianism, Cartesian hypothetical philosophy, and Newton's experimental physics, to determine the best approach to study natural phenomena. As a result, he concluded that Newton's method was the best, because the propositions postulated to describe and explain nature were experimentally demonstrated and mathematically explained. However, whilst in the *Preliminary discourse* Mutis deals with the epistemological and methodological aspects of the issue,

[220] *Cf.* Newton (1952), pp. 405-406. Since the publication in the 1960s of Newton's "classical scholia" there has been a growing number of studies about his theology and religious personal beliefs that has informed the current accounts of his natural philosophy. Among the more influential studies on these issues are McGuire & Rattansi (1966), Austin (1970), Casini (1984), Snobelen (1999). A good companion of Newton's theology and its implications can be found in Force & Popkin (Eds.) (1990).
[221] *Cf.* RJB III, 2, 4, 11,ff. 5v-6r.

in *Elements*, he extended the scope of the distinction. Thus, while in the former he assessed the theological implications of the methods for studying nature, as he evaluated the methodological practices carried out by the philosophers in order to know nature with certainty, in the latter, he evaluated their theological implications.[222] In this sense, for Mutis, the development of a natural religion and the perfection of moral philosophy was possible as long as Newton's experimental physics was used as a foundation for natural philosophcical investigation. In Mutis' words: "Ya no es la física, como en otros tiempos, un lenguaje bárbaro y desconocido, un conjunto de razonamientos mal fundados, ni de sistemas formados en una imaginación viva. Ya solo se estudia el libro de la naturaleza por medio de la observación de la experiencia, fundando los razonamientos en el camino más seguro de las demostraciones matemáticas" (RJB III, 2, 4, 11, f. 3r). In fact, this characterization of the experimental physics contains the central topics that Mutis developed in *Elements*. First, he considered the importance of mathematics and experiments for the development of the correct method to proceed in order to know natural phenomena. I shall argue that this characterization is framed in the use of the method of analysis and synthesis as Newton proposed it in the *Query* 31 of the *Opticks*. Second, we can also note Mutis' criticism against the systematic philosophy. A criticism that was similar to Feijoo's interpretation of the experimental philosophy, which reveals that Mutis' rejection of the systematic philosophy was a generalized position in Spain, developed during the early stages of the reception and institutionalization of experimental philosophy in the mid-eighteenth century.

In the earliest passages of *Elements*, Mutis claims that the philosophical systems have been progressively replaced in Europe by the experimental physics, arguing that such a process, though slowly, had begun in Spain as well.[223] He also discusses in this passage some historical

[222] This specific feature of Mutis' *Elements* is mostly visible in AGNC, Sección Colonia, Colegios: SC. 12, 2, ff. 9r-10v.
[223] RJB III, 2, 4, 11, ff. 3r-3v.

features of this process, by considering the role of academies in the institutionalization of experimentalism: "Nada ha contribuido tanto al adelantamiento de esta ciencia y a inspirar generalmente el gusto de la física experimental, como las academias y compañías establecidas en casi todas las ciudades principales de Europa, los frecuentes y repetidos viajes, y los grandes premios con que los soberanos han protegido las ciencias naturales en beneficio común del género humano" (RJB III, 2, 4, 11, f. 3v). It is remarkable the similitude of Mutis' position regarding the role of the experimental physics and academies in abolishing the philosophical systems to Feijoo's one as it was presented in his *Teatro Crítico Universal*.[224] According to Feijoo, it is necessary to embrace the methodological precepts of Baconian experimentalism in order to study nature. Thus, it is possible to avoid to fall in an absolute skepticism which is the consequence of using a deductive method founded on imaginary principles as it was defended in Spanish universities.[225] However, as I pointed out above, Feijoo concludes that despite using experiments and observations to study nature, it is impossible to achieve a complete knowledge of natural phenomena and explain them in terms of laws, as it entails a reduction of the power of God to act according to the principles that we can discover by studying nature.[226]

Unlike Feijoo, Mutis considered that *experimental physics* was concerned with the description of natural phenomena, the discovery of their causes, and the manifestation of their relationship in order to determine the general laws God created to rule the motion of bodies in the universe. Thus, the theological implications of studying nature via *experimental physics* and the

[224] Feijoo referred in diverse passages of the eight volumes constituting the *Teatro Crítico Universal* to the matter of the emergence of the experimental physics. For instance, in Volumes III and V it is possible to find two explicit references to this topic and to the role of academies in the development of experimental physics. *Cf.* Feijoo (1773a, III), pp. 290-291; Feijoo (1773a, V), pp. 254-290.
[225] Feijoo's references to his "moderate scepticism" and his critiques to both scholasticism and modern mechanical philosophers derived from it are in Volume III, *Discurso* XIII *Scepticismo filosofico* of his *Teatro Crítico Universal*. *Cf.* Feijoo (1773a, III), pp. 291-341.
[226] *Cf.* Feijoo (1773a, III), pp. 291-341.

particular interpretation of it that conducted Feijoo to a moderate skepticism were precisely the reasons which led Mutis to accept Newton's experimental physics: knowing nature means knowing God. In other words, unlike Feijoo, for Mutis, studying nature by experiments makes it possible to establish connections between effects and causes that, being universalized by mathematical demonstrations, lead to the postulation of universal laws which are the manner in which God acts on the creation. Hence, in Mutis' opinion, an adequate investigation of natural phenomena must lead men toward the knowledge of God's providence and conversely an inadequate one would lead them to atheism or to skepticism – like in Feijoo's case. Mutis illustrates this position by presenting the inherent problems of Epicureanism, the literal interpretation of Holy Scriptures, and Cartesianism, comparing them to his particular interpretation of Newton's *experimental physics*. In Mutis' words:

> Quién no ve que los falsos sistemas de la física pueden precipitar al hombre en el ateísmo, o por lo menos excitar opiniones muy peligrosas al género humano sobre la divinidad y el universo (…) Un partido bien numeroso en la antigüedad adoptó aquel monstruoso sistema, en que sin recurrir a la divinidad, se pretendía explicar la formación del universo por un juego casual de átomos, deduciendo la hermosura inefable de todas las cosas que vemos, aún la vida y el pensar del hombre de una cierta disposición producida casualmente en el caos confuso de átomos (RJB 2, 4, 11, ff. 5v-6r).

In the context of his explanation of the theological implications of *experimental physics*, Mutis introduced a definition of the subject of natural philosophy which makes it possible to establish a relationship between it and mathematics and consequently to present Newton's method more detaidly. According to Mutis, the main business of natural philosophy is to describe natural phenomena and its causes. In this sense, it is necessary to follow the method of analysis and synthesis, as Newton proposed it in the *Opticks*, in order to discover the causes producing specific effects. Nevertheless, as Mutis himself explains,

> No hay duda en que las observaciones y las experiencias no pueden por sí elevarnos al descubrimiento de las causas por los efectos, y explicar los efectos por las causas. Para esto se aprovechó [Newton] de una geometría sublime que siempre le servía de guía en las averiguaciones delicadas y espinosas. No hay ciertamente otro instrumento por cuyo medio se pueda conocer el mecanismo de una obra hecha con arte tan maravilloso (RJB III, 2, 4, 11, f. 8v).

Mutis introduced Newton's method of analysis and synthesis in *Elements* in order to explain how it allows to study nature without the problems of the speculative-deductive systems, by establishing a relationship between mathematics and natural philosophy. Mutis established said relationship in both methodological and conceptual levels as he argued that the study of nature should be guided by the principles of the geometrical method of analysis and synthesis to discover the laws ruling the motion of bodies in nature.[227] These laws, as we shall see, are also generalized by a mathematical procedure and consequently I shall argue that, in *Elements*, Mutis also presented Newton's method to mathematize nature, as it was discussed in *Opticks*.[228] This entails that Mutis not only considered the utility of mathematics in natural philosophy as it provides to this discipline its external demonstrative form, but fundamentally because the laws discovered by natural philosophy are explained and generalized by the application of mathematical demonstrations. Let us consider in detail how Mutis understood Newton's

[227] *Cf.* RJB III, 2, 4, 11, f. 9r.
[228] For the methodological differences between Newton's mathematization of nature in *Optick* and *Principia* and the particular manner in which both approaches are intertwined, see Ducheyne (2012), pp. 219-225.

pronouncements on the method of analysis and synthesis in *Elements*. Later, I shall compare it with other features of Newton's method that Mutis discussed in the context of his lectures, through his commentaries to 's Gravesande's *Physices elementa mathematica*.

"The investigation of difficult things": the method of analysis and synthesis and its application to physics in Mutis' lectures

In *Elements*, Mutis characterized Newton's thought as opposed to both Aristotelian scholasticism and Cartesian hypothetical philosophy. According to him, the emergence of experimental philosophy began with Bacon's works and the virtue of such an approach consisted in that it allowed to explain nature by the effects known through observations, which lead to know the causes producing them.[229] Nevertheless, Mutis claims that observations are not sufficient to postulate the causes discovered as *universal* causes. For him, it was necessary to use several mathematical explanations in order to explain the relationship between any cause with the multiple effects it can produce. Consequently, he introduced Newton's method of analysis and synthesis as it was applied to the investigation of nature to universalize the causes discovered via experiments. I quote Mutis' characterization *in extenso*:

> Para proceder con toda seguridad, y dar de mano para siempre a las disputas, [Newton] se sujetó a valerse siempre en el estudio de la naturaleza de los métodos analítico y sintético; de tal suerte que habiendo comenzado por los fenómenos o los efectos pudiere después pasar al descubrimiento de las potencias o causas, que obran en la naturaleza. Estableció asimismo que de las causas particulares se fuera subiendo a otras más generales; y de estas finalmente a las más generales entre

[229] *Cf.* RJB III, 2, 4, 11, ff. 7r-8v.

> todas. Este es el método analítico. Después de haber descubierto estas causas se debe bajar por un orden contrario, considerándolas ya como principios establecidos para explicar por este medio las causas menos generales, y después los fenómenos que son sus consecuencias; haciendo ver de este modo la solidez y firmeza de estas explicaciones. Este es el método sintético. Ya se ve que en la física como en las matemáticas se debe proceder en las cosas más difíciles por el método analítico, para hacer después el debido uso del sintético (RJB III, 2, 4, 11, f. 9r).

There are several elements in this passage which are convenient to analyse in detail in order to account with precision for Mutis' presentation of Newton's methodology. I would like to begin by its final statement. It is remarkable the similarity of Mutis' presentation of the order in which the methods should be applied to that of Newton in the *Query* 31 of the *Opticks*, where Newton claims: "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" (1952: 404). 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 is not produced by the mere observation of natural phenomena. Conversely, Newton argues that it is necessary to apply different mathematical procedures in order to determine the causal connection between a particular phenomenon and its possible cause. 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" (1952: 404). 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 and that such an investigation only can been managed by articulating an experimental approach to nature with a mathematical analysis of the observed phenomena.

Another revealing aspect of the quoted passage is the particular concepts 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 by the influence of 's Gravesande and his concerns regarding the very possibility of being understood by his students. In the manuscript containing the translation of the *Physices elementa mathematica* – which I shall study in detail later –, we can see that Mutis conceived natural phenomena in mechanical terms as he defined *fenómenos naturales* as "todos los movimientos y todas las situaciones de los cuerpos naturales que no dependen inmediatamente de la acción de un ser inteligente; y que son perceptibles por nuestros sentidos" (RJB III, 7, 1, 5, f. 282r). 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 "potencies" [*potencias*]. For Mutis, physics is the study of powers causing the motion of the bodies in nature. Thus, he proposed a mechanical physics that was opposed to the Aristotelian physics taught in New Granada during the first half of the eighteenth century.[230] Consequently, Mutis' use of Aristotelian terminology to define causal relationships, as it is the case of defining causes as potencies and effects as phenomena, should be understood as a consequence of Mutis' interest in arguing in favor of this mechanical interpretation of the application of Newton's method via 's Gravesande's interpretation of it in the scholastic context of New Granada's university milieu.

[230] For the history of the teaching of physics in New Granada during the colonial times, see Martínez Chavanz (1993). In García Bacca (1955) and Rivas Sacconi (1993) it is possible to find some transcriptions and translations of a good deal of manuscripts regarding the teaching of physics in New Granada.

Henry Guerlac, Alan Shapiro, and Niccolò Guicciardini have amply explained Newton's method of analysis and synthesis as it was applied to natural philosophy.[231] According to them, for Newton, the method of analysis is fundamentally a method of discovery. He used it in order to discover either the causes of natural phenomena or the structural constitution of bodies. Thus, when he dealt with the motion of bodies, the causes were the forces causing them. In Guicciardini's words: "Analysis, whether modern algebraic or ancient porismatic, is in any case, in Newton's opinion, unfit to be presented as demonstrative. Analysis, even the ancient analysis, is a complex procedure made of trials and error and constitutes the process of discovery adopted by the skilled mathematician" (2009: 312). Consequently, as Mutis considered physics as the study of the motion of bodies, the method of analysis aims to discover the forces (*potencies*) causing them. Correspondingly, the method of synthesis for Newton, as these historians pointed out, is a method of demonstration. Once a particular cause of a phenomenon has been discovered, Newton proceeds to demonstrate it mathematically, supposing the cause as given and deducing the phenomenon that follows.[232] In Mutis' case the power to accelerate a body, the "force" in Newton's terms, is supposed and then he deduces the motion caused when such a force acts. However, it is worth of notice that this procedure only can produce a causal explanation of a particular phenomenon by the postulation of particular causes. In this sense, both Newton and Mutis conclude that postulating the universality of the cause only is possible by studying it mathematically. That is precisely what Mutis understood by Newton's application

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[231] *Cf.* Guerlac (1973); Shapiro (2004); Guicciardini (2009), pp. 309-327. I have compiled their explanations on this particular topic and some others in Molina-Betancur (2014).

[232] As Guicciardini and Guerlac comment, in Newton's application of the geometrical method of analysis and synthesis to natural philosophy, the synthesis cannot be considered, as in mathematics, as mere "reversal of the steps followed in the analysis" (Guicciardini, 2009: 312). By contrast, in Newton's opinion, the synthesis only can be considered as true demonstration as it eliminates any trace of the heuristic and complex process of synthesis, thus making it possible to generalize the principle postulated. *Cf.* Guerlac (1973), Guicciardini (2009), pp. 312-313.

of a "sublime geometry" which allows him to discover that a single force can be the cause of different phenomena.

For Mutis, the mathematical explanation of the principles discovered by the use of the method of analysis is one of the most important features of Newton's method for three reasons. 1. It illustrates the importance of mathematics for physics. In this context, for instance, we can compare these pronouncements with Mutis' characterization of the general conclusions to which it is possible to arrive by using Descartes' geometrical procedures, as he discussed it in his translation of Book I of Descartes' *Géométrie*. 2. It allows to propose the particular causes discovered by observation and experiments as general causes and consequently to postulate them as universal laws. This is a really important point for Mutis, because 3. It leads to know how God acts on his creation. According to him, God interacts with his creation through a set of universal laws, established in order to rule and govern the motion of bodies. The importance of this theological implications should not be overlooked, because they were a permanent concern for Mutis as it is evidenced in his translation of 's Gravesande's general axiom of his *Physices elementa mathematica* where the latter establishes a theological foundation to the laws of motion:

> El examen de todas estas cosas nos descubre una verdad que debe mirarse como un axioma, que es el fundamento de todos los razonamientos en las cosas físicas. Axioma. El criador [sic.] del universo gobierna todas las cosas con determinadas y constantes leyes, propias de la sabiduría, o que nacen espontáneamente de la naturaleza misma de las cosas (RJB III, 7, 1, 5, f. 282v).[233]

As we can see, Mutis' initial introduction of Newton's methodology in New Granada is characterized by his insistence in the theological implication of the application of the method of

[233] *Cf.* 's Gravessande (1748), p. 2.

analysis and synthesis in the investigation of nature. But, unlike the lectures on mathematics, where he merely presented them, in these lectures he developed them in detail by following 's Gravesande's postulation of the theological foundation of Newton's physics.[234] By doing so, Mutis illustrated the importance of the articulation of mathematics and physics in his intepretation of Newton's experimental physics.

However, the importance of 's Gravesande in Mutis' appropriation of Newton's experimental physics is not limited to the establishment of the theological foundations of physics. Likewise, Mutis' use of 's Gravesande's characterization of the laws of attraction reveals other aspects of the Newtonian character of Mutis' discussion of the method of analysis and synthesis and its implications. For Mutis,

> La atracción entendida en estos términos, y que se observa entre las partecillas que componen los cuerpos, es la que colocamos entre las leyes de la naturaleza. La atracción de las partecillas mínimas guarda estas leyes: 1. Su mayor fuerza consiste al tocamiento mutuo de las partecillas, y al punto disminuye de golpe, de tal suerte que en la distancia más mínima y perceptible, ya no obra. 2. Que a cierta distancia que es la mayor, se apaga enteramente la fuerza de atracción y se cambia en una fuerza repelente, por la cual las partecillas huyen mutuamente las unas de las otras (RJB III, 7, 1, 5, f. 297r).

As we can see, Mutis did not hesitate in teaching on attractive forces as they were mathematically explained by Newton in the *Principia*. Furthermore, he illustrated them with 's Gravesande's set of experiments with which he tried to demonstrate the reality of attractive forces, because of the

[234] A detailed study of 's Gravesande's considerations on theology and its relationship with physics is in Ducheyne (2013).

effects they produce.[235] Thus, despite that attractive forces between particles, such as those that both Mutis and 's Gravesande were describing, cannot be identified with gravity as an attractive force, the fact that they both used attractive forces to explain mechanical phenomena in causal terms is a key aspect of their reception of Newton's physics.[236]

One of the most interesting aspects of Mutis' characterization of physics, its subject, and Newtonian method used to study it is its application to mechanics. As I previously explained, he conceived physics in mechanical terms, thus limiting its scope to the study of the motions caused in a body when there is a power – a force – acting upon it. This mechanization of physics is clearer by considering Mutis' manuscript entitled *Elements of mechanics* [*Elementos de mecánica*], which probably contains the theoretical elements he taught on this discipline in New Granada. The probability for this manuscript being part of the set of Mutis' lectures on physics relies on its structure, which is similar to the ones of the manuscripts containing his lectures on mathematics and physics, and on the fact that it has the same structure as Wolff's Volume II of *Elementa Matheseos*.[237] A fact considerably important for determining the pedagogical purpose of the manuscript, considering the role of this work in the development of Mutis' lectures on mathematics.

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235 's Gravesande's experiments regarding attractive forces are in 's Gravesande (1748), pp. 18-24.
236 As the passage quoted reveals, attractive forces between particles were considered as different kind of attractive force as regards to gravity. In general, in the early-eighteenth century, it was a well-known fact that attraction between particles do not follows the same ratio as gravity, but it is worth of notice that Newton's conception of attractive forces and mostly his mathematical approach to them provided to the natural philosopher tools to speculate on forces of this kind. I shall briefly deal with this topic in Chapter 5 as I analyse the role of attractive forces in Newtonian medicine. For a general reconstruction of the concept of attractive forces in the early-eighteenth century, see Hall & Hall (1960). Domenico Bertoloni Meli studied Newton's concept of attractive forces in the light of Newton's pronouncement on the inherent character of the force in the *Principia*. *Cf.* Meli (2006a)
237 It must be borne that Wolff divided his *Elementa matheseos* in two volumes. Thus, whilst the first one encompasses arithmetic, trigonometry, geometry, and calculus, the second volume deals with the mathematical analysis of mechanics, hydraulics, statics, and hydrostatics. A study of Wolff's mechanics is in Borzeszkowski & Wahsner (2001).

As in the cases of the other pedagogical manuscripts, in *Elements of mechanics*, Mutis begins by postulating a set of basic definitions upon which he establishes the principles of the field. After defining mechanics in Definition 1 as the science of motion, Mutis defines the cause of motion: "Def. 2. La causa que produce el movimiento se llama potencia. También se suele llamar momento. Aquello que se mueve se llama peso. También se suele llamar resistencia" (RJB III, 7, 1, 5, f. 334r). By considering potencies as causes of motion and 's Gravesande's definition of natural phenomena as the motion of bodies – a definition that Mutis used in his translated version –, we can argue that Mutis saw mechanics as the science studying natural phenomena. It entails that, in Mutis' opinion, there were no differences between mechanics and physics. This conceptual confusion is clearer by reading Mutis' corollary to the recently quoted Definition 2, where Mutis seems to present physics as an extension of mechanics: "Por donde se ve que el hombre, los animales, el aire, el agua, el fuego, y cualesquiera cosa elástica pueden servir de potencia. *Y por esta razón trata la mecánica de todas las cosas*" (RJB III, 7, 1, 5, f. 334r).[238] For Mutis, natural bodies have an elastic virtue which turn them into possible causes for the motion of some other bodies and consequently they should be considered as part of the subject of a study of nature framed in the field of mechanics. It is also important to highlight that, by indistinctively considering the human body, the body of animals, air, and fire, Mutis was not thinking mechanics as it was related to the study of the motion caused by simple machines, but in the more general sense of Newton's *rational mechanics*.[239]

[238] My emphasis.

[239] In the Preface to the first edition of *Principia*, Newton argues that by studying the forces causing natural phenomena, it is possible to extend the scope of mechanics to not only embrace the study of the motion caused by artificial causes – simple machines – but also to study the forces that produce the motion of "natural" bodies. For Newton, this is precisely the "main business of natural philosophy". For Newton's pronouncements in the preface of *Principia*, see Guicciardini (2009), pp. 293-299.

Nevertheless, in the first scholium to Definition 12, which defines a machine as "an instrument for motion", Mutis presented a characterization of machines which allows to perceive several disciplinary differences between mechanics and physics. According to Mutis, "Por esta razón se llaman generalmente máquinas todos aquellos cuerpos, que sirven para producer el movimiento de tal suerte que se pueda ejecutar o con menores fuerzas, o en menor tiempo" (RJB III, 7, 1, 5, f. 335v). Thus, for Mutis, mechanics has a utilitarian purpose as it mostly deals with motions produced by machines with the purpose of economizing time and efforts for men. Conversely, physics deals *mechanically* with the motion of natural bodies, producing natural phenomena. In other words, Mutis established a difference in the fields by following the classical precept of establishing a difference in the subject of each field.[240] Thus, whilst mechanics deals with artificial subjects, physics does it with natural ones. However, it is important to highlight that, for Mutis, this differentiation is merely conceptual, because, in the end, the universal character of the laws created by God to rule the universe determines the motion of both artificial and natural bodies. As Mutis puts it,

> Como los efectos de todas las máquinas nacen de la composición arreglada siempre a las leyes inmutables de los movimientos, por eso todas las operaciones de las cosas corpóreas se llaman operaciones mecánicas; pues ellas obran siempre según conviene a su composición, y según las leyes constantes de los movimientos. De aqui se ve claramente que los físicos filosofan mecánicamente siempre que razona(n) manifestando evidentemente de que modo se producen

[240] The determination of mechanics as a field of study related to natural philosophy and its historical development in the seventeenth and eighteenth centuries has been studied in detail by Dugas (1958), Bennett (1986), and Meli (2006b).

> los efectos de las cosas en fuerza de las leyes del movimiento y en fuerza de la estructura (RJB III, 7, 1, 5, f. 335v).

For Mutis, physics and mechanics can study motion in a similar manner, as both of them are founded on the universal laws of motion created by God. In this sense, the investigation of nature in order to determine the laws ruling such motions also have practical purposes as these laws were used for the creation of machines making it easier the daily works of men and increasing their efficiency. Thus, the difference between these disciplines, as I argued above, relies on the particular subject on which they are applied and not on the intellectual superiority of any of them.[241] This consideration is important chiefly by considering the Aristotelian nature of Mutis' audience. According to him,

> Por aquí se conocerá también cuan justo sea vindicar la filosofía mecánica de aquellas calumnias, con que el vulgo y los necios escolásticos satisfechos de su vana filosofía han querido averiguar la verdadera física o examen de la naturaleza. Deberían tales filósofos haber conocido que es temeridad querer filosofar en asuntos de cosas naturales sin el conocimiento de las matemáticas (RJB III, 7, 1, 5, f. 335v).

In general, Mutis' *Elements* – and his subsequent lectures dealing with the basic elements of physics and mechanics – presents Newton's methodology as an approach to nature which allows to use both experiments and mathematics in order to explain natural phenomena. By reducing natural phenomena to phenomena of motion, Mutis argued in favour of a mechanical physics in which the causes of motion – the powers of bodies – were discovered by experimenting and observing nature. Thus, once forces acting as causes were discovered, they are mathematically

[241] For the critiques to mechanics based on its intellectual inferiority, see Rossi (2001), pp. 122-139.

studied in order to explain how they act as causes. In Mutis' opinion, the application of mathematics to the study of nature allows to explain the universality of the forces as long as the studied phenomena follow the same mathematical ratios. In this sense, the explanation of the causal action of the force is strictly mathematical and consequently it falls out of the causal explicative scheme of Aristotelian physics and Cartesian mechanical philosophy.

By considering Mutis' methodological pronouncements, we can see two interesting aspects of Newton's methodology that Mutis introduced in New Granada. First, he completed the explanation of the articulation of mathematics and natural philosophy presented in his *Preliminary discourse* of 1762. In it, Mutis presented mathematics as the discipline that provides certainty to the explanations of natural phenomena. In his lectures on physics, Mutis completes this idea, arguing that mathematical demonstrations allow to universalize the causes discovered by observations and experiments. In other words, Mutis claims that mathematical demonstrations allow the physicist to know the laws God created to rule the motion of the bodies. Second, in these lectures we can also see that Mutis introduced in New Granada his interpretation of Newton's application of the method of analysis and synthesis to natural philosophy. His particular interpretation is based on Newton's *Query* 31 of the *Opticks*, and I argued that it is similar to Newton's methodological statements there in both the content of the method and in the form of presenting it: Mutis used the same concepts Newton used and he defended Newton's method as the best manner to study nature. Nevertheless, these methodological aspects are not the only ones Mutis introduced in New Granada. I shall explain in the next section some other methodological pronouncements that he presented in the context of his lectures on physics, where he commented and explained Newton's rules for the study of natural philosophy, as it is evidenced by his translation of 's Gravesande's *Physices elementa mathematica*.

Newton's Rules for philosophy in New Granada

Mutis' explanation of Newton's rules for natural philosophy is in his translation of 's Gravesande's *Physices elementa mathematica*. 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 's Gravesande work, emphasizing on the definition of concepts and the problems emerging from those definitions.[242] In it, we find the translation of the first five chapters of Book I of *Physices elementa mathematica*, where 's Gravesande discusses the basic constitution of bodies, the theological foundation of the laws of nature, and the role of Newton's rules for studying nature.[243] This translation also confirms the idea held by historians such as Arboleda, Albis, and Martínez Chavanz that Mutis' introduction of Newton's experimental physics in New Granada was deeply influenced by the interpretation of the Dutch and French Newtonians.[244] As Arboleda argues: "Hay que recordar que las ideas newtonianas penetraron en España a través de los experimentalistas holandeses 's Gravesande y Musschenbroek y franceses Sigaud de la Fond y Nollet, a los cuales se refiere tantas veces Mutis en sus escritos" (1993: 64). Nevertheless, by considering the role of translating in Mutis' pedagogical practices, we can see that this influence was more determining than it has been previously thought, as he did not only use their works as external references to explain Newton's natural philosophy, but, in the case of 's Gravesande's work, he directly used it as textbook in his own translated version. As in the case of the translations of Wolff's *Elementa matheseos* and Descartes' *Géométrie*, the identification of Mutis'

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[242] *Cf.* RJB III, 7, 1, 5, ff. 282r-302r.

[243] It is worth of notice that rather than explaining Newton's theoretical concepts and tenets from a strictly theoretical point of view, 's Gravesande aims to illustrate them with several experiments and scholia which aim to articulate Newton's theoretical principles to his natural philosophical methodology. *Cf.* 's Gravesande (1748), pp. 1-28.

[244] *Cf.* Albis & Arboleda (1988), Arboleda (1993), Martínez Chavanz (1993).

manuscript on the physical consideration of the body as a translation of *Physices elementa mathematica* is one of the results of my research in the archives of the *Real Jardín Botánico* of Madrid. As in the case of Wolff's *Elementa*, this translation is the only version in Spanish of a work of 's Gravesande, although it only includes the first five chapters of Book I.[245] However, it is interesting to highlight that Mutis also translated the scholia, to which he added three scholia dedicated to explain Newton's rules for natural philosophy.[246]

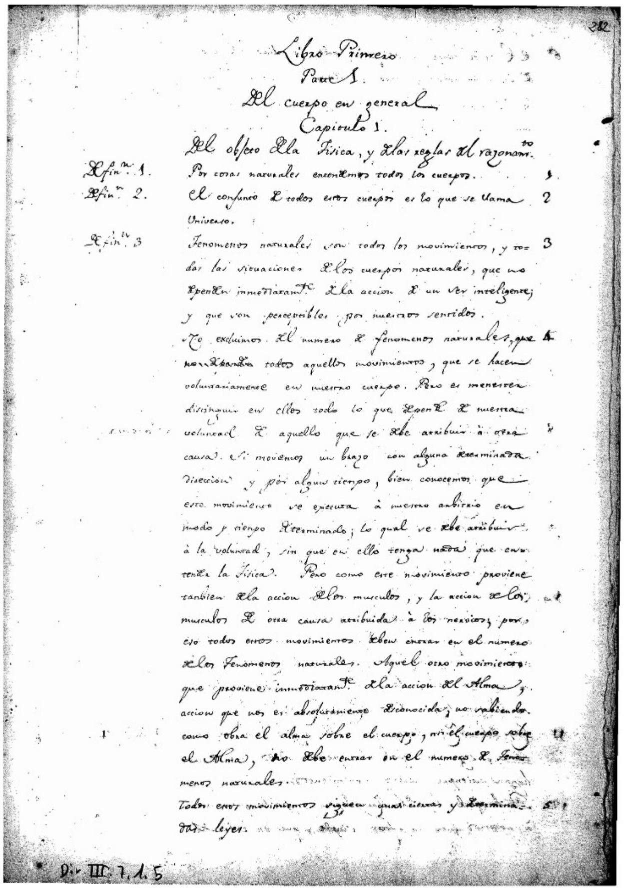
Libro Primero
Parte 1.
De el cuerpo en general
Capitulo 1.

Figure 11. Front page of Mutis' translation of 's Gravesande Physices elementa mathematica, RJB III, 7, 1, 5, ff. 282r-302r.

245 Published in 1720-1721, 's Gravesande's *Physices elementa mathematica* had a deep impact on the early stages of the diffusion of Newtonianism in Europe – even in England, where an English version was published by Desaguliers in 1747. I have transcribed every quote from *Physices elementa mathematica* from Mutis' manuscripts, comparing them with the fourth Latin edition of the *Physices*, published at Leiden in 1748 and corrected by 's Gravesande – in every quotation I also include the reference to this edition. In some cases, I also compared them with Desaguliers' translation as well.
246 Mutis' scholia on Newton's rules are in RJB III, 7, 1, 5, ff. 283r-284v.

In chapters one through four of *Physices elementa mathematica*, 's Gravesande defines several basic concepts of physics, arguing in favour of the existence of vacuum and the idea that solidity is one of the primary qualities of the bodies. Likewise, he discusses the problems related to the divisibility of matter, using both physical and mathematical arguments.[247] However, the most interesting chapter that Mutis included in his translation is the fifth one. There, 's Gravesande deals with the cohesion of the parts of bodies and the qualities resulting from the different degrees in which these parts cohere. The importance of the translation of this chapter relies on the fact that 's Gravesande refers there to the cohesion of parts in terms of an attractive quality, which is based on Newton's description of attractive forces. Thus, by including this characterization of forces in terms of attraction, and presenting it in the context of his lectures on physics at the *Colegio del Rosario*, we can see that Mutis embraced a Newtonian conception of force which lead him to criticize Cartesian mechanics and the scholastic causal explanations of nature. In fact, the rejection of these approaches to the study of natural phenomena helped him to reaffirm his position regarding the debates on the causality of the force which he had already characterized in his *Elements*. I shall analise later this particular feature of Mutis' translation, when I study Mutis' considerations on the reception of Newton's ideas in Europe and their introduction in New Granada.

In chapter one of *Physices elementa mathematica*, 's Gravesande establishes that in order to study natural phenomena, it is necessary to begin by knowing the constitution of bodies and studying the particular phenomena which are produced when they are accelerated by a force.[248] Such a consideration shed light on Mutis' considerations on mechanics as they were presented

[247] 's Gravesande's pronouncements on the composition of matter are in Book I, Chapters II and III. *Cf.* 's Gravesande (1748), pp. 3-7.
[248] This particular feature of 's Gravesande's consideration is clear in Definition III, in which he considers natural phenomena in terms of motion of natural bodies from which it is possible to deduce mathematical laws. *Cf.* 's Gravesande (1748), pp. 1-2.

in *Elements of mechanics*. As 's Gravesande puts it: "En el examen de estas causas se debe proceder examinando primeramente con toda atención el cuerpo en general. Después se ha de intentar descubrir por qué reglas ha querido el Criador que se ejecuten todos los movimientos. Estas reglas se llaman leyes de la naturaleza" (RJB III, 7, 1, 5, f. 282v).[249] Therefore, 's Gravesande proposes a specific order for the physical study of nature: the study must begin by considering the constitution of the bodies and how they interact; then, it is necessary to discover the laws of motion created by God in order to rule the motion of the said bodies. In using 's Gravesande's *Physices Elementa mathematica* as a textbook for his lectures on physics, we can see that Mutis adopted a Newtonian conception of the laws of motion, in which the laws are discovered by the study of the constitution of bodies and their motions. As I pointed out in the last chapter, in his lectures on mathematics, Mutis had argued that the determination of the law-character of the rules that God created to rule the motions of the bodies was produced by the application of sophisticated mathematical procedures – Newton's "sublime geometry" –, to physics. It allows him to argue that Newton had been capable of discovering the regularities in the motion of bodies and consequently he was able to postulate the forces causing such motions as laws of nature. However, by considering 's Gravesande's version of the Newtonian methodology, I shall argue that Mutis also included to his "Newtonian agenda" a diligent consideration of Newton's rules for philosophy, which made it possible for him to explain to his students how to proceed in the universalization of the principles mathematically discovered.[250]

's Gravesande introduced his reference to Newton's rules for philosophy with the purpose of explaining how to proceed in order to determine the regularities of the motions of

[249] *Cf.* 's Gravesande (1748), p. 2.
[250] Historians such as Cohen, George E. Smith, and Ducheyne argued that Newton's process for universalizing the laws of nature deeply depended on the particular methodology he had developed in the *Principia* which allowed him to identify the mathematical models of nature drawn up in Book I and II with the natural phenomena studied in Book III. *Cf.* Cohen (1980), pp. 52-120; Smith (2004); Ducheyne (2012), pp. 55-179.

the bodies and propose them as laws of motion: "Se debe también notar que en la averiguación de estas leyes se han de observar *con toda exactitud* las reglas del Método Newtoniano, las cuales se fundan en el axioma que dejamos establecido" (RJB III, 7, 1, 5, f. 283r).[251] It is worth of notice that, in his translation, Mutis emphasized the need to apply Newton's rules *with total precision* (*con toda exactitud*) because such an emphasis is not present in 's Gravesande's version. This fact suggests that Mutis was absolutely convinced of the utility of Newton's rules in the study of nature and promoted them as the *unique* method to achieve a diligent study of natural phenomena. On the other hand, the axiom to which 's Gravesande is referring to is the one I quoted in the last section: "Axioma. El criador [sic.] del universo gobierna todas las cosas con determinadas y constants leyes, propias de la sabiduría, o que nacen espontáneamente de la naturaleza misma de las cosas" (RJB III, 7, 1, 5, f. 282v).[252] Mutis' use of 's Gravesande's characterization of the theological foundation of Newton's rules for philosophy in the context of his lectures on physics reveals that he based 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 know his providence. This idea confirms the fact that Mutis aimed to introduce Newton's physics in New Granada by highlighting the theological implications of a mathematical approach to nature. In this sense, this theological foundation of the relationship between mathematics and physics was not only based on Newton's approach to nature, but it also was highly determined by Mutis' interests in establishing an opposition to the scholastic tradition of New Granada's universities. An opposition that was reflected in his polemics with the Dominicans regarding the Copernican system.

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[251] *Cf.* 's Gravesande (1748), p. 3. My emphasis.
[252] *Ibid.* p. 2.

After explaining the theological foundation of Newton's rules for philosophy, 's Gravesande introduces the rules as Newton proposed them at the beginning of Book III of *Principia*:

> Regla 1. No se deben admitir por causas de las cosas naturales sino aquellas que son verdaderas y bastan para explicar sus fenómenos.
>
> Regla 2. Los efectos naturales de una misma especie tienen unas mismas causas.
>
> Regla 3. Las cualidades de los cuerpos que son siempre unas mismas sin aumentarse ni disminuirse en ningún tiempo, y que convienen a todos los cuerpos, sobre los cuales se pueden hacer experimentos, deben ser colocadas en la clase de cualidades communes a todos los cuerpos (RJB III, 7, 1, 5, f. 283r).[253]

In the original version of the *Physices elementa mathematica*, 's Gravesande used the rules as a conclusion of Chapter I, which deals with the determination of 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, after the rules, he included three scholia, which aimed to explain Newton's rules in detail. Let us analyse Mutis' interpretation of the rules, as it can shed light on his particular conception of Newton's methodology.

[253] It is important to highlight that 's Gravesande transcribes *verbatim* Newton's rules for philosophy as they appear in the second edition of *Principia* with an exemption: he did not included the "*Ideoque*" at the beginning of Rule II. Such an omission makes it difficult to understand that, in Newton's opinion, Rule II was an epistemological and logical consequence of Rule I and the simplicity of nature that it supposed. I shall argue that such an omissions had an impact on Mutis' interpretation of Rule II. *Cf.* 's Gravesande (1748), p. 3. In Desaguliers' translation there are some variations which I think make it clearer the sense of the rules, Desaguliers (1747), p. 3. For a study of Newton's rules and 's Gravesande's appropriation of them, see Ducheyne (2014), Ducheyne (2015).

In general, as his insistence in following Newton's rules *with total precision* suggests, Mutis considered that they were the *only* method to study nature correctly, as they were based on observations and experiments and were aimed to discover the laws of nature. In Mutis' words:

> Para que la física se adelante, y los filósofos puedan aprovechar en sus descubrimientos, se ha de conocer todo el mérito de las Reglas newtonias [sic.], sin las cuales es imposible comprender los fenómenos que se manifiestan, ni descubrir sus causas, ni hacer el debido uso de las observaciones y experiencias (RJB III, 7, 1, 5, f. 283r-283v).

Likewise, in these scholia it is possible to see also an anti-Cartesian interpretation of Newton's rule, emphasized by Mutis' insistence on the need to avoid the speculative explanations derived from a hypothetical approach to nature. This is particularly important, because it reflects that Mutis not only presented Newton's rules as an alternative to the methodological foundation of the physics taught in New Granada's universities, but also as a valid alternative to any hypothetical-deductive system of natural philosophy.

This characterization is clear in Mutis' explanation of Newton's first rule for philosophy: "En la Regla primera se establece abandonar las suposiciones; porque suponer una causa para explicar un fenómeno que se nos presenta, es lo mismo que manifestar claramente, que se ignora la verdadera causa de aquel efecto; pues si se conociera no era necesario suponerla" (RJB III, 7, 1, 5, f. 283v). Unlike Newton, whose formulation of and commentaries to this rule are concentrated on its epistemological character, Mutis avoids this particular issue, being concerned in characterizing the problems derived from a hypothetical-deductive approach to nature. Let us consider Newton's characterization of the rule as it appears in the second edition of *Principia*, which was the one 's Gravesande used for *Physices elementa mathematica*,[254] comparing it with Mutis' particular interpretation:

> Reg. 1. *Causas rerum naturalium non plures admitti debere, quam quae & verae sint & earum phaenomenis explicandis sufficiant.*
>
> Dicunt utique philosophi: natura nihil agit frustra, & frustra fit per plura quod fieri potest per pauciora. Natura enim simplex est & rerum causis superfluis non luxuriat (Newton, 1713: 357).

According to Newton, there is no need to postulate more causes to natural phenomena when only few are enough to explain them. This rule entails an explicative economy in an epistemological level, which is based on the ontological assumption of the simplicity of nature. Such an assumption, in turn, is founded on the theological principle of the connections between God's perfection and the simplicity of his work: "Nature does nothing in vain, and more causes are in vain when fewer are suffice" (Newton, 1999: 794).[255] Conversely, Mutis focused on the need to admit as causes of natural phenomena only those which can be considered as true and sufficient. In this sense, he did not refer to the need to avoid the postulation of multiple causes for a single effect. In other words, Mutis' discussion of Newton's first rule reveals his pretension of defending an anti-hypothetical approach to nature rather than a presentation of the ontological consequences of Newton's approach to nature. Certainly, Mutis had as a target Cartesian mechanical philosophy, but the consequences of his anti-hypothetical interpretation of Newton's first rule could be also applied to Aristotelian physics, which Mutis understood as

[254] Ostensibly, Mutis only was aware of Newton's rules for philosophy in the version presented by 's Gravesande. As Arboleda has argued, Mutis only had a direct contact with Book III of Newton's *Principia* in its first-edition version, in which Newton did not include his Rules *quam* Rules. *Cf.* Arboleda (1987).

