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The Place of the “Laws of Nature” in the Conceptual Structure of the Scientific Revolution

1. Preliminary Remarks

The belief that something very important happened to our conception of the world somewhere in the seventeenth century has been for a long time a commonplace in the history of philosophy. One way of expressing this change is to say that from a wide range of competing anti-Aristotelian philosophies, a “new philosophy” emerged, the mechanical philosophy.¹ Another way to put it is to say that a wide range of competing Aristotelian philosophies were defeated by a more or less unique brand of anti-Aristotelianism, the mechanical philosophy.² The two are not necessarily mutually exclusive. They simply try to formulate the deep conceptual change that took place in the seventeenth century, sometimes described as the Scientific Revolution.³

The beginning of the seventeenth century has been characterized by a continuous quest for a “new philosophy”⁴ and a struggle to harmonize several of the traditional difficulties of the Aristotelian metaphysics with the constraints imposed by theology.⁵ The rediscovery of several ancient alternatives to Aristotelianism provided a fertile reservoir of ideas to be incorporated in the syncretic construct of Renaissance philosophies. Atomism, Neoplatonism, Hermetic philosophy, together with some other powerful influences as Skepticism and the revival of natural magic were considered both as alternatives and as possible ingredients of a new “Aristotelian” synthesis.⁶ It is important to emphasize that the enterprise in which most of the sixteenth and seventeenth centuries’ natural philosophers were engaged was a completion, emendation or reformation of the Aristotelian system and not a replacement of it.

The Aristotelian tradition was for a long time the dominant trend in the intellectual life, the core of the academic curriculum, the basis of knowledge for every educated European. However, Aristotelianism had been under challenge since late Middle Ages. The fourteenth and fifteenth

centuries can be described as a continuous struggle to accommodate Aristotelianism with Christian theology and the Christian tradition.⁷

Therefore, the failures or shortcomings of Aristotle's metaphysics were not a discovery of the seventeenth century's natural philosophers. At best, some of them engaged in the rethinking of several already discussed "problems" of Aristotle's natural philosophy, sometimes from the new perspective of the Neoplatonism, Hermetic philosophy, Atomism, and so on.

In what concerns natural philosophy, the issues at stake bear on the doctrine of Hylemorphism. In Peripatetic natural philosophy, a substance is a composite of "form" and "prime matter". Both are metaphysical principles, directing the becoming. We can talk about bodies and substances only because their intelligible form has been impressed in "matter". Generation is the very process of "informing" matter. The disappearance of a substance/body means the disappearance of its form. Any change of state in a given substance (modifications of its dimensions, colour, temperature, place, etc.) constitutes *motion* and can be described in terms of a variation of forms in the same matter. In any given body there are many forms. One of them is the substantial form; without it the body will not be the same body anymore. Others are mere "accidents". The modification of accidents accounts for "motion". A tree can be big or small or can be just the seed of the future tree. In all cases, the substantial form is the same: the "tree-ness". In the case of man, his substantial form is the rational soul. A man is, in the last instance, a rational soul impressed upon prime matter and endowed with some other "accidents" (secondary forms).

Of course, a couple of different shortcomings of these doctrines are more or less obvious. One is the endless multiplication of substantial forms. Another is the possibility of distinguishing between forms of an unknown substance or object (as the magnet, for example, or an unknown substance obtained as a result of an alchemical experiment) and its substantial form. There is a large class of problems concerning the intention and remission of forms. What happens when a white body becomes whiter, for example, how can we describe that motion?

And, of course, the most striking difficulties involve Aristotle's explicit emphasis upon the inseparability of forms and matter. If the substantial form cannot have an independent existence, how can we explain the immortality of the soul? What is the soul, if not the "form" of the body?

Does soul have matter itself? Moreover, the “non-existence” of matter in itself is no less problematic than that of forms.

In the attempt to solve the above mentioned problems, natural philosophers turned to ancient philosophical traditions different from Aristotelianism. The considerable success of ancient Atomism may be explained as an answer to some of these difficulties. Atomism offered an entirely different structure of explanation founded upon the existence of ultimate material particles in motion and their coexistence with “void” (a complementary principle and one of Atomism’s big flaws).⁸ Now a substance or a body is an aggregate of atoms with certain properties. It is not at all clear how many of the usual properties of bodies should be transferred to the microscopic realm of atoms. Generally speaking, a body is an aggregate of material particles and its properties should be reduced to similar or entirely different properties of its parts. Despite its appeal as a general description, the explanatory power of ancient Atomism is very limited.⁹ First, it gives rise to various questions as: What keeps the atoms together? What are the properties of individual atoms? What is the explanation for the emergence of different properties of the aggregate of atoms?¹⁰ Why many atoms together have different properties than the single atom? Secondly, ancient Atomism is unable to explain the classes of phenomena previously described as “changes” in forms: the variation of the states of a substance, the variations in colours, temperature, etc. In its ancient form, then, Atomism merely translated many of the traditional problems to the microscopic level.

It is relevant to stress how many new brands of Atomism appeared in the seventeenth century in an attempt to correct the previous mistakes.¹¹ There are “Aristotelian Atomists”,¹² Atomists, which advocated the non-existence of void,¹³ “mathematical Atomists”,¹⁴ “Neoplatonic Atomists”¹⁵ and “mechanical philosophers”. Therefore, Atomism is less a “new philosophy” than a label stick upon a large group of reformers of the Aristotelian philosophy in the direction of “materialism”. What most “Atomists” advocated was the independent existence of matter and its “uniformity”, “homogeneity”, and divisibility. This “matter” is the “stuff” which actually constitutes the world. The number of atoms and their density is what counts as difference between substances and bodies, at least in principle. Unfortunately, most part of Atomistic theories which reject the forms, and formal causality as well, were led into obvious difficulties concerning:

- a. The constitution of physical bodies;

- b. The problem of individuation of a physical body/substance;
- c. The intelligibility of the world (previously given by forms);
- d. The sources of "activity" in nature.