[255] There are several studies on Newton's Rules, their variations in the different editions of the *Principia*, and their role in Newton's work. Some of the most influential are Koyré (1965), pp. 261-272; Finocchiaro (1974); Cohen (1980), pp. 83-96; Mamiani (2004); Ducheyne (2012), pp. 159-179.

they were founded on imaginary principles. It means that his interpretation of Newton's first rule for natural philosophy was aimed to the determination of the superiority of Newton's method when it was compared to the one defended in New Granada's universities.[256] In Mutis' opinion:

> Todos saben, que las conclusiones deducidas de una suposición ni satisfacen ni convencen al entendimiento, que siempre aspira a razonamientos más sólidos (…) Por cual es mucho mejor, para hacer progresos en la verdadera ciencia, confesar abiertamente que se ignora la causa del efecto que se ve, si en efecto no se ha podido descubrir. Mucho más importa esta genuina confesión, que perder inútilmente el tiempo en hacer suposiciones, cuya falseddad conoceremos tarde o temprano, y en inventar sistemas, que para hacerlos plausibles a los ingenios humildes y de poca penetración que todo lo reciben y creen como se les enseña, es necesario revestirlos con otros adornos igualmente falsos (RJB III, 7, 1, 5, f. 283v).

Mutis concludes his explanation of this rule by claiming that this hypothetical approach to nature was replaced by Newton's methodology in the eighteenth century: "Todos los esfuerzos de los genios sistemáticos son de ningún valor en nuestro siglo, en que semejantes autores no grangean más que el desprecio de los verdaderos filósofos que solo aspiran al adelantamiento de la verdadera ciencia" (RJB III, 7, 1, 5, f. 283v). A characterization that complements the idea presented in the *Preliminary discourse*, where Mutis argued that the experimental physics had

[256] Mutis' criticism against New Granada's scholastic education on physics is mostly revealed in the letters he sent to Viceroy Manuel Guirior in the 1770s in the context of his polemics with the Dominicans. In them, Mutis characterized New Granada's university milieu as retrograde and obscure, accussing the Dominicans of being the responsible of that situation. I shall analyse the polemic and its cultural and political consequences in Chapter 6. A transcription of Mutis' letters is in Lanning (1944).

emerged in the late-seventeenth century as a response to the systematic thought that had led to philosophical sectarianism.

Another important aspect of Mutis' explanation of this rule is that he argues that Newton's method did not neglect every hypothesis, as some of them can lead to the postulation of experiments and, as a result, to the discovery of general principles. This consideration was also visible in *Elements*, where Mutis discussed Newton's *Queries* in the *Opticks* as non-proved hypotheses, which Newton posed with the purpose of motivating further investigations on the corpuscles that compose the bodies and their mutual interactions. Undoubtedly, his acceptance of the particular condition in which the use of hypothesis is valid proves that Mutis read Newton's pronouncements on the hypothetical character of the *Queries*, as they were expressed in the introduction to them and in the final paragraphs of the *Query* 31.[257] In the case of the explanation of the first rule, Mutis suggests that hypotheses can be admitted only under the conditions proposed by Newtonians like Musschenbroek and 's Gravesande: "Para saber las ocasiones y las circunstancias en que deban emplearse con las debidas motivaciones sería muy conveniente observar las reglas que sobre este punto prescriben Musschenbroek y 's Gravesande' (RJB III, 7, 1, 5, f. 283v). This statement reveals the influence of an experimentalistic approach to Newton's natural philosophy in Mutis' interpretation of it. Nevertheless, it is important to nuance this influence, because Mutis also stressesed the importance of the mathematical explanation of the principles of natural philosophy. Accordingly, Mutis considered that experiments play a fundamental role in the sense that they provide the evidence upon which any

[257] Despite that Newton constantly manifested against hypotheses as he claimed in his famous *hypothesis non fingo*, in his *Opticks* he praised the role of hypotheses in natural philosophical investigations. Particularly important is his pronouncement to introduce the *queries*, in which he claims that as he could not finish the experiments to prove them, he proposed the *queries* as guidelines "in order to a farther search to be made by others". *Cf.* Newton (1952), pp. 338-339. For studies on Newton's pronouncements on hypothesis and their role in his natural philosophy, see Raftopoulos (1999), Shapiro (2004).

mathematical explanation could be proposed. Despite that such an approach to the experimental physics was not a novelty, it is interesting to highlight that Mutis proposed it in a context in which the disciplinary boundaries between experimental and theoretical physics were redefined.[258]

Mutis explains the second rule in the following terms: "La segunda regla es, que los efectos de la misma naturaleza son producidos por las mismas causas" (RJB III, 7, 1, 5, f. 284r). The first thing to be highlighted of Mutis' explanation of Newton's Rule II for philosophy is the lack of connection between Rule I and II. Undoubtedly, such an omission is based on the fact that 's Gravesande did not include the "*ideóque*" that in Newton's version of the rules establishes a logical and epistemological connection between these rules. It must be borne that Newton's formulation of Rule II is presented as a consequence of the principle of simplicity established in Rule I: "*Ideóque* effectuum naturalium ejusdem generis eædem assignandæ sunt causæ, quâtenus fieri potest" (Newton, 1713: 357).[259] As Ducheyne has argued: "Given that Newton wrote 'ideoque' at the beginning of Rule II, the second rule is to be conceived as a consequence of Rule I" (2015: 145). Nevertheless, it is important to claim that the "ideoque" – usually translated as "therefore" – in Newton's formulation of the second rule has not only a logical meaning, connecting the second and first rules as logical premises for deductions in natural philosophy. It also entails the ontological assumption that any causal relationship between two different phenomena, as long as they behave in similar manners, could be subsumed to a single principle. The simplification of explanations of different kinds of natural phenomena plays a fundamental role in Newton's demonstrations of the universality of the force in Book III of the *Principia*. The

[258] Despite that Newton's experimental natural philosophy advocated for an articulation of both theoretical and experimental aspects of natural philosophical investigation, during the eighteenth century theoretical and experimental physics were defined as independent fields. For the historical circumstances of the development of this disciplinary distinction, see Ducheyne & Besouw (2017).
[259] My emphasis.

importance of this matter is evident in the variation that Newton included in the definitive version of Rule II in the third edition of his *magnum opus*: "[t]herefore the proximate causes to be assigned to natural effects of the same kind are the same" (Newton, 1999: 795). As we can see, Newton claims that when effects of the same kind are produced by causes which are "proximate", they should be considered as causes of the same kind as well. As George Smith argues: "First, in every case in which he [Newton] deduces some feature of celestial gravitational forces, he has taken the trouble in Book I to prove that the consequent of the "if-then" proposition licensing the deduction still hold *quam proxime* [that is, approximately] as long as the antecedent holds *quam proxime*" (2002: 156).[260] Conversely, by emphasizing the anti-hypothetical character of Newton's Rule I, Mutis missed the importance of the principle of simplicity which supports it and consequently the second rule appears to be logically and epistemologically unconnected to the first one. As Mutis' omission was partially caused by 's Gravesande's omission, it is possible to conclude that the former's interpretation of Newton's methodology as it is presented in the Rules for philosophy was informed by 's Gravesande's appropriation of them.[261]

Mutis illustrated this explanation with two examples extracted from the daily experience and gravitational phenomena. In the first case, he says that as we perceive that every time we rub two objects their temperature increase, it is possible to claim that friction is the cause of the increment of their temperature, with no regards to whether they are different kinds of bodies or not.[262] In the case of gravitational phenomena, Mutis exemplifies Rule II by explaining the

[260] It is important to claim that Smith's interpretation is influenced by Cohen's "Newtonian style". A similar position to Smith's can be found in Harper (2011), pp. 84-160.
[261] *Cf.* Ducheyne (2014). As we shall see when I analyse Mutis' translation of Newton's *Principia*, this idea is emphasized by the fact that Mutis did not know Newton's formulation of the Rules as they were in the *Principia*, as he only knew Book III, where Rules are contained, in the version of the first edition, before the Rules were added.
[262] *Cf.* RJB III, 7, 1, 5, f. 284r.

universal character of gravity as it accounts for both the fall of objects on earth and the motion of the planets around the sun: "De esta regla se deduce, que si los cuerpos terrestres caen por su gravedad hacia el centro de la tierra, que es su centro de gravedad, también los planetas, que giran alrededor del sol, tiran continuamente a caer por su peso hacia el sol, que es su centro común de gravedad" (RJB III, 7, 1, 5, f. 284r). There are different elements in this passage which is convenient to point out. First, Mutis illustrates Rule II by postulating the multiplicity and diversity of effects caused by gravity. Regretfully, he did not provide any mathematical explanation to this characterization and consequently there is no evidence of how he demonstrated this explanation to his students. We can only assume that he based the universalization of the force on Newton's rules. Second, it is not clear how Mutis proposed that from Rule II it is "deduced" that the gravitational force causing bodies to fall on earth is the same as that the one causing planets to orbit around the sun. As Smith and Cohen have argued, Newton's rules establish the epistemological conditions upon which it is possible to postulate a universal cause for different phenomena. Nevertheless, this epistemological conditions are applied in the mathematical demonstrations of Book I and II, where Newton explains the ratios of the force required to accelerate bodies. Thus, as long as in explaining the universality of the force Mutis did not consider either the mathematical conditions of the motions of bodies nor the phenomena that Newton referred to in Book III, it would be impossible for him to demonstrate the universality of gravity as the cause of phenomena as different as the orbital motions and the fall of bodies on earth.[263]

[263] As Cohen, Smith, and Ducheyne commented, the establishment of methodological procedures for generalizing causes in the *Principia* played a fundamental role in Newton's demonstration of the universal nature of gravity. In this sense, despite that the mathematical apparatus of Book I and II and the experimental evidence of Book III – especially the moon test – were considerably important for the postulation of gravity as a universal (not inherent) property of bodies, Newton's rules constitute the cornerstone on which said universalization is possible. *Cf.* Cohen (1980), pp. 83-93; Smith (2002).

Nevertheless, by considering the fact that Mutis included the gravitational phenomena that Newton described in Book III of the *Principia*, we can argue that his lectures on physics not only were based on 's Gravesande's *Physices elementa mathematica*. Likewise, he had to use Newton's *Principia*, in order to explain the particular phenomena which can be explained by the action of gravity. As Ducheyne has argued: "By mobilizing Rules I and II in Proposition IV and V (and their scholia), Book III, Newton was entitled to claim that the inverse-square centripetal forces drawing the primary planets to the sun and those drawing the secondary planets to the earth, Jupiter or Saturn are instances of the same cause" (2015: 146). Therefore, although Mutis probably only knew Book III in the version of the first edition – which does not contain the rules –,[264] he still found there Newton's presentation of the epistemological conditions to universalize the force as the cause of both the motion of the planets around the sun and the fall of bodies on the earth. Let us take Proposition V of Book III as an example of Newton's use of his rules to universalize the force. In this Proposition, Newton argues that the force retaining secondary planets around the primary planets is the same as the force retaining primary planets around the sun: "Nam revolutions Planetarum circumjovialium circa Jovem, & Mercurii ac Veneris reliquorumque circumsolarium circa Solem sunt phænomena ejusdem generis cum revolutione Lunæ circa Terreram; & propterea per Hypoth. II à causis ejusdem generis pendent" (Newton, 1687: 407). Hypothesis II, renamed as Rule II in the the second edition, justifies the universalization of the force and consequently by justifying the extension of the action of the force by Rule II, Newton concludes that it must be one and the same force the cause of the orbital motion of Jupiter's satellites around Jupiter, the orbital motion of the moon around the earth, and the orbital motion of the primary planets around the sun. Therefore, by considering

[264] A brief reconstruction of the history of the transformations of Newton's Rules in Book III is in Cohen (1999), pp. 198-200. A scheme of the transformations of the rules in the three editions of the *Principia* is in Newton (1999), p. 794.

the fact that Mutis used gravitational phenomena as exemplary cases of the application of Newton's Rule II for philosophy, we can see that he had a good understanding of the implications of Newton's rules to study nature, probably informed by the direct lecture of Newton's *Principia*. Another interesting aspect of Mutis' explanation is that in dealing with the motion of primary planets around the sun, he openly related his treatment of Newton's Rules to his defence of the Copernican system, thus making it an implicit part of his lectures on physics since the 1760s. I shall explain in detail this feature in Chapter 5, when I deal with Mutis' polemics with the Dominicans concerning the defence of the Copernican system.

In general, Mutis' explanation to the third rule is the most similar to the terms Newton used in his commentaries to the rules. Like Newton, Mutis argues that the properties which are regularly observed in all the bodies can be gathered as universal properties of them, as long as they do not vary in time. In Mutis' words, "La tercera y última regla es, que las cualidades de aquellos cuerpos, sobre los cuales podemos hacer experimentos, y que hallaremos ser unas mismas sin aumentar ni disminuirse en ningún tiempo, pueden colocarse en la clase de propiedades comunes a todos los cuerpos" (RJB III, 7, 1, 5, f. 284v). He exemplifies this rule by analyzing the different properties of earthly bodies and claiming that their common properties should be considered as universal properties of the bodies, no matter the particular differences between different kinds of bodies. However, one of the most interesting features of Mutis' explanation of this rule is the fact that he describes himself as Newtonian:

> Semejantemente concluiremos, que si todos los cuerpos terrestres tienen extension, solidez o impenetrabilidad, y están dotados de una fuerza que los *Newtonianos llamaremos* fuerza de inercia, propiedades todas sin grados ni cantidad,

concluiremos también que los cuerpos celestes tienen las mismas propiedades (RJB III, 7, 1, 5, f. 284v).[265]

So far, I have argued that, in his lectures on physics, Mutis introduced different aspects concerning Newton's methodology. I have explained that in his lectures on mathematics, especially in the *Preliminary discourse* and some other manuscripts, he proposed an articulation of mathematics and physics, based on the utility of mathematics, which is expressed in the development of mathematical explanations to different physical phenomena. Likewise, I presented Mutis' pronouncements on the method of analysis and synthesis as Newton applied it to natural philosophy. Finally, I have studied Mutis' particular interpretation of Newton's *Regulæ*. As a consequence, I have concluded that one of the main features of the introduction of Newton's experimental physics in New Granada was the presentation of Newton's methodology as the paradigmatic example of the application of mathematics to physics. However, by presenting Mutis' interpretation of Newton's methodology, as it was discussed in his translation of 's Gravesande's *Physices elementa mathematica*, I also commented that he also presented in New Granada several theoretical aspects of Newton's natural philosophy. These theoretical aspects were mostly focused on the characterization of the infinite mathematical divisibility of matter and Newton's absolute space.[266]

After defining the concepts "law" and "natural phenomena" in the frame of his theologically-founded axiom, 's Gravesande presents a general characterization of the properties of bodies and how they are determined both mathematically and experimentally. According to him, in considering a body, the first emerging property is its *extension*: "Lo que primeramente se

[265] My emphasis.
[266] 's Gravesande's ideas on the infinite divisibility of matter and the absolute space are in Chapter IV and VI of Book I of *Physices elementa mathematica*. *Cf.* 's Gravesande (1748), pp. 7-15, 28-29.

ha de considerar en el cuerpo es su extensión. La idea de la extensión está casi siempre presente a nuestra mente, ella es muy simple; y por eso no se puede manifestar con palabras. Todo cuerpo es extenso: quitada del cuerpo la extensión se quita todo el cuerpo" (RJB III, 7, 1, 5, f. 285r).[267] However, he argues that despite that the intuition of a body in our minds depends on its extension, there are some other properties which are more important in order to define it in ontological terms. For 's Gravesande, "No por eso todo lo que es extenso es cuerpo. Y no se puede determinar en qué se diferencia el cuerpo del espacio sin examinar antes las otras propiedades del cuerpo" (RJB III, 7, 1, 5, f. 285r).[268] Accordingly, these other properties were not determined intellectually, but through the sensible study of the bodies that allows to determine the properties that differentiate it from space. In this sense, by considering the experimental foundation of the determination of the properties differentiating the body from the space, it is possible to see how Mutis' criticism to Descartes' mechanical philosophy was not only aimed toward its hypothetical-deductive methodology, but also to its considerations regarding the elementary constitution of the bodies and the metaphysical principles underlying it.[269] I shall argue that, by distancing himself from the Cartesian tradition, Mutis embraced 's Gravesande's Newtonian ideas on the absolute space.

By considering bodies from the point of view of their sensible properties, 's Gravesande claims that the other property that should be considered in order to differentiate bodies from extend spaces is their solidity. He defines this property in terms of the impenetrability of matter:

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[267] *Cf.* 's Gravessande (1748), pp. 3-4.
[268] *Ibíd.*, p. 5.
[269] It must be borne that the cornerstone of Descartes' mechanical philosophy was his conception of extension as the essential properties of corporeal substances. Such consideration was mostly developed in the days IV and V of *Méditations* and in the Book I of *Principia*. Although it remained unpublished until the publication of *Unpublished scientific papers of Isaac Newton* in 1962 – which means that neither Mutis nor his contemporaries had an open access to it –, Newton's commentaries in his *De Gravitatione* are representative of his general criticism against Descartes' conception of extension and the nature of space. *Cf.* Newton (1962), pp. 89-157.

> Si consideramos la idea de la solidez conoceremos, que adquirimos la idea de lo sólido por medio del tacto. Lo cierto es, que percibimos la resistencia que nos hacen los cuerpos, y que nos están resistiendo continuamente todos aquellos, que nos impiden caer. De esta misma resistencia deducimos que el cuerpo excluye del lugar, que ocupa, a cualquier otro cuerpo. Y esto es lo mismo que decir que el cuerpo tiene solidez (RJB III, 7, 1, 5, f. 286r).[270]

Mutis' presentation of 's Gravesande's characterization of solidity allows to understand several features of his own thoughts regarding experimentalism and his adoption of some of Newton's theoretical elements. It illustrates the importance of experiments and observations, as they do not only provide evidence to explain natural phenomena, in the sense of the motion of bodies, but they also are the foundations on which it is possible to construct a matter theory. This consequence is fundamental for Mutis in the development of his *General plan for medical studies*, as we shall see later, because it lead him to postulate the need to teach mathematics, physics, and chemistry as ancillary disciplines of medicine.[271]

In this context, it is important to highlight that 's Gravesande's explanation of the solidity as one of the fundamental properties of the bodies is framed in his explanation of the elasticity, fluidity, and solidity as the results of the different degrees of cohesion of the particles composing the bodies.[272] In his opinon, a body is a set of extended particles that cohere because of their attractive forces. The different degrees of their cohesion define different sensible qualities of the bodies, namely, their solidity, fluidity, and elasticity. In this sense, 's Gravesande applied a Newtonian conception of attractive forces as the cause of the cohesion of the particles

[270] *Cf.* 's Gravesande (1748), p. 5. Desaguliers' version is much clearer in this point, Desaguliers (1747), p. 5.
[271] *Cf.* Mutis (1983), pp. 63-97.
[272] *Cf.* 's Gravesande (1748), pp. 16-18.

composing bodies. This idea, informed by the tradition of Newtonian medicine, was strongly developed by Boerhaave in his chemical treatises and had a deep impact on his medicine. Consequently, by including it in his translation, Mutis also adopted a Newtonian conception of attractive forces for explaining several physical phenomena and a Newtonian matter theory, in which particles cohere because of the action of such forces. I shall treat this issue in detail in Chapter 5.

On the other hand, by presenting 's Gravesande's considerations on the solid constitution of bodies as the feature that differentiate them from space, Mutis also embraced Newton's ideas on the absolute space.[273] This interpretation is emphasized by considering 's Gravesande's characterization of the absolute space, discussed in the experiments he introduced in Chapter III of Book I of *Physices elementa mathematica*[274] – also included in Mutis' translation:

> El espacio no se diferencia tan solamente del cuerpo por la privación de solidez. El espacio es infinito. Y si cualquiera se pone a considerarlo atentamente conocerá que el espacio no puede estar determinado por ningunos límites (…) Por lo cual los límites del espacio, considerándolo todo entero, encierran contradicción. No obstante debemos confesar que hay cuerpos limitados. Vemos claramente, que en el espacio hay partes, que no pueden ser separadas las unas de las otras. Ellas son inmóbiles como el mismo espacio; pero las partes del cuerpo están sujetas a traslación; y por esta causa padecen separación (RJB III, 7, 1, 5, f. 286v-287r).[275]

[273] The *locus classicus* of Newton's references to the absolute space and time is the scholium to the definitions in *Principia*. *Cf.* Newton (1999), pp. 408-410. He also made some commentaries on the absolute nature of space in his *De gravitatione*. An introductory study to the concept of absolute space in Newton's *Principia* is in Cohen (1999), pp. 85-109.
[274] *Cf.* 's Gravesande (1748), pp. 5-7.
[275] *Cf.* 's Gravesande (1748), pp. 6-7.

As we can see, in establishing the distinction between bodies and space, 's Gravesande considered that the parts of the former could be conceived as different from the parts of the latter, in the sense that they can be accelerated and separated one from the other. Conversely, in the case of space, he contends that its parts are physically inseparable and their separation is only mathematically ideated. Consequently, following Newton's ideas in the scholium to the definitions, 's Gravesande endowed absolute space with mathematical properties, accentuating the difference between it and the body. It does not mean that bodies have no mathematical properties, since, being solid and extended, they have measurable quantities.[276] Rather, it means that the mathematical properties of absolute space are distinguished of the properties gathered from the bodies. Thus, by presenting 's Gravesande's characterization of Newton's absolute space, Mutis introduced in New Granada several ideas of Newton on the absolute space which were based on the mathematical determination of its properties, as it is distinguished from the bodies. Certainly, in his translation Mutis did not referred to the important role of absolute space for Newton's physics, but we can argue that he presented several preliminary aspects of Newton's physics that allowed him to discuss its central features in the context of his lectures on physics at the *Colegio del Rosario*. It must be borne that, as Mutis only translated the first chapters of Book I of *Physices elementa mathematica*, it is likely that he used the translation for the lectures following his lectures on Newton's methodology. I mean, as the initial lectures of his plan for the teaching of physics that was complemented by teaching several aspects of Newton's

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[276] It is important to highlight that Newton's absolute space is differentiated from relative space in the sense that the latter is determined by the position of the bodies occupying it. Consequently, relative space also has mathematical properties. However, these properties are only relative to the position of bodies and, as a result, they do not belong to the space. Conversely, Newton's absolute space is endowed with mathematical properties which are defined by its very nature and that determine the particular manners in which the motion of bodies are produced. Interesting studies on Newton's ideas on absolute space are in Power (1970); DiSalle (2006), pp. 20-54, Huggett (2008).

physics as they were discussed in his translation of the *Principia* and the manuscript entitled *Knowledge required for understanding natural phenomena*.

Laws of nature and the motion of bodies in conic sections: theoretical aspects of Newton's physics in Mutis' lectures on physics

Amongst the set of Mutis' manuscripts containing his lectures in New Granada that nowadays are in the archives of the *Real Jardín Botánico* of Madrid, there are four dealing with different matters of physics, mechanics, and natural philosophy: his translations of 's Gravesande's *Physices elementa mathematica* and Newton's *Principia*; the manuscript entitled *Elements of mechanics*, which I assume was influenced by Wolff's *Elementa matheseos*; and the manuscript entitled *Knowledge required for understanding natural phenomena*. These manuscripts, probably written between 1764 and 1777, deal with several matters of Newton's physics and mechanics and, by studying their content, it is possible to see that in Mutis' lectures on physics converge several traditions which are reflected in the topics he studied: the considerations of body based on Newton's matter theory as it was developed in the Netherlands – and especially at Leiden – during the early-eighteenth century;[277] 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 the motion of bodies in conic sections.[278] Likewise, these manuscripts also present

[277] It should be noticed that the Dutch interpretation of Newton's matter theory was informed by the development of Newtonian medicine in the early-eighteenth century. In this sense, it was deeply influenced by the consideration of British Newtonian physicians, such as Pitcairne, Cheyne, and James Keill. I shall explain this influence in Chapter 5.

[278] In particular, the manuscript entitled *Knowledge required for understanding natural phenomena* presents Mutis' considerations on the motion of bodies in conic sections, accelerated by centripetal forces. The manuscript is in

forces framed in the theological foundation of the laws of nature and the application of mathematics to the natural philosophy that, as I commented above, underlies in Mutis' argumentative structure. In addittion, in these manuscripts it is possible to find Mutis' critiques to the scholastic conception of physics as it was taught in the Spanish and New Granada's universities. In other words, by introducing some of Newton's theoretical aspects regarding natural philosophy, Mutis strengthened his image as the "oracle of the kingdom" and he set the definitive differences with New Granada's traditional system of education. A considerably point in order to understand Mutis' position in his polemics with the Dominicans in the 1770s that I shall study in Chapter 6.[279]

I pointed out above several of the theoretical elements of Newton's physics that Mutis presented in the *Elements of mechanics* and his translations of 's Gravesande's *Physices elementa mathematica*. I shall focus now on the two remaining manuscripts, which are considerably richer in details and more important to explain the scope of Mutis' Newtonianism in his lectures on physics. One is a brief manuscript entitled *Knowledge required for understanding natural phenomena* in which 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, he treated the subject with geometrical demonstrations, applying it to planetary motion. Likewise, I shall argue that the manuscript ostensibly 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 his mathematical models of nature to the phenomena of motion of heavenly

RJB III, 7, 1, 5, ff. 325r-328 and its analysis is complemented by Mutis' studies on curves in RJB III, 7, 1, 5, ff. 329r-330v.

279 For Mutis' Copernicanism and his polemics with the Dominicans, see Lanning (1944), Mutis (1982), Negrin Fajardo & Soto (1984), Arboleda & Soto (2006).

bodies. As a result, I shall conclude that the manuscript completes the characterization of Newton's Rules that Mutis had presented via the translation of 's Gravesande's *Physices elementa mathematica*. The second manuscript is more interesting, as it is an unpublished translation of Newton's *Principia*. The first translation into Spanish of Newton's *magnum opus*. This translation, discovered by Arboleda among Mutis' manuscripts,[280] was firstly cataloged as a "treatise on mechanics" by Hernández de Alba and Gredilla,[281] and it precedes by more than two hundred years the only Spanish version of Newton's *Principia* available nowadays.[282] I shall study the manuscript in detail in order to determine the origins of the enterprise of the translation, the public it was aimed to, the context of its production, and its main features. But, first, let us analyse Mutis' study about the motion of bodies in conic sections, as it was presented in his *Knowledge required for understanding natural phenomena*.

So far I have explained that by defending a mathematical explanation of natural phenomena and postulating attractive forces as causes of the cohesion of the particles that compose bodies, Mutis introduced several important aspects of Newton's physics as they were interpreted by 's Gravesande. These elements, as I argued above, were derived from the medical interpretations of Newton's *Principia*, developed by the so-called Newtonian physicians, and they only were related to some general aspects of Newton's theories in his *magnum opus* which are framed in his particular mathematical approach to nature. However, in *Knowledge required for understanding natural phenomena*, Mutis deals with the motion of a body in an ellipse when a centripetal force is accelerating it. He focused on different elements of Newton's demonstration, which confirms that Mutis did introduce several theoretical aspects of Newton's mathematical analysis of the motion of bodies in New Granada. In the manuscript, Mutis, 1. argues that the

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[280] Arboleda describes the details of his discovery of the translation in Arboleda (1987).
[281] *Cf.* Gredilla (1911) and Hernández de Alba's introductory study in Mutis (1982).
[282] Newton (1982).

centripetal force accelerating a body traversing an ellipse should be directed toward a 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.[283] I shall study each of these elements in detail, but let us consider first some general features of Mutis' mathematical thought as they are revealed in this manuscript.

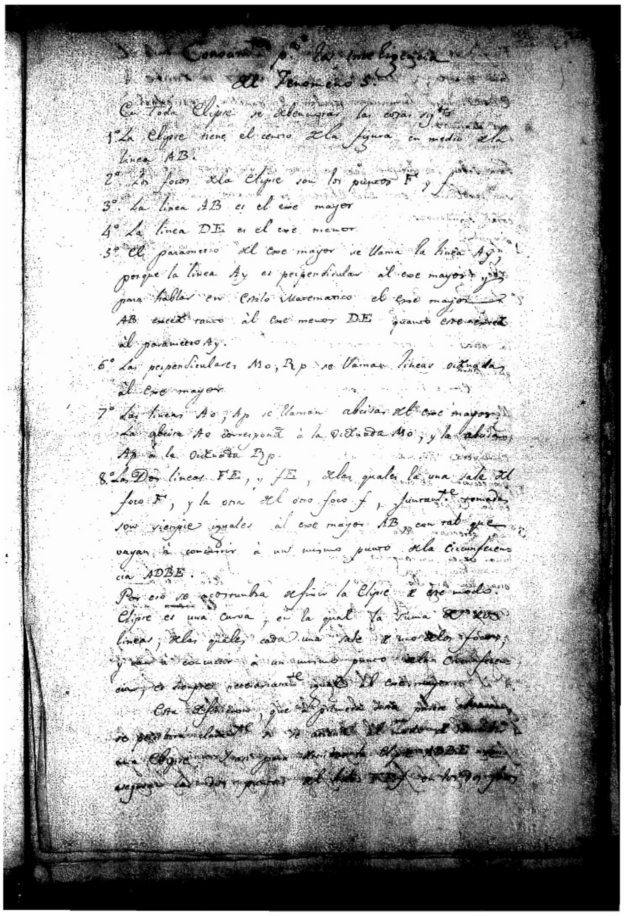

Figure 12. Front page of Knowledge required for understanding natural phenomena, RJB III, 7, 1, 5, ff. 325r-328r.

Mutis begins *Knowledge* defining the concept of ellipse and its geometrical properties in a strict mathematical sense. Interestingly, he claims that the mathematical definition could be obscure, arguing that it is clarified by considering how to draw it. According to Mutis,

[283] *Cf.* RJB III, 7, 1, 5, ff. 325r-328r.

> Elipse es una curva, en la cual la suma de dos líneas, de las cuales cada una sale de uno de los focos, y van a concurrir a un mismo punto de la circunferencia, es siempre necesariamente igual al eje mayor. *Esta definición, que a primera vista parece obscura, se percibirá claramente si se atiende al modo de describir una elipse* (RJB III, 7, 1, 5, f. 325r).[284]

For Mutis, the mechanical description of an ellipse, made up with string and pins, is a method to clarify its understanding for students. This consideration reveals an important feature of Mutis' mathematics as it was concerned with the introduction of Newton's natural philosophy in New Granada which had not been so far considered. It shows that Mutis was interested in the *geometria organica*, since he is considering that, in order to understand any geometrical curve, it is necessary to know their tracing mechanisms. This field of geometry, advanced in the seventeenth century by mathematicians like Frans van Schooten and Isaac Barrow and that Newton explored principally in the Preface to the edition of 1687 of the *Principia*, helped Newton to argue the superiority of geometry over algebra and its use to study natural phenomena.[285] Accordingly, Newton argues that the nature of a curve is better understood by knowing its tracing mechanisms. Thus, by extrapolating the consequences of this field of geometry to the study of nature, in the Preface to the first edition of the *Principia*, he argues that it is possible to get a better understanding of the nature of the orbit traced by the trajectory of a body, by considering the force that is acting upon it as a tracing mechanism.[286]

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[284] My emphasis.

[285] Some insights regarding the *geometria organica* and especially Maclaurin's *Geometria organica* can be found in Whiteside (1961); Guicciardini (1989), pp. 36-37. For the role of the *geometria organica* in Newton's Preface to the *Principia*, see Domski (2003); Guicciardini (2009), pp. 293-308.

[286] Newton (1999), pp. 381-382. In this sense, as Guicciardini commented, Newton establishes the possibility to study natural phenomena from a mathematical point of view. *Cf.* Guicciardini (2009), pp. 293-299.

We do not have evidence to claim whether Mutis read and understood Newton's pronouncements on this particular topic in the Preface to *Principia* or not, because in his translation of Newton's *magnum opus* he directly began with the Definitions and certainly the debate regarding the superiority of algebra and geometry, which was the background of Newton's acceptance of the *geometria organica*, was not one of Mutis' concerns in his lectures on mathematics and physics.[287] However, it is possible to see that, in his definition of the ellipse as a curve generated by the combination of a centripetal and a "projective" force, Mutis considered the need to study curves in general as they were the result of forces.[288] Thus, it is likely that Mutis' considerations on the *geometria organica* were founded on the knowledge of another Newtonian work, Colin Maclaurin's *Geometria organica: sive description linearum curvarum universalis* (1720), which Mutis knew through Benito Bails' interpretation, appearing in *Elementos de matemáticas*.[289] As a consequence, we can argue that Mutis' acceptance of Newton's mathematical approach to nature not only was informed by the Newtonianism of the Dutch experimentalists, but also by Maclaurin's ideas on the *geometria organica* – ideas that, in the end, were representative of Newton's own position as it is evidenced in his Preface to *Principia*. This conclusion is confirmed by considering that, in addition to his reading of Bails' commentaries on Maclaurin's *Geometria organica*, Mutis also read Maaclaurin's *Treatise on fluxions* (1742), where Maclaurin referred to the superiority of Newton's geometrical approach to the study of curves over Descartes' algebraic infinitesimals.[290] Consequently, after explaining the reasons why it is important to study the

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[287] It is a well-known fact that as of the late 1670s Newton was commited to the defence of the superiority of the method of ancient geometers over the algebraic method of Descartes and the moderns, which he characterized as less elegant and based on "spurious" postulates. For a study of Newton's pronouncements on the superiority of ancient geometry over modern algebra, see Guicciardini (2009), pp. 106-107, 145-148. As Newton's considerations on geometry and algebra were deeply informed by Isaac Barrow's position, see Panza (2008).
[288] *Cf.* RJB III, 7, 1, 5, ff. 325v.
[289] Bails' *Elementos de geometría*, where he treats Maclaurin's works are in Volume I of *Elementos de matemáticas*. *Cf.* Bails (1779), pp. 196-360.
[290] Maclaurin's commentaries on the superiority of Newton's method are in the introduction. *Cf.* Maclaurin (1801), pp. 1-50.

motion of bodies in an ellipse through the determination of the forces producing them, Mutis dedicates himself to study such forces, as they were presented in the case of a body orbiting a center of revolution. Thus, he considers the case where, when a motion is supposed, it is necessary to deduce the force causing it – as if he dealt with a tracing mechanism in nature.[291]

Based on the manuscript evidence, it is impossible to claim if Mutis embraces this idea from Newton's *Principia* itself, but the resemblance is remarkable. In Book I of his *magnum opus*, Newton argues that he studies the motion of bodies as they are considered as mathematical points tracing a curve. In other words, for Newton, in Book I and II of the *Principia*, bodies were conceived as mathematical entities, as if they were devoid of any physical property.[292] When these considerations are used to study the system of the world, as Koyré, Cohen, Smith, Guicciardini, and Ducheyne explained, Newton replaced these mathematical points with planets and consequently the curves were no longer considered as mere mathematical entities, but as trajectories produced by bodies in nature. One of the most interesting points related to this procedure in the *Principia* emerges by considering the problems related to the tracing mechanism. Whereas in the mathematical Book I, string and pins – and other more complex devices – were the tracing mechanisms of the geometrical figures, in the physical Book III they are replaced by the forces accelerating the bodies in the system of the world. As a consequence, as Newton claims in his Preface to the reader, "the main business of natural philosophy" is to discover the forces causing the motions that we observe in nature. Thus, in Newton's opinion forces should be deduced from natural phenomena and they were explained in mathematical terms as they were considered causes of the trajectories the bodies traverse in nature – like geometrical

[291] *Cf.* RJB II, 7, 1, 5, ff. 325v-326r.
[292] See, for example, Newton's clarifications of the mathematical language he used in Definition VIII, and in Section XI of Book I.

instruments are tracing mechanisms of geometrical figures on a paper.[293] As we can see, in going from a strictly mathematical analysis of the ellipse to the considerations of the forces required to produce elliptical motions in real bodies, like the planets, Mutis also embraced the idea of applying mathematics to the study of nature in the very same manner that Newton used it in the *Principia*.

After establishing the initial conditions of the mathematical investigation of the elliptical motion of bodies in nature, Mutis determine the basic elements of the force required to cause an elliptical motion in a body. Therefore, he proposes a set of elements describing the mathematical study of the motion of a body in an ellipse as it is applied to the planetary motion and the establishment of a system of the world, which is another evidence of Mutis' introduction of several theoretical aspects of Newton's physics in the context of his lectures on physics at the *Colegio del Rosario.*

The first element describes the directionality of the force and reveals that, rather than describing elliptical motion from a strictly mathematical point of view, Mutis directly considered observed planetary motions: "La fuerza centrípeta del cuerpo, que describe una elipse, debe dirigirse, no al centro *P*, sino algo foco *F*" (RJB III, 7, 1, 5, f. 325v). Before analyzing it, there are three important features to be underlined in this characterization of the force required for producing an elliptical motion. First, it is remarkable the fact that Mutis did not hesitate in using the term "centripetal force" to describe the force causing the elliptical motion of a body. The importance of this fact relies on the implications of the acceptance of centripetal forces by accounting them only in a mathematical manner. As it is well-known, in Section II and III of Book I of the *Principia*, Newton demonstrated that the orbital motion of a body around a center

[293] *Cf.* Koyré (1965); Cohen (1980), pp. 83-96; Smith (2002); Guicciardini (2009), pp. 293-327; Ducheyne (2012), pp. 55-107.

of revolution is produced by the combination of two motions: one rectilinear, caused by its inertia, and the other, toward the center of revolution, caused by the centripetal force.[294] Mutis tacitly assumed Newton's results in these sections and he only referred to these forces when he described the need for them to be in equilibrium, but I shall explain it later. Second, it is worth of notice that there is a small imprecision in Mutis' description of the direction of the force. He claims that it should be directed toward the focus F. However, the force should be directed toward *a* focus of the ellipse. Third, this imprecision reveals that Mutis was referring to a concrete geometrical figure, produced by the motion of a concrete body – probably the earth orbiting the sun. It confirms that this manuscript was part of his lectures on physics as Mutis was not dealing with theoretical geometrical figures drawn in the loneliness of his room, but with figures he used and discussed with his students in his lectures. Likewise, the pedagogical character of the manuscript is confirmed by the manner in which Mutis finish it: "Por si hubiese tiempo para aprender esta doctrina, la añado. Y entonces se ha de proponer antes de la doctrina de los movimientos en la elipse" (RJB III, 7, 1, 5, f. 327v).

In Propositions X and XI, which are in Sections II and III of the *Principia*, respectively, Newton considers a body moving in an ellipse and attracted either toward the center (Prop. X) or a focus (Prop. XI) of the ellipse by a centripetal force. In Proposition X, he demonstrates that when a body traversing an ellipse is attracted by a centripetal force toward the center of the ellipse, the resulting force is elastic, which means that it is proportional to the distance: if the distance squares, the force squares, etc. Whereas, in Proposition XI, we find the famous demonstration that when a body is traversing an ellipse and it is attracted by a centripetal force toward one of the foci of the ellipse, then such a force is inverse to the square of the distance.[295]

294 *Cf.* Newton (1999), pp. 444-472. A detailed analysis of Newton's demonstrations and the mathematical techniques he used is in Guicciardini (1999), pp. 48-58.
295 *Cf.* Newton (1999), pp. 459-463.

As it is well-known, in these passages, Newton did not consider that the elliptical motions were caused by a particular ratio and directionality of the force. Conversely, he evaluated all the possible scenarios of the motion of bodies in conic sections and the forces required to produce them, in order to be able to account for every possible circumstance which could be presented when the mathematical model of the world proposed in Book I were applied to the study of nature in Book III. In this sense, by considering natural phenomena in Book III, his mathematical analysis of Book I and II made it possible for him to conclude the precise ratio of the centripetal force.

In this sense, in order to present in New Granada the idea that the force is directed toward one of the foci of the ellipse (*F*) instead of its center (*P*), which is the foundation of Mutis' presentation of Newton's system of the world at the *Colegio del Rosario*, we have to assume that Mutis not only knew Newton's mathematical demonstrations of the *Principia*, but that he also introduced them in his lectures. In other words, by considering Mutis' explanation of the directionality of the centripetal force in an elliptical motion, we can assume that he introduced in New Granada Newton's mathematical demonstration of the motion of bodies in conic sections as they were presented in Book I of the *Principia*. However, one of the most interesting elements of Mutis' presentation, as his manuscript shows, is that he moved from a strictly mathematical point of view to the consideration of the motion of bodies in Newton's system of the world.

According to Mutis, the second required element for the construction of an ellipse is that the inertial and centripetal forces should be in equilibrium. In his opinion, "La fuerza de proyección y la fuerza centrípeta deben combinarse de tal modo, que la una nunca destruya a la otra. La razón para el movimiento elíptico es la misma que para el movimiento circular" (RJB

III, 7, 1, 5, f. 325v). In the description of this element, Mutis introduced two revealing features of his appropriation of Newton's *Principia*. On one hand, he considered the inertial force as a *projective force* [*fuerza de proyección*]. Therefore, we can see that until this point of the manuscript he was still thinking on the ellipse as a geometrical figure, as it allow him to describe the trajectory of the body without any reference to the nature of the force that is producing it. On the other, by emphasizing that the reason for this conclusion is the same in circular motions as in elliptical ones, we can assume that Mutis presented the study of the forces using as a reference the entire spectrum of conic sections as they were studied by Newton in Sections II and III of the *Principia*.[296] Regretfully, although we have sufficient evidence to determine that Mutis taught the motion of bodies in different conic sections and the forces required to produce them, these manuscripts only contain few commentaries on the motion in circles. However, by considering this kind of statements, we can assume that it was a part of his lectures.