That all these problems have been taken into consideration by the natural philosopher is proved, for example, by Descartes' theory of matter, which is explicitly neither Aristotelian nor Atomistic. It can be shown that in constructing a new theory of matter in the second part of its *Principles of Philosophy*, Descartes started from a refutation of the previous competing doctrines in order to build something "new".¹⁶

As it has been pointed out, the "new" mechanical philosophy had been undermined, from the beginning by the same problems as most of the Atomistic doctrines.¹⁷ The main source of difficulties was the fact that with the rejection of the Hylemorphism, the basic conceptual structure of natural philosophy was destroyed.¹⁸ Not only that several main concepts had to be redefined, but also the very condition of possibility of physics crushed¹⁹ together with the established structure of the explanation.²⁰

Therefore, not only that the concepts of "matter", "form" and "motion" acquired a new meaning during the second half of the seventeenth century, but also, from this conceptual restructuring emerged a new structure of the "scientific explanation". Further on I shall approach only an aspect of this conceptual revolution, the emergence of a new meaning for another "old" concept of natural philosophy, the concept of the "laws of nature". I will follow the meaning of this concept in the works of Bacon, Descartes and Newton and I will show how we can see it as a measure of the immense change in the world picture that took place in the second half of the seventeenth century.

2. The "Laws of Nature" before the Seventeenth Century

The belief that God imposes laws on nature is by no means new in the early seventeenth century. Even the term "laws of nature" may be traced back, at least to the twelfth century. However, although being a part of the medieval disputations around God's relations with the Creation, the laws of nature did not play any significant role in the explanation of the phenomena or in the "descriptions" of the world. Or, at least, as one of the oldest scholars of the "laws of nature" put it:

... historians generally agree that in the course of the seventeenth century the idea of the laws of nature sprang from comparative obscurity into a lasting prominence.²¹

Although there was a considerable consensus between the historians of “laws” in the past decades as to the origin and development of the concept before its appropriation by the natural philosophy as the core of the scientific explanation, recent and more contextualized analyses tend to draw a very different picture of the importance and meaning of the “laws of nature”. The “classical” picture of Zilsel and Needham,²² who insisted upon the political and legal origins of the term, was strongly amended by several authors as Oakley (1961, 1998, 1999), Funkenstein (1986) and Osler (1994) pointing out in the direction of theology and the reopening of several traditional theological debates concerning God’s omnipotence and wisdom.

As a matter of fact, the “laws of nature” were at the very core of one of the “intrinsic contradictions” of the medieval view of the world. As several authors pointed out²³ the medieval synthesis contained two different conceptions of order and laws. The Greek concept of order emphasizes the interdependence of things and the isomorphism between the essences and the relations. As a counterpart, this conception accommodates a “natural law” immanent in the structure of reality.²⁴ The other conception of order, ascribed usually to the Semitic roots (Oakley, 1961, 436-37, Funkenstein, 1986, Crombie, 1996) of Christianity stressed upon the imposed order, with the laws given by God “from outside” of the creation. Consequently, the later was consistent with a metaphysical theory of external relations. The laws of nature–God’s commandments–decided for–or were reduced to–imposed patterns of behavior at the level of individual bodies. As a consequence, the laws are more or less contingent and do not bear a direct relation with the “essences” of things.

Roughly speaking, the seventeenth century marked the victory of the second view upon the first. At almost any level of intellectual elaboration, seventeenth century thinking emphasized the voluntaristic theological aspect of the laws of nature, and this was the meaning appropriated by natural philosophy.

It is difficult and maybe dangerous to speak about “reasons” for this conceptual transfer from theology to natural philosophy. Several different hypotheses are already available.²⁵ It is however clear that we cannot speak of a unique reason and that many concurrent factors should be

taken into consideration. The most widely discussed was the general interest in theology of the seventeenth century natural philosopher, together with the effacing demarcation between natural theology and natural philosophy. For our purpose, though, it would be interesting to ask another question. Is the “new” conception of the laws of nature as divine commandments imposed from outside on the material world especially compatible with mechanical philosophy? Can we say that mechanical philosophers had to consider a voluntaristic theology as a favorable context of their own ideas?

In an interesting analysis, Keith Hutchinson²⁶ shows how the program of mechanical philosophy involved a supernaturalistic ontology of action. Not only that mechanical philosophy was an ideal soil for a voluntaristic theology, but also, the intrinsic features of the mechanicism, as the inert matter and the elimination of mediators, deprived the natural world of any source of activity. As we shall see, for Bacon, Descartes and Newton, as for Boyle and all English natural philosophers of the seventeenth century, God is not only the guarantor of law and order, but also the only source of activity and power,²⁷ as well as the Sovereign, which actually and efficiently rules the Universe.²⁸ This attitude went together with the destruction of Aristotelian forms (van Ruler, Hutchinson, Osler) and with the radical transformation of the concept of matter.

Of course, it is very difficult to speak here of causes and effects. On one hand, the representatives of the “Scientific Revolution” insisted upon the necessity of a voluntaristic theology that would *provide* the basis of a continuous and effective divine action into the world. In this respect, natural philosophy is a natural theology and the real presence is manifest into the frame of the world. On the other hand, there was an emphasis on the complete inertness of matter, on a mechanical world deprived of any activity *requirements*, and in the meantime the divine presence and assistance at any instant.²⁹ We don’t need to trace the cause of these trends of thought or to reduce one to another. It is sufficient to underline their presence in almost all the natural philosophers of the seventeenth century, which shaped our modern view of the world.

Therefore, from the beginning of the seventeenth century, the concept of the “laws of nature” seen as God’s commandments, imposing “from outside” the order into the natural world, began to play an important and *active* role in the search for explanation in natural philosophy. Following its meaning through the works of several representative authors of the “Scientific Revolution”, we will be able to see how its new and precise

meaning shaped a new and precise structure of what counts as a “scientific explanation”.

3. Francis Bacon: Laws and Forms: Reading the *Book of Nature*

Francis Bacon was one of the first and most convincing advocates of the necessity of a “conceptual revolution”. In an open critique of Aristotelian method in natural philosophy, he showed that nothing “new” would emerge from the old syllogistic model. One of the reasons for this flaw is the deficient definition of several concepts (notions):

The syllogism consist of propositions, propositions of words; words are the signs of notions. If, therefore, the notions (which form the basis of the whole) be confused and carelessly abstracted from things, there is no solidity in the superstructure. Our only hope, then, is genuine induction.³⁰

A list of the notions which are ill defined and need a new definition comprises not only matter and form, but also a whole bunch of “abstract” notions.

We have no sound notions either in logic or physics; substance, quality, action, passion, and existence are not clear notions; much less weight, gravity, density, tenuity, moisture, dryness, generation, corruption, attraction, repulsion, element matter, form and the like. They are all fantastical and ill defined.³¹

Common names are also sources of confusion, but, at least, they can be used as starting points for a subsequent natural philosophy. As for the entire previous list of traditional concepts, it has to be partly abandoned and partly redefined. It is to be noticed that Bacon’s “restoration” went together with a “conceptual revolution” of the traditional philosophical vocabulary and that redefining “matter” and “form” have been but the first step of it. From all the concepts of the old physics/philosophy, matter and form are the first to be analysed/redefined. The interesting aspect is that the whole conceptual reconstruction preserves the “form” and the “matter” as concepts of the theory, but with an entirely different meaning. As, for example:

... forms are mere fiction of the human mind, unless you will call the laws of action by that name.³²

This is just the first occurrence in *Novum Organum* of a strange equivalence between “forms” and “laws” which makes the characteristics of Bacon’s construction. The redefinition of the form, as it appears in the second part of the work is:

For although nothing exists in nature except individual bodies, exhibiting clear individual effects according to particular laws, yet in each branch of learning, that very law, its investigation, discovery and development, are the foundation both of theory and practice. This law, therefore, and its parallel in each science, is what we understand by the term ‘form’, adopting the word because it has grown into common use, and is of familiar occurrence.³³

Notice how much is the Aristotelian vocabulary preserved in this definition. As opposed to modern conception of laws, we have here a “formal” conception of laws, according to which the very individuality of particular bodies depends on “particular” laws. Moreover, according to Bacon, the preservation of the term “form” is due to its philosophical career. It is a strange statement, though, the one through which the preservation of “forms” with an entirely different meaning is justified. There are many traditional concepts in the Aristotelian philosophy, which have been already abandoned by the proponents of the new philosophy, including Bacon’s himself. Why is the status of the “form” different? Notice also the terminological imprecision concerning the “laws”. We have “particular laws”, “laws of action”(II, 17), “laws of matter” (II, 4), “laws of processes” (I, 51) and, eventually, the “supreme and summary” law (and not laws, as we shall see) of nature.³⁴ What are the “laws”, then, and what is their status in Bacon’s theory? How well defined is this (new) concept and why did Bacon insist on using indifferently “form” and “law”?

There are several attempts to answer the previous questions, but also a strong disagreement concerning them. Some authors interpreted Bacon’s usage of the *laws* as mainly “metaphorical” (Steinle, [1995], 332-3) or unsuitable for its purposes (Ress). I want to emphasize that, despite the inherent difficulties due exactly to the conceptual “revolution” undertaken by Bacon, his “laws” do play a role in the program and are very important for further developments of natural philosophy in the seventeenth century.

Bacon's laws are one of the few signs of a deep conceptual change, which was not yet obvious in his time.

First of all, from the above passages and comments it is quite clear that Bacon himself was aware of the deep conceptual change he was proposing, as with the novelty of his terminology. There are many statements which might be invoked in this respect, showing the degree of Bacon's awareness of the boldness of his program. Here are but a few of them:

An instauration must be made from the very foundations, if we do not wish to revolve forever in a circle, making only some slight and contemptible progress.³⁵

He insists upon the fact that his plan opens "an entirely different course to the understanding":

Our only remaining hope and salvation is to begin the whole labor of the mind again; not leaving it to itself, but directing it perpetually from the very first, and attaining our end as it were by mechanical aid.³⁶

The first step in this direction is "the formation of notions and axioms".³⁷ But the pursuit of this very process is not the same anymore. If the "old" philosophy operates with "abstractions", the "new" will employ "experiments" to "dissect" nature:

The human understanding is, by its own nature, prone to abstraction, and supposes that which is fluctuation to be fixed. But it is better to dissect than abstract nature; such was the method employed by the school of Democritus, which made greater progress in penetrating nature than the rest. It is best to consider matter, its conformation, and the changes of that conformation, its own action, and the law of this action or motion, for forms are a mere fiction of the human mind, unless you will call the laws of action by that name. Such are the idols of the tribe, which arise either from the uniformity of the constitution of man's spirit, or its prejudices, or its limited faculties, or restless agitation, or from the interference of the passions, or the incompetency of the senses, or the mode of their impressions.³⁸

I have quoted this passage in length because I think it of an extreme importance. I already gave a part of it as one of Bacon's attempt to preserve the term "form" with an entirely different meaning. But it is useful now to

look at its context, as well. The main point is, I think, the difference between “dissecting” and “abstracting” nature. The reference to Democritus here is also significant. Notice how relative is the “new” in what concerns natural philosophy. Even someone like Bacon whose attitude towards ancient philosophy and authority is not the usual one still feels the need to invoke a tradition when stating the radical changes he has in mind. Because what he does in this passage is a bold change indeed. He claims that natural philosophy has to begin with the study of matter, the “conformation” of matter and the changes of it. Until him, the natural philosophers have been concerned with the study of individual substances and their dynamical net of relations. Here we see the claim that we should begin by studying “matter” and its conformation. It is not at all clear what exactly “matter” means and that is why the reference to Democritus is again useful. Although not a declared Atomist himself (quite the contrary, as he stated the inexistence of atoms and the void), Bacon is nevertheless on the side of corpuscularionism since he talks about the conformation and the change on the conformation of matter. Moreover, he speaks about the action inherent in matter (or in its confirmation) which is striking and at variance with the whole “new” mechanical philosophy, as we shall see.

What we have in this passage is a new conception about matter as an actual substance endowed with properties to be discovered, subject to our activity of dissection. “Form” in its received meaning is a mere fiction, as the reference to the idols of the tribe is showing, but can be used as the law of action/motion of matter or particles of matter. Together with the reference to the ancient Atomism, this passage seems to summarize the whole new doctrine of the mechanical philosophy.

However, there is a considerable danger of oversimplification if we take this path of inquiry, because there are other numerous places in Bacon in which he is as far from any mechanical philosophy as possible (Rees). If we attempt to disclose the underlying ontology of Bacon, we can see that:

- A. What really exist in nature are individual bodies, subject to particular laws (forms).
- B. What counts as knowledge is the knowledge of laws (forms). They make the intelligibility of the world, by giving a unity to a large variety of phenomena. Forms are eternal and immutable.³⁹

- C. There is an entire hierarchy of forms. At the bottom level, they determine the particular nature of a body.⁴⁰ In this respect, there are less “forms” as “conformations” or “configurations” (of matter) (II, 1, II, 9). Any body can be considered an aggregate of simple natures. The very idea is that there are some external “forms-properties” (logical, intelligible), which, once imposed on a “stuff”, will make a determined substance.⁴¹
- D. Each body or substance has a characteristic process of formation/transformation, which can be related with “those fundamental and general laws, which constitute forms”.⁴² In principle, the “perfect knowledge” of a body, meaning a knowledge of his forms (laws), will allow us to transform it into something else (II. 7).