Likewise, by considering the manner Mutis presented the construction of conic sections in *Knowledge*, we can conclude that he proceeded in a synthetic manner instead of an analytical one – like Newton did in Book I of the *Principia*. After considering the motion of bodies in conic sections as the effects of the combination of two forces, Newton proceeds to apply the analytical method of geometry, with the purpose of discovering the resulting forces and the mathematical laws governing their actions on the bodies.[297] Conversely, in Mutis' manuscripts, we can see that he assumed the ratios of the forces and, from them, he deduces the motions. In this sense, we can see that he simply assumed the results achieved by Newton's investigations in the *Principia*,

[296] It is worth of notice that Newton not only included conic sections in his analsysis of the motion of bodies accelerated by centripetal forces. Likewise, he studied the forces required to cause a body to move in an equiangular spiral. *Cf.* Newton (1999), pp. 457-459. Interesting studies on Newton's analysis of the motion of bodies in spirals are in Erlichson (1994), Wilson (1994).
[297] A study of Mutis' use of the geometrical methods of analysis and synthesis in the argumentative structure of Newton's *Principia* is in Guicciardini (2009), pp. 235-290.

being limited to their presentation in the frame of the explanation of the elliptical planetary motions.

After postulating the required equilibrium of forces, Mutis justified such an assumption: "Esta es la razón: porque si la fuerza de proyección llegara a poder destruir enteramente la fuerza centrípeta, el cuerpo se escaparía por la tangente y si la fuerza centrípeta llegara a poder destruir enteramente la fuerza de proyección, el cuerpo caería en el centro, a que se dirige en la elipse, que es el foco *F*" (RJB III, 7, 1, 5, f. 325v). The equilibrium of forces makes it possible for the body to describe an elliptical trajectory. In this context, we find the evidence to argue that Mutis considered the elliptical planetary motion in terms of geometry. According to him, from the fact that the centripetal and inertial forces are in equilibrium it does not follow that they are equivalent. Indeed, as Mutis argues, in the motion of a planet in an ellipse it is possible to see that sometimes there are fluctuations in the intensity of either one or the other. As Mutis puts it:

> En el movimiento de planetas por la elipse, unas veces la fuerza centrípeta es mayor que la fuerza centrífuga; y otras veces la fuerza centrífuga es mayor que la fuerza centrípeta. Cuando el planeta baja desde el afelio *A* al perihelio *H*, la fuerza centrípeta es mayor que la fuerza centrífuga. Y al contrario cuando el planeta sube del perihelio *H* al afelio *A*, la fuerza centrífuga es mayor que la fuerza centrípeta. Un célebre autor newtoniano ha descubierto que en la elipse, la fuerza centrípeta sigue la ley de la razón inversa de los cuadrados de las distancias; pero la fuerza centrífuga sigue la ley de la razón inversa de los cubos de las distancias al foco (RJB III, 7, 1, 5, f. 325v-326r).

All in all, by considering several theoretical aspects of Newton's physics presented in Mutis' *Knowledge*, it is possible to reconsider the general assumption held by several historians of science in Colombia for whom Mutis strictly focused on the methodological aspects of Newton's natural philosophy. A good example of such position is made by Arboleda:

> Mutis no comparte, en lo general, este enfoque newtoniano de aplicar las matemáticas a la realidad. Para él tal aplicación se refiere a una operación mecánica en virtud de la cual la matemática demuestra o presta la *forma externa* de su discurso al razonamiento. La utilidad del método matemático, en aquellos textos de Mutis cuyo objeto específio es reflexionar a fondo sobre la cuestión, es entendida como una intervención igualmente externa: que los experimentos suministren resultados numéricos; que se establezcan manipulaciones o medidas numéricas; que el razonamiento utilice la forma lógica (en lo posible, silogística) de argumentación y que el método de exposición siga la organización axiomático-deductiva que presentan las ideas en los tratados matemáticos (1993: 59).

Being the historian who has studied in more detail Mutis' manuscript, Arboleda's position is considerably influential and it resembles the general characterization of how Mutis' lectures are perceived nowadays. However, similar characterizations of Mutis' lectures and his introduction of Newton's ideas can be found in the classical works of Gredilla and Mendoza, as well as in the introductory studies made by Hernández de Alba to Mutis' published manuscripts.[298] Likewise, Arboleda's position is also held by recent historians like Martínez Chavanz, for whom Mutis "fue, pues, el mensajero, el oráculo, expositor y defensor del método newtoniano, de su manera de aprehender el universo y de la ciencia moderna" (1993: 73), and Mauricio Nieto Olarte, who

[298] *Cf.* Mendoza (1909), pp. 12-150; Gredilla (1911); and the introductory study of Hernández de Alba in Mutis (1982).

has argued that "las enseñanzas de Mutis sobre Newton parecen limitarse a la retórica y a la metodología de la nueva mecánica newtoniana más que al contenido físico-matemático de los *Principia*" (2006: 218).

Figure 13. Mutisia Clematis. Salvador Rizo Blanco, RJB III A1154[299]

[299] Despite that I have not consider Mutis' botanical endeavours, which was certainly his main activities in New Granada, it is important to highlight that botanical drawings constituted the central matter of his botanical investigations. More than 5000 drawings were produced in the cloisters of the botanical expedition, under the supervision of Mutis. Despite that the ultimate purpose of the botanical expedition – the publication of the *Flora de Bogotá* – was not achieved, Mutis' activities as a botanist made him a name in the botanical scene of the late-eighteenth century. In the image, for instance, we have the drawing made by Salvador Rizo of the Mutisia Clematis, the plant named after Mutis by Linnaeus.

However, as I explained above, Mutis' lectures on physics were not only concerned with the presentation of the methodological elements of Newton's natural philosophy. Conversely, by studying the unpublished manuscripts containing his lectures, we can see that he also was deeply interested in introducing in New Granada the theoretical aspects of Newton's physics related to natural philosophy as they were presented in the *Principia* and especially the mathematical principles underlying his system of the world. By doing so, we can see that the introduction of Newton's ideas in New Granada was a more complex enterprise than it had been previously thought and that Mutis firmly believed in the power of mathematics to explain natural phenomena and not only as a formal structure of the investigation of nature. I am not saying that in Mutis' investigations in New Granada we can see an effective use of a Newtonian mathematization of nature. This idea cannot be sustained because it is well-known that Mutis' investigative enterprises were focused on botany and natural history. In this sense, his investigation of nature was focused on the description and drawing of plants and rather than on the creation of explicative theories about them based on mathematical principles (Fig. 13).[300] In addition to which, despite that Mutis used Newton's mathematical analysis of the motion of bodies, he did not make original investigations on physics, mechanics, and astronomy – although Mutis did some astronomical calculus and measurements, they were merely descriptive works, rarely connected with a deep study of physical phenomena.[301] In fact, we have evidence of only one project related to the investigation of physical phenomena in which Mutis was interested in: the observation of the transit of Venus across the disc of the Sun of 1769. However, the

[300] There are several studies regarding Mutis' practices for natural history dealing with both the practical and the theoretical aspects of his studies. In the field of the practical issues, see Crawford (2009, Marcaida & Pimentel (2014). For the theoretical aspects of the investigation, see Restrepo Forero (1991), Arboleda & Soto (1995), Wilson & Gómez Durán (2010), Bleichmar (2012). However, the best primary source is Mutis (1828).

[301] Most of Mutis' astronomical works are reduced to the measurement of certain latitudes and longitudes, used for delimitation of territories and the measure of heights. Almost all of them are found in the archives of the *Real Jardín Botánico* of Madrid. This interest by Mutis in astronomy can shed light on his project of building up Santafé's astronomical observatory. For Mutis' project of building the astronomical observatory in Santafé, see Martín (2011).

manuscript containing the description of the project is only a general characterization of its importance and it does not deploy any systematical study of that.[302] In other words, by claiming that Mutis was interested in introducing several theoretical aspects of Newton's physics, I do not mean that Mutis used those elements to study nature in New Granada. Conversely, I suggest that by studying Mutis' manuscripts we can see that the diffusion of Newton's physics in New Granada was related to the introduction of Newton's mathematical principles of natural philosophy as they were related to theoretical, practical, methodological, and even theological matters – a consideration which is going to be particularly important in order to understand Mutis' defence of the Copernican system.

Attractive forces as occult qualities in the context of Mutis' lectures on physics

It is a well-known fact that one of the greatest problems that Newton's *Principia* faced was related to the reception of its characterization of forces in terms of attraction. As Cohen pointed out, in the very first review of Newton's *magnum opus* made in the continent, it is possible to see that they considered that Newton was re-introducing scholastic categories – *occult qualities* – to explain natural phenomena.[303] This criticism was based on two basic assumptions. First, that in the *Principia*, Newton did not explain either the cause of the attraction between bodies or the particular manner in which such attraction was performed. Consequently, second, that by describing forces in terms of attraction, he was considering that such forces act at a distance. In general, these assumptions were focused on the fact that Newton did not develop a causal

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302 The observation of the transit of Venus through the disc of the sun was one of the most important facts of observational astronomy of the eighteenth century, motivating, for instance, the first scientific expedition to the southern regions of modern-day United States. For this expedition, d'Auteroche (1772).

303 *Cf.* Cohen (1980), pp. 96-99. Some analysis of the criticism against Newton's *Principia* based on the idea that he was reintroducing the scholastic occult qualities as valid explanations of natural phenomena can be found in Hall (1983). pp. 306-331; Henry (1994); Copenhaver (1998); Attfield (2005).

explanation of forces under the precepts of the mechanical philosophy. Following the advice of Roger Cotes, editor of the second edition of the *Principia*, Newton included a sharp rebuttal to these critiques in the penultimate paragraph of the *Scholium generale* – added to the 1713 edition.[304] This paragraph, containing Newton's famous *hypotheses non fingo*, is centered on explaining that mathematical demonstrations are sufficient to prove the existence of gravity and that, as long as it can be explained mathematically, it can be postulated as a real force acting in nature, regardless that Newton had not been able to discover the cause of the force.[305] Newton's pronouncements concerning the defence of the existence of the force in terms of mathematical laws established the general principles upon which a Newtonian physico-mathematical science came to be developed in the eighteenth century.[306]

Interestingly, among Mutis' manuscripts, we also find some references to the problem of the reception of Newton's theories in Europe and a defence of Newton's approach to nature and the results he achieved in the *Principia*. These references are found in Mutis' translation of 's Gravesande's *Physices elementa mathematica*. In the context of the presentation of 's Gravesande's interpretation of Newton's methodology in *Elements*, Mutis described the reception of Newton's conception of attractive forces in Europe, arguing that it had been widely criticized in both the scholastic and mechanical contexts:

> Este método tan riguroso no ha gustado a aquellos ingenios, que acostumbrados a tratar la filosofía sin tanto trabajo, y con mayores rasgos de lucimiento, conocieron que para seguir este nuevo camino era preciso abandonar sus antiguos

304 A description of the first commentaries on Newton's *Principia* in Europe as well as the editorial consequences for the second edition is in Cohen (1980), pp. 96-120.
305 The story of the writing of the *Scholium generale* and the modifications that Newton added to it is described in detail in Cohen (1999), pp. 274-292.
306 *Cf.* Heimann & McGuire (1971), Hall (2001), Grabiner (2004). A general compendium of Newton's influence in the eighteenth and nineteenth centuries can be found in Scheurer & Debrock (Eds.) (1988).

> sistemas, y sacrificar sus amadas opiniones (…) Los cartesianos creyeron haber hallado una entera semejanza entre la atracción newtoniana y los abandonados preceptos de la filosofía escolástica. Les pareció en efecto que ya habían conseguido el triunfo, si perseguían la doctrina de la gravedad, tratando a este principio general con el desprecio que merecieron las cualidades ocultas de los antiguos: fundando toda la fuerza de su oposición en que Newton no pretendió deducir este principio de su causa (RJB III, 2, 4, 11, f. 10r-10v).

According to Mutis, the mechanical arguments against Newton's ideas on gravitation were based on the idea that Newton's method was not consistent with the method of the systematic philosophy. This inconsistency, as Mutis pointed out, was evidenced by the fact that the principles that Newton had discovered by the use of his method did not correspond to the ones proposed by the Cartesian mechanical philosophers. By presenting the rejection to Newton's explanation of the action of the force in the *Principia* in such a manner, Mutis presented the problem of the rejection of forces as a problem related to the determination of the most suitable method to study nature in the early-eighteenth century. Thus, he interpreted the debates between Newtonians and Cartesians to the debate between Newton's mathematical approach to nature and Descartes' hypothetical-speculative system, arguing in favour of the superiority of the former:

> El poder general que la gravedad tiene sobre todo el sistema de la naturaleza, y que nosotros conocemos claramente sobre todos los cuerpos de la tierra, la explicación que de este principio deduce Newton sobre el modo más concluyente de los movimientos y de las influencias de los cuerpos celestes, las medidas que él determina sobre los diferentes movimientos que la gravedad produce,

valiéndose en todo de una sabia y ajustadísima aplicación de la geometría a la naturaleza, todo esto no tiene mérito para tales filósofos, porque Newton no ha señalado la causa mecánica de la gravedad (RJB III, 2, 4, 11, f. 10v).

Accordingly, Mutis defended Newton's use of the force to explain natural phenomena by arguing that it allows to explain a great variety of natural phenomena by applying geometry to nature. In other words, Mutis claimed that the superiority of Newton's mathematical approach to nature over any mechanical system consisted in the application of mathematical principles to explain natural phenomena, which allow to build a more simple explicative system to account for the structure world and how the bodies interact in it. In this system, different phenomena were accounted in terms of one single cause, the gravity. Arguably, Mutis' defence of Newton's conception of gravity as a causal, mathematically-explained principle acting in nature recalls Newton's arguments in his *General scholium* to the *Principia*, where he argues that it was sufficient that the effects produced by the action of the force were determined by the mathematical principles established in Book I and II in order to determine the reality of the force.[307]

One of the most suggestive consequences for Mutis of Newton's approach to nature was its implications for studying those physical phenomena of which we do not have any experimental evidence. In Mutis' opinion, as I pointed out above, one of Newton's main achievements was to make it possible to postulate the action of several entities, like the gravitational force, from the observation of its physical effects and the mathematical explanation of its properties. Thus, despite that we cannot *see* the force, we do perceive its effects and consequently we can argue that it exists as it operates in the ratios that we can mathematically describe and reduce to natural laws. Accordingly, by following Newton's method, it would be

[307] *Cf.* Newton (1999), p. 943.

possible to postulate explanations for different phenomena we do not have enough experimental and observational evidence and even to postulate the existence of certain entities or properties which are derived from the manifest effects they produce. For instance, as Mutis suggested, following the tradition coming from the Newtonian physicians in the late-seventeenth century, we can apply Newton's methodology to explain several microscopic phenomena which are not visible by our naked senses. Thus, we can deduce certain phenomena occurring at a microscopic scale through the observation of their physical effects and their mathematical explanation. Mutis developed this argument in his lectures by studying it as it was presented in Chapter V of 's Gravesande's *Physices elementa mathematica*.[308]

In this chapter, 's Gravesande studies the cause of the cohesion of the particles that compose bodies, arguing in favor of the existence of an attractive force acting as its cause. This reveals his commitment to a Newtonian matter theory, in which the basic structure of matter is explained in terms of attractive forces between particles. In his opinion, the bodies were composed of particles which attract each other by some kind of force that, varying in function of their distance, produces different qualities in bodies: "La dureza, blandura, y fluidez de las partes dependen de la cohesion. Y así cuando más estrecha y fuerte sea la cohesion de las partes, tanto más se aproxima el cuerpo a la dureza" (RJB III, 7, 1, 5, f. 296r).[309] However, according to 's Gravesande, there are two elements in this characterization of the corpuscular constitution of bodies that cannot be accounted with clarity: the ultimate attributes of the particles constituting bodies and the cause of their cohesion. As there is no sufficient experimental evidence, he argues that it is necessary to explain the properties of the particles that compose the bodies by analogy. For him, we can infer that these particles are endowed with the same sensible properties of

[308] *Cf.* 's Gravessande (1748), pp. 16-18.
[309] *Cf.* 's Gravessande (1748), pp. 16-17.

perceptible bodies and consequently they should be solid and extended as well. But the most interesting consequence is that, as a result, we also can postulate an explanation of their cohesion. Accordingly, he argues that bodies are formed by particles endowed with an attractive force making them to cohere. In this sense, 's Gravesande establishes a general law of nature: "todas las partecillas de cualquier cuerpo tienen cierta fuerza de atracción, esto es, que si están próximas se inclinan espontáneamente las unas hacia las otras" (RJB III, 7, 1, 5, f. 296v).[310] 's Gravesande contends that this law is deduced from natural phenomena, but that the cause of such an attraction cannot be accounted for by them. This is evidenced in his commentaries on the conception of the attraction between particles as an impulse, where he presents a characterization of attractive forces which clearly resembles Newton's position in several passages of the *Principia* concerning the ontological causality of the force and his rejection to make any pronouncement regarding its physical action:

> Puede ser que esto se haga por impulso; pero como lo ignoramos no debemos afirmarlo. Y así se debe tener entendido, que con el nombre de atracción queremos manifestar solamente el fenómeno, pero no la causa. Por eso se conocerá que no cambiamos aquí la significación vulgar de esta palabra. Y así decimos generalmente que un cuerpo es movido por atracción siempre que este cuerpo se inclina hacia otro, si la presencia de ese cuerpo es necesaria para producer ese movimiento (…) Y ésta es la razón porque en muchas ocasiones no dudaremos atribuir a la atracción todos aquellos movimientos en los cuales es

[310] *Cf.* 's Gravessande (1748), p. 17.

> manifiesto el impulso. Siempre es nuestro ánimo manifestar con el nombre de atracción el efecto sin attender a la causa (RJB III, 7, 1, 5, f. 296v).[311]

's Gravesande's pronouncements regarding the physical action of the force were very similar to the one that Newton presented in Definition 8 of the *Principia*, in which he clarifies that despite that he referred to the force in terms of attraction, he did not aim to define the way in that gravity acts:

> Further, it is in this same sense that I call attractions and impulses accelerative and motive. Moreover, I use interchangeably and indiscriminately words signifying attraction, impulse, or any sort of propensity toward a center, considering these forces, not from a physical, but only from a mathematical point of view (Newton, 1999: 408).

Newton completes this characterization of the terminology he used to describe the action of the force, warning the reader that it should not be thought that he was characterizing forces in physical terms because he was considering just "mathematical points". In this sense, by neglecting any definition of the physical action of the force, as he was strictly dedicated to its mathematical description by the physical effects that it produces, 's Gravesande adopted the same caution as Newton did in the *Principia*.

Consequently, we can argue that, by including this chapter in his translation of 's Gravesande's *Physices elementa mathematica*, Mutis also introduced in New Granada a Newtonian matter, in which chemical phenomena and the basic composition of the bodies were explained

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[311] *Cf.* 's Gravessande (1748), p. 17. One of Newton's most known pronouncements on the mathematical language he used in the *Principia* to characterize the force as an attraction is in Section XI, Book I, where he claims that his indistinct use of the term "attraction" was caused by his purpose of being understood by the mathematical readers of the work.

by the postulation of gravity-like forces. Said forces were explained by the effects they produce that we can perceive and mathematically explain in the bodies and consequently they can be postulated as real entities acting in nature.

However, there is another feature of 's Gravesande's arguments in *Physices elementa* mathematica which leads to understand the role of this work in Mutis' lectures. Despite the fact that it is not possible to causally explain the force of cohesion, for 's Gravesande, it is indeed possible to discover the laws determining the behavior of the particles composing the bodies. According to him, these laws are:

> 1. [The greatest force of cohesion] consiste al tocamiento mutuo de las partecillas, y al punto disminuye de golpe, de tal suerte que en la distancia más minima y perceptible, ya no obra 2. Que a cierta distancia que es la mayor, se apaga enteramente la fuerza de atracción y se cambia en una fuerza repelente, por la cual las partecillas huyen mutuamente las unas de las otras (RJB III, 7, 1, 5, f. 297r).[312]

The characterization of the cohesion of particles as the result of the action of an attractive force between them which can be reduced to mathematical terms and consequently can be described as a law of nature, reflects 's Gravesande's commitment with the Newtonian approach to nature developed in the context of the early-eighteenth century Newtonian medicine and chemistry. In these traditions, forces that were similar to gravity, explained in mathematical terms, were assumed as explicative principles to account for the cohesion of particles. This idea, present in some of Newton's published and unpublished works – like the *Queries* of the *Opticks* and *De natura acidorum* –, was adopted by some Newtonian physicians, such as Pitcairne, Cheyne, James Keill, and Boerhaave, in order to explain several physiological phenomena. 's Gravesande was

[312] *Cf.* 's Gravessande (1748), p. 18.

probably influenced by Boerhaave's works on medicine and chemistry on this particular issue. As a consequence, it is possible to claim that, by adopting the notion of attractive forces between particles in his translation of 's Gravesande's *Physices elementa mathematica*, Mutis established the physical foundations of what he considered the ideal practice of medicine in the frame of his teaching on the theoretical aspects of Newton's physics. I shall discuss this particular issue in Chapter 5, when I explain the influence of Boerhaave in Mutis' conception of medicine.

The translation of Newton's *Principia* in the context of the lectures

One of the most interesting manuscripts of Mutis in the archives of the *Real Jardín Botánico* of Madrid is his unpublished translation of Newton's *Principia*. Discovered in 1984 by Arboleda, it is a partial translation of Books I and III of Newton's *magnum opus*, based on both the first edition of 1687 and the commented edition by Leseur and Jacquier of 1739-1742. Likewise, it also contains the translation of the commentaries to Section I until Section VII of Book I made by these Minim friars. The translation, which Arboleda has studied and described in detail in different papers, was probably made in the 1770s, preceding by more than two hundred years the only published translation into Spanish made by Antonio Escohotado in 1982.[313] Nevertheless, one of the problems of Mutis' translation regards its purpose and the public it was aimed to. In solving these issues, Arboleda and Soto explained that Mutis' translation was made up in the context of his debates against the Dominicans, which is framed in the reformations to education proposed after the expulsion of the Jesuits in 1767.[314] These historians argued that it is necessary to understand Mutis' Newtonianism in the context of his polemics with the

[313] In the preface to the reader that Escohotado made, he pointed out that there is no version of Newton's *Principia* in Spanish and that he used Cohen's and Koyré's *Variorum* edition from 1972 and Motte-Cajori's English edition from 1934 as references.
[314] *Cf.* Arboleda (1987), Arboleda & Soto (2006), Soto (2009).

Dominicans concerning Copernicanism. Their studies show that the enterprise of translating the *Principia* should be understood as one of Mutis' strategies for consolidating and institutionalizing Newton's approach to nature against the scholastic methodology reigning in New Granada's university milieu.

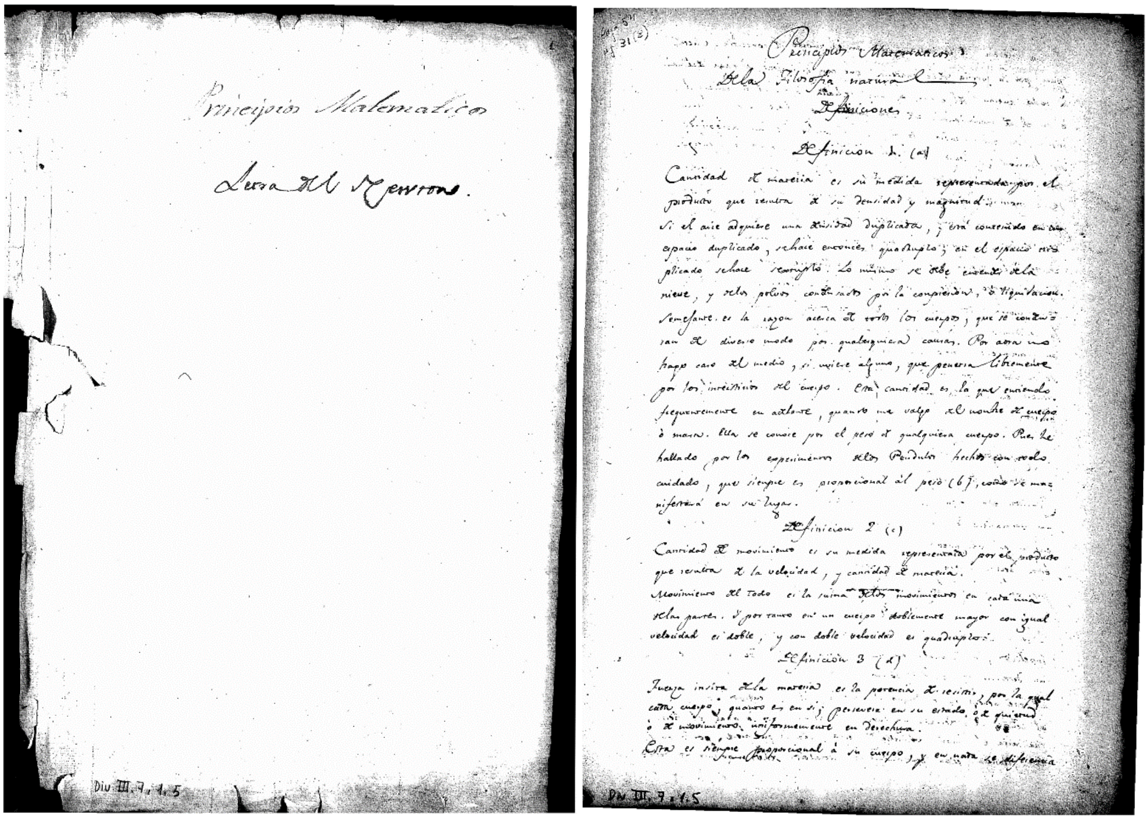

Figure 14. First pages of Mutis' translation of Newton's Principia, RJB III, 7, 1, 5, ff. 1r-1v.

However, I think that this historical reconstruction of Mutis' project of translating Newton's *Principia* only provides a partial explanation of the purpose of the manuscript. By being centered on the polemics about education in New Granada, this interpretation leaves aside the inner contents of the translation itself and the theoretical problems that Mutis dealt with in the lectures in which he used it. My thesis is based on two premises. First, the important role of translating as a pedagogical practice in Mutis' lectures, which I pointed out in the last sections. Second, the progressive difficulty of the issues and subjects Mutis dealt with in his lectures. As I highlighted above, the development of Mutis' lectures on mathematics and physics reflects a progressive presentation of the more complex features of Newton's experimental physics and mathematics. From the simple establishment of the basic concepts of mathematics and its method, Mutis moved through geometrical and arithmetical problems and demonstrations, with the purpose of establishing their application to different fields – especially to natural philosophy. Thus, at the end of the first period of his lectures, between 1765 and 1766, we find several manuscripts dealing with basic subjects of Newton's method of analysis and synthesis which lead Mutis and his students to study the more complex aspects of the analysis of the motion of bodies and the interaction of forces.[315] As Arboleda, Albis, Martínez Chavanz, and Soto suggested, this progressive introduction of Newton's natural philosophy was produced through the use of the works of Dutch and French Newtonian experimentalists, because it was a simpler manner to understand the application of Newton's principles to the explanation of natural phenomena. In this context, for instance, Mutis translated 's Gravesande's *Physices elementa mathematica*, using it as a textbook for his lectures on physics in the early 1770s.[316] Thus, Mutis' translation of Newton's *Principia* should not be considered as a source for the theoretical debates concerning Copernicanism in the context of the polemics between Mutis and the Dominicans, but also as a textbook for his lectures that complemented the training of his disciples. Let us see in detail some of its general features, following Arboleda's reconstruction of the text.

The first explicit reference to the existence of the manuscript containing the translation of Newton's *Principia* appears in Diego Mendoza's *Expedición botánica de José Celestino Mutis al Nuevo Reino de Granada y memorias inéditas de Francisco José de Caldas*. In general, Mendoza's classical

[315] As I pointed out above, to this period correspond the manuscripts *Elements of arithmetics*, *Elements of mechanics*, and *Elements of trigonometry*, as well as Mutis' translation of Descartes' *Géométrie*.
[316] Arboleda, Soto, and Martínez Chavanz argued that Musschenbroek also played a considerable influence on Mutis' conception of Newtonianism. *Cf.* Arboleda (1993), Martínez Chavanz (1993), Soto (2009).

book discusses several aspects of Mutis' works in New Granada, including his role as professor of mathematics and astronomy, which he presents in the apologetic manner that characterizes the early studies about Mutis in Colombia.[317] However, Mendoza did not consider the manuscript as a translation of Newton's *Principia*, but as a treatise written by Mutis on the system of the world in the context of his lectures on astronomy: "Para el curso de Astronomía escribió un corto texto de 63 páginas. El Libro III trata del Sistema del Mundo. Enuncia con timidez el sistema de Copérnico, que más adelante daría lugar a una controversia célebre en los anales de la colonia" (Mendoza, 1909: 45). Likewise, he describes the rest of Mutis' translation as a mixed manuscript containing some elements of mechanics and the mathematical principles of natural philosophy, arguing that he did not know whether the manuscript was a translation or not: "115 páginas tiene el fragmento de sus Elementos de Mecánica, y 65 los Principios Matemáticos de Filosofía Natural, que no sabemos si serán original o traducción; tampoco sabemos si Mutis es o no autor de un copioso trabajo titulado 'Comentarios de Newton'" (Mendoza, 1909: 45). Several excerpts of Mutis' translation were published by Guillermo Hernández de Alba as isolated pieces, so we can assume that he did not perceive either that it was a translation of Newton's *Principia*.[318] The particular manner in that these historians presented the manuscript reveals both the lack of knowledge of the extent of Mutis' works – and the problems derived from the study of specific historical cases without putting them in a more general context – and the problems derived from the lack of organization when the manuscripts were moved from New Granada to Spain.

[317] *Cf.* Mendoza (1909), pp. 7-150. It is important to point out that Mendoza is more interested in studying Caldas' works than in Mutis' ones. In this sense, despite that the section dedicated to the analysis of Mutis' works is considerably large and it describes several interesting episodes of Mutis' endeavours of Mutis' life in Santa Fé, they are aimed to the determination of the influence of Mutis on Caldas' personal and intellectual life.
[318] *Cf.* Mutis (1983a).

Like the translations of Wolff's *Elementa matheseos*, Descartes' *Géométrie*, and 's Gravesande's *Physices elementa mathematica*, Mutis' translation of Newton's *Principia* proves the importance of translating as a pedagogical practice for him. It also proves the significant role of the commented editions of these works in the development of Mutis' lectures as he not only translated the main body of the texts, but also the commentaries and scholia that the authors included. Thus, translated versions of the commented works became for Mutis in indispensable instruments for his lectures not only because they let him to overcome the difficulties posed by the lack of books on modern natural philosophy in New Granada's libraries.[319] However, when compared to his other translations, Mutis' translation of Newton's *Principia* is extremely rare several aspects. First, its extension is considerably larger. As Arboleda showed, the translation is almost the third part of the total amount of Mutis' manuscripts on mathematics and physics which are nowadays in the archives of the *Real Jardín Botánico* of Madrid.[320] Second, despite that it is a partial translation of Newton's *Principia*, it is more complete than Mutis' versions of Wolff's *Elementa matheseos*, Descartes's *Géométrie* and 's Gravesande's *Physices elementa mathematica*, which generally only encompassed the first books of the works. Third, it was made up in a period in which Mutis was engaged in the defence of Newton's physics out of cloisters, when he was more committed to the political implications of Moreno y Escandón's reforms to New Granada's educational system than to his own lectures. Let us see some general aspects of the translation in order to determine its purpose and its potential public.

[319] For that purpose the tradition of the *dictados* that I commented in Chapter 3, described in detail by Rivas Sacconi, played a fundamental role. *Cf.* Rivas Sacconi (1993), pp. 64-65. Despite that Mutis had a negative opinion on this tradition, New Granada's conditions forced him to make his own *dictados*. Further research in the archives of the *Universidad del Rosario* and the *Archivo General de la Nación de Colombia* must provide evidence on the existence of *mamotretos* related to Mutis' lectures on these issues.
[320] *Cf.* Arboleda (1987), p. 122.

The manuscript, as Arboleda reconstructed it and as it is nowadays in the archives of the *Real Jardín Botánico* of Madrid, is composed by the definitions, axioms, and several sections of Books I and III. From Book I, Mutis included Sections I up to X; and from Book III, he translated since Newton's introductory commentary, where he explains the mathematical character of the language he used in Books I and II, until Proposition XXXVIII.[321] Book II is not included in the manuscript and there is no evidence that it has been ever translated.[322] Likewise, after the translation, Mutis included a set of commentaries, which are a translation of Leseur's and Jacquier's commentaries to their edition of Newton's *Principia*, published in Geneva, between 1739 and 1742 – these probably are the *Comentarios de Newton* to which Mendoza referred to. The structure of the manuscript, the translation of Leseur's and Jacquier's commentaries, and the variations that we can find between the translations of Book I and III reveal that Mutis used different editions for the enterprise of translating Newton's *magnum opus*. Thus, whilst definitions, axioms, and Book I was directly translated from Leseur's and Jacquier's commented edition, Book III was translated from the 1687 edition of the *Principia*, as it still contains the hypotheses – that Mutis translated as *Suposiciones* –, which were turned into Rules and Phenomena in the second and third editions of 1713 and 1726.[323] Throughout the translation of the definitions, axioms, and Book I, it is possible to find in several passages of the manuscript, multiple letters which correspond to the letters where Leseur and Jacquier included a commentary to the text. Mutis translated the complete set of commentaries of these Minim friars from the Definitions up to the end of Section VII, Book I.[324]

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321 The entire manuscript of the translation, including the translation of Leseur's and Jacquier's commentaries, is in RJB III, 7, 1, 5, ff. 1r-231v. It is the first manuscript of the signature dedicated to Mutis' manuscripts on education.
322 *Cf.* Arboleda (1987), p. 122.
323 On the modifications of Book III of Newton's *Principia* in its different editions, see Cohen (1999), pp. 195-274.
324 Published in Geneva between 1739 and 1742, Leseur's and Jacquier's commented edition of the *Principia* played a fundamental role in the diffusion of Newton's mathematical explanations of nature in the continent. *Cf.* Guicciardini (2015). In my analysis, I used the version of this work published in Glasgow in 1833.

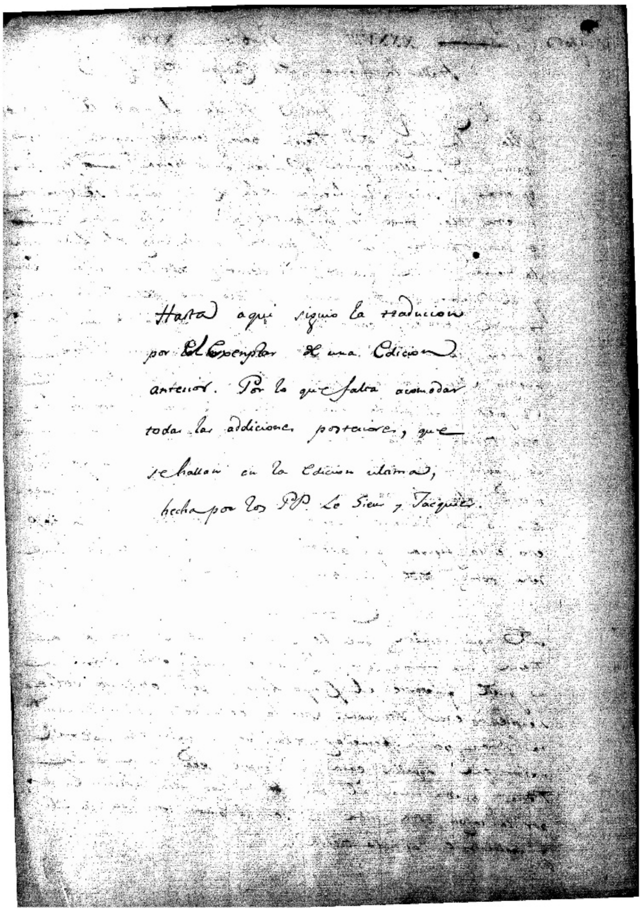
Hasta aquí siguió la traducción
por el exemplar de una edición
anterior. Por lo que falta acomodar
todas las adiciones posteriores, que
se hallan en la edición última,
hecha por los PP. Le Sieur, y Jacquier.

Figure 15. Mutis' reference to Leseur's and Jacquier's edition, RJB III, 7, 1, 5, f. 164v.

At the end of the manuscript, we find a brief commentary of Mutis which allows to understand the important role of Leseur's and Jacquier's edition in his own translation and the fragmentary nature of the sources he used for that: "Hasta aquí siguió la traducción por el ejemplar de una edición anterior. Por lo que falta acomodar todas las adiciones posteriores, que se hallan en la edición última, hecha por los PP. Le Sieur [sic.] y Jacquier" (Fig. 15). (RJB III, 7, 1, 5, f. 164v). As Arboleda argued, this annotation suggests that Mutis only had access to the first volumes of Leseur's and Jacquier's edition during the translation and consequently that he used the first edition to translate Book III: "no disponiendo de los dos tomos de la edición de Leseur y Jacquier de 1739-1742, correspondientes al Libro III, realizó su traducción en base a una edición anterior, y esperaba hacerle luego la adición de los comentarios (no estaba al tanto Mutis de todos los cambios en el propio texto de las varias ediciones) (Arboleda, 1987: 128).

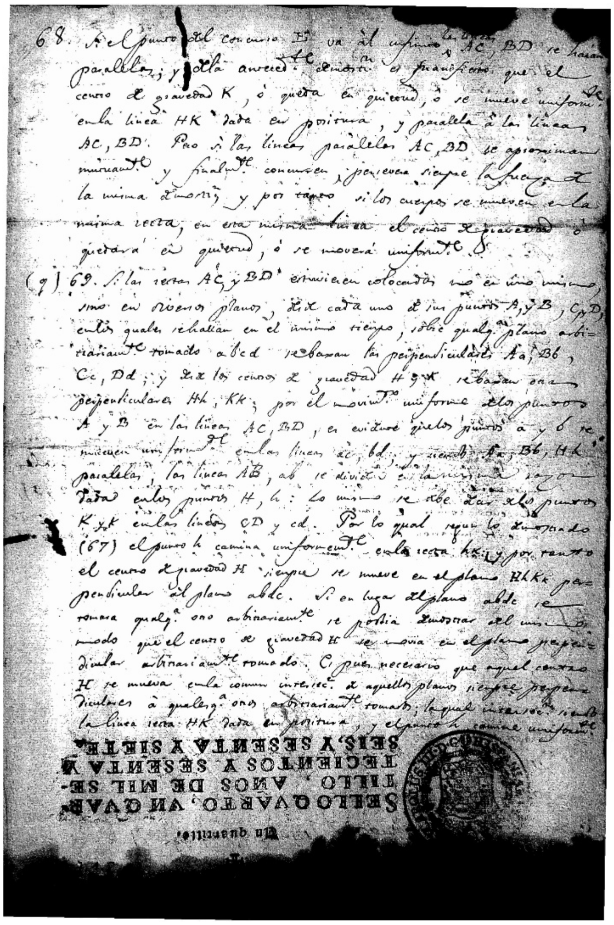

Figure 16. Page with royal seal of 1776-1777, RJB III, 7, 1, 5, f. 189r.

Another important feature of the manuscript is the papers Mutis used for making it. Because of the lack of paper to write, Mutis frequently used the verso side of the sheets of letters he received. As Arboleda suggested, this particularity in the translation helps to date the manuscript. In his opinion,

> Esta circunstancia tal vez desfavorable para su conservación integral, ha permitido sin embargo ubicar la fecha aproxima de elaboración de la traducción, a falta de cualquier otra información complementaria. Las cartas tienen fechas que se

ubican entre junio de 1764 y junio de 1773, con un punto de aglomeración a mediados de 1772. Este dato, sumado a consideraciones que posteriormente expondré sobre el momento histórico en que esta traducción era más viable, permite suponer que fue realizada entre 1772 y 1773 (1987: 123).

Nevertheless, I found that the manuscript also contains a folio in which it is visible a royal seal of the years 1776 and 1777 (Fig. 16).[325] It would imply that the date of the production of the manuscript could be later than it had been thought, probably *circa* the late 1770s and the beginning of the 1780s, just before the official establishment of the Royal Botanical Expedition in 1783.

Unlike the evidence we have regarding the sources and details of the translation, which are provided by the manuscript itself, the purpose of such an enterprise and the context in which it was produced are not so clear. In effect, the translation is considered by historians like Arboleda, Albis, and Soto as a part of Mutis' endeavours for introducing Newton's physics in New Granada's university milieu.[326] Thus, by translating the *Principia*, he provided the most powerful instrument to his students in order to understand the kind of natural philosophy he was teaching as of the beginning of his lectures in 1762. This idea is reinforced by the fact that the translation, as Arboleda commented, was probably done in the 1770s, so it was used as a source for the debates regarding Copernicanism between Mutis and the Dominicans. However, I think that this interpretation faces one basic problem: by considering that Mutis' students were formed in Latin and that Latin was the official academical language of the universities in New Granada, what was the purpose of translating the work?[327] This particular problem has been

[325] *Cf.* RJB III, 7, 1, 5, ff. 189r
[326] *Cf.* Arboleda & Albis (1988), Soto (2009).
[327] About the teaching of Latin in New Granada, see Rivas Sacconi (1993).

tackled by Arboleda and Albis by arguing that the translation was produced in the context of the debates between Mutis and the Dominicans. Thus, it has to be considered not only as a pedagogical device that Mutis used in the context of his lectures but as a source for responding to the Dominicans, as it presents the results of applying Newton's methodology that he defended as of his arrival in New Granada. Consequently, as Arboleda argues, Mutis' translation of the *Principia* allowed him to reach a better understanding of the problems and implications of Newton's physics, especially the mathematization of nature and the arguments for the Copernican system.[328] Thus, Arboleda describes the purpose of the translation:

> El medio más directo, pero al mismo tiempo el que menos se prestaba para descifrar el entramado hermético del discurso de los *Principia* era una traducción en lengua natural. Se trataba de hacer reflejar en ella, con toda fidelidad, los matices y complejidades del "verdadero método de filosofar". En efecto, si para desempeñar la función divulgadora de la filosofía natural que había asumido prácticamente desde su llegada a Santafé se sirvió Mutis sobre todo de fuentes ssecundarias, la lectura-traducción de los *Principia* vendría a aclarar, confirmar e incluso corregir su comprensión del auténtico núcleo de la nueva racionalidad; aquello en que se soportaba el "verdadero método". Sólo entonces pudo aprehender en su profundo significado dos claves de esta racionalidad: en primer lugar, la eficacia explicativa de la matematización newtoniana de los fenómenos naturales (estructura causal simple y universal) y, en segundo lugar, el proceso de construcción de la teoría basada en la experiencia (1992).