What is the difference between this summary and Aristotle’s ontology of individuals? This crucial question has no straightforward answer. Usually, the analyses of Bacon’s natural philosophy are very concerned with his method and less interested in his ontology, mainly because of the considerable distance between the two. If Bacon’s method looks “modern”, his cosmology and his theory of matter bear the traces of the “old” philosophy. However, beyond its confusing terminology there are important aspects in which Bacon is a representative of the “new” philosophy and a strong opponent of Aristotle. Bacon himself has strongly emphasized the fact that his “forms” cannot be equated with Aristotle’s (II, 17). Secondly, there are two main characteristics of the laws which are coherent with the future doctrine of mechanical philosophy: the laws are imposed on matter as from outside, they do not inhere in the essence of matter or its configurations, and they are seen as a source of activity.

It is not surprising that Bacon uses the “laws” in many instances and with different meanings. One reason for that is the coexistence in his writings of old and new terms, the very sign of a deep conceptual ongoing change. Another is that he emphasized a hierarchy of laws both at the epistemological and at the ontological level. The laws are not only laws of action concerning the motion and configuration of matter but also laws of the Universe as such, imposed by divine commandment on the creation. Hence the very notion of order and meaning came under the same concept.

4. Bacon’s Plan of the New Philosophy and the Program of “The Advancement of Learning”

In the order of knowledge there is a twofold schema comprising theoretical and practical philosophy. The basis of our knowledge is provided by natural history; Bacon’s celebrated collections of facts. The next stage in the theoretical knowledge is natural philosophy. The objects of natural philosophy (physics) are “latent processes” or “latent confirmations” of bodies and their laws. Bacon calls these laws, laws of matter. The next level of knowledge is metaphysics, with a correspondent object, the forms. In what concerns our theoretical knowledge, both processes and forms are steps in a hierarchy of “laws”: laws of matter, laws of action, laws of nature. Only practical philosophy deals with objects as objects, natural philosophy deals with corresponding laws. The implication of this epistemological counterpart of the original construction is that the differences in the meaning of the different aspects and stages of the hierarchy of laws can be grasped through the differences between natural philosophy and metaphysics. While natural philosophy is concerned with the laws of matter (meaning the configurations) and laws of processes (meaning its motions and transformations of the configurations), and these are somewhat similar with the later notion of the “laws of motion”, metaphysics deals with “forms” meaning the essence of reality and the corresponding laws of nature.

Practical philosophy	Theoretical philosophy	Object	Laws
Magic	Metaphysics	Forms	Laws of nature, eternal and fundamental
Mechanics	Physics	Latent processes Latent conformations	Laws Laws of matter

We find here an interesting point to be stressed. In the conceptual framework of the “new philosophy” one of the significant changes involves

the very conception upon what rests metaphysics and what task should be ascribed to it. In opposition with the Aristotelian tradition, Bacon denied the equivalence between metaphysics and a *philosophia prima*. The latter comprises the very foundation of all knowledge; the former merely took over half of the natural philosophy, the formal and final causation and connected it with elements previously outside the realm of philosophy.

For metaphysic, we have assigneth unto it the inquiry of formal and final causes; which assignation, as to the former of them, may seem to be nugatory and void, because of the received and inveterate opinion, that the inquisition of man is not competent to find out essential forms or true differences: of which opinion we will take this hold, that the invention of forms is of all other parts of knowledge the worthiest to be sought, if it be possible to be found. As for the possibility, there are ill discoverers that think there is no land, when they can see nothing but sea.⁴³

On one hand, the task of the metaphysics is to find forms, but not the forms of things (as a lion or a god). Not because there are not such “forms” (formal and final causes of individual natures) but because there is an objective impossibility to discover them. It is not the same thing with the forms of processes, natures and qualities.

... But to inquire the forms of the sense, of voluntary motion, of vegetation, of colours, of gravity and levity, of density, of tenuity, of heat, of cold, and of all natures and qualities, which like an alphabet, are not many, and of which the essences (upheld by matter) of all creatures do consist; to inquire, I say, the true forms of these, is that part of metaphysics which we now define of. (Ibid.)

In other words, the object of metaphysics is the same as the object of physics and we have here another clear statement of the basis of “new philosophy”. What “really” exists is matter in some configuration and exhibiting some qualities, which are in a finite number and reducible to regular behavior or definite laws. Both physics and metaphysics are analysing motions and qualities of the material substance,⁴⁴ but from different perspectives. Natural philosophy deals with material and efficient causality while metaphysics is searching for formal and final causes. Natural philosophy is concerned with the visible part of the world, with the phenomena, while metaphysics deals with essences of reality, formal and final causes. Therefore, the laws of nature seem to have something in

common with the formal and final causes. But formal and final causes for what? There is another aspect of the “new metaphysics” under discussion, its unifying power (II, VII, 6). In its celebrated image, Bacon draws the hierarchy of “knowledge” as pyramids. The basis consists of natural history—Bacon’s “facts”—and the next stage pyramid is natural philosophy. The top of the pyramid is metaphysics, while the “vertical point” is the “summary law of nature” (II, VII, 6). Moreover, these stages are said to be united “in a perpetual and uniform law”. Therefore, the major role of metaphysics is to provide the principles of unification. From the diversity of “facts” to the unity of laws and towards the unique and summary law of nature: this seems to be the path of both knowledge and the essence of reality. It is not surprising that Bacon’s metaphor will prove itself one of the most powerful and appealing images during the seventeenth century (MacLaurin, etc.). It contains, in a nutshell, the basic principles of the new program of reforming the knowledge: the separation between the phenomenal realm and the hidden realm of essences, the non-similarity of the causes and their effects (Bechler), the imposed order and regularity (on the model of the law/laws of nature imposed by divine will in the moment of creation). It also foresaw the main “ideals” of the “scientific knowledge”: order, simplicity, univocation.

As for laws, their hierarchy has a twofold meaning, showing on one hand what kind of explanation we should look for and on the other ensuring us that we are on the right track. With a common inference in the seventeenth century, the discovery of the laws of nature is able to bring us (the humanity as such) closer to God.

5. Descartes: Who Is the Subject of the Laws of Nature?

There are several very different interpretations with respect to the meaning and the purpose of Descartes’ laws of nature in his *The World* and in the *Principles of philosophy*. At first sight, Descartes is the first to use the term with its modern meaning, speaking about “rules” or “laws” indifferently. It seems also quite clear that the laws of nature are laws of conservation, connected with a global principle of conservation grounded in God’s immutability. The claim is that they *follow* from God’s immutability, having, at the same time, the same ontological status as the created “eternal truths”. However, it is not at all clear neither in which way they follow from God’s immutability, nor on what basis do their

character of conservation laws stand. Moreover, it is not clear what is the place of the “laws” in the general program. As Descartes said many times, the explanation of natural phenomena can be made in many ways according to the laws. Special explanatory devices, hypotheses, are necessary in order to decide, from many aspects in which things could be, the way in which things behave (up to a “moral certainty”).

Therefore the laws of nature do not describe the real motions of the individual objects. First of all because between the phenomenal realm and the realms of laws, mathematical truths and intelligible principle there is an unbridgeable gap. Secondly, because in a plenum there are no material objects moving along straight line or preserving their state of rest (there is no rest at all). Thirdly, because in Descartes’ Universe the very existence of individual objects is problematic. What exists as such is an indefinite, homogeneous matter, without any other quality than extension. There is no “space” outside matter and no “gaps” inside it and there is no clear formulated “principle of individuation”. Matter is, at least in principle, indefinitely divisible, so there are no atoms or ultimate particles.

This brief sketch of the Cartesian Universe shows how different are his conceptions about “matter in motion” in comparison with ours or, as a matter of fact, with most of his contemporaries. No external space and no ultimate particles, but matter and motion and laws... Who is, then, the subject of these laws?

5.1 Laws Describing the Evolution of the Universe?

At first sight, Descartes’ purpose in introducing the rules or laws of nature in his early *The World* seems to be connected with a cosmological theory. The context and the structure of the treatise both support such interpretation. The laws are part of the imaginary construction of a “new world”.⁴⁵ Moreover, Descartes himself stressed that the laws are laws created by God in the beginning and that, through their action, the world evolved to a state similar to the present one.

... for God established these laws in such a marvelous way that even if we suppose he creates nothing beyond what I have mentioned, and sets up no order or proportion within it but composes from it a chaos as confused and muddled as any the poets could describe, the laws of nature are sufficient to cause the parts of this chaos to disentangle themselves and arrange themselves in such a good order that they will have the form of a

quite perfect world—a world in which we shall be able to see not only light but also the other things, general as well as particular, which appear in the real world.⁴⁶

The same kind of claim can be found later in the *Discourse*.⁴⁷ Yet, the subsequent development of the argument in *The World* does not plainly support this view. In what way can the laws of nature “disentangle” parts of matter out of the initial chaos in order to create a structure? Descartes’ world is very close to a chaotic one even in the “last” stage of the alleged process of “disentanglement”. We still have a holistic picture of the world, still no individual bodies but only geometrical shapes of variable dimensions. Moreover, the definition of motion is confusing. There is nothing in his model that can account for a dynamical picture of the world,⁴⁸ and is debatable if we have a kinematics either.⁴⁹ As a matter of fact, it has been pointed out that there are in Descartes *two* conceptions about motion: motion as inherent in bodies (in *The World*), and motion as a purely relational quantity. The only connection between them is that of inherent instantaneous tendency to move in a straight line. In this way, the motion in a straight line acquires a special status. Although in the “real” holistic world there are no straight lines.

All the motions which take place in the world are in some way circular. That is, when a body leaves its place, it always enters into the place of some other body, and so on to the last body, which at the same time occupies the place vacated by the first.⁵⁰

There are no individual interactions and no individual motions. Each part of matter is always moved by the surrounded parts and imparts motion to all other world.⁵¹ However, each body has its own tendency to move in an instant, on a straight line. Why is so?

One reason is that there is something very special in the very essence of the motion in a straight line: the fact that it can be grasped in an instant.

So it is that of all motions only motion in a straight line is entirely simple and has a nature which may be wholly grasped in an instant. For in order to conceive such motion it suffices to think that a body is in the process of moving in a certain direction, and that this is the case at each determinable instant during the time it is moving. By contrast, in order to conceive circular motion or any other motion it is necessary to consider at least two of its instants, or rather two of its parts, and the relation between them.⁵²

Any “real” motion needs time, but not the straight-line motion since its nature can be fully grasped in an instant. This means that Descartes’ understanding of motion is very peculiar. The motion is characterized by a *number*, the speed at a given instant, and a *direction*, its tendency to move in a straight line. The first law talks about the conservation of that number, and the third (second law in the *Principles of Philosophy*), about the tendency to move in a straight line. For a special class of motions, the motions in a straight line, those two laws are only one. But there are no motions in straight line in the Universe since “no motion ever takes place which is not circular”.⁵³ Why talk about straight lines then, at what is the significance of the “law of inertia”?

Another reason why “the motion in an instant” is important is in the perspective of the laws of nature as laws of conservation. The conservation of the total quantity of motion in the universe, granted in God’s immutability (II. 36) has a striking feature. God’s continuous action of preservation is an instantaneous action:

... this rule ... depends solely on God preserving each thing by a continuous action, and consequently and his preserving is not as it may have been some time earlier but precisely as it is at the very instant that he preserves it.⁵⁴

Therefore, what God is preserving, recreating, is the tendency to move in the straight line. The previous passage reads:

According to this rule, then it must be said that God alone is the author of all the motions in the world in so far as they exist and in so far that they are rectilinear; but it is the various dispositions of matter which render them irregular and curved.

There is an additional difficulty with this view; it contains in it seeds of the early Cartesian theory of “absolute motion” (Barbour, Bechler). In the light of its relational definition of motion in the *Principles of Philosophy*, the previous passage loses entirely its meaning. What remains, however, is a strange definition of an instantaneous tendency to move which will not represent the actual motion, but which has in itself all the elements of a definition of motion: speed and direction. Meantime, the “real” motions are almost entirely relational. There is no intrinsic speed (but there is an

intrinsic tendency to move, and moreover, there is still the conservation of the total quantity of motions in the world).

There are many attempts to overcome previous difficulties of the Cartesian program. Their success is relative to the precise question to be asked. For what concerns us here, the “subject” of the laws of nature, it suffices to say that neither the parts of matter nor the universe as a whole seem to move according to the laws of nature.