[328] *Cf.* Arboleda (1993). I study in detail the political and social circumstances of the reforms to New Granada's educational reforms in the 1770s as well as the role Mutis played in them in Chapter 6.

Likewise, Arboleda suggested that the translation was part of a more generalized strategy in Spain of translating works in order to introduce multiple aspects of early modern science to the Spanish public. According to Arboleda, this strategy, promoted by King Charles III, entailed two things: first, it promoted the useful sciences based on the application of mathematics to the study of nature among the people who can use them and that frequently did not know Latin. Second, by popularizing some scientific works, it diminished the control of the education by religious orders, which insisted on the need to educate exclusively in Latin.[329]

However, I believe that Arboleda's arguments regarding the reasons motivating Mutis to translate Newton's *Principia* are problematic. First, he assumes that Mutis' translation was part of a more generalized strategy which emerged in Spain in the second half of the eighteenth century, characterized by the interest in promoting the study of what Arboleda calls the "European scientific culture".[330] Nevertheless, it is unlikely that Mutis' translation of Newton's *Principia* as well as his other translations and his general pedagogical enterprise were linked to the Spanish approach to the European scientific culture developed in the late-eighteenth century. In fact, Mutis' pedagogical activities at the *Colegio del Rosario*, and their implications in the diffusion of Newton's physics in New Granada seem to be more isolated endeavours than the result of a Spanish policy, caused by his formation in Spain and his need to establish material conditions for his projects in the Viceroyalty. As I commented above, although Charles III and his enlightened ministers created several policies incentiving the training in useful modern sciences in universities, thus promoting Newton's physics in Spain, such policies only had a real impact on the Spanish Atlantic world after the 1780s. Too late to be considered as influential for Mutis. The fact is that Mutis' diffusing activities of Newton's experimental physics took place, more or

[329] *Cf.* Arboleda (1987), pp. 140-142.
[330] *Cf.* Arboleda (1987), Arboleda (1989).

less, twenty years earlier than the first public policies for introducing Newtonianism in the universities in the Spanish overseas territories. As Brockliss explains:

> In Spain from the early 1770s, the Bourbon king Charles III oversaw a painstaking curricular revision of each university in turn. By the late 1780s reform had reached as far as Peru. In 1787 Toribio Rodríguez de Mendoza (1750-1825), the rector of the college of San Carlos at Lima, introduced a new plan of studies that ordered the teaching of Newton as the only acceptable modern natural philosopher (2003: 61-62).

Therefore, Mutis' lectures and his translation of Newton's *Principia* were not related in any way to the reforming activities developed during the reign of Charles III. Certainly, it does not mean that Mutis was not a beneficiary of the modernizing attitude of the King, as he was appointed Director of the botanical expedition. What I am arguing is that Mutis' pedagogical activities in New Granada were not a consequence of Charles III's projects of modernization of Spain's educational system.

Furthermore, I disagree with Arboleda when he claims that, by translating Newton's *Principia*, Mutis discovered the potential of Newton's natural philosophy and Newton's particular manner to mathematize nature. This idea implies that Mutis was not aware of the explicative virtues of Newton's *Principia* and that he actually did not know Newton's work at all before he committed himself to the enterprise of translating it. As I explained in Chapter 2, such an interpretation is contrary to both the textual evidence and the historical circumstances of the education of Mutis in Cadiz. Conversely, by studying Mutis' manuscripts before the possible date of his translation of Newton's *Principia*, it is possible to conclude that he had a good understanding of several theoretical aspects Newton's *Principia* and that he taught them in his lectures in the 1760s and the early 1770s. Mainly, he understood Newton's explanations of the motions of bodies and how to discover the ratios and directionality of the forces when a body is being accelerated in a conic section. Similarly, as Mutis used 's Gravesande's *Physices elementa mathematica* as a textbook, it is possible to claim that he also understood the implications of Newton's mathematical approach to nature, like the postulation of attractive forces to explain natural phenomena. I argued above that these ideas actually reveal that Mutis presented in his lectures of the 1760s and 1770s an opposition to the explicative models of the scholasticism and the mechanical philosophy defended in New Granada's universities and colleges, thus openly declaring himself as a Newtonian. Likewise, Arboleda's interpretation seems to contradict the idea widely accepted by historians, and that he himself highlighted,[331] that Mutis discovered Newton's physics while he was a student in Cadiz. As I explained in Chapter 2, there he was familiarized with Newton's theories as they were applied to physiology, astronomy, and navigation, thanks to the influence of Virgili and Juan.

By translating Newton's *magnum opus*, Mutis extended the scope of his lectures on physics, as he illustrated the application of mathematics to the explanation of natural phenomena, but fundamentally because he established the foundations for demonstrating a system of the world under the explicative model that he introduced since his arrival in New Granada. However, my interpretation faces a difficulty that I have not been able to solve yet and that require further research on Mutis' manuscripts: if Mutis used his translations as textbooks for his lectures, why did he translate these works? Considering that his students were well-trained in Latin, why did he feel the need to translate these works instead of presenting them in their original Latin

[331] *Cf.* Arboleda (1993).

versions? Arboleda suggested that Mutis' interest in translating was part of the Spanish interest of intensifying the teaching of useful sciences rather than the learning of Latin. For him,

> No se tenía que someter a los pocos individuos con talento para las ciencias, a las dificultades adicionales que suponía su aprendizaje en latín particularmente en aquellas que exigían mayor aplicación como la física y las matemáticas newtoniananas. El tiempo empleado en tener un conocimiento solvente en latín como para disponer de un buen entendimiento de las obras científicas escritas en esa lengua, podría emplearse en adquirir conocimiento científicos más útiles (1987: 141).

However, Mutis was not teaching to students that were just learning Latin. As Rivas Sacconi explained, before the formation in universities and colleges, like the *Colegio del Rosario* where Mutis' lectures took place, students were required to study Latin, as all of their lectures were dictated in that language. Latin was taught since the first infancy, so the young students were ready to copy the volumes – *mamotretos* – that their professors dictated them.[332] Regretfully, there is no evidence in order to determine the potential public of Mutis' translation and, as a result, the purpose of the translation remains unknown.

[332] *Cf.* Rivas Sacconi (1993), pp. 41-117.

Chapter 5. Newtonianism, medicine and Mutis' *General plan for the medical study*

Newtonian medicine in New Granada

As requested by Viceroy Pedro Mendinueta Múzquiz, Mutis wrote a report about the state of the medical practices in New Granada in 1801, entitled *State of the Medicine and Surgery in the New Kingdom of Granada in the eighteenth century and means to solve its regrettable backwardness* [*Estado de la Medicina y de la Cirugía en el Nuevo Reino de Granada en el siglo XVIII y medios para remediar su lamentable atraso*], in which he described, in a general manner, the health condition of the Granadians and the problems related to the treatment of their diseases.[333] As regards their health, he claimed that the endemic diseases they suffered were the result of the "casual y arbitraria elección de los sitios en que se han congregado sus pobladores".[334] Accordingly, Mutis declared to Viceroy Mendinueta, that the ill-founded choice of the sites where cities were founded was the cause of two plagues: scrofula, vulgarly known as *cotos*; and syphilis. Likewise, he claimed that it was possible to frequently find two more diseases caused by the weather of the ill-founded cities: leprous [*Lazarina*] and Pinta [*caratosa*] – a tropical disease transmitted through contact with the skin of sick individuals, and characterized by discoloration of the skin.[335] On the other hand, for the treatment of such diseases, he argued that as populations were already established in those places and their relocation was impossible, in order to solve their health problems, it was

[333] *Cf.* Mutis (1983a), pp. 33-62.
[334] *Cf.* Mutis (1983a), p. 34.
[335] *Cf.* Mutis (1983a), p. 35.

necessary to look for another solution to the problem. In his opinion, special attention should be paid to the state of the medical practices in New Granada.[336] In this sense, by including a general characterization of the medical studies in the Viceroyalty, which he described as retrograde, Mutis extended the scope of his report to include not only a characterization of the health of Granadians and the cause of their diseases but, more importantly, a description of the state of medical studies in the Viceroyalty. According to him, the slow development of medical practices in New Granada was caused by the problems of educating well-trained physicians at the *Colegio del Rosario* – which had been the only college authorized to teach Medicine in New Granada since 1651.[337] As Mutis described it:

> Para la Facultad de Medicina, sólo ha sido una ilusión de pura perspectiva la concesión de su cátedra. La total falta de su dotación con la circunstancia de ser única y por lo mismo incapaz de abrazar todos los ramos esenciales de su enseñanza, ha ocasionado la indiferencia y al fin la total deserción con que la han servido desde su institución muy pocos profesores por el aliciente de estar unido a ella el Protomedicato (1983a: 36).

As we can see, for Mutis, the lack of well-trained physicians was the result of the lack of the material conditions at the *Colegio del Rosario* for educating them. Furthermore, he argued that the only reason for assuming the role of Professor of Medicine at the *Colegio del Rosario* was the social role of *Protomédico* it entailed. As a consequence, Mutis concluded that since his arrival he had only known two professors for the course of Medicine, Vicente Canzino, and his pupil, Juan

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[336] *Cf.* Mutis (1983a), pp. 35-36.

[337] The history of medicine in Colombia is an underdeveloped field. However, in recent times, important economical and intellectual efforts have been made out by Emilio Quevedo sponsored by pharmaceutical company *Tecnoquímicas*. For the development of the lectures on medicine during the colonial period, see, in particular Quevedo (Ed.) (2007), Quevedo (Ed.) (2008).

Bautista Vargas. Mutis' characterization of the state of the course of Medicine in New Granada was actually very accurate, albeit focused exclusively on one aspect of the issue. Founded in 1651, the course of Medicine at the *Colegio del Rosario* was the only one on this discipline in New Granada with the royal authorization to graduate students as physicians. However, as the eighteenth-century hierarchical structure of Santafé's society was similar to that of Spain – which I briefly described in Chapter 2 when addressing Virgili's foundation of the *Colegio de Cirugía* in Cadiz –, the title of Physician did not help students gain a position in the traditionally ecclesiastical society of New Granada. A concern that was very important for the wealthy families of New Granada which were the only ones who could finance the academic careers of their sons.[338] Unlike the titles of Doctor in Law or any ecclesiastical position, the role of Physician was not worthy for Santafé's families and, consequently, their sons did not enroll in a faculty which, in any case, was incapable of offering them any incentive to change that image. Thus, along with the lack of material conditions for teaching, described by Mutis, the social status that the title of Physician gave to the student and his family should also be considered as a cause of the lack of motivation for studying medicine in Santafé. Due to the lack of professional training in New Granada, Mutis stressed that the problems for public health were multiplied by the proliferation of healers, whose knowledge was merely empirical and not based on in-depth deep knowledge of the theoretical principles supporting medicine as a professional practice. Indeed, although Juan Bautista Vargas – one of the professors of Medicine that Mutis mentioned in his report – held the title of Physician, it was true that his assessment was made by individuals who were not physicians either.[339] In Mutis' words,

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[338] For the social profiles of New Granada's students during the eighteenth century, see Soto (2005a) and Soto (2005b).
[339] *Cf.* Mendoza (1909), p. 104.

> Todas las naciones bárbaras, aunque privadas de las luces de las ciencias útiles, conocen la necesidad de una medicina empírica, que ejercen casi por instinto socorriendo a sus semejantes; pero contentarse con tales socorros una nación civilizada y culta desde su conquista, sería confundirse con aquellas, apartándose del común consentimiento de todo el mundo racional (1983a: 35).

As a result of his report, Viceroy Mendinueta asked Mutis to create a study plan for the course of medicine at the *Colegio del Rosario* after its reestablishment in 1799. It must be recalled that the course of medicine in Santafé had been closed in 1774, with the reforms made by Moreno Escandón, under the pretense of restructuring its curriculum according to the model of modern medicine. However, such an enterprise was never achieved and consequently, in 1776, when the course was reopened, only Juan Bautista de Vargas applied for the position of Professor of Medicine, which he held until 1799, when he moved to Popayán, leaving behind both his position and the course of medicine. In 1799, thanks to the pressure of the Director of the *Colegio del Rosario*, Fernando Caicedo – who was a student of Mutis in the 1760s –, the course was finally reestablished and Miguel de Isla – another pupil of Mutis – was appointed as its interim professor. However, meanwhile the Viceroy was establishing a formalized study plan guiding the course that Isla had been holding since 1799 and which would carry on the reforming trend in education that had been established in New Granada in the 1780s – I shall discuss in detail in the next chapter.[340]

The plan that Mutis presented in 1802 was entitled *General plan for the medical studies, set up according to the proportions of the country to the teaching of all its subordinated professions* [*Plan general de los estudios médicos, arreglado según las proporciones del país a la enseñanza de todas sus profesiones subalternas*].

[340] Details of this episode of the course of medicine at the *Colegio del Rosario* are in Wilhite (1980).

It was used as a reference for the creation of the study plan for the course of medicine at the *Colegio del Rosario* by its Director, Andres Rosillo y Meruelo, and Professor of medicine, Miguel de Isla, in 1804. The *General plan* postulated Mutis' strategies for establishing the conditions for a formalized medical education in New Granada, based on the principles of modern physiology and surgery that he had learned during his time as a student in Cadiz in the 1750s. In it, he described the theoretical content, extension of courses, breakdown of the lecture topics, and even the time of the day when they would take place. Characterized by the presence of Boerhaave's works as the theoretical foundation, Mutis elaborated a curriculum in which he not only included the theoretical elements of Boerhaave's *Praelectiones academicae in proprias institutiones rei medicae* (1708) and *Aphorismi de cognoscendis et curandis morbis* (1709) – as well as the therapies that the latter contained – but also a preliminary training in chemistry, mechanics, and mathematics which would allow to the students to understand the physiological elements underlying the medical education as of the first year of their career.

After praising the training imparted at the *Colegios de Cirugía* that Virgili had created in Spain in the 1750s,[341] Mutis claimed that the plan he proposed was based on the principles of the reformed plans of the *Colegios* and Spanish universities, in which it was decided to "desterrar de sus aulas de filosofía y medicina los antiguos métodos de su enseñanza peripatético-arábiga"[342]. In his opinion, one of the central features of those plans was the training of students according to the principles of the ancillary disciplines of medicine in order to overcome the simple know-how that had characterized medicine of the peripatetic tradition in Spain and that had brought about social discredit of the physicians in Spain and its overseas territories. Accordingly, in his plan, Mutis began by establishing the connection existing between physics

[341] *Cf.* Mutis (1983a), pp. 64-67.
[342] *Cf.* Mutis (1983a), p. 66.

and medicine as the result of the possibility that the former discipline gives to the latter instruments for rationally explaining the physiological functions and possible causes of the diseases affecting the human body. Following Boerhaave's commentaries in his *Institutiones medicae* and *Aphorismi* concerning the need for the physicians to have a complete understanding of the physiological functions of the body, Mutis established a curriculum based on the chemical and mechanical study of the animal economy. As I shall argue, that was precisely one of the fundamental pillars of Boerhaave's Newtonianism in medicine. For Mutis,

> Renovadas finalmente las ciencias naturales y abrazado el partido de cultivar la física, se advirtió desde luego la estrecha unión que tenía esa ciencia con las matemáticas y demás ramos que ya constituyen la física particular. Sería pues imposible llamarse médico el que careciera de la suficiente instrucción de las ciencias matemáticas, física experimental, botánica y química. Tales son los conocimientos auxiliares, que pueden prestar las luces necesarias para aprender y ejercitar con acierto la medicina dogmático-racional, según los adelantamientos y aplaudidos sucesos que la han hecho tan sobresaliente como estimada en nuestros días (1983a: 67).

Certainly, such a characterization of the role of the ancillary disciplines in the training of the medical students highlights the importance that both physics and chemistry had for Mutis in understanding the functioning of the human body. Interestingly, in his plan, he argued that students should have a preliminary knowledge of the ancillary disciplines of medicine – mathematics, physics, chemistry, and botany – and their training on those issues should not be a part of the curriculum of the course itself.[343] For him, medical education should only be

[343] *Cf.* Mutis (1983a), p. 67.

followed by those students who, wishing to be physicians, had finished the course of philosophy which included detailed teaching of physics and mathematics.[344] Arguably, it shows how in the plans for restructuring education in New Granada that Mutis had been committed to since the 1770s, there was a clear articulation between faculties and the theoretical knowledge that any field could impart. Mutis defended such an articulation as it was founded on the precepts of "Newton's experimental physics" that he had introduced in the 1760s. It also reveals another important facet of Mutis' appropriation of Newton's experimental physics: for him, the theoretical tenets and concepts of Newton's physics were useful in accounting for the motion of bodies and the mechanical phenomena observed in nature. As we shall see later, by considering the human body as a machine, Mutis also defended the possibility of applying these tenets and concepts to the fields of physiology and therapeutics as well.

In the description of the lectures of the second year of medicine, we find the source of Mutis' appraisal of mechanical and chemical knowledge as the basic foundations for understanding physiological phenomena. He believed that after studying both theoretical and practical human anatomy in the first year, which required the creating of an amphitheatre for anatomical studies,[345] students should dedicate themselves to the study of the organs through lectures on physiology:

> Se reduce su enseñanza a entender y penetrar bien el mecanismo de los órganos del cuerpo humano, conocidos el año anterior por el estudio de la anatomía. Abraza pues la fisiología todos los conocimientos pertenecientes a la economía

[344] This characterization is evidence of the evolution in the debates in New Granada between the promoters of the enlightened reforms and the Dominicans concerning the course of philosophy after the 1770s. It shows how at the beginning of the nineteenth century, the idea of the inclusion of mathematics and physics in the course of philosophy had already been adopted and was working. I shall give details of the debate in the next chapter.
[345] *Cf.* Mutis (1983a), pp. 76-77.

> animal, deducidos de su organismo y de la más prudente y cautelosa aplicación de las matemáticas puras y mixtas, procurando no incurrir en los peligrosos paralogismos que resultarían del abuso de esas ciencias mal aplicadas (Mutis, 1983a: 81).

The image Mutis used for describing the activity of the organs of the human body demonstrates his acceptance of a mechanical approach for accounting for physiological phenomena and his belief that physiology be reduced to understanding the *mechanism* of the organs of the human body. In so doing, students would be able to understand the mechanical functioning of the organs from the application of mathematics to the observations they had performed during the anatomy course in the first year. In this sense, in the explanation of the physiological study to be taught in the second year, Mutis reveals his own conviction of the power of mathematical analysis for accounting for multiple phenomena; thus articulating the explicative capacity that mathematics demonstrate in the field of physics with the physiological phenomena of medicine. Again, such an articulation depended on the assumption that the human body was a machine that could be described in mathematical terms. I shall explain in the next sections that such an approach made the emergence and development of Newtonian medicine possible in the early-eighteenth century. Thus, whilst in the case of natural phenomena it is used for instance for accounting for the motion of bodies in conic sections, in the case of physiology it should be applied to explain the mechanism underlying the functioning of the organs. Immediately following, Mutis specifies the source of such a conception:

> Por esa razón, después de la renovación y restablecimiento de las letras, se creyó con más o menos restricción, según la propensión de los profesores a sus diferentes ramas, que para entender los fenómenos de la economía animal era

> indispensable recurrir a los auxilios que podían prestarles las ciencias naturales. Al ejemplo del inmortal Boerhaave, que supo hermanar con profundo discernimiento en su admirable Fisiología sobre el sólido cimiento de la Anatomía, los auxilios necesario de las otras ciencias, se ha continuado dirigiendo el estudio de la fisiología por ese mismo método, adoptado generalmente por todas las escuelas de medicina fuera y dentro de nuestra España (Mutis, 1983a: 81-82).

The Boerhaavian origins of Mutis' plan are reinforced in the final plan written by Andres Rosillo y Meruelo – Director of the *Colegio del Rosario* after Caicedo – and Miguel de Isla in 1804, in which the definitive presence of Boerhaave is confirmed for teaching the basic tenets of physiology and therapeutics.[346] Boerhaave's influence on Mutis' plan is also evident in the fact that Mutis not only recommended to study his works directly, but to do so with the commentaries of multiple interpreters, including, inter alia, Albrecht von Haller's *Elementa physiologiae corporis humani* (1775), Georg Erhard Hamberger's *Physiologia Medica* (1751), and Philipp Ambrosius Marherr's *Praelectiones in Hermanni Boerhaave Institutiones Medicas* (1785).[347] Boerhaave's influence on Mutis' plan is completed in his description of the courses of the third year, in which he claims that students should learn by heart Boerhaave's *Aphorismi* on therapeutics[348] which implies that Boerhaave was not merely recommended as a source for the physiological analysis. In Mutis' eyes, by considering the mechanical and chemical foundations of physiological functions, Boerhaave had developed effective therapeutics that must be strictly followed by physicians during their training.

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[346] A transcription of Caicedo and Isla's plan, as well as a brief analysis of its content and the elements influenced by Mutis can be found in Mendoza (1909), pp. 62-95.
[347] *Cf.* Mutis (1983a), p. 83.
[348] *Cf.* Mutis (1983a), p. 83.

As we can see, the opposition between empirical medicine and theoretical medicine, as Mutis suggests, derives from the fact that theoretical knowledge in medicine is supported by the mathematical, physical, and chemical study of nature. He baseded this suggestion on Boerhaave's characterization of medicine in his *Institutiones Medicae*. Thus, in order to understand Mutis' characterization of the medical knowledge in his *General plan*, we should take a look at Boerhaave's work to search for references to the mechanical and mathematical foundations of the medical practice.

In general, Boerhaave adopted an eclectic approach to physiology, combining elements of mechanics and chemistry as he suggested that bodies consist of universal-mechanical properties and several particular-chemical ones. By claiming this, he adopted some features of so-called Newtonian medicine, which I would like to clarify in this chapter, in an attempt to determine the Newtonian character of Boerhaave's medicine underlying Mutis' *General plan*. In this way, I intend to lay the foundations for explaining that Mutis' introduction of Newton's ideas in New Granada was not limited to the lectures on mathematics and physics he gave at the *Colegio del Rosario* in the 1760s and 1770s. Conversely, I shall argue that Mutis' introduction of Newton's ideas was a greater enterprise, encompassing Newton's mathematics and physics not only as strict theoretical elements related to natural philosophy but also because they were related to the medical and chemical fields. In other words, I shall argue that by using Boerhaave's works as textbooks for his *General plan*, Mutis embraced a Newtonian conception of medicine in which mathematics, physics, and chemistry play a fundamental role in the explanation of multiple physiological phenomena. Let first us consider some historical details that will help us to understand the emergence of so-called Newtonian medicine in the early-eighteenth century.

The mechanical approach to physiology in the seventeenth century

In general, it is a well-known fact that the mechanical approach to physiology emerged in the seventeenth century as a response to both the Galenic and the iatrochemical traditions, in which the dynamical relationship between humours and a vitalistic conception of nature, respectively, determined the explanations of physiological phenomena.[349] For scholastic Aristotelians, the only exception to the rule "omne quod movetur ab alio movetur" are precisely living things which possess the capacity for self-motion. Thus, for instance, plants grow or animals can determine their own movements according to their need or, in the case of human beings, according to their will. Consequently, anything capable of moving by itself was considered to be alive.[350] Similarly, the iatrochemical tradition advanced a principle of motion in the sense of spirits acting as the causes of multiple physiological phenomena. In this way, both the Galenic and the iatrochemical traditions established a clear ontological difference between living and inert things, which allowed them to determine the principles upon which it was possible to develop an explanation of physiological phenomena. In general, they resorted to the postulation of occult qualities, spirits, and humours, in order to explain physiological functions, diseases and – more importantly – their treatments. In other words, in the seventeenth century diverse physiological traditions converged which focused on the determining of the properties of living things, thus making it possible to postulate the most suitable treatments for the multiple diseases affecting them.[351]

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349 The application of mechanics to physiological phenomena has been considered as one of the main features of the scientific revolution. Historians such as Henry, Brown, Schofield, inter alia, have pointed out that Harvey's discovery of the circulation of blood in *Exercitatio anatomica de motu cordis et sanguinis in animalibus* (1628) as well as the development of more precise anatomical studies after Vesalius' *De humanis corporis fabrica* (1543) made the emergence of mechanical studies of the animal economy possible. For references on the history of medicine in the early modern science, see Schofield (1969), 3-88. Rothschuh (1973), 76-80; Jackson (1983), Henry (2013). A good compendium on the history of medicine in the seventeenth century is in French & Wear (Eds.) (2008).

350 *Cf.* Effler (1962), Wheisheipl (1965).

351 This reconstruction of the application of alchemy and mechanics in medicine is founded on Brown (1974), Henry (1987), Clericuzio (2012), Černý (2013),

In this context, a mechanical physiology which introduced non-vitalistic accounts of physiological phenomena emerged. Mostly developed by Descartes, so-called iatromechanics was an attempt to explain such phenomena by considering bodies in general as machines which can produce motion, though they are not necessarily alive. In the Cartesian mechanical universe, physiological phenomena were limited to the laws of motion which rule the motion of inert bodies according to the principles determining the motion of particles in contact.[352] As a result, iatromechanics in the seventeenth century emphasized the need to establish the universality of the principles of the motion of bodies and, in so doing, it brought with it the possibility of postulating the most suitable therapies for multiple diseases, as they were considered under the precepts of the universal laws of motion.

For instance, Anita Guerrini, in her doctoral dissertation, claims that the application of mechanical philosophy to physiology is the result of postulating analogies between macrocosmic and microcosmic phenomena: "The appeal of a mechanical macrocosm was nonetheless so strong that, especially in the second half of the seventeenth century, men endeavored to mechanize the microcosm as well, in particular the kindred phenomena of chemistry and physiology" (1983: 1). Consequently, she concludes, in a machine-like world, such as the Cartesian one, the same laws regulating the behavior of macrocosmic phenomena should be applied to the invisible realm by analogy. If the world were a machine these phenomena would necessarily be kindred spirits; and as these laws ruled visible events, they would be able to rule the motion of invisible things as well: "Analogy was the sole methodological dictate upon which all seventeenth-century men of science agreed, although its origin was hardly mechanistic"

[352] *Cf.* Brown (1964), pp. 1-64. Descartes' application of mechanics to the study of physiological phenomena was developed mostly in his account of the process of nutrition in his *Description of the human body and all of its functions* (1647), while some insights can also be found in his *The world and Treatise on man* (1677). *Cf.* Descartes (1984), pp. 99-108.

(Guerrini, 1983: 1). Karl E. Rothschuh presents a similar characterization when he argues that "Under the influence of the success achieved in science and technology with physical methods, medicine likewise attempted to attain a theoretical basis founded on physics and especially mechanics during the sixteenth and seventeenth centuries" (1973: 76). He illustrates his position by mentioning the role of Galileo's mathematical works on physics for the development of iatromechanical physiology: "Because of his success in other fields, Galileo indirectly contributed much to the promotion and application of physical methods of measurement to organic functions, especially in Italy" (1973: 76). Among the studies about the development of iatromechanics in the seventeenth century, particularly influential is Theodore M. Brown's doctoral dissertation in which he also describes iatromechanics in a very similar fashion: "Medical theory in these years [between 1670 and 1710] was thoroughly 'iatromechanistic', which means that it was concerned with explaining pathology and therapy in terms borrowed from the contemporary mechanical philosophy" (1969: iv-v). A position which he confirms in his study on the reception of iatromechanics at the London College of Physicians:

> Iatromechanism (sometimes also called "Iatrophysics" or "Iatromathematics") is generally considered a byproduct of the Scientific Revolution, representing the attempt, foolish at worst and premature at best, to achieve in the medical domain what had already been achieved in the physical by the "mechanization of the world picture" (Brown, 1970: 12).

As the newly developed mechanical philosophy acquired adepts in the seventeenth century, the mechanical approach to physiology soon gained importance in the intellectual and cultural panorama of Europe in the seventeenth century.[353] A permanent debate was established between

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353 As Henry points out in his study on the reception of Cartesianism in England, such a reception and acceptance was troublesome and faced several difficulties as it had to deal with the growing acceptance of vitalistic and

iatromechanics and vitalism which informed the development of physiology and medicine during the seventeenth and eighteenth centuries. One of the most important centers for the development of mechanical physiology in this context was Italy, where the works of Borelli, Bellini, and Steno introduced the newly developed Cartesian iatromechanics to the Galilean mathematical approach to nature, in the aim of reducing physiological phenomena to the rules underlying the motion of bodies.[354] Thus, in his *De motu animalium* (1680) for example Borelli reveals how he was interested in the mechanical, quantifiable properties of bodies, as long as they could be subsumed under mathematical demonstrations of the kind that Galileo had developed in his mechanics. In this sense, in Borelli's work it is possible to see an approach to physiology in strict mathematical terms as though the demonstrations were not dealing with physical entities – muscles, fluids, and bones – but rather, with mathematical ones. Therefore, Borelli studied the muscular contractions as though muscles were composed of "rhomboid-shaped vesicles, arranged in long chains" (Rothschuh, 1973: 80).

As Brown and Guerrini have commented, the so-called iatromathematics developed in Italy acquired some adepts in Great Britain – particularly in London and Edinburgh – where it acted as the background for the emergence of Newtonian medicine during the last decade of the seventeenth century.[355] In this context, rival versions of vitalism found in some assumptions of

experimental traditions. Interestingly, in his interpretation, Henry suggests that the appropriation of these different traditions made the emergence of the scientific revolution possible. *Cf.* Henry (2013).

[354] As Rothschuh has commented, it is likely that the Cartesian sources for Borelli's *De motu animalium*, presumably, came through Malpighi as well as Niels Stensen, whose anatomical works in the 1660s considered several mechanical consequences of the Cartesian mechanical approach. *Cf.* Rothschuh (1973), pp. 73-97. In general, Borelli's aim in *De motu* is the mathematical study of the contraction of muscles and parts of the body, thus reducing the action of the body to a set of geometrical figures from which it is possible to determine the necessary forces in the production of effective muscular motion. See, for instance, Borelli's analysis of muscular contraction in jumping in Borelli (1968), pp. 195-203.

[355] Probably, one of the most important cases for the study of the influence of Borelli's mathematical approach to physiology on British medicine is Walter Charleton's *Cutlerian* lectures at the London College of Physicians in 1683. Particularly interesting is his *Praelectio I*, entitled *Of the circular motion of the bloud, and the admirable effects thereof*, in which he argues against the idea of multiple and invisible ferments in order to explain the circulation of blood, thus supporting a strict mathematical approach. *Cf.* Charleton (1683), pp. 4-6. An interesting study of Charleton's *Three anatomic lectures* is in Booth (2006).

iatromathematics a way to articulate mathematics with diverse traditions – some dependent on chemical ideas, such as fermentation, active niter, and so on, and others simply dependent on self-moving Gassendian atoms –, in order to cope with the critiques coming from strict iatromechanics. Consequenytly, although the Cartesian mechanical philosophy never fully achieved a firm foothold in Britain,[356] we can find some references to iatromathematics as it was associated with various traditions of vitalism. One of the most interesting was undoubtedly the one accomplished by the Newtonian physicians led by Archibald Pitcairne, who expressed the need to explain every physiological phenomenon in mathematical terms in line with the idea of attractive forces acting as their causes.

Newtonian medicine: mathematical and experimental approaches to physiology

One of the most interesting aspects of Newtonianism is the implications it had for the development of different disciplines during the eighteenth century. To some extent, multiple disciplines tended to follow Newton's methodological and theoretical tenets and concepts in their particular fields, either because they could be subsumed under the mathematical principles that Newton proposed in *Principia* or the experimental program delineated in *Opticks*.[357] In the former case, the use of Newton's theories was based on the idea that the mathematical principles he proposed in the *Principia* were universal, thus accounting for every physical phenomenon. For Newton, the laws of motion are *axiomata* and therefore it is possible to mathematically describe motions of mathematical entities which, by comparing them with the world through experiments

[356] *Cf.* Henry (2013).

[357] As I explained in the Introduction, the category of Newtonianism has recently been subjected to intensive revisionism among Newton scholars. However, the appropriation of Newton's methodological and theoretical principles in several disciplines during the eighteenth century continues to be one of the central topics of these reconsidered conceptions of Newtonianism. *Cf.* Guerrini (1983), Jacob & Dobbs (1995), Ducheyne & Van Besouw (2017).

and observations, can eventually be considered as representative of the world itself. Thus, the universality of the laws emerges as a consequence of the possibility of reducing every phenomenon to mathematical terms.[358] On the other hand, as regards the influence of methodological matters, the influence of Newton depended not so much on the universality of the laws or their mathematical explicative power, but rather, on the success of his methodology in explaining physical and astronomical phenomena and the possibility of having the same success by applying it in other sciences. Nonetheless, this twofold influence of Newton's *Principia* was not necessarily exclusive: in the 1690s and the early-eighteenth century, it was possible to find disciplines which attempted to follow Newton's example by using both his mathematical principles and his method. The development of Newtonian physiology and medicine during the 1690s and the early-eighteenth century is a good example.

As Anita Guerrini explained, a Newtonian approach to medicine and physiology emerged in the early 1690s through the works of the Scottish physician Archibald Pitcairne presented as lectures in the University of Leiden and brief texts about the treatment of continual fevers.[359] He knew Newton's *Principia* in 1687 thanks to his friend, David Gregory, who he read it together with while living in his house after the death of Pitcairne's wife. However, Pitcairne had a more direct contact with Newton's ideas in 1692. He was elected professor of practical medicine at the University of Leiden, and on his trip from Edinburgh he stopped off in

[358] *Cf.* Guicciardini (2009), pp. 3-17, and especially 235-290.
[359] Pitcairne's works are published in Pitcairne (1727). Some interesting studies can be found in Cunningham (1981); Guerrini (1983), pp. 56-145; Guerrini (1986); Guerrini (1987); Friesen (2003).

Cambridge, where he discussed with Newton himself, the latter's manuscript *De natura acidorum* (1692),[360] in which he presents several ideas regarding the role of forces in matter theory.[361]

In his lectures at Leiden, Pitcairne rejected the Cartesian mechanical physiology by considering a mathematical study of physiology inspired by Newton's *Principia*. Despite not using Newton's name directly in his lectures, his influence was evident. One example is his inaugural lecture from 1692 in Leiden, when he discussed the advantages of a mathematical approach to physiology, neglecting the position of what he called "a sect of philosophers".

The lecture entitled *An oration proving the profession of physic free from the tyranny of any sect of philosophers* (1692) begins with the establishment of a historical relationship between medicine and astronomy that justifies the possibility of adopting the method of the latter in the former. According to Pitcairne:

> But since there are goods grounds to believe, that the antient physicians attributed diseases to the anger of the gods, and that astronomy was the first science which was cultivated by the elder philosophers, and that the names of the gods were at the same time affixed to the stars, it is probable that those antient physicians began their enquiries with those distempers which generally attend upon the changes of seasons (1727: 7)

For Pitcairne, ancient physicians explained diseases under the precepts of an astrological approach, by postulating that they were caused by the anger of the gods, thus giving their names

[360] The original manuscript of the *De natura acidorum* is in Cambridge University Library, MS Add. 9597/2/18/81. There are two translations in English: Harris (1723), pp. B1-B2 and Newton (1961), pp. 205-214. Harris' version is Newton's only manuscript on chemistry published during his lifetime.
[361] *Cf.* Guerrini (1987), p. 70. A description of the meeting between Newton and Pitcairne is in Turnbull (1961, III), pp. 212-213.

to the stars.[362] Therefore, he argued that the origins of medicine should be traced back to ancient astrology: "From whence it follows, that according to the notion of both the antient physicians and philosophers, the method of reasoning in physic ought to depend upon the same principles as are of use in astronomy" (Pitcairne, 1727: 7). Since medicine in ancient times was considered an extension of astrology in the sense that it studied the influence of the stars upon people's health condition, it was necessary to postulate the same method for both of them. This method was founded upon two premises: first, that it "is not allowable to advance any thing into a principle either in the theory or practice of physic, which the mathematicians, and persons who are the least entangled with prejudice, call in question" (Pitcairne, 1727: 8). And, second, "that such enquiries after physical causes as are generally proposed by philosophers, are entirely useless and unnecessary to physicians" (Pitcairne, 1727: 8). Thus, Pitcairne argued that the certainty of medical practices, which encompass not only a certain theoretical knowledge of physiological phenomena but also effective therapeutics, should be founded on the principles that the mathematicians have established for demonstrating their propositions.[363]

The practical implication of Pitcairne's characterization of the medical practices is remarkable: as long as the foundation on mathematical principles produces certain knowledge about the functioning of the body, it is possible for physician to create effective treatments for any disease. In Pitcairne's words: "But however, tho' I know, nor am at all surprised, that the physical causes of these symptoms, and their intimate natures, should escape the diligent enquiry of physicians, yet I think I have explained either their mathematical or medical causes, that is such as are most useful for a physician to know" (1727: 21-22). This characterization makes more sense when considering that Pitcairne was appointed teacher of practical medicine.

[362] *Cf.* Pitcairne (1727), pp. 7-12.
[363] *Cf.* Pitcairne (1727), pp. 9-22.

Likewise, the Newtonian character of Pitcairne's explanation of the common method of ancient astronomy and modern medicine is revealed by considering his commentaries about the futility of any kind of causal explanations in medical practices. For him, the rejection of an enquiry of the cause of physiological phenomena in medicine is related to a practical ideal of medicine, where the final purpose of the discipline is healing the body and not explaining its behaviour by causes. In Newton's case, the practicality of the method he developed in his *Principia* relies on the effectiveness of the postulated principles in order to explain natural phenomena. Thus, although there is not causal explanation of gravity, as he claims in the *General scholium* to the *Principia*, the reality of the force is demonstrated because it allows for explaining[364] the phenomena of motion studied.[365]

In this context, Pitcairne introduced a more detailed characterization of the mathematical method as it is applied to medicine, which reveals some other Newtonian aspects of his approach to physiology in his lectures at Leiden. According to him,

> It is evident to any one who has been a little more than ordinary conversant in the mathematics, or the practice of physic, that our knowledge of things is confined to the relations they bear to one another, the laws and their properties of powers, which enable them to produce changes in some things, and to become altered by other things: I speak of corporeal things. Now these powers, and their laws, are discovered by their mutual action and reaction upon each other (1727: 9).

[364] For Newton's use of the verb "explain", see Spencer (2004).
[365] Newton's rejection of the causal explanation of gravity and its methodological implications have been studied in detail in Guicciardini (2009), pp. 293-327.

The "powers" producing physiological phenomena and their mathematical properties which can be postulated as laws, are evident from the visible changes that can be perceived from their mutual interactions. Certainly, as Pitcairne claims, such powers depend on various causes, however as there is no mathematical certainty for determining their causes or how they act on the body to produce the physiological phenomena experimented – and this is sufficient for the physician – the physician should omit them. In other words, as Pitcairne was teaching medical practice, the main purpose of the method he was defending was to identify the visible effects that certain interactions among powers can produce in the body. In this case, it would be possible to establish the best treatment for any disease, avoiding the need to refer to any kind of causal explanation. It presupposes a rejection of both the Galenic tradition, as its treatments for diseases are founded upon the causal interactions between the body's humours.[366] More importantly, such an approach implied a rejection of the Cartesian approach to physiology and its therapeutic implications. As Descartes comments in Part VI of his *Discours de la méthode* (1637), one of the consequences of his method is an improvement of the medicine in his time – the Galenic one – which he claims does not "contain much of any significant use". By contrast, Descartes argues that by applying the principles of physics discovered via use of his method in medical problems, it is possible to maintain health as said principles provide adequate knowledge of the causes of diseases. In Descartes' words "we might free ourselves from innumerable diseases, both of the body and of the mind, and perhaps even from the infirmity of old age, if

[366] It is a well-known fact that the development of modern medicine took place during a period in which Galenic medicine began to be discredited outside the university context as iatromechanical and alchemical approaches were consolidated. For the emergence of modern medicine in the context of the decline of Galenic medicine, see Henry (1987); Henry (2002), pp. 30-53; Moran (2005), pp. 67-98, Cook (2011)

we had sufficient knowledge of their causes and of all the remedies that nature has provided" (AT VI, 62).[367]

As regards Pitcairne's characterization of his practical approach to medicine it is not crystal clear what he means by "powers". Anita Guerrini has argued that Pitcairne considered powers as forces in the way Newton explained them in his *De natura acidorum*. For Guerrini, "It is possible that these "Powers" (*vires*) were forces similar to what he could have inferred from Newton's essay 'De natura acidorum'; he had met with Newton only two months earlier" (1987: 73). Thus, she claims that Pitcairne inherited from Newton his particular conception of attractive forces acting to produce phenomena on both a macroscopic and a microscopic scale; which he applied in the field of medicine. In *De natura acidorum*, Newton defends the idea that acid particles have attractive powers which allow them to produce specific phenomena on a microscopic scale.[368] As a consequence, by considering powers in the same sense that Newton does in the *De natura acidorum*, we can see how Pitcairne was using Newton's ideas regarding a theory of matter in the explanation of physiological phenomena. Moreover, he did so within the context of his appropriation of Newton's methodological precepts. According to Guerrini, Pitcairne's characterization of the main business of medicine in his lecture resembles Newton's methodology in his *Principia*:

> Such knowledge would in any case be "of no advantage" to a physician, whose duty was "to weigh and consider the Powers of medicines and diseases as far as they are discoverable by their operations, and to reduce them to laws." This was

[367] Some insights on Descartes' pronouncements on medicine in the *Discours* in the light of the practical character of early modern science can be found in Shapin (1996), pp. 140-142; Shapin (2000). One of the most detailed studies of Descartes' medicine is Lindeboom (1978)
[368] *Cf.* Newton, MS Add. 9597/2/18/81, Cambridge University Library.