Notice also that another important aspect of Descartes’ Universe is its evolutive character. There is no constancy in size (extension), either at the macroscopic or at the microscopic level. The planets can become comets and the comets can be transformed in planets again. The initial order and the present order of the Universe are not the same, at least “locally”. As a whole, the Universe is a vortex or an ensemble of vortices with a remarkable homogeneity. In its parts, there are no more than variable geometrical shapes in a perpetual change.

The main problem is that, if we consider Descartes’ program as a cosmological theory, the laws of nature do not describe the dynamics of this Universe or its parts, nor its “global evolution” from an “initial” to an “actual” state.

5.2 Laws of “Matter”?

In both *The World* and the *Principles of Philosophy* Descartes suggested that “the nature” subject of laws is, properly speaking, matter. But in addition to this we find a rather peculiar specification:

Note, in the first place, that by “nature” here I do not mean some goddess or any sort of imaginary power. Rather, I am using this word to signify matter itself, in so far I am considering it taken together with all qualities I have attributed to it, and under the condition that God continues to preserve it in the same way that he created it. For it follows of necessity, from the mere fact that he continues thus to preserve it, that there must be many changes in its parts which cannot, it seems to me, properly be attributed to the action of God (because that action never changes), and which therefore I attributed to nature. The rules by which these changes take place I call the “laws of nature”.⁵⁵

I have quoted this paragraph in length because it displays some of the most striking features of Descartes’ construction. First of all, the meaning

of matter here is quite awkward: all the qualities attributed to it are related to extension; in addition, the condition that God continues to preserve matter in the same way that he created it is a very strong claim that imposes not only direct and continuous divine creation, but seems also to imply that this is a new creation of the Universe.

And now we come to the main problems raised by this model. The first one concerns the material “stuff” submitted to the laws: with such a definition, the laws of nature do not touch upon the world, or the extended substance, or the individual bodies. The very definition of matter as extension has as a consequence the impossibility of defining any particular body. What we have in the Cartesian world are only geometrical boundaries and a geometrical movement.

The second problem put forward by the previous quotation concerns the relation between the action by which God preserves the same amount of matter in motion in the world and the claims that there are changes in the world’s “parts” that cannot be attributed to God and need special rules according to which they take place.

5.3 Is God the Only Subject of the Laws of Nature?

One of the most quoted excerpts of the Third Meditation reads:

All of my life can be divided into innumerable parts, each of which is entirely independent of each other, so that from the fact that it existed a short time ago, it does not follow that I ought to exist now, unless some cause as it were creates me again in this moment, that is, conserves me.⁵⁶

There are two important aspects here. First of all, one can argue that this is a strong argument of the non-existence of any source of causality in the physical world (Garber, 1992, 1983, van Ruler, 1996, Nadler, 1993). As a consequence, one can adopt the occasionalist position in interpreting Descartes on the issue. Secondly, and more important at this moment of our analysis, the quoted passage is a powerful expression of the equivalence between creation and conservation. We can find many other explicit passages as, for example:

... plainly, the same force and action is needed to conserve any thing for the individual moments in which it endures as it was needed for creating it anew, had it not existed.⁵⁷

The same position can be found in *The World* and the *Principles of Philosophy* (II. 36). I want to point out some of its possible consequences.

- A. Thinking substance and extended substance are in fact both excepted from the real action of the laws of nature, being the subject of the direct and permanent divine action. In a way, the laws of nature are laws only for God.
- B. These laws do not represent a dynamical evolution but an instantaneous preservation of a tendency of movement.⁵⁸ Accordingly, what is really determined is the inertial rectilinear motion, the only one that needs only an instant to be “fully grasped”.
- C. We were left, in a way, with a sort of a dualistic picture of the Universe in which the connection between the two separated substances is given by God’s instantaneous re-creations of the whole Universe in an instant (including my mind).

I think it is extremely difficult to find a coherent explanation for this contradiction. On one side, we have matter in motion in an evolving Universe set in motion at the beginning and governed by the laws of nature—the picture that clearly appeared in the beginning of *The World* and *The Principles* (as in the celebrated abstract of *The Discourse*, as well). On the other side, we have the successive instantaneous creation of the world.

I suggest that a possible way to look at this contradiction is through the purposes, not the achievements of the theory.

The infinite multiplicity of God’s creation may be seen as representing an infinite number of possible worlds, organized upon the same basic rules (conditions of possibility). At the same time, each of these worlds, left by itself, has a tendency to evolve in the way determined by the particular model presented in *The World*. The divine action of conservation represents, then, not a change in one of them, but a creation of a new world in the very moment in which the previous one starts to deteriorate, because of the imperfect quality of its matter.

6. The Meaning of Descartes’ Cosmology: Defining the Object of Physics and the Subject of the Laws

As we saw already, both in *The World* and in the *Principles of Philosophy*, Descartes’ introduction of his laws of nature occurs in the

context of a global approach to the Cosmos. He claims that his laws of nature follow from his global conservation principle, grounded in God's immutability.⁵⁹ Several commentators have said that there is no logical route from the global conservation principle to the laws of nature seen as laws (of motion) for parts of matter.⁶⁰ The issue of the connections between God's immutability, the global conservation law and the conservation laws applying to the parts of matter is considered to be problematic⁶¹ indeed, because, for example, from the fact that God is conserving the global state of the Universe it does not follow that the laws are conservation laws. However, I think that there is a way in which we can consider that the laws of nature "follow" from a global conservation principle and also they are laws of conservation and this is *by analogy*.

In order to explain the fact, I suggest to start from considering the question of individuation as a possible key to the interpretation of Descartes' conservation principles. I have argued elsewhere⁶² that Descartes attempts to individuate bodies over time by a conservation principle applying to the state of the body. What the first law states is that, due to God's immutability and veracity we are living in a Universe in which "the state" of each part of matter is "naturally" preserved through time. The state of a body is characterized by its shape and its motion, and hence individuation of a given part of matter is achieved by appeal to conservation principles for extension and motion. The second law of nature is that at a given instant each part of matter, *of itself* (from its own nature), tends to move on a straight line. Therefore, the instantaneous direction of motion, Descartes' *determinatio*, might be seen as an attempt to characterize a given individual feature of a "body". It is obvious that this determination is not unique, but nevertheless, the conjunction between the previous two laws might be seen as an attempt to state what a body really is in this peculiar Universe. Now, the interesting fact is that the same account may be applied to the Universe as a whole. What is preserved for the individual parts of the world—extension⁶³ and quantity of motion—is the same as what is preserved for the Universe as a whole. In this case, the total quantity of motion is the quantity of motion that God has put into the Universe at the beginning.⁶⁴ The conservation of the indefinite extension and the total quantity of motion over time are grounded in the immutability of divine *action*.⁶⁵ This is the way in which God guarantees that the Universe at any given instant is the same one as at the previous instant. Thus the Universe as an object of our knowledge is given by the global conservation principle, which allows us to move from

the intelligibility of matter in motion to a world existing through time. This claim is supported by the fact that Descartes introduces his conservation principles at the point in his argument where he needs to provide the object of his physics: the Universe.