> strictly analogous to Newton's method in the *Principia*, especially in Book II,[369] in which he had studied the effects of gravity without reference to its cause, and Pitcairne said as much: "Physicians ought to propose the method of astronomers as a pattern for their imitation" (Guerrini, 1987: 74).

Accordingly, by considering Pitcairne's lectures in the light of Newton's methodological pronouncements in his *Principia*, it is possible to characterize in a really precise manner the Newtonian approach to practical medicine that Pitcairne introduced in his lectures at Leiden. As we can see, following Guerrini's interpretation, Pitcairne presented the idea that the duty of a physician was to weigh and consider the mutual interactions between a disease and a medicament in the human body through the physical effects that they cause each other. Therefore, his conception of practical medicine was founded on Newton's principles in the sense that he referred to powers – which are similar to Newton's forces – but also to the use of Newton's mathematical approach to nature. Such a Newtonian approach to medicine is clearer by comparing Pitcairne's characterization of the main business of physicians with Newton's conception of the main business of natural philosophy as it is presented in the Preface to the first edition of his *Principia*. According to Pitcairne,

> The business of a physician is to weigh and consider the powers of medicines and diseases as far as they are discoverable by their operations, and to reduce them to laws, and not lay out their time and pains in searching after physical causes, which can never be deduced till after the laws of their powers are found out; and when they are found out, will be of no service to a physician (Pitcairne, 1727: 10).

[369] It is likely that she meant Book I.

Let us compare this with Newton's pronouncements in his Preface:

> But since we are concerned with natural philosophy rather than manual arts, and are writing about natural rather than manual powers, we concentrate on aspects of gravity, levity, elastic forces, resistance of fluids, and forces of this sort, whether attractive, or impulsive. And therefore our present work sets forth mathematical principles of natural philosophy. For the basic problem of philosophy seems to be to discover the forces of nature from the phenomena of motions and then to demonstrate the other phenomena from these forces (1999: 382).

As we can see, Newton claimed that the purpose of natural philosophy was to discover, from the phenomena of motion, the physical effects caused by the action of a force; thus establishing the mathematical principles through which such a force operates in the world. Similarly, in Pitcairne's characterization of the business of physicians, their work was to weigh and consider the "operative" action of a certain power present in the medicaments or diseases, and reduce it to a mathematical law. Mutual interactions between medicaments and diseases could be accounted for because of the physical effects they cause in the human body. In other words, in his inaugural lecture, Pitcairne proposed medicine based on a Newtonian conception of physics, using not only several Newtonian theoretical concepts, like forces, or powers, but also a Newtonian methodology of investigation, founded on the establishing of the purpose of the practical medical enterprise. In his *Oratio*, he explained that it is necessary to develop a mathematical approach to medicine, in order to acquire the greatest certainty possible. In so doing, he argued that the physician should reject the need to causally explain the properties of diseases and medicines used to heal the human body. By contrast, a mathematical approach allowed the physician to establish relationships between the measurable properties of bodies which could be reduced to mathematical laws. In this context, he concludes: "Physicians ought to propose the method of astronomers as a pattern for their imitation" (1727: 11).

However, among Pitcairne's lectures at Leiden, there are some which more clearly illustrate the Newtonian mathematical character of his medicine and physiology. Let us consider, for instance, the lectures about the circulation of blood in the glands, and the one about secretion, which were the main problems Newtonian medicine had to face during its development in the early-eighteenth century.[370] In his *Dissertation upon the circulation of blood through the minutest vessels of the body* (1693), Pitcairne advances a strong criticism of both the Helmontian iatrochemical and the strict Cartesian mechanical explanations of the circulation of blood and the secretion of substances. The rejection of a Helmontian iatrochemical explanation of the circulation of blood is based on the idea that it depends on the stagnation of the blood in the minutest vessels of the glands which would allow enough time to carry out some alchemical operations, produced by the action of a ferment, in order to cause a qualitative change in the stagnated blood. For Pitcairne, "But they who have embraced this hypothesis, though in words they acknowledge the circulation of the blood, yet in effect they have destroyed it" (1727: 41). Thus, he claimed that the stagnation of the blood denies the continual circulation of blood in the vessels.[371] In this sense, Pitcairne's rejection of the iatrochemical explanation of secretion relies upon the empirical evidence regarding the circulation of blood. As a result, the action of a ferment would not only be unnecessary, it would also be impossible, as there would not be

[370] Since its discovery by Harvey in the seventeenth century, the problem of accounting for the circulation of blood was one of the main concerns of anatomists and physiologists. For the particular conception of circulation by the so-called Newtonian physicians, see Guerrini (1985). Undoubtedly, Newton's pupil who was most dedicated to the matter of circulation was James Keill. I shall deal with his pronouncements on circulation further on.
[371] Certainly, the question of whether van Helmont knew about Harvey's discovery of the circulation of blood or not is an unsolved issue in the historiography of medicine. Nevertheless, his commentaries on the coexistence of pure and impure blood in the body's vessels suggest that he had some kind of familiarity with the matter of circulation. *Cf.* Pagel (1951), Donaldson (2017).

enough time for a ferment to produce a qualitative change in the blood in order to produce the fluid to be secreted.

As Pitcairne's rejection of the explanation of secretion associated with a strict mechanical system, such as the Cartesian one, is founded on mathematical reasoning, it is more revealing of the scope of his Newtonian approach to the problem of circulation. According to Pitcairne, the mechanical explanation is based on the idea that blood is composed of different fluids consisting of qualitatively similar particles, differentiated only by their particular shapes. Thus,

> they [the Cartesian mechanists] have supposed that there are within the glands bodies of a sieve-like form, to which the arteries convey the blood, which upon its arrival there adapting it self to the holes of that figure, which is peculiar to the mass of the fluid, it conveys or forces some part of the blood into those holes, in order to be carried off to the secreting vessels, while the other fluids return again thro' the veins. So that the pores of the glands must be of different figures in different parts of the body, according to the diversity of the figure of the parts of every fluid contained in the blood (Pitcairne, 1727: 43).

Pitcairne describes the Cartesian mechanical explanation of circulation in the minutest vessels as the result of the shapes of the secretory channels coinciding with some of the particles composing the fluids in the blood. The blood flowing in the vessels consists of geometrically-shaped particles which coincide with the geometrical forms of the secretory vessels. Thus, for instance, a fluid consisting of particles with a triangular shape are secreted through the triangular-shaped vessels. Other fluids, with other shapes, are secreted through other vessels, whilst the main body of the blood keeps flowing towards the veins. Pitcairne states that some authors have defended fermentation by combining it with a mechanical approach, where rather than producing a qualitative transformation in the blood fluids, the fermentation of the blood in the glands gives rise to a transformation of the figures of the particles they are made up of.[372]

In order to reject the mechanical explanation of secretion, Pitcairne used some geometrical and arithmetical demonstrative reasoning. First, he claims that the argument of mechanists concerning secretion depends on the size of the particles and not so much of their shapes. For him, the sieving function of the vessels only works when particles are bigger than their entrance orifices.[373] Therefore, the variation in the shapes does not matter when a particle is smaller than the orifice through which it will be secreted. Second, considering that the particles can be introduced into the secretory vessels in infinite degrees of inclination, Pitcairne proceeds to explain that cases of entering of particles into the vessels will always happen, irrespective of whether their shapes correspond to the shape of the vessel or not. In Pitcairne's words:

> Let A signify the conditions of admission; E, the conditions of exclusion; q the turns of admission; p the turns of exclusion; then the quantity $\frac{Aq+Ep}{q+p}$, as is evident from the demonstration of the great *Huygens*. And since, as is proved, the quantity p is finite, but q is infinite, therefore p is lost, and the product will be $\frac{Aq}{q}$, and by consequence the case of admission will always happen (1727: 46-47).

Therefore, for Pitcairne, the fact that many kinds of bodies can pass through any secretory vessel proves the falsity of the Cartesian mechanical theory of secretions and circulation of the blood in the minutest vessels of the body. By contrast, he proposes a theory of secretion characterized by the use of forces as the causes of secretion. In his theory, he uses the concept of force in two

[372] *Cf.* Pitcairne (1727), pp. 42-44.
[373] *Cf.* Pitcairne (1727), p. 46.

different ways. On one hand, there is an attractive force that produces the union of certain substances in the blood, separating them from others. As Guerrini has argued, I think correctly, Pitcairne inherited this conception of force from his direct contact with Newton and his reading of the *De natura acidorum*, where Newton derived diverse phenomena from the attractive powers of acids, such as the repulsion of the particles of other substances.[374] On the other, Pitcairne uses the term "force" in a mechanical way, describing the pressure exerted by the heart and the vessels upon the blood while it is traversing the body. He does so by considering secretion as the result of two forces interacting in the motion of the blood. For Pitcairne,

> If a fluid is forced down into the cavity of a tube with a great force, that is, a force far exceeding the gravity of the fluid, it is evident from reason, and confirmed by frequent experiment, that the perpendicular force toward the sides of the tube is always joined to the motion of the tube towards its length, which force endeavours on all sides, rom the very axis of motion, to propel outwards, and that with an equal force (1727: 54).

As a result, Pitcairne argued that the secretion of a fluid in the minutest vessels is produced by the combination of three different forces: the attractive force between the particles composing blood, which separate the different kinds of fluids in the vessels; the force impressed on the blood by the pressure of the heart, which is stronger than gravity; and the perpendicular force exerted by the elastic constitution of the vessels through which the blood is flowing. Therefore, the fluid to be secreted flows more slowly attached to the walls of the vessels, from where it is diverted toward the secretory vessels of the glands.

[374] *Cf.* Newton (1961), pp. 205-214.

As Guerrini has argued, Pitcairne's academic lectures and dissertations at Leiden were deeply influential for an entire generation of physicians: Richard Mead, Geoge Cheyne, George Hepburn, and William Cockburn, for instance, were educated by him.[375] She also claims that Herman Boerhaave was educated by Pitcairne, who introduced the former to Newton's theories as they are applied to medicine; however, evidence proves that Boerhaave did not enroll at the University of Leiden while Pitcairne was there.[376] The origins of Boerhaave's Newtonianism will be discussed in the next section.

Despite the important role these lectures played in the emergence of a generation of Newtonian physicians, the fever dispute in Edinburgh during the 1690s represented the main scenario where they discussed and presented their ideas. Initiated as a debate concerning the best therapies against continual fevers, it encompassed not only therapeutic issues but also methodological and disciplinary ones, which gave rise to the use of a Newtonian approach in medicine.[377] According to Andrew Cunningham, the fever dispute appeared in the context of the establishing of some policies in Scotland governing the practicing of medicine. The Royal College of Physicians was created in Edinburgh in 1681, for the purpose of establishing the policies regulating medical practices in Scotland. One of the first policies was to establish the need for the physicians to have an M.D. in order to obtain a public license to the practice medicine. It was aimed at abolishing empirical medical practice which had characterized Scottish

[375] *Cf.* Guerrini (1983), pp. 97-138.
[376] Boerhaave's interest in medicine can be traced to the late 1680s, but they were only "formalized" in 1690, thanks to the advices of Johannes Van der Berg. As John Burton describes it, Boerhaave began to study medicine at the University of Harderwijk in July of 1693, the same year that Pitcairne left Leiden. This makes it improbable that Boerhaave would have attended his lectures. *Cf.* Burton (1743), p. 19; Knoeff (2002), pp. 22-51; Grier-Casteel (2007), pp. 110-115; Powers (2012), pp. 13-36.
[377] The best account of the fever dispute is in Cunningham (1981).

medicine during the seventeenth century.[378] Thus, some physicians, like Andrew Brown, whose education was empirical and whose therapies and medical practices were based on their own experiences treating diseases, were forced to obtain an official degree in order to continue exercising their practices. The case of Brown, as Cunningham suggests, is extremely important because he based his therapies for treating diseases, and particularly fevers, on Sydenham's methods. It must be recalled that Sydenham derived his therapies from a wide range of trial-and-error experiments, performed on his clients – most of whom poor people, which allowed him to perform a lot of experiments.[379] For Brown, therefore, it seemed reasonable to follow Sydenham's recommendations for the treatment of continual fevers as they were presented in his *Schedula monitoria de novae febris ingressu* (1686). Thus, for instance, when Lord Creichton – probably, Charles, Lord Crichton, son of the second Earl of Dumfries –[380] fell sick with a fever, he followed the therapy recommended by Sydenham. However, Lord Creichton died under the cure and Brown and his method received a great deal of criticism.

The therapy proposed by Sydenham, and applied by Brown on Lord Creichton, as Cunningham explains, "In essential consisted of: (1) bleeding; (2) purging; (3) paregoric (a 'quietener'). The purging and quieting were repeated in turns, until the fever had quite abated" (1981: 76). This method emphasized the role of purging for treating continual fevers and, most importantly, it did not consider sweating and perspiration as effective methods for eliminating the morbific matter causing the fever. Likewise, Cunningham argues that Brown's method was also openly opposed to the method defended by the Royal College of Physicians defended and

[378] For the history of seventeenth-century Scottish medicine and surgery, see Comrie (1927), pp 93-123; Guthrie (1959); Cunningham (1981); Dingwall (1993); Dingwall (1995). A history of the Royal College of Physicians of Edinburgh is in Craig (1976).
[379] *Cf.* Cunningham (1981).
[380] *Cf.* Cunningham (1981), p. 74.

which was used by most of the physicians of Edinburgh, based on bleeding and perspiration. As Cunnigham describes it:

> The first operation was to bleed the patient (…) Theen, as the antecedent cause was usually judged to be some ingested matter likely to continue to be moved into the blood and sustain its febrile condition, the patient was *vomited* to empty the stomach (…) Next it ws necessary to assist the process of concoction by giving *inciders* –medicines believed to have the sharp particles which would cut up and render the offending fluid less viscous (…) Finally, the physician turned to nature's own way of eliminating the peccant matter. Nature uses sweats, so a *diaphoretic* should be administered, which was called "the universal cure of feveres, Nature pointing with its finger to their use (1981), p. 76.

Unlike the method suggested by the Royal College of Physician which attempted to *facilitate* the "nature's own way of eliminating the peccant matter", Brown's therapeutics did not even recommend a medicine for increasing the patient's sweating. Lord Creichton's death under the cure provided a solid base for the criticism against Brown and his therapy. He defended himself by publishing his *A vindicatory schedule concerning the cure of fevers* in 1691,[381] in which he argued in favour of Sydenham's therapy, as it is a combination of the best results of the various physicians working on fevers in the seventeenth century.[382] This position was reinforced in 1695, when a

[381] The complete title of Brown's book is indicative of Sydenham's influence upons his approach: *A vindicatory schedule concerning the cure of fevers: containing a disquisition theoretical and practical, of the new and most effectual method of curing continual fevers, first invented and delivered by the sagacious Dr. Tho. Sydenham: also shewing by way of preliminary, the indispensable charge lying on physicians to improve themselves and the art*. The book also includes an appendix on Sanctorius' *Medicina static* (1614) which is revealing of Brown's interest in proving that his approach was consistent to the anatomical discoveries of the seventeenth century, despite that he criticized the mathematical approach that underlied it.

[382] *Cf.* Brown (1691), pp. 29-30. In this passage in particular Brown refers to Sydenahm's therapies as the foundation of the works of the different authors he referred to in his *Vindicatory schedule*. However, it is noteworthy that whenever Brown referred to Sydenham he did so in laudatory terms.

brief anonymous manuscript appeared, entitled *Apollo mathematicus or the Art of curing Diseases by the Mathematics, a work both profitable and pleasant* – which Cunningham attributes to Edward Eizat. In the manuscript, the author criticized the strict mathematical approach developed in physics and its application to physiology. By contrast, he praised the value of Aristotelian qualitative explanations, which he related to Galenic medicine and Sydenhamnian empiricism.[383]

Since Brown's publications of *A vindicatory schedule*, some anonymous pamphlets appeared criticizing his position, but, as Brown replied all of them, he forced the Edinburgh physicians to take an "official" and non-anonymous position in the polemics. This occurred in 1694 when James Forrest published *A brief defence of the old and successful method of curing continual fevers*.[384] However, for our current purpose in this dissertation, the most important rebuttal to Brown was made by George Hepburn, a pupil of Pitcairne, who used his professor's *A dissertation concerning the cure of fevers by evacuation* (1692) – which was Pitcairne's lecture on the treatment of fevers in Leiden – to argue in favor of the mathematical approach to physiology that had been introduced in the late-seventeenth century. In Hepburn's *Apollo staticus or the art of curing fevers by the mathematics, invented by Dr Pitcairne and published by him in Latine; now made English by a well-wisher to the mathematics* (1695), as Cunningham argues, "The Newtonian dimension was introduced into the dispute" (1981: 87).

Using Pitcairne's treatment of continual fevers and especially his mathematical approach, Hepburn argued that, as fevers consist of a suppression of evacuations, especially perspiration, their treatment should cause a "crisis" in the body, leading to an evacuation. Interestingly, by

383 A study of the manuscript is in Stigler (1992).

384 It is worth noting that Forrest's *Brief defence* summarized the majority of objections advanced by the members of the Royal College of Physicians of Edinburgh who argued that the main problem of Brown's approach was that he considered fevers to be caused by one single factor, the obstruction of the blood-vessels. For Forrest, such an idea was the result of Brown's empirical approach. *Cf.* Forrest (1694), pp. 145-147.

assuming Pitcairne's mechanical approach to fevers, Hepburn actually established the conditions according to which a mathematical approach to physiology is possible. Moreover, in so doing he criticized the idea of fermentations as the cause of fevers.[385] In regard to Pitcairne's idea of producing a "crisis" in the body to cure fevers, as Cunningham suggests, "The only question then remaining was to decide through which exit evacuation could be most efficiently made" (1981: 92). By using Sanctorius' 59th aphorism, Pitcairne determined the best way for evacuations:

> The excretions made in a given time have commonly this proportion, that if the Excretion by stool be as 4, that by urine is as 16, and that thro' the pores of the skin as 40, or more. It is plain by this, that perspiration is a secretion which is double the sum of the other secretions, (we take here the mean quantity of perspiration), and twelve times as great as the excretion by stool' (Pitcairne, 1727: 200-201).

As we can see, the two conflicting positions in the fever disputes were based on the same ideas concerning the cause and the general treatment of continual fevers. For both of them, fevers were caused by an obstruction in the body's vessels which impeded the correct evacuation of its morbific matter. Accordingly, any treatment against fevers had to postulate a way to make the evacuations possible by increasing them. On one hand, Brown, following Sydenham's recommendations, proposed that the best way to achieve that was through purging; on the other, Pitcairne and his disciples, argued that the best way to treat fevers was by increasing perspiration and sweating. However, underlying this therapeutic debate, there was actually a debate concerning the theoretical and methodological foundations of the medical practice. Indeed,

[385] *Cf.* Pitcairne (1727), pp. 192-195. Pitcairne's position regarding Steno's analysis of secretions and the treatments for fevers is ambiguous. Whilst he praised it for its mathematical content, he also criticized Steno's idea that secretions were the result of the correspondence between the shape of particles to be secreted and the shape of the secretory vessels. An idea which undoubtedly resembles Descartes' siege-mechanism of secretion.

Brown based his arguments on the experimental knowledge acquired by Sydenham in his abundant bedside medical practice, which was possible because of his interest in treating poor people. Conversely, for Pitcairne, therapies should be the consequence of a mathematical study of physiology, which makes it possible to measure the quantity of the substances evacuated through each route. In this sense, the best therapy would result in considering the effectiveness of the different routes to evacuate any morbific substance of the body which, in his opinion, was through perspiration.[386]

The evidence for assuming the Edinburgh fever dispute was a debate of theories and methodologies and not just a debate on therapies is the continual reference by its protagonists to the mathematical and vitalistic approaches to the issue of treating fevers. Whilst the author of the *Apollo mathematicus* (Eizat?) advocated for a strictly qualitative approach in which the Galenic tradition and bedside medicine were praised; in his *Apollo staticus*, Hepburn (Pitcairne) not only rejected such a qualitative approach, but he did so in such an emphatic manner as to encourage the use of a mathematical approach to create medical treatments. A conviction that turned into the official position of the Royal College of Physicians of Edinburgh in the early-eighteenth century and which, in the end, promoted the use of Newton's physics for medicine and physiology.[387]

The fever dispute continued during the first decade of the eighteenth century, and, invariably, Pitcairne's disciples attempted to defend his position by considering the greatest efficacy of sweating over purging in the light of strict mathematical reasoning. One of the most

[386] Pitcairne measures and compares the quantities of morbific matter evacuated through each route, thus concluding that "It is plain by this, that perspiration is a secretion which is double the sum of the other secretions, (we take here the mean quantity of perspiration), and twelve times as great as the excretion by stool". *Cf.* Pitcairne (1727), pp. 200-201.
[387] The original version of the lecture that Pitcairne used for his *Apollo staticus* can be found in Pitcairne (1727), pp. 192-211. The version published in 1695 is Pitcairne (1695).

interesting and revealing arguments in this context was the one developed by George Cheyne in his book *A new theory of continual fevers* (1701). Interestingly, Cheyne advanced Pitcairne's ideas about sweating and perspiration in a more mathematical fashion, developing a strong iatromathematical position founded on the use of Newton's forces and methodology. Even in the preface of his work, Cheyne reveals the mechanical character of his physiology and its mathematical implications. For him, the human body is nothing but a set of "branching and winding" canals, through which different liquors are flowing constantly. Therefore, as he explains, a disease is the consequence of a malfunctioning of the mechanical system of the body and, because of this, any treatment should be gathered from the experimental data provided by the anatomical studies and the mathematical analysis performed by the physiologist.[388]

The mathematical character of Cheyne's study about continual fevers is revealed both in the form he chose for presenting his ideas and in the content of the theory itself. Explained in a geometrical way, Cheyne begins by establishing a couple of *Postulata* and *Lemmata*, deducing from them a general proposition, in which he explains the cause of fevers.[389] In *Postulatum I*, he defines the body as "nothing but a congeries of canals, the greatest (at least considerable) part of which is *Glands*, properly so called, design'd for the separation of some fluid" (Cheyne, 1701: 1). The evidence of this *postulatum* is based on the observation of the swollen parts of the body and Leuwenhoek's and Malpighi's microscopic observations.[390] *Postulatum II* establishes the mechanical character of Cheyne's analysis by means of the use of the metaphor of the machine: "That when a machine is disordered, if we should see it righted by adjusting such a particular

[388] *Cf.* Cheyne (1701), pp. 1-2.
[389] The characterization of Cheyne's election of the geometrical method for presenting his physiological ideas is in his Preface. It is worth noting that in using a mathematical approach, he claims to be following the example of Borelli and Bellini, which reveals one of the possible origins of Newtonian medicine practiced in the early-eighteenth century. *Cf.* Cheyne (1701), Preface.
[390] *Cf.* Cheyne (1701), p. 2.

part, we might without scruple affirm, that it was some injury done to that part, which had dissorder'd the machine" (Cheyne, 1701: 2). By comparing the human body to a machine, Cheyne provides a holistic conception of the body, where all the parts are intimately related one to other. Therefore, the malfunctioning of a single part may produce the malfunctioning of the entire body. In this conception of the body and its internal functioning, the determination of the specific site of the disease is possible because of the healing process. Thus, from *Postulata*, Cheyne establishes two *Lemmata* where he explains, in a mathematical way, 1. that the cause of a disease must be an obstruction to the flowing of the blood and, as a result, 2. the corrupted blood, namely, the blood while the body has a disease, is qualitatively the same as the blood in health, so the cause of the disease could be explained by the obstruction, neglecting any iatrochemical approach.[391] At this point, he introduces the *General proposition* on which the entire argument of his study about continual fevers is based:

> The general and most effectual cause of all fevers, is the obstruction or dilatation of (the complicated *Nerve* and *Arterie*, *the excretory duct & conservatory*, one, or rather all these; which, as shall be afterward shewn, make up) the *Glands*, and they receive their denomination as these or those *Glands* are more or less obstructed or dilated (Cheyne, 1701: 11).

For Cheyne, fevers should be accounted for as the result of the obstruction of the minutest vessels in the *Glands*, impeding the correct secretion of the morbific matter produced by the body. An interesting implication of this account is that, for Cheyne, fevers were not diseases by themselves, but rather the physical effect of a disease which produced the obstruction of the

[391] *Cf.* Cheyne (1701), pp. 2-11.

Glands' vessels.[392] In this sense, he explained the physical effects of a fever – as rise in the strength and frequency of the heart rate, headaches, violent and burning heat, and so forth – from his general proposition.[393]

The last "appearance of continual fever" described by Cheyne allowed him to determine that the best way to treat a fever was by fomenting the body's secretions.[394] In so doing, he assumed Pitcairne's position in the Edinburgh fever dispute. Like Pitcairne, Cheyne used several mathematical demonstrations to determine the effectiveness of each treatment proposed for overcoming continual fevers. First, he rejected the treatment focused on purging and vomiting. According to Cheyne, various physicians had proposed vomiting and purging as the best ways to treat fevers, since, in some cases, fevers are accompanied by vomiting and, consequently, they assume that morbific matter is generated in the stomach where it mixes with the blood.[395] Cheyne rejected these ideas and proposed a set of propositions which demonstrated the mathematical and Newtonian nature of his approach to physiology. In general, in these propositions, Cheyne argued that secretions are produced in the secretory vessels of the glands as a result of the combination of three forces. In *Proposition III*, he postulated that "in a mixt fluid, consisting of greater and lesser cohesion of parts, of greater and lesser fluidity: that which has the least cohesion and greatest fluidity, is first separated" (1701: 38). Thus, he argued that the specific gravities of the particles composing the blood produced different degrees of cohesion, which makes it possible to explain how certain substances are only secreted by some specific glands of the body. As Guerrini has pointed out, it is possible to see the role of a Newtonian theory on matter characterized by the attraction of particles, in Cheyne's description of the evidence for

[392] Such a consideration of fevers is highlighted in his explanation of the consequences of considering fevers as the effect of an obstruction. *Cf.* Cheyne (1701), pp. 13-21.
[393] *Cf.* Cheyne (1701), pp. 13-21.
[394] *Cf.* Cheyne (1701), p. 22.
[395] *Cf.* Cheyne (1701), pp. 57-75.

the most efficient mechanism of secretion.[396] In addition to this idea, the Newtonian nature of Cheyne's iatromathematical approach is evident in *Proposition II*, where he develops Pitcairne's idea of secretion as the combination of two forces in the flowing of the blood in a more sophisticated mathematical way. According to Cheyne:

> Separation or secretion is perform'd by the composition of two motions in the fluid; one propagated through the length of the canal, another transversely through its sides (for it is demonstrable that all fluids press *undiquaq*; and that the direction of their pression is perpendicular in every point to the sides of the containing vessel). The composition of which two, is the motion (or rather direction) of the separated fluid (1701: 37-38).

Like Pitcairne, Cheyne explains secretion as the result of the combination of a longitudinal inertial force of the blood, produced by the pressure of the heart with a perpendicular force, caused by the elastic pressure of the sides of the vessels on the blood. The combination of such forces means that the differentiated fluids, separated due to their specific gravities, move toward the sides of the vessels; towards the secretory vessels. Consequently, Cheyne proceeds to demonstrate that, knowing the quantity of secretory orifices and the celerity of the fluid, the physician can determine the quantity of fluid that is separated. One of the corollaries of this demonstration shows the influence of Newton's geometrical treatment of the motion of bodies in Cheyne's description of secretion. In *Corollarium V* to the demonstration, he contends:

> That secretion may be perform'd the most easily that may be the insertion of the separating canal ought to be at an *Angle* of 45 degrees with the *Artery* […] For let

[396] *Cf.* Guerrini (1985).

AB represent the *Artery* (if it make a right line) or it's *tangent* (if it make a curve) and let the motion of the fluid be from A to B, the right line AB will likewise represent its direction, propagated from the Heart. Erect at A the perpendicular AC; this will represent the direction of the lateral pression of the fluid. Compleat the parallelogram ABCD. The direction of the composition of these two motion will be the diagonal AD, as is known [Fig. 17] (Cheyne, 1701: 41-42).

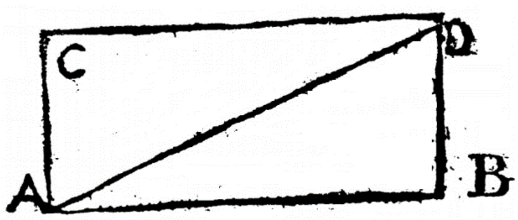

Figure 17. Parallelogram formed by the pressure of the heart on the blood and the elastic pressure of the vessels.[397]

It is easy to observe the similitude of this geometrical demonstration with that of Newton in *Corollary I* to the Laws, in the *Principia*, in which he geometrically demonstrates, by means of the so-called method of the parallelogram, that the distance traversed by a body, accelerated by two forces – one inertial and the other centripetal – is equal to the distance it traverses even when only accelerated by the inertial force [Fig. 18].[398]

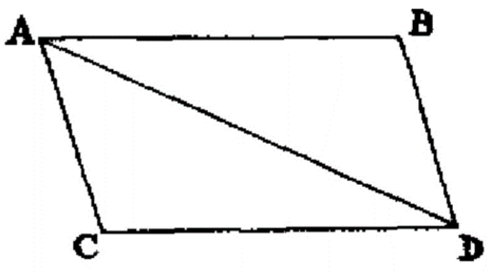

Figure 18. Parallelogram formed by the action of two forces upon a body.[399]

[397] Cheyne (1701), p. 42.
[398] Newton (1999), pp. 417-418.
[399] Newton (1999), p. 418.

So far, I have explained the development of a Newtonian approach to medicine as the result of the articulation of a mechanical approach to physiological phenomena and their strictly mathematical treatment, which ended in Cheyne's iatromathematics. As Guerrini suggests, such an articulation is found in the application of forces between particles as causes for several physiological phenomena and, particularly, those of secretions.[400] By emphasizing the mathematical elements of the demonstration, Newtonian physicians such as Pitcairne, Cheyne, and James Keill, attempted to reduce every physiological phenomena to geometrical terms, in order to achieve the same success in their demonstrations as Newton had in *Principia*. However, Newtonian medicine varied at the beginning of the eighteenth century, shifting from its focus on the mathematical aspects of physiological issues to more experimental aspects, certainly inspired, by the speculative character of Newton's *Queries* in the *Opticks*.

The process of transformation of Newtonian medicine has also been discussed by historians like Guerrini and Brown, but the reasons for the transformation still need to be explained. Guerrini, for instance, limits her analysis by claiming that there was another tradition emerging from the experimental branch developed in the light of the *Opticks*.[401] She therefore contends that such an articulation was the result of the emergence of new socio-political conditions in England after the Glorious Revolution that made Newton's experimental philosophy more attractive for both physicians and the new social and political order.[402] Likewise, Brown has suggested that the causes for the transformation of Newtonian medicine can be found in the death of the most important figures of the first stage of the Newtonian

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[400] Guerrini illustrates this point in her analysis of James Keill's use of the notion of attractive forces in his *An account of animal secretion*. See, Guerrini (1985), pp. 256-259.
[401] *Cf.* Guerrini (1983), p. 217.
[402] This interpretation follows the guidelines established by historians like Shapin, Schaffer, Friessen, and Dobbs, concerning the social uses of science and the role of post-revolutionary conditions in the acceptance and diffusion of Newtonianism. *Cf.* Shapin (1981), Guerrini (1986), Schaffer (1989), Friesen (2003).

mathematical approach to physiology – as well as that of Newton himself – during the first decades of the eighteenth century. According to Brown: the "English scientists generally relieved themselves of the heavy burden of mathematical, quantitative Newtonianism and turned eagerly to natural philosophical studies of new experimental phenomena, like those of electricity" (1974: 191).

The analysis of the causes of the transformation of Newtonian medicine from a highly mathematical approach to a more experimental and speculative perspective exceeds the limits of this chapter, however I would like to suggest that a possible reason helping to understand this transformation can be found in the problems that Newtonians faced in the early-eighteenth century for consolidating Newton's mathematical approach to nature in different academic contexts. As John Gascoigne, E. W. Strong, and J. Bass Mullinger have demonstrated, Newton's theories were hardly taught at all in academic contexts before the beginning of the eighteenth century. Not even in Cambridge – where Newton was *Lucasian* Professor until 1701 – were Newton's mathematical techniques and its implications for the study of nature taught to students before 1700.[403] The most probable reason for this is the inherent difficulty of *Principia*. Nevertheless, as Christina Eagles has suggested in her study on Gregory's teaching of Newton's concepts and tenets in Edinburgh, it is possible that the personal beliefs of professors would also have played a considerable role.[404] Evidence for this position is found in the fact that convinced Newtonians, such as the Keill brothers, who dominated the mathematical aspects of Newton's demonstrations, decided to develop their courses at Oxford by emphasizing the experimental demonstrations rather than the mathematical ones. Indeed, as we shall see, James

[403] *Cf.* Mullinger (1888), 155-171; Strong (1957); Gascoigne (1985); Gascoigne (1988), pp. 69-184.
[404] *Cf.* Eagles (1977).

Keill's *An account of animal secretions* (1708) is a good example of the transformation of Newtonian medicine to more experimental medicine.

Probably in the wake of the example of his brother, John Keill, who in 1702 had published *An introduction to natural philosophy; or, philosophical lectures read in the University of Oxford*, in which he attempted to empirically demonstrate Newton's mathematical principles, in his *An account on animal secretions*, James Keill tried to explain physiological phenomena with some experiments founded on mathematical demonstrations. According to Keill, as he explains in the Preface, experiments and mathematical demonstrations are complementary, because the art of curing begins with the performing of experiments; however, as experiments do not provide an appropriate explanation of any disease by themselves, it is necessary to base them on accurate mathematical demonstrations.[405] In this sense, mathematics in Keill's analysis allows the physiologist to gain accurate knowledge of the mechanical functioning of the animal economy. In so doing, it is possible for him to postulate some experiments in order to demonstrate the veracity of mathematical explanations. In Keill's words: "Experiments are the only foundation upon which by a just reasoning we come at the knowledge of any phaenomenon of nature […] without them the raising of theories and hypotheses is but building of castles in the air" (1708: X-XI). In the context of this apologetic consideration of the relationship between mathematics and experiments, Keill establishes the purpose of his work: calculating the force of the air upon the blood in breathing, the quantity of blood in the human body, and its velocity in the aorta.[406] However, before giving an account for these specific issues, he begins his work by explaining

[405] Keill's considerations on the articulation of mathematics and experiments for explaining physiological phenomena and diseases can be found in Keill (1708), pp. VIII-IX.
[406] *Cf.* Keill (1708), pp. IV-V.

the problem of secretions, which, as we can see, was the main case for the development of a Newtonian approach to physiology in the early-eighteenth century.

In Keill's explanation of secretion, there is a deeper influence of the Newtonian attractive forces on the explanation of the segregation of certain fluids than in Cheyne's or Pitcairne's. Keill divides the explanation of animal secretion into two sections. In the first, by postulating attractive forces as causes he explains how fluids to be secreted come to be formed. In the second, he demonstrates how fluids are separated from the blood in the glands.[407] Using empirical evidence provided by microscopic observations, Keill claims that blood is composed of two kinds of particles: red globules and some other corpuscles, varying in form and magnitude. The main characteristic of the red globules is their ability to attract each other in such a way as to be, "swimming in a limpid fluid (…) unite like spheres of quicksilver, which, as they touch, run into one another" (Keill, 1708: 2). The other particles composing the blood, unlike red globules, only unite one to the other "till some part of the fluid, in which they swim, has been evaporated by heat; and then they likewise attract one another, and form a coagulum, as the globules did" (Keill, 1708: 2). In this characterization, we can see that Keill resorts to the differences of the attractive forces between particles in order to explain how specific particles of the blood attract each other. However, unlike Pitcairne and Cheyne, whose use of Newtonian attractive forces between particles to explain secretion is based on Newton's speculations on the

[407] Keill describes the purpose of his *An account*, as well as its general structure in the last part of the Preface.*Cf.* Keill (1708), pp. XXIV-XXVIII. Interestingly, in this passage, he refers to the similitude between the astronomers' method and that of the physiologists, using Gregory's works as an example. In so doing, he emphasized the idea advanced at the beginning of the Preface in which he suggests that the mathematical-experimental approach required for physiology is the same one as used for astronomy and natural philosophy. *Cf.* Keill (1708), pp. XIII-XIV.

theory of matter, Keill used microscopic evidence to explore the characteristic of the globules composing the blood.[408]

The Newtonian character of the consideration of the attractive forces between the particles of blood in Keill's *An account* is revealed when he compares this kind of attractive forces with the general attractive forces that produce natural phenomena. According to Keill: "This power, by which the particles of the blood attract one another, is the same with that which is the cause of the cohesion of the parts of matter" (1708: 7). For him, fermentation, elasticity, dissolution, and coagulation of the blood particles are examples of the phenomena that can be reduced to some kind of force acting in the universe. In this sense, he suggests that Newton's conception of attractive forces can be used as a universally applied causal principle for explaining not only macroscopic phenomena, but also physiological phenomena in the constitution of blood:

> And since it will appear, that the whole animal oeconomy does likewise depend upon this attractive power; it seems to be the only principle, from which there can be a satisfactory solution given of the *phaenomena*, produc'd by the *minima naturae*; as that other attractive principle, which is of a different kind from this, and was first discovered by the incomparable Sir *Isaac Newton*, demonstratively explains the motions of the great bodies of the universe (Keill, 1708: 8).

Arguably, Keill considered here that attractive forces between particles produce every microscopic phenomenon. Certainly, this conception includes phenomena related to secretions. These "inter-particle" forces are similar to the attractive forces that produce the motion of

[408] Keill explicitly refers to microscopical observations when he deals with the constitution of glands. *Cf.* Keill (1708), pp. 82-84. In this passage he also makes reference to Malpighi's microscopical observations.

bodies on a macroscopic scale. Nevertheless, it is important to highlight that he does not consider the application of attractive forces for explaining physiological-microscopic phenomena by analogy with Newton's use of attractive forces for explaining macroscopic phenomena. By contrast, Keill extends the explicative power of Newton's attractive forces comparing them with mathematically-based experiments, as they are applied to physiological phenomena and, particularly, to the phenomena of secretion.[409]

Such an application of forces for explaining physiological phenomena is clear when Keill explains how the different particles composing blood are separated via the exercising of different attractive forces between each other. According to him, from the separation of fluids to be secreted in the blood from the "red part of the blood", it follows that:

> the red part of the blood consists of particles which attract one another, more than they do the watry fluid, in which they swim; and that the other particles, which are in the watry fluid of the serum, are more attracte by it than by one another. But if part of this watry fluid be evaporated, by this means, the partciles attracting approaching nearer, the force of their attraction is increased, and then they unite; and consequently this force must be much stronger in particles that are very nigh one another, than when they are at a distance (Keill, 1708: 6-7).

By explaining secretion as the effect of forces, Keill rejected the idea that such fluids are produced in the secretory glands themselves. Conversely, he assumes that the fluids to be secreted are formed in a continual process produced by the attractive powers of the particles

[409] Such a characterization is clear in the Propositions accounting for the formation of substances to be secreted in the glands of the human body. *Cf.* Keill (1708), pp. 9-23. An exemplary case of the kind of arguments that Keill used is in Prop. III, where he explains the variation in the force between particles depending on their mutual distances; thus concluding that it would be infinitely greater with their contact. *Cf.* Keill (1708), pp. 13-16.

composing blood. However, the attraction between particles is repelled by the velocity of the blood caused by the pressure of the heart, so that the particles cannot attract each other. It explains the need to determine the velocity of the blood in the aorta which is one of the ultimate purposes of his book.[410] The union of the particles due to their attractive forces, as Keill pointed out, is only produced when the velocity of the blood diminishes. The reduction of its velocity is caused by the friction generated by the motion of blood through the cavities which are in the vessels. Thus, the more the cavities, the less the "intestinal motions" of the blood, and, as a result, greater unity between particles is produced by their attractive forces. Interestingly, by considering the role of the velocity of blood in vessels and the attractive forces in the explanation of secretions, Keill also explains the physiological constitution of the human body and the different placement of its organs.[411]

After demonstrating that different fluids are produced as a result of different attractions between the particles composing the blood and the velocities of its internal motions, Keill proceeds to explain how fluids are secreted in the glands. According to him, "This does depend entirely upon the figure and structure of the gland; which must be therefore first determined" (1708: 82). Glands are nothing but convolutions of small arteries. The circular orifices of the glands vary only in magnitude, and all sorts of particles of a lesser diameter than that of the orifice of the gland may enter inside. The separation of fluids in the glands is the result of the size of the excretory artery and the size of the particle to be secreted. For him,

> The circular orifices therefore of the glands can only differ in magnitude, and all sorts of particles of a lesser diameter than that of the orifice of the gland may

[410] *Cf.* Keill (1708), pp. 29-38.
[411] Keill illustrates this position in his explanation of the position of the kidneys and liver, *Cf.* Keill (1708), pp. 33-44.

> enter it; so that without some farther contrivance, that fluid which contains the biggest particles, must likewise consist of all the particles of all the other secretions; neither could any fluid thicker than the blood be separated from it, because of the great proportion of the aqueous fluid, whose particles being vastly smaller than any other; and invisible to the best microscopes, must enter all the glands, and be mixt with the secerned fluid (1708: 83-84).

The size of the secretory vessel only allows particles of a specific size (or lesser) and some aqueous liquid to flow through. The fluids of the blood gradually diminish by flowing through other ducts which do not receive the particles to be secreted because they are bigger than their diameter. Finally, the biggest particles are secreted. Therefore, Keill completely neglects the role of the shape of the particles in the secretion, implying a rejection of the Cartesian mechanical account of secretion. By contrast, he proposes a theory of secretion based on both the size of the ducts and the particles, and the attractive forces of particles composing the blood. This theory is illustrated by several experiments and microscopic observations advanced on the basis of mathematical demonstrations.[412]

As I have explained above, the development of Newtonian medicine during the 1690s and the first decade of the eighteenth century can be divided into two periods. First, there was a period characterized by the emphasis on the mathematical demonstrations of the mechanical physiology. In this period, physiologists and physicians like Pitcairne and Cheyne – just to mention the cases I have studied – tried to explain physiological phenomena, and particularly secretions, through the use of Newtonian forces, reduced to mathematical terms and mechanical

[412] Keill (1708), pp. 82-88.

laws.[413] The difficulties for the transmission of the mathematical elements inherited from the Newtonian tradition, which were basic for the study of physiology following the example of Newton's *Principia*, provided an academic milieu where experimental – and not mathematical – demonstrations were used as the basis for the theoretical foundation of practical medicine. In this context, during the first decades of the eighteenth century, Newtonian physicians saw in Newton's *Opticks*, rather than in the *Principia*, the methodological model for studying physiology and developing their medical practices. As I shall explain in the next section, the works of Herman Boerhaave are clearly compatible with this version of Newtonian medicine.

Newtonianism in Boerhaave's medicine: universal and peculiar properties of bodies

Boerhaave's works on medicine, both practical and theoretical, have been considered fundamental by historians of science and medicine for explaining the development of this discipline during the eighteenth century, as they unify mechanics and chemistry in a medical system characterized by the explanation of physiological phenomena based on experiments and theoretical formulations.[414] In Boerhaave's *Institutiones Medicae*[415] and *Aphorismi*, his major works on medicine and physiology, he advanced the idea that bodies are composed of both universal

[413] In this chapter I assume that this mathematical period of Newtonian medicine occurred in the 1690s and the early years of the eighteenth century, while it is possible to trace some elements of iatromathematical Newtonian medicine to the 1720s in the work of Stephen Hales. However, as Robert Schofield has explained, as of the 1710s theoretical medicine moved in a more vitalistic and experimental way, making Hales the exception confirming the rule. *Cf.* Schofield (1969), pp. 63-87.
[414] For Boerhaave's works and their influence on medicine and chemistry in the eighteenth century, see Kerker (1955), Knoeff (2002), Knoeff (2006) Powers (2007), Knoeff (2007), Anderson (2010), Powers (2012), Orland (2012).
[415] Boerhaave's *Praelectiones academicae in proprias institutiones rei medicae* are popularly known as *Institutiones Medicae*. For this dissertation I use the English edition published in London in 1751, entitled *Academical lectures* is a translation of his *Praelectiones academicae in proprias institutiones rei medicae*, published in 1708. There is an edition of the *Academical lectures* published in 1743. I have used the second edition of this work, published in London in 1751.

and peculiar properties that make them behave in certain ways.[416] In *Institutiones Medicae*, for instance, he explains that the reaction of the body to a disease is produced by an automatic, involuntary motion, triggered by a mechanical reaction. In this sense, he defines the human body as "an assemblage of small elastick solids, by whose conjunct and regular actions, life and health are produced" (Boerhaave, 1751: 7). Therefore, the study of the body for determining the functioning of its mechanical parts should be performed following the principles established by hydraulics, hydrostatics, and mechanics. In Boerhaave's words, the actions of the body "are performed agreeable to the *laws* or principles of *hydrostatics*, *hydraulics*, and *mechanics*; by which they ought therefore to be explained" (1751: 85). Accordingly, he argues that the explanation of the motions of the solid and liquid parts of the human body is based on mechanical grounds, because of the universal properties the human body shares with any other kind of bodies.[417] However, in these works he also suggests that the human body is composed of some "peculiar properties", which are hardly discernible through a mechanical study of the same. As he explains in his *Institutiones Medicae*:

> But then, there are other principles not to be explained by these universal laws, but by some particular disposition in the certain body; these properties are called physical. But a physician ought to consider both the affections of bodies in general, as well as those only proper to the human body, that from a judicious comparison and just reasoning, he may never subject the human body to those laws only, to which the generality, but not all bodies, are liable (1751: 64).

[416] *Cf.* Boerhaave (1715), pp. 1-23; Boerhaave (1751), pp. 51-96.
[417] For Boerhaave's mechanical conception of the body, see Jackson (1983). A detailed general explanation of physiological mechanics in the eighteenth century is in Schofield (1969), pp. 17-87, Brown (1974).

The human body is composed of both peculiar and general properties and the physician should consider them both in order to determine not only the theoretical explanation of its functioning but, more importantly, the best therapies for its diseases. For Boerhaave, diseases may affect both the mechanical parts of the body – the solid and the liquid parts – and those parts the functioning of which cannot be reduced to a mechanical explanation. The classification of these diseases can be clearly seen in *Aphorismi*, where he establishes a particular order to explain diseases from the simplest to the most complex, following a geometrical method.[418] He then studies "The diseases of the solids consequently, and their cure" (1715: 5), gradually moving towards the study of the diseases of the other solid and liquid parts of the body; concluding with the study of internal diseases, where the notion of "particular qualities", and their chemical study, is fundamental.[419] In addition, I must argue that in considering these "particular properties", Boerhaave adopts Newton's conception of attractive forces, thus making it possible for him to establish the articulation between chemistry, physics, and physiology that characterizes his approach to physiology. Let us take as an example the explanation of how fevers end in good health in order to illustrate the role of these "particular qualities" of the body in explaining the cure of a disease.

According to Boerhaave, in some cases, fevers end in good health as they overcome the material cause that produced them, breaking it and making it moveable.[420] This explanation, certainly, is based on mechanical principles with the underlying idea of fevers as obstructions.

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418 *Cf.* Boerhaave (1715), pp. 4-5.

419 Boerhaave presents this classification in a more detailed fashion in *Aphorismi*, where he deals with the distempers of "fibers" and the distempers of vessels, establishing sub-classifications of the different parts of the human body. *Cf.* Boerhaave (1715), pp. 5-16. He begins to study the internal parts of the body by considering the composition of the liquid parts of the body and their "defects". *Cf.* Boerhaave (1715), p. 16.

420 Boerhaave presents his conclusions on how a fever ends in health within the context of his explanation of the different ends a fever could have. *Cf.* Boerhaave (1715), pp. 132-133. In this section, he also claims that the determination of the best method for curing a fever depends on the kind of substance that is producing the obstruction. *Cf.* Boerhaave (1715), p. 134.

However, there are other occasions when fevers end in good health by overcoming the "particular quality" in the material cause that produced the fever:

> Or if the matter of the same disease being overcome by the power of the very fever, be loosen'd and render'd moveable, yet has retain'd one particular quality, which will hinder an equal circulation, and yet stimulates and irritates the vessels, and is for that reason drove out by some sensible evacuation which it occasions; such as sweats, spitting, vomitings, diarrhaeas, and urine, after the coction and height of the fever when the crisis is completed almost within fourteen days (Boerhaave, 1715: 133).

For Boerhaave, there is a *particular quality* in the material cause of the fever which remains in the body, even after the material cause has been made movable through the mechanical action of the body or the effects of therapies. This quality "hinders" the normal flow of the blood, thus irritating the vessels. Fever, consequently heats this quality, leading the body to its secretion in natural ways. The fire-like action of fever, heating the particular quality causing the disease, should not be overlooked as it highlights the role of chemistry as an ancillary discipline for medicine in Boerhaave's eyes.

In the chemical studies of his *Institutiones Medicae*, Boerhaave defines chemistry as "the observation of those changes which arise in different bodies from the application of certain degrees of fire" (1751: 46). Meaning that he attributes to fever the features of a chemical operation, taking place in the human body, through which qualitative transformations of substances are produced in the particular properties of matter. This definition is extended in his *A new method of chemistry*,[421] where states that:

> Chemistry is an art which teaches the manner of performing certain physical operations, whereby bodies cognizable to the senses, or capable of being render'd cognizable, and of being contain'd in vessels, are so changed, by means of proper instruments, as to produce certain determined effects; and at the same time discover the causes thereof; for the service of various arts (1753: 65).

In this definition, there are some elements which are worth highlighting. First, Boerhaave's definition of chemistry establishes a disciplinary distinction that makes it possible to consider chemistry as an independent discipline of medicine. He based this characterization on the idea that chemistry is not used just for creating pharmacopeia or for the analysis of the effects of the *materia medica*. By contrast, for him chemistry is in fact able to study properties of the bodies through the analysis made with fire.[422] In so doing, he refused the very limited approaches of seventeenth-century iatrochemical and mechanical traditions, proposing instead, the idea that both chemistry and mechanics should be applied for studying the basic structure of nature. In this way, it would be possible to determine their influence on medicine, as it would also be possible for the physician to determine the best therapies for any disease, depending on whether they are produced in the parts of the bodies responsible for either the mechanical or chemical effects.

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[421] As Knoeff pointed out, I think correctly, some historians have confused Peter Shaw's Newtonian commentaries in the translation of Boerhaave's *Elementa Chemiae* into English with Boerhaave's own beliefs about Newton's theories. Though it is difficult to neglect Boerhaave's Newtonianism, it is also true that Shaw exacerbates it. *Cf.* Knoeff (2002), pp. 107-109. For Peter Shaw and his role as "communicator" of chemical novelties, see Golinski (1983). Boerhaave's *Elementa chemiae* was published in 1732. I have used Shaw's translated edition published in 1753.

[422] *Cf.* Boerhaave (1753), pp. 1-5. Though Boerhaave points out the importance of chemistry as an independent discipline, in the historical analysis of the evolution of chemistry in *A new method of chemistry*, he also alludes to the role of chemistry in the medical field. *Cf.* Boerhaave (1753), pp. 35-60.

Another important aspect of Boerhaave's definition of chemistry is that he considers chemistry and mechanics as basic disciplines for physicians who intend to heal a disease through their knowledge of the functioning of the body. In this sense, as Boerhaave argues in his *A new method of chemistry*: "Now it is evident, that of all the sciences chemistry is best adapted for discovering these latent peculiar powers of bodies: whence we may safely conclude, that the chemical art is best and fittest means of improving natural knowledge" (1753: 173). Interestingly, he illustrated this characterization of chemistry in the light of its utility for medicine, claiming that the former is used in medicine for the same purposes as in natural philosophy.[423] Finally, despite the theoretical potential of chemistry, Boerhaave considered it an important instrument for practical purposes, as he described it as the action of dividing material by means of an appropriate instrument: fire.[424]

As I have argued, Boerhaave contended that the human body is composed of certain general properties that can be accounted for mechanically through the application of the laws of motion. However, as the body has some peculiar properties which should be explained through chemistry, he concludes:

> And as those skilled in mechanics and hydrostatics account for a multitude of appearances observed in the affair of health; and as other naturalists daily make other discoveries; so do chemists render many things intelligible, otherwise impossible to be learnt; insomuch that we must or necessity own, that many of

[423] According to Boerhaave, the main business of natural philosophy is to explain all the modifications suffered by the body. In this sense, there are two methods of studying them: by patient observations and by performing experiments. In the second case, chemistry plays a fundamental role as it makes it possible to introduce qualitative changes in matter through the exercising of fire. Thus, Boerhaave establishes articulation between chemistry and natural philosophy within the framework of an experimental approach to nature that entails the modification of the body studied. *Cf.* Boerhaave (1753), pp. 172-173.
[424] *Cf.* Boerhaave (1753), pp. 65-66.

> the most important parts in all the medical physiology are only to be known by chemistry (1753: 174).

One of the most suggestive aspects of Boerhaave's distinction between peculiar and universal properties of the body is its implications in the distinction between chemistry and physics. According to him, unlike physics, the explanations of which are theoretical and the demonstrations mathematical, chemistry is essentially a practical discipline: 'They who are possessed hereof [of a chemical knowledge] will be able, by a truly active knowledge, to produce physical effects, without resting in subtilties of words, or idle speculations of theory' (Boerhaave, 1753: 173). Interestingly, such a characterization of the practical character of chemistry is consistent with the practical character of Boerhaave's medicine: in both disciplines, the development of the theories does not depend upon knowing the ultimate causes of phenomena. Thus, whereas in the case of medicine the effect is healing the body, in the case of chemistry, the main purpose of the chemist is to produce physical changes in matter through the action of fire.[425]

The action of fire in Boerhaave's conception of chemistry reveals the influence of several Newtonian elements that is important to consider in order to know how some specific Newtonian ideas were adopted by Boerhaave in medicine – and, as a result, by Mutis himself in his *General plan*. For him,

> Fire cannot penetrate into the last and least elements of bodies, but is repelled therefrom, as often as it attempts it; and this with the more force, by how much it endeavours to penetrate more forcibly. By this means there must arise a kind of

[425] This practical character of Boerhaave's medicine is clear in his explanation of the method of medicine in *Aphorismi*. *Cf.* Boerhaave (1715), p. 2.

> attrition betwixt fire and other bodies; and consequently fire is never lodg'd in the proper substance of bodies, but only in the interstices, which are lest between the particles, even of the most solid bodies (1753: 247).

Boerhaave claimed that fire is composed of the most solid and smallest particles of nature and it acts in the interstices of the particles composing bodies, separating them one from the other. The Newtonian character of this consideration of fire is revealed when he explains that the cohesion of particles is the result of some attractive forces between them. Let us consider, for instance, his explanation of the composition of blood. In his study of physiology in *Institutiones Medicae*, he argues that the fluids of the human body cannot be studied by means of hydraulics alone as in the case of water, because "many of our fluids contain elastic globules, and all of them are compounded of oil, salt, earth and water, variously attracting and repelling each other" (1751: 89). Consequently, the fluids of the human body do not strictly follow the mechanical laws of hydraulics and hydrostatics. This position is clearer when Boerhaave explains that chemical reactions caused by fire can hardly be limited to mechanical causes: "On the contrary, it rarely happens that any menstruum exerts all its dissolving power mechanically. And hence, Sir *Isaac Newton*, in his researches has found reason, from observation, to add other necessary causes" (1753: 511). The non-mechanical character of Boerhaave's chemistry allows him to suggest that forces are explicative principles for the cohesion of particles. Consequently, chemical operations with fire make an analysis of matter by separating the particles which cohere as a result of their attractive forces. As Knoeff explains: "Not long after his graduation in 1690, after having read the first edition of Newton's *Principia*, Boerhaave started explaining his *affectionis corporae principium* and *occultae qualitates* in terms of Newtonian forces" (2002: 119). However, it is necessary to clarify that, unlike Pitcairne, Cheyne and Keill, for whom forces were causes of mechanical physiological phenomena, for Boerhaave, forces are causes of both chemical and mechanical physiological phenomena. In other words, by considering the role of chemical reactions in the functions of the human body, he used forces to also explain physiological phenomena related to the mechanical parts of the human body. Equally important, according to Boerhaave, chemical reactions can also account for the chemical phenomena occurring in the body which cause physical effects.

In short, for Boerhaave, it was necessary for the physician interested in knowing and explaining physiological phenomena to have an in-depth knowledge of both chemistry and mechanics. Newtonian elements in Boerhaave's physiology and medicine are not limited to the use of the laws of motion in order to explain the physiological phenomena related to the solid and liquid parts of the body. We can see how, by considering the role of chemistry in physiological and medical investigations, Boerhaave also used a Newtonian matter theory characterized by the presence of forces causing certain phenomena which are only explicable in chemical terms through the use of fire. Thus, whereas analysis made with fire in chemistry allows the chemist to determine the peculiar properties of the bodies, the physician can use a chemical approach to physiology for determining how such properties affect the constitution of the human body; thus leading to the best therapy for a specific disease.

As I have pointed out in the beginning of this chapter, these considerations played a fundamental role in Mutis' *General plan*, as is evident from his description of the faculty of chemistry which should be attached to the faculty of medicine. According to Mutis:

> Esta cátedra como las de matemáticas, física y botánica, no limita su enseñanza a los médicos, para quienes se consideran como ramos auxiliares de su principal facultad. Son ellas unas ciencias más generales en que pueden igualmente instruirse los cursantes de otras profesiones y demás jóvenes aficionados, según

> la inclinación de su genio a promover algún ramo de la felicidad pública. Por lo perteneciente a la química, que de ahora se trata, siendo su objeto investigar la naturaleza y propiedades de todos los cuerpos, difunde sus luces por todas las ciencias y artes que sin ellas no podrían hacer los progresos que admiramos en el día (1983a: 271).

Mutis, like Boerhaave, considered chemistry in a twofold way: on one hand, chemistry is a practical discipline for the physician who should study it like he studies mathematics or physics, namely, as an ancillary discipline. In this sense, chemistry is nothing but a discipline attached to the medical studies, useful for pharmacopeia. However, following Boerhaave's considerations, we can see that Mutis did not consider it only in the way it relates to this practical purpose. Chemistry, for Boerhaave and Mutis, is a discipline that allows the physician to discover, explain, and interact with the specific properties of the human body. On the other hand, in relation to this idea of the value of chemistry as a theoretical discipline, Mutis considered it a theoretical discipline independent of others, the main purpose of which is "investigar la naturaleza y propiedades de todos los cuerpos".

Chapter 6. Reforms of education and the debates on the Copernican system in New Granada

The debates on Copernicanism in New Granada as a historiographical problem

Mutis' lectures related to his defence of the Copernican system are particularly interesting from a historiographical point of view as they were the center of fierce polemics concerning the diffusion and acceptance of modern science in New Granada in the late-eighteenth century. In 1767, before the Jesuits were expelled from Spain and the Spanish overseas territories, Mutis gave a lecture entitled *Apology of the Copernican system. Dissertation read at the Colegio Máximo de la Compañía de Jesús of Santafé de Bogotá city* [*Defensa del sistema copernicano. Disertación leída en el Colegio Máximo de la Compañía de Jesús de la ciudad de Santafé de Bogotá*] at the *Colegio de San Bartolomé*, in which he discussed several general features of the Copernican system, arguing that it could be defended as a hypothetical description of the system of the world.[426] In Mutis' opinion, the European enlightened culture of the eighteenth century not only made it possible to "tolerate" the Copernican system, but also "proponer todas las razones a favor y en contra de los dos sistemas florecientes, sino también defender como hipótesis el sistema prohibido" (Mutis, 1982: 105). In this context, Mutis argued that the Copernican system can be discussed as a valid hypothesis for explaining the system of the world because it was the most suitable for accounting the observed natural phenomena from a mathematical point of view, as it was based on

[426] Mutis' *Apology* has been transcribed by Hernández de Alba in Mutis (1983a), pp. 104-116.

observations and precise measurements rather than on mere deductions founded on any hypothetical assumption.

Mutis reinforced such a characterization of the Copernican system in 1773, by declaring to be a convinced Copernican in a lecture attended by Viceroy Manuel Guirior and his wife María Ventura de Guirior at the *Colegio del Rosario.*[427] The lecture, entitled *Defence of Copernicus' heliocentric system in public conclusions given at the Colegio Mayor de Nuestra Señora del* Rosario*, in honor to the very excellent Viceroy Don Manuel Guirior and Doña María Ventura* [*Sustentación del sistema heliocéntrico de Copérnico en conclusiones públicas celebradas en el Colegio Mayor de Nuestra Sra. del* Rosario*, en honor de los excelentísimos virreyes Don Manuel Guirior y Doña María Ventura*],[428] was a public lecture that Mutis prepared for the *Conclusiones*[429] of his course on mathematics and he divided it in two parts: first, he presented several reasons to defend the Copernican system as a valid hypothesis for explaining astronomical phenomena, arguing that it was based on observations and it was a basic assumption of Newton's physics.[430] As I shall argue, such a characterization allows to understand that Mutis' Copernicanism actually was an extension of his Newtonianism and, as a result, that his defence of the Copernican system was a part of his introduction of Newton's physics in New Granada. Second, in his *Defence*, Mutis assumes a more radical position in respect to *Apology*, in the sense that, in the former, he defended the Copernican system as a thesis, discussing different theological and physical arguments aimed to convince his highly scholastic audience of the veracity of the Copernican system.

[427] A contextualization of this lecture and its social and political consequences is in Soto & Negrín Fajardo (1984).
[428] A transcribed version of Mutis' *Defence* is in Mutis (1983a), pp. 69-91.
[429] The *Conclusiones* was a special public lecture aimed to conclude any course in the Granadian colleges and universities. In it, a scholar defended a previously published thesis from the counterarguments that other students and the public posed. Rather than a simple academic lecture, in Santafé, the *Conclusiones* were considered a public event, generally attended by members of the vice regal court, thus motivating a great interest in Santafé's social life. *Cf.* Huarte (1988).
[430] *Cf.* Mutis (1983a), pp. 72-74.

However, Mutis' characterization and defence of the Copernican system in New Granada had a greater impact than he initially expected. In 1774, the Dominicans invited him to the *Conclusiones* of their course on philosophy in which they aimed to argue that the Church rejected the Copernican system as it was theologically and religiously dangerous.[431] In Mutis' opinion, the invitation letter he had received contained several substantially different statements in respect of the invitations sent to the rest of the public. Likewise, he complained to Viceroy Guirior that it was a theologically-founded attack against him, as he had defended the Copernican system in his lectures on mathetmatics at both the *Colegio del Rosario* and the *Colegio de San Bartolomé*. The exchange of letters between Mutis and the Dominicans in 1774 began a polemic in Santafé concerning the acceptance of Copernicanism that had a deep impact on Mutis' pedagogical endeavours and on the configuration and establishment of the reforms to New Granada's educational system in the late-eighteenth century. As a consequence, as I shall argue, the Dominicans-Mutis debate was centered not only on the discussion of several ideas regarding the Copernican system – which was probably the least important issue dealt with by both the Dominicans and Mutis –, but it also was used by both of sides of the debate to establish the control of New Granada's educational monopoly during the 1770s and the 1780s.

Certainly, such a characterization of the polemic had been already explored by historians as Soto and John Tate Lanning.[432] Thus, I shall base my analysis on their interpretations, arguing that not only the Dominicans strategically used the polemic to delay the process of reformation of New Granada's educational system, but that it was also used by the reformers of education –

[431] The details on polemic between Mutis and the Dominicans can be seen in the *Legajo* created by Viceroy Guirior in AGNC, Sección Colonia, Colegios: SC. 12, 2, ff. 278r-337v.
[432] *Cf.* Lanning (1944); Soto & Negrín-Fajardo (1984); Soto (2005a), pp. 59-62; Arboleda & Soto (2006); Soto (2009), pp. 66-76.

Viceroy Guirior, Moreno Escandón, and Mutis himself – to promote their reforms to education and their pretension of introducing modern science in New Granada's university context.

I shall develop my analysis chronologically. Thus, I divide this chapter in two parts. First, I study the general frame of the polemic between Mutis and the Dominicans. I further divide this part in two sections: in the first place, I study Mutis' lectures on the Copernican system, exploring his arguments with the purpose of describing his defence of the Copernican system in New Granada and the reasons why he declared himself a Copernican. In this section, I shall argue that Mutis interestingly appropriated Galileo's argumentative strategy as it was presented in the *Dialogo sopra i due massimi sistemi del mondo* (1632). In general, I shall argue that, in appropriating Galileo's physical arguments, Mutis interestingly modified them with the purpose of emphasizing the veracity of the Copernican system as a thesis rather than as a hypothesis. In the second place, as the Dominicans-Mutis debate emerged as a polemic regarding the control of New Granada's educational monopoly after the expulsion of the Jesuits, I briefly discuss the reasons why they were expelled from the Spanish territories and the impact of their expulsion on New Granada's academic milieu. In the second part of the chapter, I detaidly study the polemic between Mutis and the Dominicans. I begin by considering the polemic itself and the reasons that both of them used in order to defend their own positions. Then, I explain how the polemic was used to promote the creation of Moreno Escandón's study plan which was thought as the foundation to create a new public university in New Granada.

The defence of the Copernican system in Mutis' lectures on physics

In general, in the *Apology* and the *Defence*, Mutis aimed to argue in favour of the Copernican system by three different kinds of arguments: methodological, sociological, and physical. Before being expelled from New Granada – and from Spain and the Spanish Atlantic world –, the Jesuits invited Mutis to lecture at the *Colegio de San Bartolomé* – the Jesuit college at Santafé. In this college, during the 1750s, the professor of physics, Francisco Javier Trías, had already discussed the Copernican system comparing it with the Tychonic and Ptolemaic ones.[433] In his *Physica specialis et curiosa*, Trías evaluated these systems of the world, thus concluding: "Quaeres 2: Quodnam tenendum systema? Respondeo tolemaicum et pythagoricum repugnant observationibus astronomorum. Tychonicum vix percipi potest. Copernicanum est simplicius, sed creditur parum catholicum" (2005: 102). In Trías' opinion, despite that the Copernican system had been neglected in the Hispanic world as a thesis because of its theological implications, it had also been considered as valid hypothesis to explain natural phenomena by several natural philosophers. In Trías' words, "Ipsum tamen repugnare fidei, in qua multi textus quietem Terrae, Soli et Astris motum concedunt. Fatentur Copernicani ita loqui Scriptura, sed ideo quia se conformat sermonibus vulgi ita putantis et loquentis" (2005: 102). Therefore, by discussing the validity of the Copernican system at the *Colegio de San Bartolomé*, Mutis had a well-informed audience, with a relatively good tolerance regarding it. In other words, he was not dealing with the usual audience he found at the *Colegio del Rosario*, educated under the aegis of New Granada's scholasticism, but conversely with a disposed audience that was receptive of his teachings.

After establishing the theological and natural philosophical conditions of the discussion on the Copernican system, Mutis begins his *Apology* by establishing the general methodological conditions of his defence of the Copernican system: the use of observations and mathematics for explaining them. Following the principles he had defended in his *Preliminary discourse* and *Elements*, he claims that it was necessary to adopt an experimental approach to natural philosophy

[433] There are certain historiographical problems in determining the identity of the professor of Physics of the *Colegio de San Bartolomé* in the 1750s. I assume the position of José del Rey Fajardo and Germán Marquínez Argote who have attributed the work to Francisco Javier Trías. *Cf.* Fajardo (2005).

in which any explanation of natural phenomena must be based on observations and the use of precise measurements. In this sense, he introduced his considerations regarding the Copernican system, arguing that despite that it was initially neglected because of the lack of empirical evidence to support it, since the publication of Galileo's telescopic observations it was possible to present counterarguments to that criticism:

> ¿Si las fases de Venus se hubieran descubierto en tiempo de Copérnico y hubiera constado entonces por la observación que este planeta tenía ciertamente sus crecientes y menguantes, no hubiera sido esta observación una prueba solidísima para la formación de aquel sistema? Los astrónomos contemporáneos de Copérnico le argumentaban diciendo, que si fuese verdadero su sistema deberían observarse crecientes y menguantes en Venus. Confesaba Copérnico que así debía suceder; y que el defecto de esta observación consistía en no haber hallado los astrónomos el medio de perfeccionar la vista; profecía que llegó a verificarse en los tiempos de Galileo por la felicísima invención de los telescopios (1983a: 96).

Thus, Mutis defended the Copernican system as one of the most important results of the explanations derived from an experimental approach to natural philosophy, as it had been already observationally proved by Galileo's telescopic observations. It means that, by considering that there is observational evidence for the Copernican system, Mutis argued that it must not be considered as a mere hypothesis deduced from some metaphysical assumptions, as they were presented, for instance, by the ancient and modern atomists.[434] Conversely, the Copernican system had for Mutis a well-established empirical foundation which was predicted by Copernicus

[434] It must be borne that in the *Preliminary discourse* Mutis argued that the major difficulty of hypothetically-founded natural philosophical systems was their atheistic implications, illustrating his position by referring to the ancient atomism and the modern natural philosophical systems that followed their principles. *Cf.* Mutis (1982), p. 35.

himself through the use of mathematical models of nature and proved by Galileo's astronomical observations.

Nevertheless, Mutis did not reduce his explanation of the hypothetical character of the Copernican system – and consequently its possibility to be defended – to its characterization as an observationally supported system that was not deduced from any metaphysical assumption.[435] Interestingly, before explaining his main arguments to defend the Copernican system as a valid hypothesis, Mutis also commented several sociological reasons to support it. According to him, the main reason for neglecting the Copernican system relies on the fact that it was opposed to the scholastic tradition:

> Podría decirse que la dominación del sistema Ptolemaico, que pasa por ridículo (…) que reinaba entonces en las escuelas peripatéticas, no habiendo podido sacudirse un yugo tan pesado hasta después de dos siglos, bastó para inspirar los celos más enfurecidos en el peripato, poco acostumbrado entonces a que le disputasen su pacífica posesión (1983a: 97).

However, Mutis claims that, after two centuries, the "ridiculous" Ptolemaic system was abandoned in favour of the Copernican system and that it occurred precisely in the core of the Catholic Church:

> Podría decir que la sabia y respetable conducta de la Iglesia Romana en la prohibición del sistema de Copérnico se manifestó entonces tan suave como acostumbra cediendo a las instancias de los poderosos perseguidores, pero con la reserva de levantar la prohibición si los copernicanos mejorasen su causa. Y

[435] As I pointed out above, Mutis had a twofold conception of hypothesis. Undoubtedly, his discussion of the Copernican system as a hypothesis only can be understood in the frame of his acceptance of hypothesis as they were presented by Newton's experimental physics in the *Opticks*. *Cf.* RJB III, 7, 1, 5, f. 283v.

> viendo la iglesia que el universal consentimiento de los astrónomos se ha declarado en favor de Copérnico, se ha dignado relajar su prohibición mandando expresamente que pueda ya defenderse como una suposición probable (Mutis, 1983a: 98).

In Mutis' opinion, the Catholic acceptance of the Copernican system was evident by the fact that it was not only promoted amongst the northern, heretic, Protestant nations, but also in Italy and Spain themselves.[436] This argument, as I shall argue in the next section, constituted for Mutis one of the most important reasons for supporting the Copernican system in the context of his debates with the Dominicans. As Mutis considered the acceptability of the Copernican system in a Catholic context, he argued that it cannot be considered as opposed to the Holy Scriptures, thus neglecting the arguments of the Dominicans and their appeal to the Roman Inquisition.[437]

After considering the sociological issues of the acceptance of the Copernican system and the methodological aspects on which it can be postulated as a plausible hypothesis, Mutis established the two propositions to be demonstrated from a physical point of view in his argumentation of the system: "1. Que la tierra es la que se mueve como los demás planetas, permaneciendo el sol y las estrellas fijas en quietud, a excepción de un momento particular que tiene el sol sobre su eje; 2. que el sistema copernicano en nada se opone a las Sagradas Escrituras"

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[436] Religious differences between Catholicism and Protestantism, as well as its theological and cultural implications was a recurrent issue in the acceptance of early modern science in Spain. Consider, for example, Feijoo's criticism to the Spanish intellectual environment and his defence of the utility of the philosophy coming from Protestant regions in Feijoo (1773b), Vol. II, pp. 215-234; or his references to Bacon's experimentalism as the best method to study nature despite its Protestant origins in Feijoo (1773a), Vol. III, pp. 346-347.
[437] Soto has concluded that Mutis' support of royalism in the context of his polemics with the Dominicans can be considered as a form of Jansenism. *Cf.* Soto (2009).

(1983a: 99).[438] Mutis begins his defence from a physical point of view by strongly criticizing the Tychonic system based on three premises:

> 1. Que establecer dos centros principales el sol y la tierra, se opone a la regularidad y perfección de la obra maravillosa del universo; a la uniformidad y simplicidad del orden natural de los cuerpos. 2. Que se opone a todas las leyes del movimiento la celeridad incomparable con que suponiendo a la tierra en quietud, deberían caminar el sol y las estrellas fijas en el espacio de 24 horas, pareciendo increíble que el sol pueda caminar en un minuto 125000 leguas; y que el planeta Saturno que dista de la tierra 350 millones d eleguas debería caminar en cada minuto 1 millón y 200 mil leguas, siendo esta celeridad increíble casi nada en comparación del movimiento de una estrella de primera magnitud (…) 3. Que los argumentos formados en la apariencia de la quietud de la tierra y del movimiento del sol y de las estrellas; son de ningún valor para los que están instruidos en las reglas de la óptica (1983a: 100).

Undoubtedly, Mutis' reference to the "simplicity" as a basic foundation for accepting any explanation of nature is founded on his acceptance of Newton's methodological statements as he had taught them with his translation of 's Gravesande's *Physices elementa mathematica*.[439]

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[438] Certainly, such propositions to be demonstrated imply that, for Mutis, it is as necessary to explain the astronomical and physical implications and consequences of the Copernican system as pointing out its religious conformity to the Holy Scriptures in order to make it plausible. In general, Mutis argued, the theological debate regarding the Copernican system was based on the problems of a literal interpretation of the Holy Scriptures which, he alleged, should be interpreted in a more "free" manner. He illustrated his position by considering the case of Cosmas Indicopleustes' *Topographia Cristiana*. *Cf.* RJB III, 2, 4, 11, f. 6v. Interestingly, in regards of the religious implications of the defence of the Copernican system, Mutis also referred to Galileo's affair via Muratori's *Annali d'Italia* (1744-1749). *Cf.* RJB III, 8, 1, 24.

[439] Certainly, the principle of simplicity is not an exclusively Newtonian methodological assumption. However, I already highlighted the Newtonian foundations of Mutis' natural philosophy and consequently we can assume that in criticizing the Tychonic system, Mutis adopted a Newtonian methodology to the problem of the acceptance of the Copernican system. Interseting surveys on the principle of simplicity and its historical evolution can be found in Sober (1988), pp. 37-70 and Wilson (2011).

However, his second premise for neglecting the Tychonic system is the most revealing one. In it, Mutis uses astronomical measurements derived from Tycho's system in order to demonstrate that the ratios of the velocity of motion of heavenly bodies are opposed to the laws of motion.[440] It is important to highlight that, in this point, Mutis referred to the "laws of motion" in a general sense. It means that, in considering the Tychonic system, he was not dealing with, for instance, Kepler's laws or any specifical law of nature drawn up for astronomy. Conversely, Mutis was concerned with the explanation of the incompatibility of the Tychonic system with the laws of motion in general terms, claiming that it was not possible to reconcile them with the velocity that a heavenly body must have in that system in order to correspond to the observed phenomena.

By emphasizing the physical issues related to the Tychonic system, Mutis deliberately avoided the problems that emerged from the fact that Tycho's system was actually consistent with Galileo's astronomical observations – especially with the observation of the phases of Venus. It is possible to claim that he did so because, despite that he was a well-informed practitioner of astronomy,[441] he did not have the required training in the field to criticize the Tychonic system. However, I think that it can be more easily explained by considering Mutis' pretension of presenting physical arguments for the Copernican system in the context of his lectures on mathematics. In general, Mutis defended the Copernican system as a valid hypothesis by arguing that it can easily explain the motion of heavenly bodies by the precepts of the laws of motion. In this sense, he used a set of physical and astronomical observations which could only be explained satisfactorily by considering the earth in motion: the retrograde motion of the

[440] *Cf.* Mutis (1983a), pp. 100-101.

[441] I commented above that among Mutis' manuscripts in the *Real Jardín Botánico* of Madrid it is possible to find several studies of astronomy related to the measurement of distances by triangulation with stars, probably used for the determination of frontiers.

planets from east to west; the time that a planet uses for turning around an axis; that every planet, excepting Venus and Mercury, have opposition in respect of the Sun; the lesser gravitation in the Equator of the Earth in respect of its poles.[442] Thus, he concludes:

> Ahora bien: admitiendo el movimiento diario de la tierra sobre su eje se explican con mayor facilidad y claridad todos estos fenómenos, como se demuestra en Volffio, debiendo deducirse como una consecuencia natural del movimiento de la tierra todos los fenómenos alegados: luego la tierra se mueve permaneciendo el sol y las estrellas fijas en quietud. Que es lo que me propuse demostrar a favor del sistema copernicano y en contra del tyconico (Mutis, 1983a: 102).

Interestingly, Mutis included among the set of natural phenomena that the Copernican system explains with easiness and clarity not only astronomical phenomena – like the motion of heavenly bodies on the firmament or that Venus and Mercury, unlike the other planets, have no opposition to the sun – but also physical earthly phenomena. In so doing, he not only evaluated the Copernican system from an astronomical point of view but, more importantly, from a physical one in which natural phenomena related to the laws of motion can be accounted by assuming a geokinetic system. Thus, by using a physical approach to the problems of the determination of the best system of the world, Mutis followed a Galilean demonstrative strategy in which the criticism against the Tychonic system was founded on the construction of an entirely new physical science which was based on a non-Aristotelian conception of motion.[443]

[442] *Cf.* Mutis (1983a), pp. 101-102. It is worth of notice that Mutis included the Earth's shape among the physical phenomena that could be accounted by the Earth's motion. It reveals the important role of Juan's diffusion of the results of the geodesic expedition in Mutis' appropriation of «Newton's experimental physics».

[443] Probably, Galileo's revolution in physics is one of the most studied topics in the historiography of science. Interesting studies can be found in Koyré (1943); Hall (1965); Hall (1981), pp. 36-77; Hooper (1998); Naylor (2003).

However, Mutis' physical approach to the demonstration of the motion of the earth was mostly developed in his *Defence* of 1773.

By considering the Copernican system as a hypothesis in his *Apology*, Mutis reveals himself cautious and concerned of the implications of such statement in the highly scholastic context of New Granada. Nevertheless, in the 1770s, circumstances dramatically changed as *Fiscal* Francisco Antonio Moreno Escandón and Viceroy Manuel Guirior attempted to promote a set of modernizing reforms in New Granada's educational system.[444] Probably moved by such reformism, and by the fact that he already had begun to be considered as the "oráculo del reino", Mutis took a step forward in his defence of the Copernican system and, in 1773, he lectured his *Defence* at the *Colegio del Rosario*. Interestingly enough by its content, this lecture also had some external factors that played a fundamental role in the determination of its impact on New Granada's academic milieu and its historical importance. Firts, it presented Mutis' discussions of the central arguments for defending Copernicanism and his interpretation of Newton's experimental physics to an audience that consisted of the newly elected Viceroy Manuel Guirior and his wife, María Ventura de Guirior, to whom Mutis dedicated his lecture.[445] By doing so, he was assuring his position as a promoter of the modernization of education in New Granada – one of the key aspects of Guirior's educational policies in New Granada –[446] and the viceroyal support in the upcoming events of the polemic with the Dominicans. Second, it is also remarkable that Mutis lectured at the college of the Dominicans, die-hard defenders of the scholastic tradition that he himself criticized in his lecture. In this sense, he claimed that New

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[444] As of the 1760s, one of the main interests of New Granada's viceroys was adopting the enlightened educational policies that were being developed by Charles III and his enlightened ministers. Their strategies are well described in their *Relaciones de mando*. Among them, Guirior's and Caballero y Góngora's *Relaciones* are revealing of the struggles for modernizing education in New Granada. *Cf.* Guirior (1869), pp. 111-180; Caballero y Góngora (1869), pp. 181-280.
[445] *Cf.* Mutis (1983a), pp. 117-121.
[446] *Cf.* Guirior (1869), pp. 111-180.

Granada's students should be educated out of the precepts of the Aristotelian physics, thus postulating that they should be educated in the light of Newton's experimental physics.

The *Defence* begins by establishing the main thesis that is going to be defended: "En fuerza de las reflexiones que iba haciendo a mis solas en la dulce soledad de esos espacios inmensos, a donde felizmente ni penetra ni pudo inquietarme la gritería confusa de las aulas, acabé de conocer finalmente que la tierra, en que habitamos, *es un verdadero planeta*, adornado de aquella hermosa luz que presta el sol a todos ellos" (1983a: 107).[447] I would like to draw attention upon two specific points of this characterization. First, Mutis clearly compared his approach to the problem of the determination of the system of the world with that of New Granada's scholasticism, arguing that, in order to understand the basic elements of the Copernican system, it was necessary to abandon the scholastic approach to study nature as it only confuse the mind of the young students.[448] As we shall see, he did so by insisting on the need to adopt Newton's experimental physics. This conclusion is particularly interesting because I commented above that Mutis opposed Newton's experimental physics to the hypothetical-deductive systems – mostly to the mechanical systems derived from Cartesianism. Accordingly, by considering here that he also opposed his interpretation of Newton's experimental physics to the scholastic tradition, it is possible to understand other features of his appropriation of it. For instance, that he used it as a foundation for his rejection of the scholasticism of New Granada's university context and consequently as a way to support the reforming projects emerging in the 1770s.

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[447] My emphasis. It is worth of notice that, in the *Defence*, Mutis depicts the system of the world by describing an imaginary travel in which he is accompanied by James Ferguson, a well-known Scottish promoter of Newton's physics in the eighteenth century. His works were focused on the astronomical aspects of Newton's works and they came to be highly used in Spain as textbooks for understanding Newton's astronomy. *Cf.* Ferguson (1809). A study on Ferguson's works as promoter of Newtonianism is in Robin (1998), pp. 103-140.

[448] *Cf.* Mutis (1983a), pp. 110-115. It is interesting to highlight that in presenting his criticism against the scholastic approach in the *Defence*, Mutis explicitly referred to Newton's experimental physics.