The global conservation principle gives the conditions for the Universe to be an object of Descartes' knowledge; the conservation laws for the parts of matter similarly give the conditions for these parts of matter to be physical bodies. The route from the global conservation principle to the conservation laws for the parts of matter is not intended to be deductive; it is an analogy based on God's immutability and the intelligibility of the world. Although the relation of analogy is logically symmetric, the global conservation principle has ontological priority, and it is in this sense that by means of the analogy the conservation laws for the parts depend on the global conservation principle.⁶⁶

7. Newton's Cosmology and the Laws of Nature

The general opinion of those who saw in Newton the "father figure" of modern science agreed upon the fact that he discovered the laws of nature. In what follows I am interested in a very specific problem, one of the problems that bear the mark of an ongoing debate. What laws of nature did Newton discover, why didn't he call them "laws of nature" and in which contexts did he use this phrase?

In short, the problem is the following: Newton's followers understood by Newton's "laws of nature", mainly his law of universal attraction. The meaning of the "laws of nature" was, as we shall see "God's commandments for the world". In the meantime, Newton never called his theorems concerning gravitation (in the *Principia*) laws of nature or referred to them in this way. The following generations of Newtonians tend to attribute the status of "laws of nature" rather to the laws of motion,⁶⁷ explaining their importance and unifying powers⁶⁸. As the scientific conception prevails and the science evolved, the concept of "laws of nature" lost its old meaning, connected with God's power and ways of intervention into the world. But this was the meaning when Newton had been working on his theory.

7.1 How Did the Newtonians Interpret the Laws of Nature

All of Newton's disciples and intellectual friends seem to agree that he did indeed discover the laws of nature. When Cotes, Clark, Bentley or the younger generation: MacLaurin, Pemberton, etc. talk about Newton's laws, they understand by that mainly the law of gravitation. Not in the same way, though. In his most criticized preface, Cotes talks of laws of forces.⁶⁹ Laws are then causal statements about the actions of forces on the components of the world. Several pages later, he, interestingly enough, mentions the law of inertia as the "Law of nature"⁷⁰ (on which all philosophers agree). This passage is a variance of the opinions stated by Newton in *Principia* and the related manuscripts. Moreover, Cotes himself expresses a different opinion in the following pages. The laws of nature are this time connected to the frame of the world. They are the expression of God's commandments and a manifestation of his power and wisdom.

Without all doubt, this world, so diversified with that variety of forms and motions we find in it, could arise from nothing but the perfectly free will of God directing and presiding over all.

From this fountain it is that those laws, which we call the laws of Nature, have flowed, in which there appear many traces indeed of the most wise contrivance, but not the least shadow on necessity.⁷¹

Strange as this passage may seem to us today, it is the expression of a common opinion in seventeenth century natural philosophy. God's laws for Nature are not the expression of an intrinsic universal order of things, but as commandments, imposed from outside on the world and its objects.⁷² That the laws of nature are contingent on the will of God is by no means a new idea in the seventeenth century. What is new is that they are seen as the laws used by God in framing this world in the first place and preserved, ever since, as commands for all the powers of Nature. They are connected with the creation and the frame of the world. Although Cotes claims in his *Preface* that the search for the laws of nature is the purpose of true philosophy,⁷³ others are not so bold in their claims. Although he insists that natural philosophy is a foundation for natural religion and a way to know God, MacLaurin emphasizes that the ultimate causes cannot be discovered. It is worth noticing that one of the main "scientific" disciples of Newton in the eighteenth century still preserves the seventeenth century beliefs in the hidden plan of the divine creator and the causal chain set up by God in the beginning. MacLaurin's way

out from the dilemma of the unknown cause of gravitation is to state that ultimate causes must remain hidden:

The great mysterious Being, who made and governs the whole system, has set a part of the chain of causes in our view; but we find that, as he himself is too high for our comprehension, so his more immediate instruments in the universe, are also involved in an obscurity that philosophy is not able to dissipate; and thus our veneration for the supreme author is always increased, in proportion as we advance in the knowledge of his works. As we arise in philosophy towards the first cause, we obtain more exhaustive views of the constitution of things, and see its influences more plainly. We perceive that we are approaching to him, from the simplicity and generality of the powers or laws we discover; from the more and more complete beauty and contrivance, that appears to us in the scheme of his works as we advance...⁷⁴ but still we find ourselves at a distance from him...⁷⁵

Therefore, a way to know that we are on the right track is the unifying power of the laws we discover;⁷⁶ and this is indeed consonant with Newton's program of unification. Once some few fundamental forces are discovered, we can determine their laws of motion and their domain of applicability. At once we have to notice that there is a difference in status between the laws of nature and the laws of motion. Bentley, the first to popularize Newton's natural philosophy, carefully made this distinction. For Bentley, the laws of motion are the laws that describe the behavior of matter. Entirely passive, they are not able to account for the creation or for the perfect regularity of the frame of the world.⁷⁷

To conclude, several of Newton's contemporary disciples consider that the laws of nature are connected with the "first causes", have an active character – as opposed to the passive laws of motion – and are "hidden" beyond the phenomena. It was seldom argued that Bentley's and Cotes' opinions do not reflect Newton's and are seriously misleading.⁷⁸ In what will follow I will suggest that Newton's own opinions are rather close to those held to be his opinions by Bentley, Cotes or MacLaurin, especially concerning the laws of nature.