After establishing the general frame of his discussion regarding the Copernican system and the conditions upon which it is possible to defend it, Mutis continues describing the landscape he had seen in his mental journey. Focusing on the mathematical description of the ratios and proportions of the motion of planets and how they lead to the postulate the Copernican system, he declares himself a convinced Copernican:

> Vuelvo ya, Excelentísimo Señor, de mi viaje mental, aunque fatigado y rendido, mucho más ilustrado. Y hallándome instruído con finos conocimientos y claras luces que nunca pude descubrir en las tinieblas de la vieja filosofía, *me confieso públicamente declarado copernicano* (…) *defendiendo ahora como tesis lo mismo que propuse entonces como hipótesis* (Mutis, 1983a: 112).[449]

Interestingly, Mutis' defence of the Copernican system as a thesis in the *Defence* is based on both the authorities to which he alluded in its first pages – the Church authority and the royal authority who had embraced the system – and the mathematical approach to nature that had led to the discoveries accomplished by physicists such as Galileo and Newton. In Mutis' words:

> En esta admirable máquina de planetas y cometas se eleva la tierra a la dignidad de planeta, que injustamente se le había negado. Se ajustan y componen todas las apariciones con que se engañan los ojos de los que miran al cielo sin estudio. Se explica la aberración de la luz de las estrellas fijas. Se averiguan las magnitudes y distancias de los planetas. Se calculan los tiempos periódicos de sus revoluciones. Se computan los lugares de los cometas. Y, finalmente, lo que parece más oculto

[449] My emphasis. As I pointed out in Chapter 4, it is important to highlight that despite that Mutis only declared himself a Copernican in 1773, the manuscript evidence reveals that he used the Copernican system as a reference to discuss several natural phenomena related to the motion of bodies in conic sections. *Cf.* RJB III, 7, 1, 5, ff. 325r-328r. It is likely that in his lectures at the cloisters of the *Colegio del Rosario* he defended several times the Copernican system as a thesis.

> y que tal vez nunca hubieran llegado a penetrar los hombres, que pronostican la aparición de cometas, verificada ya en el que estaba pronosticado para el año de 1759; laurel con que se coronó la memoria del ilustre Newton y con que triunfará eternamente la filosofía newtoniana de las otras filosofías (1983a: 115).

In this passage there are various features of Mutis' Copernicanism that should be underlined. First, we can see that he accepted the Copernican system on the basis that it explains several natural phenomena that cannot be accounted by other systems – both systems of the world and philosophical systems. Second, the list of natural phenomena that Mutis refers to in this passage is strictly astronomical. As we shall see, it was complemented by the list of physical phenomena that can be accounted by accepting the Copernican system, as Mutis discussed it in the development of his *Defence*. As a result, it is possible to claim that Mutis' acceptance of the Copernican system was a part of his commitment with the defence of modern science and his rejection of the Spanish university traditions; in the sense that the Copernican system depicted the reestablishment of the disciplinary boundaries between physics and mathematics that characterized his interpretation modern science of it. This feature is particularly interesting as it reveals that, when Mutis' Copernicanism led him to face the polemics with the Dominicans, he preferred to change the strictly debate of ideas – as he presented it in his *Defence* – to a rather sociological and political debate.[450] Third, Mutis considered that the mathematical approach to nature developed in the context of Newton's experimental physics allowed him to explain counter-intuitive features of the Copernican system. Thus, any characterization of nature based on appearances is corrected by a mathematical study of nature which leads to calculate the precise ratios and proportions of the motions of heavenly bodies – including comets – and

[450] *Cf.* AGNC, Sección Colonia, *Colegios* 12,2, ff. 274r-278r.

consequently to a better explanation of nature. This last feature of the passage reveals another interesting aspect of Mutis' Copernicanism: it does not stand by itself; rather, it is a consequence of his appropriation of Newton's experimental physics. Indeed, Mutis assumed the Copernican system as an extension of his commitment to Newton's experimental physics. In so doing, he focused on the explanation of several physical phenomena that can be accounted by assuming the Copernican system. In other words, I shall argue that Mutis' *Defence* is centered on the explanation of physical phenomena and consequently that he used a similar argumentative strategy as Galileo did in *Dialogo*.[451]

Mutis divided his lecture into two sections. In the first one, he discussed the general aspects of his Copernicanism, openly declaring to be a Copernican, and relating the Copernican system to the Newtonian methodology in which mathematics provides the basis for supporting the counter-intuitive assertions derived from the postulation of the motion of the earth.[452] In the second section, on the other hand, he decisively developed the arguments for supporting the Copernican system, presenting the earth's motion as a thesis. Interestingly, in his *Defence*, Mutis discussed three physical arguments that recall Galileo's physical arguments in the *Dialogo*, in which he analyses the motion of bodies in earthly atmosphere and advances a theory of tides that constitutes, for Galileo, the main evidence for the Copernican system.[453] Thus, it is important to highlight that Mutis moved, in his lecture, from superficially commenting some astronomical arguments in favour of the Copernican system – the motion of heavenly bodies, the lack of opposition of Venus and Mercury – to discuss in detail the physical arguments that

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[451] It must be borne that despite that in the third day of the *Dialogo* Galileo presents asronomical observations of the phases of Venus and the Jupiter's moons as evidence supporting the Copernican system, he only considers as a decisive evidence the physical arguments that he develop in the second day and particularly the argument derived from the ebb and flow of sea. *Cf.* Palmieri (1998).

[452] *Cf.* Mutis (1983a), pp. 99-102.

[453] For Galileo's theory of tides and its importance on the demonstration of the Copernican system, see Drake (1990), pp. 70-82; Palmieri (1998), pp. 224-227; Graney (2008); Schmaltz (2015).

Galileo advanced as evidence to support it. In this sense, the variation in the quality of Mutis' analysis of astronomical and physical arguments reveals what they represented for him and his mastery of the principles of each field. Certainly, although he had some insights regarding astronomy – the manuscript evidence suggests that he was interested in the astronomical observation in that period –,[454] there is no doubt that Mutis' training in physics was more solid than in astronomy and consequently it is not strange that his commentaries regarding the physical arguments for supporting the Copernican system were richer in details than his commentaries based on astronomical observations. Mutis' use of Galileo's physical arguments as they were presented in the *Dialogo* is also revealing of the intellectual traditions influencing Mutis' appropriation of the mathematization of nature[455] and the problems in the reception of early modern science in Spain and the Spanish Atlantic world in the eighteenth century.[456]

The first physical argument that Mutis considered in his *Defence* accounts for earth's motion by considering the physical implications of such a motion on the bodies when they are moving inside the earth's atmosphere. For him, the bodies in the earthly atmosphere are accelerated by the motion of the atmosphere itself. In Mutis' words: "Las nubes, las aves y los demás cuerpos libremente pendientes en la atmósfera son arrebatados y llevados con la misma atmósfera por el mismo movimiento que tiene la atmósfera, común al de la tierra" (1983a: 116). According to Mutis, the short distance between the Earth's surface and the objects hanging in its atmosphere, like birds and clouds, is the key aspect for accounting for their motion in the

[454] *Cf.* RJB III, 1, 2, 59; RJB III, 8, 1, 13; RJB III, 4, 10, 1. For Mutis' astronomical knowledge, see Arias de Greiff (1993), pp. 209-2212; González de Posada (2009); Martín-Fernández (2011).
[455] So far, I have not been able to determine Mutis' sources for his appropriation of Galileo's physical arguments. Further research in the archives of Spain and Colombia, on the catalog of Mutis' personal library, and the works he used for references, could shed light on this particular issue, depicting a more detailed panorama of the sources for the appropriation of modern science in America in the eighteenth century.
[456] It is a well-known fact that Galileo's physical arguments – especially his theory of tides – were soon discredited and replaced by the physical arguments developed in the frame of the progress of the mechanical philosophy and Newton's theory of tides. *Cf.* Palmieri (1998).

frame of the Copernican system. In other words, as bodies in the atmosphere are not attached to the earth's surface, they are accelerated – or moved *a motore traslato* – by the impulse caused by the earth's diurnal motion. Thus, Mutis concludes:

> Y así como el Padre Fortunato [Fortunato da Brescia][457] confiesa que todos los argumentos contra los copernicanos tomados del movimiento de los graves arrojados horizontalmente, o en alto, son de ningún valor, porque él mismo reconoce ser pequeña la distancia y que es muy poderosa la solución de los copernicanos, reconociendo el mismo Fortunato ser verdaderamente llevados los cuerpos por el impulso impreso a motore traslato: la misma solución conviene a su argumento siendo pequeña la distancia a que suben las nubes y las aves (1983a: 117).

Along with the motion of birds and clouds, Mutis also considered free-falling and the motion of projectiles as exemplary cases supporting the Copernican system. As a consequence, any argument coming from the supposedly perceived lack of their motion should be neglected because they actually share the atmosphere's diurnal motion. For Mutis, such a dragging force of the atmosphere, caused by the earth's diurnal motion, is progressively reduced as the distance to the Earth's surface increases. As he contends: "Confesamos abiertamente que en las partes mucho más superiores se halla ya el aire incapaz de este impulso, pero también es cierto que hasta allí no suben las aves, porque no podrían respirar; ni los vapores de la tierra a formar las nubes, porque su propio peso les impide subir donde no podrán mantenerse, por estar el aire

[457] Fortunato da Brescia's works were really influential in the projects of modernizing education in New Granada. Mutis, Moreno Escandón, Caballero y Góngora, and other important reforming figures used them as textbooks in their different plans of study for different fields. In physics particularly they used *De qualitatibus corporum sensibilibus dissertation physico-theologica* (1749). In Madrid, it was also influential *Geometriæ elementa ad philosophiam comparandam accommodate* (1734).

demasiadamente ligero" (1982: 116). Therefore, in the highest points of the atmosphere gravitational forces of the Moon and Sun interact with the atmosphere's diurnal motion for moving the upper clouds and the air.[458] Certainly, such an idea implies that, in Mutis' defence of the Copernican system, there is an articulation of a Galilean mechanic of fluids with a Newtonian conception of gravitational forces. I shall explain it in detail in a moment.

In reading Mutis' argument it is easy to see a similitude with Galileo's argument deduced from the motion of birds and clouds in the atmosphere, as they are discussed in the second day of *Dialogo*. There, by considering the motion of birds and clouds, Salviati replies to Sagredo that their motion cannot be considered as a counterargument for the earth's diurnal motion because he has demonstrated that the atmosphere's diurnal motion has enough strength to move both animate and inanimate bodies.[459] However, whilst for Galileo the motion of bodies in the atmosphere "nè apporta aiuto, nè disaiuto" (Galilei, 1632: 177) to the conception of the universal motion – it means, that it cannot be considered as an argument either for accepting or neglecting the Copernican system –, in Mutis' opinion, it should be considered as one of the arguments in favour of the Copernican system. Undoubtedly, this little twist in Mutis' argumentation is caused by his articulation of Galileo's physical arguments with his appropriation of "Newton's experimental physics", as the latter allowed him to assume a mathematically deduced conclusion as a true explanation of natural phenomena.

This idea is reinforced by the fact that, a few lines after establishing the motion of birds and clouds as evidence for the Copernican system, Mutis referred to a Newtonian conception of the motion of the highest parts of the atmosphere: "Es evidente que si no hubiera otras causas que produjeran la irregularidad de los vientos, se observaría una constant regularidad en el modo

[458] *Cf.* Mutis (1982), pp. 82-83.
[459] *Cf.* Galileo (1632), pp. 177-178.

de soplar el aire; y ésta sería la que resulta del movimiento de la tierra de oriente a poniente (1983: 117). However, daily experience reveals that they move following different paths, not necessarily following such a pattern. Accordingly, Mutis concludes that winds are affected not only by the earth's motion but also by other causes, thus changing the direction of motion of the upper clouds in the atmosphere – lower clouds and animals moving in the atmosphere are not affected by those causes as they are dragged by the atmosphere. Mutis considered the gravitational influence of the moon and the sun and how they modify the motion of fluids among the causes that vary the direction of their motion: "Entre estas causas es muy poderosa la atracción del sol y de la luna, que hacienda en la atmósfera un continuado flujo y reflujo altera aquella regularidad de oriente a poniente que debería observarse por el movimiento de la tierra" (1983a: 117). Certainly, by considering the gravitational influence of the sun and the moon on the fluids in the atmosphere, Mutis distances from Galileo's position, embracing a more Newtonian mechanic of fluids for the analysis of the motion of bodies in the atmosphere. In this sense, we can see that Mutis introduced an epistemological variation to Galileo's argument from the motion of birds and clouds. By considering such an argument through his *Newtonian eyes*, Mutis could see its mathematical conclusions as a validation of the Copernican system rather than as a mere description of the conditions for its acceptability.

Nonetheless, the Galilean character of Mutis' discussion of the arguments for supporting the Copernican system as a thesis is more visible in his considerations regarding the ebb and flow of tides and the theory of tides underlying it. It is presented in his second argument for supporting the Copernican system as a thesis, which is an extension of the consequences and experimental implications of the argument from the motion of the bodies in the atmosphere. According to Mutis, when any vessel containing any kind of fluid is accelerated, the substance that it contains moves in the opposite direction. He exemplifies this by considering some experiments with glass vessels that are completely filled with water and then accelerated:

> Supuesta esta constante experiencia, se deduce claramente que la superficie del agua contenida en aquel vidrio está sin movimiento alguno; pues si tuviera alguno debería ser en sentido contrario a la revolución que se le daba y al instante se derramaría alguna pequeña cantidad, pues se supone en la experiencia el vidrio perfectamente lleno (Mutis, 1983a: 118).[460]

As we can see, like Galileo, Mutis considered ebb and flow phenomena as an argument in favour of the Earth's diurnal motion. It must be borne that at the beginning of the fourth day of the *Dialogo*, Galileo advances two basic premises which support his conception of the ebb and flow of sea as the only valid physical argument in favour of the Earth's diurnal motion: "che quando il globo terrestre sia immobile, non si possa naturalmente fare il flusso, e reflusso del mare, e che, quando al medesimo globo si conferiscano i movimenti già assegnatili è necesario, che il mare soggiacia al flusso, e reflusso, conforme a tutto quello, che in esso viene osservato" (Galilei, 1632: 410). As we can see, Mutis extended Galileo's considerations regarding the ebb and flow of the sea to account phenomena of the motion of fluid bodies in the atmosphere as well.

However, the similitude with Galileo's consideration in the fourth day of *Dialogo* are not limited to pointing out the argumentative character of ebb and flow phenomena. Like Galileo, Mutis also claimed that one of the key aspects for the production of ebb and flow, as an effect of the earth's motion, is the profundity of the waters. In this sense, for both of them, the small profundity of ponds and lakes is the main cause why we do not see tides in them. In examining

[460] There is no evidence to claim whether Mutis performed the experiments he describes in his *Defence*. However, by considering the fact that we have evidence of the descriptions of multiple experiments and observations that he actually did, it is likely that he did not made them and they are rather accounts of experiments based on Galileo's *Dialogo*.

the particular phenomena caused by the consideration of the ebb and flow as an effect of the earth's diurnal motion, Galileo claims: "E prima non dovremo haver difficultà nell'intendere, onde accagia, che ne i laghi, stagni, & anco ne i mari piccolo, non sia notabil flusso, e reflusso" (1632: 425).[461] For Galileo, the lack of ebb and flow of lakes and ponds is caused by their small size, which do not provide enough space to cause variations in the accelerations of the parts of water, and by the oscillatory motion of the water caused by the impetus produced by the Earth's motion. Similarly, Mutis argues:

> A semejanza de esto podemos considerar que todos los estanques y lagunas, de que hasta ahora tenemos noticia, no llegan a la profundidad de 100 varas; y a la verdad, aunque excedieran en otro tanto era lo mismo, pues 200 varas respecto del semidiámetro de la tierra, que consta de 8.447.584 varas,[462] esto es, ocho millones cuatrocientas cuarenta y siete mil quinientas ochenta y cuatro varas y una cuarta en el mismo Ecuador, según las exactísimas observaciones hechas en Quito por don Jorge Juan, aquellas doscientas varas es una cantidad muy pequeña respecto del semidiámetro de la tierra; luego cualquier laguna se puede considerar como un pequeño vaso de agua sumamente distante del centro de la tierra, por donde pasa el eje del movimiento; luego no debe haber ondulación alguna en la superficie de las aguas contenidas en los estanques y lagunas (1983a: 118).

[461] It is important to clarify here that Galileo refers to the relationship between the profundity of water and the ebb and flow of sea in two different passages of the *Dialogo* in two different senses. Firstly, he criticizes the Aristotelian idea stand by Simplicio according to which ebb and flows were caused by the different profundities in the bottom of the seas. *Cf.* Galilei (1632), pp. 412-413. Secondly, after claiming the "pottisima e primaria" cause of the ebb and flow, he comments that tidal phenomena are also affected by the profundity of seas and, as a result, as ponds and lakes are not sufficiently depth, they do not have ebb and flow. *Cf.* Galilei (1632), pp. 421-425.

[462] A *vara* was a Spanish unity of measure that corresponded to *circa* 0,83 meters. It was highly diffused in the Spanish America and it is still used in some regions of America and the Caribbean. *Cf.* Cuadrado & Peset (1997).

Consequently, for Mutis, the undulation on the surface of water caused by the earth's motion only can be seen in the ocean waters, which, being sufficiently depth, would be accelerated toward the opposite direction of the earth's motion: "Confesamos abiertamente que en el grande océano, cuya profundidad es grandísima, deben participar las aguas del movimiento de oriente y poniente" (Mutis, 1983a: 118).

Undoubtedly, Mutis' use of Galileo's theory of tides is more than surprising. Widely discredited since the end of seventeenth century, it had been replaced with Newton's theory of tides in which the attractive force of the moon was considered as the cause of the periodical ebb and flow of the oceans and seas.[463] Furthermore, Newton's own theory of tides had been refined in the eighteenth century by Laplace.[464] What is even more shocking is that Mutis himself referred to the variations that gravitational forces from the sun and the moon produce in the ebb and flow of the sea and the air in the highest parts of the atmosphere:

> Es evidente que si no hubiera otras causas que produjeran la irregularidad de los vientos, se observaría una constante regularidad en el modo de soplar el aire; y ésta sería la que resulta del movimiento de la tierra de oriente a poniente. Mas como esta regularidad produciría muchísimos inconvenientes, el Autor Sapientísimo de la Naturaleza proveyó a nuestras necesidades, poniendo otras causas que alteraran aquella regularidad nociva al bien del hombre. Entre estas causas es muy poderosa la atracción del sol y de la luna, que haciendo en la

463 It must be borne that Newton's theory of tides accounts periodical ebb and flows as the effect of the attraction of the moon – and in a minor scale of the sun – on the fluid particles of water and the difference with which such attractive force would attract the same fluid particle if it were placed at the centre of the earth. *Cf.* Palmieri (1998), p. 248. Newton's description of his theory of tides is in Book I, Proposition LXVI of *Principia*.

464 A study on the historical evolution of the theory of tides since Galileo is in Palmieri (1998).

> atmósfera un continuado flujo y reflujo altera aquella regularidad de oriente a poniente que debería observarse por el movimiento de la tierra (Mutis, 1982: 83).

As we can see, Mutis' articulation of Galileo's and Newton's theory of tides is founded on the theological assumption that the gravitational actions of the moon and sun upon the earth have a purpose for the life of men. In this sense, it is possible to claim that Mutis' appropriation of Galileo's theory of tides for supporting the Copernican system is determined by the theological foundation of his own interpretation of "Newton's experimental physics" as he discussed it in his *Preliminary discourse* and *Elements*. Certainly, such an appropriation led Mutis to ignore several theoretical and metaphysical aspects of Galileo's theory of tides. It is reflected, for instance, in the fact that he failed in perceiving Galileo's criticism against the idea of the influence of the moon on tides as it was defended by Kepler:

> Il dire anco (come si referisce d'uno antico matematico) che il moto della Terra, incontrandosi col moto dell' orbe lunare, cagiona, per tal contrasto, il flusso e reflusso, resta totalmente vano, non solo perchè non bien dichiarato nè si vede come ciò debba seguire, ma si scoger la falsità manifesta, atteso che la conversione della Terra non è contraria al moto della Luna, ma è per il medesimo verso: talchè il detto e imaginato sin qui da gli altri resta; al parer mio, del tutto invalido. Ma tra tutti gli uomini grandi che sopra tal mirabile effetto di natura hanno filosofato,più mi meraviglio del Keplero che di altri, il quale, d'ingegno libero ed acuto, e che aveva in mano i moti attribuiti alla Terra, abbia poi dato orecchio ed assenso a predominii della Luna sopra l'acqua, ed a proprietà occulte, e simili fanciullezze (Galileo, 1632: 455-456).

This feature is particularly interesting as it emphasizes the eclectic character of Mutis' understanding of the experimental physics. All in all, I think that the lights and shadows in Mutis' interpretation of Galileo's physical arguments should be taken as the features of his own appropriation of the use of physics for arguing in favour of the Copernican system. An appropriation that was undoubtedly determined by Mutis' *Newtonianism* and his own pretension of moving the debate of ideas regarding the Copernican system out of the sphere of its religious concerns. A pretension that, as we shall see in the next part, was not completely satisfied.

The expulsion of the Jesuits from the Spanish territories and its consequences in New Granada's education

In 1767, the King of Spain, Charles III, published a *Pragmática Sanción* in which he dictated the expulsion of the Jesuits of Spain and the Spanish Atlantic world "moved by weighty reasons (…) he was locking away in his royal breast" (*Pragmática Sanción*, 1767: 1). Undoubtedly, this measure was one of the most important consequences of the *Pesquisa Secreta*; a secret investigation performed by Campomanes and the Earl of Aranda, members of the Extraordinary Council of Castille, a committee created in order to investigate the promoters of the "Hat and Cloak Riots" (*Motín de Esquilache*) occurred in 1766.[465] According to them, the *Motín de Esquilache*, produced in Madrid and some other Spanish cities as a consequence of the elevated prices of bread and some unpopular dressing codes created by Leopoldo de Gregorio, Marquis of Squillace, was promoted by the Marquis of La Ensenada and the Jesuits. Thus, they encouraged the idea of expelling the Jesuits as they were perceived as enemies of the royal sovereignty of the King.

[465] The historical details of the expulsion of the Jesuits and its political background exceed the limits of my analysis, which is focused on the study of its educative consequences in New Granada. Interesting studies about it can be found in Peset (1974), Peset (1975), García Trobat (1992), Albiñana & Peset (1996), Amalric & Domergue (2001), Pérez Estévez (2002), Dominguez (2005), Mestre Sanchis (2014),

Nevertheless, as Magnus Mörner argued, as new evidence has been progressively published since the nineteenth century, this historical reconstruction of the causes for expelling the Jesuits has resulted decreasingly satisfactory for most of the historians.[466] Different explanations have emerged in order to account the animadversion of Charles III and his ministers to the Jesuits and their educative institutions.[467] Among them, the idea of the institutionalization of regalism during Charles III's reign has been the most accepted one because it explains the political conditions of their expulsion, the general context in which it happened and its aftermaths.

In general, as Mörner defines it, regalism is "the assertion of royal rights in ecclesiastical affairs at the expense of the Pope" (1966: 157). As regards to America, these rights were introduced in 1493 through the Brief *Inter Caetera* of Pope Alexander VI, in which the Pope appointed the king of Spain Apostolic Vicar in the Indies. In this sense, the king was responsible of the government of both the temporal and spiritual issues of his subjects and territories. Likewise, the Brief also encouraged the evangelization of America and consequently it entailed an intimate relationship between the Church and the Royal Crown, as they were perceived as the two sides of the same coin.[468] As Antonio Domínguez pointed out: "La realeza tenía un matiz religioso, y el Pontificado, matices seculares. El pecado era un delito, y el delito, un pecado. La distinción entre clérigos y seglares no era nada clara; recuérdense casos como el cardenalato del

[466] *Cf.* Mörner (1966).
[467] In general, it has been accepted that the expulsion of the Jesuits was strictly related to the dispute of power between Church and State in Spain during the late-eighteenth century. Nevertheless, new evidence discovered by different historians has pointed out that there were other different causes influencing their precipitated expulsion. Thus, for instance, some historians have explained it as a result of Charles III's strong regalist policies. *Cf.* Herr (1958), pp. 11-36; Mörner (1966), and recently other historians have identify new evidence that proves that the Jesuits were involved in some conspiracies related to the British Empire. *Cf.* Pinedo (1996), Giménez López (1997-1998).
[468] It is well-known that the relationship between the papacy and the Spanish Royal Crown played a decisive role in the process of colonization of the New World. Some studies about the intricacies of such relationship are in Scott (1987); Muldoon (1994), pp. 96-109, 127-142; Bennett (2011).

duque de Lerma y el canonicato del conde-duque de Olivares" (1979: 74). However, a good relationship between the pope and the king not only assured for the latter the right to have a spiritual government in his territories as an apostolic vicar of the pope. By strengthen his relationship with the pope, the king also granted himself several fiscal benefits as he could get the payment of some ecclesiastical tributes such as the *Tres Gracias* or the tithes of the clerical orders.[469]

However, since the seventeenth century, the Spanish regalism faced serious problems as the clerical orders, especially the Jesuits, acquired a more influential and numerous representation in several state positions. Thus, for instance, the Royal Confessor had turned into a central figure in the Royal Court as he did not only direct the king's consciousness about his personal affairs, but he also participated in the decision-making process regarding the different problems affecting any sphere of the Spanish society. As Domínguez contends: "Aunque legalmente el más alto cargo civil era la presidencia de Castilla, en el terreno efectivo quizás fuera el puesto de confesor real el que confiriera más poder" (1979: 91).[470] In this context, as the Bourbons had elected Jesuits as royal confessors – thus modifying the Hapsburg tradition of electing Dominicans confessors –, the Company of Jesus had acquired a considerable influence and power among the Spanish Royal Court.

Nevertheless, as one of Charles III's main obsessions was establishing an enlightened absolutism in Spain, he encouraged an anti-Jesuitical propaganda, supported by his ministers – particularly by Campomanes, Roda, and the Earl of Aranda. Thus, by incriminating the Jesuits as promoters of the *Motín de Esquilache*, Campomanes and Aranda only tryed to emphasize the

[469] *Cf.* Domínguez (1979).
[470] Dominguez highlights the fact that the royal confessor not only had a symbolic power. He actually was the person designated to choose a great deal of the members of the court and he frequently was the president of the Council of the Inquisition. *Cf.* Domínguez (1979), p. 92.

Spanish regalism which was a condition for the acceptance and development of Charles III's enlightened absolutism. Charles III's and his ministers' regalism was accentuated during the papacy of Clement XIII, an anti-Hispanic pope who supported several Ultramontane ideas that the Jesuits embraced and encouraged as a foundation for their power and independence of the Spanish Crown. Consequently, as Mörner claims, "if we consider the general outlook of the people occupying key positions in and outside the Spanish government and the impact of what happened in Portugal in 1759 and in France in 1764, the turn of events from the 'Hat and Cloak Riots' of 1766 to the execution of the expulsion of the Jesuits one year later can come as no surprise" (1966: 162). As the Jesuits gained an enormous influence in the Spanish political sphere, and their *haciendas* provided them with a strong financial arm,[471] they were perceived as a threat to the sovereignty of the king in his attempt of advancing his enlightened policies.

One of the events that best illustrates the Spanish regalism and the enlightened absolutism to which it was related to, as well as the belligerent character of the relationship between the Catholic States and Rome that it entailed, was the so-called *Monitorio de Parma*. In the eighteenth century, Parma was a small Spanish enclave in Italy under the aegis of Phillip, Duke of Parma (brother of Charles III) and his son, Ferdinand. Both Phillip and Ferdinand, influenced by the enlightened minister Guillaume du Tillot, promoted as of 1764 different measures in order to reform the state and solve its economical problems. Among the measures, it was included the application of a set of taxes to the Church which arouse the conflict of interests between Rome and the Bourbon House. As Domínguez comments:

[471] For the Jesuits *haciendas*, their functioning, their economical benefits, and their administration after their expulsion, see Martínez Tornero (2008). A particular study of the Jesuits' *haciendas* in New Granada is in Colmenares (1969).

> Leyes desamortizadoras soñadas por Campomanes se aplicaron en un Estado pobre en el que la Iglesia era desmesuradamente rica; tributación obligada de los bienes eclesiásticos, sustanciación de las causas dentro del país, reserva de beneficios para los naturales en un ducado invadido por clérigos alógenos, establecimiento del *exequatur*, erección de tribunales especiales para urgir y velar el cumplimiento de todas estas disposiciones, tal fue el programa renovador, plenamente regalista, que, con aplauso del resto de los gobiernos, se quiso implantar en una Parma salida del anonimato en esta coyuntura (1979: 194).

As a response, Pope Clement XIII published in 1768 the Brief *Alias ad apostolatus* – also known in Spain as *Monitorio de Parma* –, in which he not only condemned the measures implemented in Parma, but he also claimed his sovereignty over it: "Alias ad apostolatus nostri notitiam non sine gravi animi nostri molestia pervenit, in Ducatu nostro Parmensi & Placentino a sæculari illegitima potestate edicta quædam contra Ecclesiæ jura" (Quoted from Campomanes, 1769: 97). In his Brief, Clement XIII claimed that the territory of Parma was part of the Pontificate States, also arguing that the tax policies were against the dispositions of the Bull *In coena domini* – in which it was established, among other things, the excommunication to those creating new taxes to clergymen without the papal authorization.[472]

In 1769, Campomanes published his *Juicio imparcial*, in which he commented Clement XIII's Brief from the perspective of the enlightened absolutism promoted by the Bourbon House. In *Juicio imparcial*, Campomanes established that the Brief had three basic problems: the assumption of the sovereignty of the Pope over Parma; the establishment of the possibility for the subjects to not being loyal to the Crown; and the influence of the General of the Jesuits and

[472] A detailed study of the conditions leading to the creation of these fiscal policies in Parma and its aftermaths is in Domínguez (1979), pp. 194-195.

the Cardinal Torrigiani in the resolutions of the Brief and Clement XIII's attitude against the Spanish control on Parma.[473] Thus, Campomanes claims:

> Sin atender la Corte de Roma al solemne Tratado de Aquisgrán [Treaty of Aix-la-Chapelle] de 1748, ni a los títulos de que se haya asistidos el Sr. Infante, empieza el Monitorio con la cláusula de apropiarse el Papa la Soberanía de Parma, y Plascencia [Piacenza]. Esta usurpación, junto con mandar a los vasallos, contra el sagrado vínculo del juramento de fidelidad, que no obedeciesen a su legítimo soberano en los puntos de que trata el Breve, no solo ofende la justicia, sino también al decoro de todos los soberanos de la Real Sangre de Borbón; y lo que es más, a cuantos potentados intervinieron en la Paz de Aquisgrán (1769: 2-3)

As we can see, Campomanes' explicitly referred to the opposition of Clement XIII's Brief to the Treaty of Aix-la-Chapelle, thus emphasizing its international consequences. Thereby, the Spanish Crown created a scenario where the papal intervention over Parma not only had regional consequences in Parma; conversely, it was seen as an affront to the Bourbon House and, by extension, to the European Catholic Crowns. As Domínguez describes it: "La habilidad de la diplomacia borbónica supo mover los hilos e internacionalizar el conflicto, de manera que toda la Europa católica, incluidos Portugal y Viena, mirasen como propio el asalto a la soberanía y a las regalías desde una Roma empeñada en identificar sus intereses con la causa de la religion" (1979: 194).

[473] *Cf.* Campomanes (1769). Several studies on Campomanes' *Juicio imparcial* and his conception of the relationship between Church and State are in Ferrer Benimeli (Ed.) (2002).

However, the most interesting feature of Campomanes' *Juicio imparcial* is his consideration that the Pope's Brief was deeply influenced by a third party, which was interested on destabilizing the already deteriorated relationship between the Crown and Rome:

> Estamos muy distantes de pensar, que el candor y mansedumbre nativa de Clemente XIII se dejase por sí llevar a un paso tan irregular, si el ánimo pontificio se hallase instruido perfectamente de la verdad. La obrepción y subrepción y las sugestiones, son lazos que arma la astucia a todos los príncipes, sin que se liberte de ellos la sublime dignidad del successor de San Pedro (1769: 6).

Despite that Clement XIII's papacy had been anti-Hispanic in the particular circumstances in which the Pope had to choice between France and Spain, for Campomanes, the direct responsible of the papal intervention in Parma was Cardinal Torrigiani and the Father General of the Jesuits, Lorenzo Ricci.[474] By incriminating them and diffusing the idea that the Jesuits were responsible of the *Monitorio de Parma*, Campomanes encouraged the Catholic States to force the suppression of the Company of Jesus, which was committed in 1773, under the aegis of Clement XIV.

One of the most important aspects of Charles III's *Pragmática Sanción* was that it ordered that the temporal goods of the Jesuits should fall under royal jurisdiction. The Jesuit's *haciendas*, universities, and in general their goods and chattels, should be administered by the Spanish crown, which created the *Junta de Temporalidades* for that purpose. As Carlos Alberto Martínez Tornero explains, the fact that one of the greatest concerns of the Royal Crown, after the expulsion of the Jesuits, was the administration of their temporalities, reveals "la existencia de

[474] Despite the apparent conciliatory character of the reference to the influence of a third party interested on the results of Clement XIII's Brief, throughout the *Juicio imparcial*, Campomanes made it clear that the royal authority neither depend on nor is connected with the papal authority. See, for instance, Campomanes (1769), pp. 321-322.

fuertes intereses económicos en el proceso" (Martínez Tornero, 2008: 537). The appropriation by the King of the temporalities aimed to cover the expenses of the expatriation of the members of the Company of Jesus and the payment oaf a life pension to the priests of the Company.[475]

The *Junta de Temporalidades* was a Spanish royal institution created for controlling and ruling the garnishment of the goods of the expelled Jesuits in Spain and its overseas territories. It was directed by the members of the Extraordinary Council of Castile who had developed the process against the Jesuits – Campomanes and the Earl of Aranda. They ruled and controlled a set of co-dependent institutions where not only the immovable properties of the Jesuits were administered but also their goods and chattels, which were stored in a *depositaría general* to be protected.[476] In 1769, as those possessions began to be deteriorated, it was decided to put in a public auction a good deal of them and, as a result, the *Junta* decided to create minor municipal and provincial *Juntas de Temporalidades* to take care of the auction processes. Said decision also affected the *Juntas* in America, which were in charge of deciding the best manner to reuse the buildings of the Jesuits there – most of them dedicated to education and to agriculture and cattle raising. As Martínez Tornero claims: "En las Indias, las Juntas superiores subalternas se ocuparían de proponer los destinos más apropiados para los edificios jesuitas en aquellos parajes, atendiendo a las particularidades de cada una de esas zonas" (2008: 538). The Superior *Juntas*, constituted by the viceroy or governor of the place where the *Junta* was established, the dean of the royal audience, and one *Fiscal*, who was the protector of the indigenous population, had the authorization to create subaltern *Juntas* in those places where it was necessary either because of their difficulties to be controlled by the local Superior *Junta* or because of the multiple properties which it should manage.

[475] *Cf.* Tornero Martínez (2008), pp. 561-562.
[476] *Cf.* Tornero Martínez (2008), pp. 538-546.

In the case of New Granada, the Superior *Junta de Temporalidades* was set up in 1768 by Viceroy Pedro Messia de la Cerda, for whom it had two major tasks. First, the alienation and sale of the goods of the Jesuits which "administradas no producían competente utilidad" (Messía de la Cerda, 1869: 108). Second, the *Junta* had the responsibility of determining how to administer the educative enterprises of the Jesuits in New Granada, which included, the administration of the building of their university and college in Santa Fe, their right to graduate students, and the administration of their library. In this sense, Francisco Antonio Moreno Escandón, *Fiscal* protector of indigenous of New Granada, promoted the idea of creating a public university, which should embrace the precepts of the enlightened reformism promoted by Charles III and his ministers in Spain.[477] As Messia de la Cerda described it in his *Relación de mando* to Viceroy Guirior:

> Al mismo tiempo en la Junta superior de aplicaciones, se ha tenido por objeto llenar las intenciones piadosas del Soberano, y promover la instrucción pública y verdadero bien de los vasallos, a que se ha dirigido la determinación de que se erija en esta capital una Universidad pública y estudios generales, que remedie el abuso y desorden que en la actualidad se experimenta (1869: 108).

Such "abuse" and "disorder", according to Messia de la Cerda, were the results of the intervention of the Dominicans in New Granada's educational milieu, as they had rejected the establishment of the public university, pretending to control the monopoly of the education because they have the right to graduate students. Likewise, Messia de la Cerda claims that, in hindering the creation of the university, the Dominicans have being backed up by the "Reverendo Arzobispo [Agustín Manuel Camacho], que como del mismo orden antepone su

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[477] A complete study on the influence of Moreno Escandón's reforms in New Granada's university milieu is in Soto (2005b).

beneficio particular al común y universal del reino" (Messia de la Cerda, 1869: 108). In Messia de la Cerda's report to the newly elected Viceroy Guirior, we can find several aspects that characterized the debates regarding education in New Granada after the expulsion of the Jesuits: the conflict between Dominicans and the viceroyalty's authorities, the debates regarding the modernization of education in Santa Fe, the opposition between Church and State that led to the polarization of positions, and the confrontation of Jansenist and Ultramontane ideas.[478]

In general, New Granada's *Junta de Temporalidades* was not only focused on the administration and sale of the goods and immovable properties of the Jesuits. More importantly, through the works of the *fiscal* Moreno Escandón, it seized the opportunity for establishing the legal conditions for creating a public university, which would make it possible to modernize the education in New Granada and the institutionalization of regalism in New Granada's administrative spheres. As I shall argue in the next section, Mutis' debates with the Dominicans concerning the Copernican system were produced in the context of emergence of the idea of creating a public university in New Granada and the debates it aroused. As a consequence, I shall argue that such debates were used by both sides in conflict as a way to support their respective positions in New Granada's educative panorama in the 1770s.

The debate between Mutis and the Dominicans and its political consequences

One of the central problems that left the expulsion of the Jesuits from New Granada in 1767 was related to the administration of education in the viceroyalty.[479] Since the seventeenth century,

[478] It is important to consider that by referring to the Archbishop of Santafé, Viceroy Messía de la Cerda is clearly establishing a precedent of the viceregal position in the polemic between Church and State as regards to education. Under these considerations, the conflict was not between the Dominicans and Mutis, but between the two institutions they represented. *Cf.* Messía de la Cerda (1869), pp. 108-109.

[479] There are several studies dedicated to the reforms that were carried out after the expulsion of the Jesuits. See, for instance, Hernández de Alba (1961), Rivas Sacconi (1993), Ocampo López & Soler Lizarazo (2012), Soto

both the *Universidad de Santo Tomás* – also known as *Universidad Tomística* –, directed by the Dominicans, and the *Universidad de San Francisco Javier* – also known as *Universidad Javeriana* –, directed by the Jesuits, were the only institutions with the royal and ecclesiastical right to graduate students.[480] Thus, the students of the different colleges in New Granada (not only in Santa Fe, but also in the other cities of the viceroyalty) had to apply to them in order to get a professional title which allow them to put in practice their respective careers. Therefore, after the expulsion of the Jesuits, the Dominicans of the *Universidad Tomística* acquired the monopoly of education in New Granada as it turned into the only institution with the right to graduate students. An exclusive right that they did not mean to give away to any other institution and that provided them with a special status in the cultural and political spheres of the Viceroyalty: their political influence grew disproportionately as their graduated students occupied different positions in the administration of the University and the Viceroyalty. In this sense, the *Universidad Tomística* turned in an almost independent center of education, in which the State had no considerable influence or power of decision.[481]

Since 1768, the *Junta de Temporalidades* decidedly tackled this problem by considering the possibility of establishing a reform of education centered on the creation of a secular public university, directed by the State. This idea was firstly thought by *Fiscal* Moreno Escandón, who argued that the new university should be guided by a new plan of studies founded on the principles of the experimental philosophy, thus neglecting any influence of the scholastic tradition.[482] As Enrique Villalba Pérez explains, one of the central aspects of Moreno Escandón's

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(2005b), Mejía (2016). An excellent source for studying the official documentation of that period is Hernández de Alba (Ed.) (1969).

480 A good survey on the early stages of New Granada's university education is in Rivas Sacconi (1993), pp. 41-57.

481 *Cf.* Soto & Negrín Fajardo (1984).

482 The original version of Moreno Escandón's Plan is in AGNC, Sección Colonia *Colegios SC*. 12,2, ff. 286r-309r. A copy of the manuscript is in RJB III, 2, 4, 11. A transcribed version of the manuscript is in Hernández de Alba (1969).

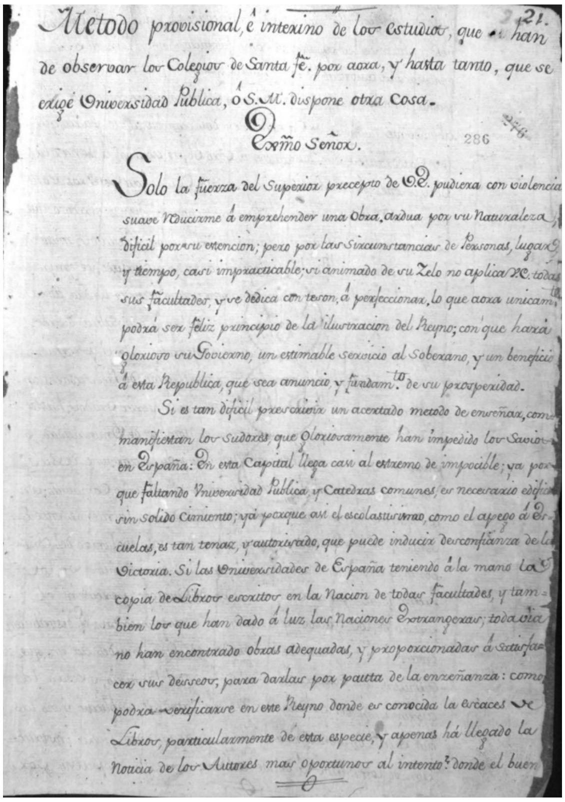
plan was the abolishment of the clerical influence on the education of the students that would occupy the administrative positions in the universities and the state: "No obstante, en su argumentación ocupa un lugar bien destacado la necesidad de acabar con el dominio de los religiosos sobre los cargos docentes y administrativos de la enseñanza superior" (Villalba Pérez, 2003: 70). That was the case, because Moreno Escandón perceived that religious orders were suitable for teaching rather for "la vida eclesiástica que para el servicio del Estado" (Villalba Pérez, 2003: 70).

The idea of creating a public university that Moreno Escandón devised in the frame of the *Junta de Temporalidades* was strongly supported by Viceroy Messía de la Cerda – president of the *Junta* – and the Cabildo of Santa Fe as it was evidenced in Messía de la Cerda's *Relación de mando*.[483] In 1770, all the members of the *Junta de Temporalidades*, excepting the Dominican Archbishop of Santa Fe, Agustín Manuel Camacho, supported the idea of Moreno Escandón. Thus, they sent the proposal to the Royal Court asking for its approval and, in the meanwhile, they forbid to the Dominicans to graduate students – a prohibition that stood until 1774.

Evidently, the Dominicans did not stand with their arms crossed. After the expulsion of the Jesuits, they promoted the idea that they should get their goods, thus holding the exclusive right to graduate students and an almost absolute control of the educative monopoly in New Granada – a monopoly that they *de facto* had. But, as Villalba Pérez comments, they doubled their bet, asking to be the legal owners of the Jesuits' *temporalidades*. In so doing, they also aimed to neglect the policies coming from the *Junta de Temporalidades*, commissioning a friar to defend their cause at the Royal Court of Madrid:

[483] *Cf.* Messía de la Cerda (1869), p. 108.

Por su lado, los dominicos, conscientes del riesgo que tal iniciativa suponía para sus intereses, comisionaron a la Corte un representante, fray Jacinto Antonio Buenaventura con el encargo de oponerse y argumentar contra las propuestas de Moreno y Escandón, a fin de conseguir la continuidad de su universidad y de sus privilegios académicos (Villalba Pérez, 2003: 72-73).



Metodo provisional, é interino de los estudios, que se han de observar los Colegios de Santa Fe. por aora, y hasta tanto, que se erige Universidad Publica, ó S. M. dispone otra cosa.

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Exmo Señor.

Solo la fuerza del Superior precepto de V. E. pudiera con violencia suave reducirme á emprehender una obra, ardua por su Naturaleza, dificil por su extencion; pero por las circunstancias de Personas, lugar, y tiempo, casi impracticable; si animado de su Zelo no aplica V. E. todas sus facultades, y se dedica con teson, á perfeccionar, lo que aora unicamente podrá ser feliz principio de la ilustracion del Reyno; con que hará glorioso su Govierno, un estimable servicio al Soberano, y un beneficio á esta Republica, que sea anuncio, y fundam.^to de su prosperidad.

Si es tan dificil prescrivir un acertado metodo de enseñar, como manifiestan los sudores, que gloriosamente han impedido los Savios en España: En esta Capital llega casi al extremo de imposible; ya porque faltando Universidad Publica, y Catedras comunes, es necesario edificar sin solido cimiento; yá porque asi el escolasticismo, como el apego á Escuelas, es tan tenaz, y autorisado, que puede inducir desconfianza de la victoria. Si las Universidades de España teniendo á la mano la copia de Libros escritos en la Nacion de todas facultades, y tambien los que han dado á luz las Naciones Extrangeras, todavia no han encontrado obras adequadas, y proporcionadas á satisfacer sus deseos, para darlas por pauta de la enseñanza: como podrá verificarse en este Reyno donde es conocida la escaces de Libros, particularmente de esta especie, y apenas há llegado la Noticia de los Autores mas oportunos al intento? donde el buen

Figure 19. Front page of Moreno Escandón's draft of his Plan, AGNC, Sección Colonia, Colegios: SC. 12, 2., f. 286r.

In this context, a hard debate emerged between the Dominicans and Moreno Escandón in the early 1770s, regarding the control of education in New Granada.[484] The hardest stages of the conflict took place after 1774, when Moreno Escandón presented his study plan entitled *Provisional and interim method of studies that should be followed in Santa Fe's colleges by now and until it is*

[484] *Cf.* Soto (2005b); Villalba Pérez (2003), pp. 70-93.

created a public university or His majesty decides something else [*Método provisional e interino de los estudios que han de observer los Colegios de Santa Fe por ahora y hasta tanto que se erige Universidad pública o Su Majestad dispone otra cosa*]. Moreno Escandón's plan, presented in September 12th of 1774, was approved by the *Junta de Temporalidades* and implemented in Santa Fe's universities that very same year. The plan was created as a foundation for the creation of the public university and, consequently, Moreno Escandón intended that it were used in the *Universidad Tomística* whilst the public university was created. Likewise, the plan suggested that the ecclesiastical colleges were integrated to the public university, turning them into royal colleges.[485]

In Moreno Escandón's plan, he argued that, in order to reform New Granada's education, it was necessary to abandon the firm adherence to the scholastic tradition that had created a kind of partisanship in New Granada making it almost impossible to advance and to institutionalize the modern science at Santafé: "En esta capital llega casi al extremo de imposible, ya porque faltando universidad pública y cátedras comunes, es necesario edificar sin sólido cimiento, ya porque así el escolasticismo, como el apego a escuelas, es tan tenaz y autorizado que puede inducer desconfianza de la victoria" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 286r). Thus, Moreno Escandón argued that his plan intended to banish the partisanship that had been encouraged among the cloisters of New Granada's universities by the ecclesiastical orders and especially by the Dominicans. Conversely, he supported some kind of eclecticism that encouraged the liberty of choice for students framed in an education based on experience and observations, "porque solo debe reinar el [espíritu] de elección de todo lo Bueno, y de lo que se hallase más conducente en los autores modernos para los elementos de una útil filosofía" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 290v). Accordingly, the plan designed by

[485] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12, 2., ff. 286r-309r.

Moreno Escandón reached every level and subject of the education in New Granada, since the primary education until the doctoral formation. The plan included the description of the curricula of law, philosophy, theology, and medicine and their basic textbooks.[486] I would like to highlight some aspects of the curriculum of Philosophy, in order to shed light on the influence of Newton's experimental physics in Moreno Escandón's plan and its possible relationship with Mutis' own insights regarding the reform of education in New Granada.

The study plan that Moreno Escandón designed for philosophy divided its study in three years. In the first one, he suggested to teach logic; in the second one, physics; and finally metaphysics was taught in the third year.[487] The teaching of logic was designed to avoid the syllogistic discussion of topics and rather to embrace the study and memorization of the precepts of logic as Fortunato da Brescia presented them. However, one of the most interesting features of this first year of study of philosophy is that Moreno Escandón included the principles of geometry, arithmetic, algebra, and trigonometry among the subjects that should be taught, as he considered them a clear illustration of the scope of logic: "Después de navidad se dará principio a los elementos de la arismetica (sic.), algebra, geometría y trigonometría del Wolfio [Wolff], como en el año antecedente se ha leído en el Seminario de San Bartolomé. En estos preliminaries para la física útil, se va extendiendo la imaginación, y solidando el juicio de los niños" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 291r). The similarity of Moreno Escandón's characterization of the utility of mathematics with Mutis' inaugural lecture of 1762 is remarkable. Moreno Escandón not only considered Wolff's work as a textbook but, like Mutis, he also assumed that mathematics supports an appropriate method for investigating any subject, as it "prepares" the mind of the students to proceed adequately from simple premises to more

[486] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12, 2., ff. 290v-309r.
[487] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12, 2., ff. 290v-294r.

complex demonstrations. Consequently, despite that there is no direct evidence to claim that Mutis had a direct participation in the reforms promoted by Moreno Escandón in the early 1770s, this kind of references suggests that Mutis was a decisive and participating figure in the projects of modernization of education in the Viceroyalty.[488] Certainly, we have evidence that he participated in the reforms that Caballero y Góngora proposed since 1787[489] but, by considering these indirect references, we can also argue that he was involved in the reforming process as of the 1770s.

For Moreno Escandón, after studying mathematics, students had enough tools to study physics. He begins the description of the second year by criticizing the studies of physics that had been advanced in New Granada by the clerical orders: "Nada tiene de física, cuanto hasta aquí se ha enseñado en nuestras escuelas con este nombre" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 291v). Conversely, in his opinion, in the universities a non-philosophical language that did not deal with nature had been used, thus preferring abstract, useless questions. In order to avoid such an approach to the study of physics, Moreno Escandón asserted that it was necessary to emphasize the liberty of choice among students, founded on the principles deduced from observations and experiment: "Queda ya prevenido que en la filosofía debe prevalecer el *electicismo* [*eclecticism*?]. En ninguna parte es tan preciso este espíritu de elección, como en la física, en que la variedad de sistemas la tuvieron abatida, hasta el siglo presente, en que últimamente se ha reconocido que los únicos medios de cultivarla, son la experiencia y observaciones" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 292r). He specified his position by claiming that the best way to cultivate the spirit of election was promoted by Newton's methodology:

[488] It is also remarkable the similitude between the reforms ideated by Escandón and the drafts of the study plans that Mutis drawn up in the 1780s in the context of the reforms to education advanced by Viceroy Caballero y Góngora. See, for instance, RJB III, 7, 1, 17, ff.1r-5v.
[489] *Cf.* Hernández de Alba (Ed.) (1969), pp. 122-155.

> Este es el plan que se proponen los físicos de nuestros siglos, renunciando a todo espíritu de sistema; y parece el mismo que siguió Fortunato en su Física. Bien es verdad que habiéndose adelantado muchas observaciones y experiencias después que la escribió, que no se han generalizado por toda la Italia, como presentemente lo está el método newtoniano, es necesario leerlo con desconfianza en todos aquellos puntos que caracterizan el método de Newton (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 292v).[490]

The creation of the plan and its implementation in New Granada – between 1774 and 1779 – was not only significant by the considerable reforms that it promoted for education but, more importantly, because it was postulated as the initial step for the definitive creation of a public university in New Granada and the Dominicans did not fail in perceiving it that way. As a consequence, in 1774, they devised various projects to hinder in the Court of Madrid the process of creating the public university. Interestingly, one of their strategies consisted in deviating the attention of New Granada's Court to some other issues and their polemic with Mutis worked as a perfect smoke screen.[491]

The polemic between Mutis and the Dominicans began in June 25th of 1774, when he received an invitation to the *Conclusiones* of the course of philosophy of the *Univerisdad Tomística*, in which the Copernican system would be criticized. The invitation sent to Mutis said:

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[490] Despite that Moreno Escandón suggests to be cautious as regards to Fortunato da Brescia's interpretation of Newton's methodology, it is important to highlight that he is using Fortunato da Brescia's works as textbook for his lectures on physics. It reveals another important aspect that could be influenced by Mutis' lectures and study plans.

[491] My interpretation of the debates between Mutis and the Dominicans as a political debate concerning the control of education is based on Soto's, Negrín Fajardo's, and Lanning's ones. *Cf.* Lanning (1944); Soto & Negrín Fajardo (1984). However, it is important to point out that Mutis' correspondence to the Viceroy asking for a clarification of the situation reveals that he himself had perceived the double interest of the Dominicans in the polemics. See, for instance, AGNC, Sección Colonia, Colegios: SC. 12, 2., ff. 275r-277r.

> Thesis theologico-physico astrologica, etc. Unanimem consensum SS.PP. præcipue M. Propt. Patris Augustini et A.D. Copernicanum systema, stante veritate Sacrae Paginae est intolerabile catholicis et indefensabile per modum thesis, intolerabiliusque inspecta Sacræ Inquisitionis prohibitione, qua propter alia via tenent astronomi coelestia phenomena explanare et def(endere); in hac thomistica. universitate, kalendis Iulii Anni Domini 1974 [Fig. 20] (AGNC, Sección Colonia, Colegios 12,2., f. 264r).

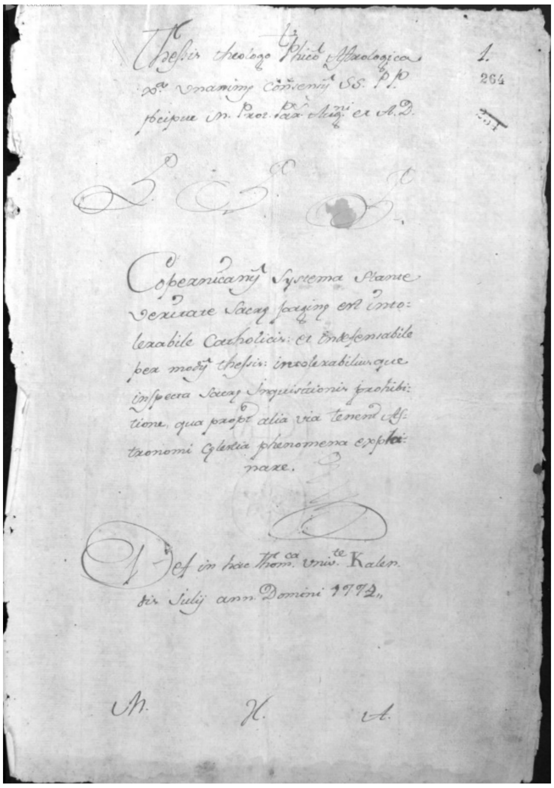

Figure 20. Invitation to Mutis, AGNC, Sección Colonia, Colegios 12,2., f. 264r.

However, two days later, Mutis complained to Viceroy Guirior that the invitations sent to the rest of the public contained a different proposition:

> Thesis theolog(ico)-phy(si)co mathematica: Unanimem consensum SS.PP. præcipue P. Propt. Parent. Augustini et Anglic. Doct. Nullus catholicus esse

deberet qui ut thesim teneret motum terrae solisque quietem, eo motivo ut haec coelestia phoenomena facilius explicarei, ut defi(ni)tum; in hac thomistica Universitate, kalendis Iulii Anni Domini 177 (RJB, III, 2, 4, 11, f. 26r.).[492]

In his letter to the Viceroy, Mutis asked for an explanation by the Provincial Superior of the Dominicans, the Director of Study, and the Lecturer, concerning the differences between the two invitations as he felt that he was being attacked because of his defence of the Copernican system in 1773. That very same day, Viceroy Guirior sent Mutis' letter to the Dominicans, asking for a reply. On June 28th, the Director of Study, Juan Josef Rojas, and the Lecturer, Josef Maria Sandoval, wrote a reply in which they accepted that both invitations were different, although they argued that such differences "no son substanciales, y provinieron de yerro material de los amanuenses, y que esto no solo acontenció respecto del Dr. Don Joseph Celestino Mutis, sino también respecto de otras muchas personas, como se puede ver siempre que sea necesario" (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 266v-267).[493] As we can see, Dominicans' argumentation regarding the differences between Mutis' invitation and the invitations sent to the rest of the public is founded on two premises. First, they commented that there was a material mistake made by the amanuenses, as there were more invitations with that very same mistake. Second, they claimed that there were no substantial differences between the invitations, arguing that the propositions that they aimed to defend were based on Goudin's works.[494]

Likewise, by considering the importance of the problem, its possible implications, and the already reforming context of New Granada's education, the Provincial Superior of the

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492 In Mutis' original complaint, he only quoted the beginning statement of the invitation sent to the public: *Nullus catholicus esse debere &c.* A transcription of the entire invitation, as well as a Spanish translation is in Soto & Negrín-Fajardo (1984), p. 58.
493 In Lanning (1944) there is an entire transcription of the correspondence between Mutis and the Dominicans. He also makes a preliminary study in which he advances the idea of the political interests of the Dominicans in their debate with Mutis.
494 *Cf.* AGNC, Sección Colonia, Colegios: 12,2, ff. 266v-266r

Dominicans, Domingo de Acuña, also replied to Mutis' complaint. In his reply, Acuña reiterated the arguments of the Director of Study and the Lecturer, emphasizing the fact that Mutis was invited as he had demonstrated a deep interest on the experimental physics and its promotion in New Granada. However, the most important aspect of Acuña's reply is at the end of his letter. There, he claims that the polemic with Mutis was nothing but a debate of ideas: "Considerando ser estas disputas de entendimiento y no de voluntad" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 268v). Consequently, he claims that Dominicans were disposed to defend any system of the world, as long as it was according to the Viceroy's will:

> Ahora V. Ex. mande lo que fuera de su superior agrado que la mayor complacencia de este humilde capellán es hacer cuanto se me ordene y *si no fuese de su superior agrado no se defenderá la dicha tesis; y también están prontos el Regente y Catedrático a defender la contraria* (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 268v-269r).[495]

As Soto and Lanning have suggested, the conclusion of Acuña's letter reveals that, in the end, the Dominicans were not really interested in the ideological debate with Mutis as they were disposed to defend even the Copernican system: "En cualquier caso, también se puede deducir de esta primera fase de la polémica que los dominicos no tenían demasiado interés en defender los planteamientos ptolomeicos y ticónicos en frente del sistema de Copérnico, sino mantener sus posiciones frente al aparato administrative ilustrado" (Soto & Negrín Fajardo, 1984: 59). Similarly, for Lanning, the Dominicans used Mutis' complaints to establish a polemic that could give them time to create a strategy to defend their cause at the Royal Court in the context of the reformation to New Granada's education that had aroused since 1768:

495 My emphasis.

> A principios de 1774 se propaló la especie de que la Junta Superior de Aplicaciones se preparaba a dictar algo concreto y drástico con la educación superior. Pensaron los dominicos anticiparse a tal medida, y aprovechándose del *statu quo*, decidieron precipitar una controversia entre los peripatéticos y los modernistas; creían con ello enturbiar y demorar las disposiciones esenciales relativas a la educación superior (Lanning, 1944: 281-282).

As we shall see, this characterization of the Dominicans' attitude was perceived by Mutis himself, who claimed that their disposition to defend the Copernican system, as it was more "pleasant" for the Viceroy, proves that they had some other, occult interests in arguing against the Copernican system.[496] Soto and Negrín-Fajardo also use the velocity with which the process was solved in the otherwise highly bureaucratic vice regal court of New Granada as evidence of the fact that, since its beginning, the debate between Mutis and the Dominicans was perceived as a political concern.[497]

Few days later, Mutis presented to the Viceroy a counterargument to the reply of the Dominicans, in which he contended that the *apparent* material mistake of the Dominican's amanuenses could not be true and that the differences between the invitations were substantial, as the one sent to him contained theological censures and accusations. First, he commented the mistakes of the amanuenses:

> Pues si los amanuenses entendían lo que escribían, ¿cómo pudieron equivocarse materialmente en cuatro proposiciones artificiosamente colocadas que contiene el singular aserto a mí dirigido, cuando los esparcidos para el común contienen

[496] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12,2., ff. 274r-278r.
[497] *Cf.* Soto & Negrín-Fajardo (1984), p. 58.

> una sola proposición? Y si no entendían lo que escribían, ¿cómo equivocándose materialmente pudieron ordenar cuatro proposiciones, dispuestas con estudioso cuidado para descubrir el verdadero objeto a que se ha dirigido este procedimiento? (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 274r).

Mutis' suspicion regarding the Dominican and their purposes was emphasized by claiming that their real purpose was "infundir horror y tedio a la juventud, al vulgo, y aun al público, para que absteniéndose de aplicarse al estudio de la útil filosofía, y al método más proporcionado para los progresos literarios, subsista el desorden con que lastimosamente se frustran las esperanzas que ofrecen los floridos ingenious que fértil produce este reino" (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 274r-274v). In this characterization, we can see that Mutis assumed the attack of the Dominicans as a strategy to deviate the reforms that were being established in New Granada's education during the 1770s. For him, the personal attack that he was suffering represented the Dominican's intentions for keeping their old educational monopoly.

On the other hand, Mutis contended that the inexistence of substantial differences between his invitation and the ones sent to the public was also a false argument as the former contains some theological censures that characterize as a heresy Mutis' defence of the Copernican system as a thesis:

> Por esta causa, aunque los P. P. quieren disculparse, declarando que la desigualdad de los asertos no es substancial, no advierten que entre una conclusión, aunque injuriosa y en las presentes circunstancias nociva, que se esparció al público y una censura teológica que particularmente se me dirigió reina una desigualdad tan notable y substancial, que si generalmente está prohibida en la escuela, militan para conmigo particulares motivos. Pues haciéndose el convite según refieren las

> respuestas no con otro fin que el de instruir la juventud en los rudimentos así teológicos como filosóficos y astrológicos (astronónomicos debería decir, sino fue material equivocación del amanuense) podría lograrse defendiendo algún sistema opuesto al copernicano, sin herirle con la nota de herético, condenado y opuesto a la Sagrada Escritura y sin ponerse por blanco y objeto de su censura (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 274v).

For Mutis, the problem of the Dominicans' invitation letter and their replies to his complaint was that they criticized the Copernican system as an indefensible heresy, opposed to the Holy Scriptures. Thus, as he had defended the Copernican system in 1773, he assumed the criticism to the Copernican system as a personal attack of the Dominicans in the context of the debates regarding the reform of New Granada's education. Accordingly, he concluded that the Dominicans used the *Conclusiones* as an excuse for polarizing the public opinion regarding the Copernican system, attempting to solidify their position and the partisanship regarding education. Thus, for Mutis, the invitations sent to him and the public are nothing but:

> unos asertos dirigidos a oscurecerlo [the Copernican system] con densas tinieblas, a inspirar entre gentes débiles el temor a las nuevas enseñanzas que promueve el gobierno, y a seducir a ignorantes incautos, fomentando la facción y el partido, para que prevaleciendo el peripato y abrazándose fanáticamente la juventud, se conserve con el antiguo desorden el predominio que hasta ahora muchos han disfrutado en la enseñanza con detrimento de las ciencias (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 275r-275v).

Consequently, Mutis concluded that the real purpose of the Dominicans by condemning the Copernican system – and him – as an intolerable heresy was to keep the *status quo* of New

Granada's educational milieu. By doing so, they tried to assure for themselves the educative monopoly as they would have the only university graduating students and, as a result, their students would keep having the administrative positions of Santafé's Court. In other words, Mutis claims that the main purpose of the Dominicans with the censure of the Copernican system was to prevent the reforms that had been promoted by Viceroy Guirior and Moreno Escandón. In Mutis' words:

> pero también convendría (que) supiesen que el objeto de tan agria censura es embarazar el establecimiento de los estudios útiles, los cuales, una vez introducidos, desterrarán perpetuamente el desorden y otra multitud de males que hoy lloran los verdaderos sabios y vasallos celosos del bien común (…) mayormente cuando observan que entre los graves cuidados que cercan a V. E. en su gobierno, se aplica con especial esmero al importante objeto de la reforma, tan necesario y encargado en nuestros días (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 276v-277r).

Nevertheless, it is worth of notice that Mutis also used the polemics with the Dominicans with political purposes which is evident, for instance, by the fact that he did not use any of the arguments he had discussed in his *Defence* for defending the Copernican system as a thesis. Instead, in his reply to the Dominican's accusation, he barely commented that any literal interpretation of the Holy Scriptures must be avoided and that Charles III's policies were aimed to the modernization of the Spanish education and consequently he had promoted the teaching of authors – Newton, Muschenbroek, and Wolff – who openly defended the Copernican system.[498] In so doing, as Soto commented, it is possible to argue that Mutis defended some kind

[498] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12,2., ff. 275vr-278r.

of Jansenism that is visible when he argues that one of the problems of the Dominicans was that they were imposing the authority of the Roman Inquisition over the Royal authority. Soto claims that Mutis' Jansenism is clear when he says that he was preparing a report to the King of the Dominican's condemnation with the purpose of

> darle circunstanciada cuenta en cuanto se interesa a su real servicio, y el beneficio común de este reino, y aún de toda la nación ya por vulnerarse una de las más preciosas regalías del soberano, pretendiendo que la prohibición de la Inquisición romana estreche y obligue sin real consentimiento de los españoles contra lo expresamente decidido por el señor Felipe cuarto en el auto acordado (AGNC, Sección Colonia, Colegios: SC. 12,2, ff. 275v-276r).[499]

Despite that Mutis emphasized the royal power over the Church's one, I think that Soto's characterization of Mutis as a Jansenist is limited as it magnifies a single aspect of Mutis' self-defense. According to Soto, "Mutis exige obediencia al soberano y recrimina a los dominicos sus manifestaciones de obediencia a la Inquisición romana: este es el motivo por el que le pide a la comunidad de Santo Domingo 'humilde obediencia a Su Majestad el Rey'" (Soto, 2009: 16). However, as I pointed out above, in order to support his defence of the Copernican system, Mutis not only used the authority of the king. Instead, he also used the ecclesiastical power by analysing the acceptance of Copernicanism by the Roman Inquisition. As a consequence, it is necessary to claim that, in defending the Copernican system from the attacks that he suffered in the polemics with the Dominicans, Mutis used both the royal and the ecclesiastical authorities

[499] Mutis referred to the *Real Orden* of September 15th of 1787 in which Phillip IV established the conditions for teaching mathematics, philosophy, and physics in Spain, and the need to use them as a compulsory requirement for a student to be accepted in any university career. Such *Real Orden* is in Volume V of the *Novísima recopilación de las leyes de España*, *Título* 7, *Ley* XIV. *Cf. Novísima* (1805), p. 43.

and their acceptance of the teaching of the Copernican system as a way to validate its teaching in New Granada.

So far, I have explained that the Dominicans used the debate with Mutis as a strategy for struggling for their position in New Granada's educational context as they attempted to reinforce their educational monopoly. Thus, historians of education and science in Colombia, like Soto, Negrín, and Lanning, have emphasized the "occult" purpose of the Dominicans, arguing that they attempted to hinder the reforming process that was developed during the 1770s. Nonetheless, what has not been hitherto considered by these historians is the fact that Mutis and the reformers – especially Moreno Escandón – also used the polemic as a reason for promoting their reforms and the creation of a public university.

After Mutis' reply to the Dominicans letter, Viceroy Guirior ordered to send the case file of the debate to Moreno Escandón, who was by then constructing the study plan that was supposed to support the entire enterprise of the establishment of the public university.[500] For Moreno Escandón, the debate between Mutis and the Dominicans illustrated the interest of the Dominicans in keeping the *status quo* of New Granada's education and the need of its reform: "El mérito de este expediente presta un nuevo convincente testimonio de cuanto el presente Ministro tiene expuesto a la Junta Superior y a S. M. sobre la necesidad de reformar los desordenes que pacede la enseñanza pública" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 278v). In this sense, he followed Mutis' interpretation of the true purposes of the Dominicans with the polemic by claiming that:

[500] *Cf.* AGNC, Sección Colonia, Colegios: SC. 12,2., f. 278v. Guirior's attitude toward the polemics and his interest in using it as an excuse for introducing reforms to New Granada's educational system can be studied in Guirior (1869), pp. 111-180.

> Los mismos asertos y cartas de los RR. PP. Provincial Regente y Catedráticos, acreditan, que la verdad no se buscan con la disputa, y que ésta se toma como una algazara de voces vacías de substancia, más propias para ofuscar el entendimiento y perder inútilmente el tiempo que para iluminar sólidamente a los jóvenes, formando unos heroes dignos a coronarse con el glorioso timbre de doctos (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 278v-279r).

In this context, Moreno Escandón, like Mutis, used the royal authority for avoiding the inquisitorial meddling that was promoted by the Dominicans; although, unlike Mutis, he just emphasized the royal authority, thus encouraging a strong regalism that was consistent with the attitude that had the enlightened ministers during the reign of Charles III. For Moreno Escandón, "Tampoco es lícito, ni puede permitirse que se alegue como precepto la prohibición de la Inquisición de Roma" (AGNC, Sección Colonia, Colegios: SC. 12,2, f. 282r) as a reason for avoiding the modernization of education and the teaching of determined subjects.[501]

In the end, the debate between Mutis and the Dominicans of 1774 was just a battle in a war regarding the control of New Granada's education, in which he and the reformers got a pyrrhic victory. Indeed, in 1774, the Inquisitor in Santa Fe, José Gregorio Díaz Quijano, suggested to the Dominicans not doing the *Conclusiones* and to send the case file of the polemic to the Tribunal of the Inquisition in Cartagena.[502] There, the Augustinian Friar Domingo de Salazar, supported the idea that the Copernican system only could be defended as a hypothesis, thus accepting the Dominican allegation, whilst the Franciscan Friar José de Escalante left the issue unsolved. However, in 1775, Mutis took the debate to the Tribunal of the Inquisition of

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[501] Interstingly, in this passage, Moreno Escandón also referred to the same law as Mutis did in his reply to the letter from the Dominicans. *Cf.* AGNC, Sección Colonia, Colegios: SC. 12,2, f. 282r.

[502] *Cf.* Soto & Negrín fajardo (1984), p. 64.

Castile, where, as Soto and Negrín Fajardo comment, "Al parecer, acabó convenciendo a sus jueces de que el sistema heliocéntrico no era contrario al dogma" (1984: 64).[503]

Mutis' episode with the Dominicans turned into a springboard for the acceptance and implementation of Moreno Escandón's plan and the creation of New Granada's public university. In fact, the plan was used since 1774 until 1779, when it finally was abolished because of the pressure of the Dominicans and their triumph in the Royal Court. The process of abolishment began in 1778, when the teaching of mathematics in New Granada was forbidden – being restarted in 1787, following the study plan that Mutis created. Finally, in 1779, it was totally suppressed, when the Royal Court forbid Moreno Escandón's plan, dictating that the plan that the Dominicans had before 1774 was the one to be followed.[504] Despite that the Dominicans got what they wanted with the polemic – hindering the acceptance of the reforms that Moreno Escandón proposed and the creation of a public university in New Granada – in a long-term scale, the five years that the plan was implemented at the *Colegio de San Bartolomé* and the *Colegio del Rosario* played an important role for the consolidation of a modern approach to study nature and the establishment of an enlightened elite in New Granada. In this context, for instance, was educated José Felix de Restrepo, who was one of the professors of the generation of independence of New Granada and the author of *Lecciones de física*, the first scientific textbook ever written in Colombia.[505]

The debate between Mutis and the Dominicans regarding the acceptance of the Copernican system is a clear example of the struggles that faced the modernization of education

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503 For the Inquisition in New Granada, see Medina (1899), Splendiani et al. (1997), Álvarez Alonso (1997), González de Posada (2009).

504 *Cf.* Villalba Pérez (2003), pp. 70-85. A detailed study on the Moreno Escandón's plan and its historical development is in Soto (2004).

505 The most complete study on Restrepo's works and their impact on the process of independence of Colombia and its early republican years is in Herrera Restrepo (2006).

in New Granada, the partisanship that characterized it, and the use of science for the establishment of a political and social control. Both Mutis – and the reformers – and the Dominicans used the debate for promoting their own positions in New Granada, relegating to the background the debate of ideas and arguments regarding Copernicanism. In this sense, it is possible to explain the apparent omissions in Mutis' explanation of the Copernican system – like the use of Galileo's theory of tides and its combination with Newton's one – as a consequence of his real interest in consolidating him as a central figure for the modernization of New Granada to the eyes of the local authorities.

Conclusions. Social uses of science in New Granada in the eighteenth century

According to Shapin, in studying the historical development of science, historians of science usually use a demarcation between the contexts in which scientific theories are produced and evaluated and the contexts in which such theories are used.[506] The criterion of demarcation leaves out the study of the contexts of the use of scientific theories for historians of science due to being considered as non-influential in the construction and validation of the theories themselves. By contrast, Shapin argues that the study of the contexts of the use of science is a fundamental part of the history of science in the sense that there is no difference between these contexts and the contexts of production and validation of science. In other words, for Shapin, the contexts in which science is produced, validated, and used are one and the same and consequently the scientific activity should also be considered in virtue of its social uses in relation with the practical problems of the society in which it emerges.[507] Simon Schaffer, John Henry, Margaret Jacob, and Betty Jo T. Dobbs have used such a historical approach to study the reception and acceptance of Newtonianism in Britain during the late eighteenth century, showing that Newton's pronouncements on the theory of matter were used by different parties for validating and justifying their own positions in the British scenario in the years following the Glorious Revolution of 1688.[508]

I believe that the introduction of Newtonianism in New Granada could represent an exemplary study case of what Shapin has called the "social uses of science". As I have pointed

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[506] *Cf.* Shapin (1980), Shapin (2010), pp. 17-31.
[507] See in particular Shapin (1980), pp. 93-105.
[508] *Cf.* Schaffer (1980), Dobbs & Jacob (1995), Henry (2007), Schaffer (2009), Shapin & Schaffer (2011).

out in the section on the education of Mutis in Cadiz, his resolution to travel to New Granada was motivated by the possibility of making a botanical expedition.[509] A resolution that was fostered by the hopes given to him as well by Viceroy Messía de la Cerda at the beginning of Mutis' exchange of correspondence with Linnaeus. The two *Representaciones* that Mutis wrote to the King in 1763 and 1764 in his quest for the royal patronage for creating the botanical expedition reveal his interest in also being appointed director of such an enterprise. More importantly, Mutis discusses the utility of drawing up a natural history of the Spanish overseas territories for the Crown which would be able to constitute an almost unlimited source of resources for placing Spain amongst the intellectual and enlightened nations of the eighteenth century. As Mutis wrote to King Charles III in 1763:

> Nadie mejor que V. M. conocerá desde luego, que sobre la Gloria inmortal que resultaría en V. M. de esta gloriosa empresa dignamente desempeñada, ninguna otra nación tanto como la Española se halla interesada en saber y conocer las producciones admirables; con que la divina providencia ha enriquecido los dilatados dominios que tienen la fortuna vivir bajo la feliz dominación de V. M. en este Nuevo Mundo (Gredilla, 1911: 25).

Clearly, Mutis was aware that the exploitation of the variety of nature of the New World was strictly related to the knowledge of such nature and, consequently, he proposed the botanical expedition as a way of controlling the productions of the New World.[510] However, that was not the only purpose of the botanical expedition. Equally important, Mutis presented his enterprise as a way to generate "honores a la Nación, utilidad al Público, extension al comercio, ventajas a

[509] *Cf.* Mutis (1957). For Mutis' projects regarding his trip to New Granada, see Bernal & Gómez Gutierrez (2010).
[510] There are several studies concerning the economical purposes of the Botanical Expedition for Mutis and the Spanish Crown. See, for instance, Amaya (1986), Restrepo Forero (1998), Lafuente & López Ocón (2006), Nieto-Olarte (2006), Crawford (2009), Marcaida & Pimentel (2014), Bruquetas (2015).

las ciencias, nuevos fondos al erario real y Gloria inmortal a V. M." (Gredilla, 1911: 31). As we can see, the *Representación* of 1763 reveals an image of Mutis strongly committed to the royalism characterizing the Bourbon House in the eighteenth century. In this sense, for him, the fact of knowing the nature of the new world was a way ofcreating a more effective way for the King to rule it. A feature that was to be accentuated in his polemics with the Dominicans.[511]

As I commented in the chapter on the polemic between Mutis and the Dominicans, in defending the Copernican system Mutis alluded to different arguments encompassing theoretical elements – an argumentative strategy similar as the one that Galileo used in his *Dialogo* –, social aspects involving the education reforms in New Granada after the expulsion of the Jesuits, and an allusion to the King's authority over Church.[512] I would like to emphasize on this last feature. In said chapter, I argued that what Mutis was doing was making reference to the sources of doctrinaire authority that he access to and considered valid in order to demerit the position of the Dominicans in the debate. In so doing, as already mentioned, he used the authority of both the King and Rome for criticizing the condemnation of the Copernican system. I therefore concluded that the idea of Mutis as a Jansenist, advanced by Soto, makes a caricature out of Mutis' arguments as it presents the image of Mutis only concerned about accentuating the power of the Crown over the Church, thus overlooking important details of Mutis arguments which are evident in the context in which they were produced. Nonetheless, the central idea underlying Soto's argument explains a very precise manner Mutis' position with regard to the Crown. Indeed, as his *Representaciones* to the King reveal, Mutis was a committed servant of the Spanish Crown in New Granada and once he realized that the policies of the Bourbon House concerning

[511] This is a general interpretation of the role of the Spanish botanical expeditions in the eighteenth century defended by different historians. See, for instance, Cañizares-Esguerra (2003), Schiebinger (2004) 23-72; Barrera-Osorio (2006), 128-134. A complete compendium of works on these matters is in Bleichmar et al. (Eds.) (2009).
[512] *Cf.* AGNC, Sección Colonia, Colegios: 12,2, ff. 275v-276r.

education were compatible with his own conception of Newtonianism and the useful modern science as he presented it in his lectures – and in which he had advocated the use of modern useful sciences –, he seized the opportunity to emphasize his royalist nature, thereby presenting himself as a loyal servant of the Spanish Crown. In the end, Mutis traveled to New Granada with the official position as appointed member of the Viceroy committee seeking the royal patronage for the creation of his botanical expedition. It was natural that when he saw the state of university education in New Granada – which was not very different of that of Spain –, he took a position in favor of the Crown and the authority that it represented in the framework of the educational reforms that had been taking place in the Spanish World since the 1760s.

All in all, Mutis used science as an instrument for the consolidation of the Spanish Crown's control over the New Granada territory. He did so in the two major enterprises he was dedicated to during the almost fifty years he was there: the Botanical Expedition and his lectures on mathematics. On one hand, with the Botanical Expedition, he exploited the conception of "ruling by knowing" in which the control of the territory was possible through the knowledge acquired by the individuals who lived there. In this sense, the natural history that Mutis was making was not merely the result of his own observations of nature. For him, for instance, the local traditions concerning the medicinal use of plants played a fundamental role as well, as can be specifically observeed in his studies about *Quina* and in his interest in learning the local dialects.[513] Yet, the Botanical Expedition did more than just collect botanical and zoological specimens for the natural history cabinets in Madrid and Europe. It turned into an academic institution where a generation of enlightened scientists were educated under the precepts of

513 For Mutis' studies on the Quina and the influence of local traditions in Mutis' conceptions of its medicinal use, see, Crawford (2009). By order of King Charles III, Mutis sent different manuscripts containing a translation of the basic indigenous vocabulary in New Granada. For Mutis' interests in local dialects, see Barras de Aragón (1950), Robledo (1956).

useful modern science. Therefore, it is important to bear in mind that Mutis did this for the purpose of educating scientists for the glory of Spain and the Spanish Crown. On the other hand, Mutis' lectures on mathematics introduced Newtonian experimental physics that supported the useful modern sciences that he had strongly defended since his inaugural lecture in Santafé in 1762. Thus, by considering Mutis' Newtonianism, it is possible to conclude that the introduction of what Mutis considered as "Newton's experimental physics" in New Granada was conditioned by the establishment of a new tradition in New Granada's universities concerning the study of nature. A tradition which, by neglecting the tradition of the ecclesiastical universities of Santafé, made it possible to consolidate material and intellectual conditions in which Mutis was to accomplish his own as well as the Crown's enterprises. In this context, in his lectures and in the polemics with the Dominicans Mutis alluded to different issues such as the authority of the King, the retrograde state of science in Spain and the problems of discussing natural philosophical matters from a religious point of view, as different strategies for establishing of his own figure on the panorama of the Spanish intellectual and academic milieu. It must be recalled that since the beginning of his journey to New Granada, Mutis had the intention of returning to Spain. Consequently, by emphasizing his role as the promoter of useful modern science in the New World, he was assured a position in Spain on his return, which, as he commentis in his *Diary*, was one of his concerns before leaving for New Granada in 1760.[514]

However, the fact that makes of this study case an exemplary for studying the social uses of science is that in spite of Mutis' royalism, the appropriation in New Granada of Newtonianism, and the useful modern science it supported, gave rise to the constitution of a generation that intellectually headed the process of independence of New Granada from Spain.

[514] *Cf.* Mutis (1957).

It reveals how the social uses of science are determined by the concerns in which science is created and that the purposes of science are directly related to the purposes of the contexts of its production. Figures like Restrepo, Caldas, Zea, Tadeo Lozano, Matis and so forth, who were educated by Mutis in the rooms of the *Colegio del Rosario* and on the Botanical Expedition, learnt the lesson about "ruling by knowing", applying it to the consolidation of the intellectual background of the revolution that led to the independence process in Colombia during the early-eighteenth century. The appropriation of the traditions of Newtonianism and the useful sciences that Mutis introduced produced in New Granada's intellectual figures the consciousness that, as they knew the local territory, they would be able to control it by themselves. Certainly, this facet of the generation of the independence of Colombia has been studied exhaustively and this conclusion is not a novelty in the historiography of science in Colombia. Nevertheless, it is interesting to highlight that such a consciousness was only caused by the appropriation of the model of what science should be and the aims it should have that Mutis introduced as of the 1760s. And as I have argued that the model of science for Mutis was "Newton's experimental physics", it is possible to conclude that the appropriation of Newtonianism in New Granada, especially of its methodology and the particular way in which it mathematizes nature according to Mutis, created the intellectual conditions leading up to the independence of Colombia in the eighteenth century.

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In most of the cases, Mutis' manuscripts in the archive of the *Real Jardín Botánico* of Madrid are not dated. In general, the archive provides tentative datation encompassing the probable years in which the manuscript could have been written – notice that in many cases the years correspond to the entire period of Mutis' stay in New Granada. The dates here included are the ones provided by the archive itself and they should be considered only as a general reference until a more precise datation is available.

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