7.2 Is Universal Attraction a Law of Nature?

One of the peculiarities of *Principia* (and they are by no means only few) is that the term "laws of nature" does not appear at all in it, except in

Cotes' preface to the second edition. Several explanations were proposed for this fact. According to one of them, Newton's avoidance of the term is connected with his polemical intentions against the Cartesians.⁷⁹ According to other readings, Newton wants to prevent the interpretation of his force of attraction as an occult quality.⁸⁰ Knowing that he cannot provide a mechanical explanation, he is trying to smuggle in the third book all the physical theory of universal attraction as a series of propositions and theorems.⁸¹

I am suggesting a line of interpretation, which, without contradicting the previous two, will put the things on a different perspective. What I am saying is that by looking at the fragments of the manuscripts in which Newton is speaking about the laws of nature, we will see that the missing cause of gravitation is the answer for Newton's avoidance of the term. I suggest that the absence of the term in *Principia* might tell us a lot about what meaning Newton associated with it.

In *Principia*, "universal attraction" appears only as a proposition inside of a string of propositions at the beginning of Book III. There is no mention of any "law" in it. Many pages have been written about the way in which Newton is introducing universal gravitation in his book about the system of the world.⁸² It was especially pointed out the role of mathematics and mathematical devices in his construction: the passage from mathematics to physics is done basically by replacing the expression "centripetal force" with the word "attraction".⁸³

The series of propositions that deal with universal attraction are constructed by a procedure which relies heavily on Newton's Third Rule and the "analogy of nature". Starting with one heavy body attracted toward the Earth, Newton points out the analogy between the motion of this body and the motion of the Moon in an infinite short period of time. Both of them tend to fall on the surface of the Earth. Moreover, if we imagine that the Moon is smaller and closer to the Earth, there is no essential difference between its motion and the motion of any other heavy body (except that it is prevented from falling by the tangential component of its speed, the centrifugal force, an effect of its inertia). Newton's next step is to extend the same kind of reasoning to Jupiter, to its moons, and so on. In each case there is a two-body interaction: between the Earth and the Moon in the first case, between the Sun and some other planets in the others. The generalization from a two-body system to a many-body interaction is clearly done by attributing a universal property to all the bodies in the Universe. The universal attraction is something connected with each body

and not a property of the system or of the space between them. I think it is fair to assert that, in the first instance, Newton considered gravity as inherent to bodies.⁸⁴ However, he might have changed his mind soon enough. Gravity, as an inherent quality in matter, is very similar to those occult qualities abhorred by the mechanical philosophers of the seventeenth century. Again, it has been a perpetual dispute between Newtonian scholars in the last decades about the status Newton ascribed to gravity.⁸⁵ The subject of this paper is closely related with these topics, because Newton's reluctance to use the words "laws of nature" in *Principia* is obviously related with his lasting ambiguity concerning the status of gravity.

Let us start first with the relevant passages from the *Principia*. Proposition VI in Book III is the first relevant one. It reads:

That all bodies gravitate towards every planet; and that the weights of bodies towards any one planet, at equal distances from the center of the planet, are proportional to the quantities of the matter that they severally contain.

This is, of course, the result of a constructional strategy, which starts from two-bodies interaction (Earth-physical body, Earth-Moon) and generalizes the result in the same schema. Until here we have nothing more than the replacement of the centripetal force from Part One with "attraction"/gravitation. The next step is the problematic one, because it ascribes a property, "gravitation", to all bodies whatsoever (regardless the configurations in which they exist, their size, etc.).⁸⁶

Proposition 7 Theorem 7

That there is a power of gravity pertaining to all bodies, proportional to the several quantities of matter, which they contain.

That all the planets gravitate one towards another, we have proved before; as well as that the force of gravity towards every one of them, considered apart, is inversely as the square of the distance of places from the center of the planet. And thence (by Prop. 69, Book 1 and its Corollaries), it follows that the gravity tending towards all the planets is proportional to the matter, which they contain.

Moreover, since all the parts of any planet A gravitate towards any other planet B; and the gravity of every part is to the gravity of the whole as the matter of the part to the matter of the whole; and (by Law III) to every

action corresponds an equal reaction; therefore the planet B will, on the other hand, gravitate towards all the parts of the planet A; and its gravity towards any one part will be to gravity towards the whole as the matter of the part to the matter of the whole.

There are a lot of ambiguities in these passages. First, gravity is described as “power” pertaining all bodies; it is a force, which resides only in matter and has a universal character. In earlier versions, Newton attributes more clearly gravity to bodies.⁸⁷ As Wesfall pointed out⁸⁸ we can consider that Newton underwent an evolution from a stage in which he considered gravitation to be an essential property of matter to the one in which he insisted upon its different character. But what is gravity, if not an essential property of matter? We can see that the quoted passage opens several questions at once:

- A. What is gravitation?**
- B. Does gravitation inhere in bodies?**
- C. What is the cause of gravitation (attraction)?**
- D. Why is the “law of universal attraction” presented as a simple proposition?**

I am not attempting to solve any of these problems in the present paper. They have been extensively discussed by almost all the scholars in the field. What I am suggesting is that their existence might be the cause, which prevents Newton to use the term “law of nature” in connection with gravity in *Principia*. His famous passages concerning Hypotheses might be seen in a different perspective if they are paralleled by examples of a suppressed association between universal gravitation and the term “laws of nature”. I have found one such example in a draft for the *General Scholium*,⁸⁹ which reads:

From the phenomena it is very certain that the gravity is given and acts on all bodies according to the laws described above in the proportion to the distances, and suffices for the motions of Planets and Comets and thus it is a law of nature although it has not been possible to understand the cause of this law from the phenomena. For I avoid hypotheses, whether metaphysical or physical or mechanical or of occult qualities.

I consider that the omission of this equivalence between gravity and “law of nature” in the published *General Scholium* is highly significant for Newton’s idea about what a law of nature should be. Far from ascribing the character of law for gravity, *Principia* and the *General Scholium* insist on its mathematical character.⁹⁰ This might suggest the form and the purpose of the concept for Newton: laws of nature must have a causal status and must refer to one of the “first” or “general” causes responsible for the existent frame of the world. The law of universal attraction is not a law of nature because we don’t know the cause of gravitation. This might suggest us that once we would discover it, that causal statement would be a law of nature. Therefore, Newton’s various imaginative devices to explain/find the cause of gravity might be seen as a quest for the laws of nature.

But before exploring these various devices, let us see what status possessed the other candidates for the “laws of nature”, namely Newton’s laws of motion.

Why are they not laws of nature?

- a) Newton never called them so.
- b) He explicitly stated their passivity in opposition with the activity/capacity of creation of the active principles.⁹¹
- c) The laws of motion in *Principia* are not the only possible laws of motion. There could exist other laws of motion for other types of interaction. Each “principle of motion” seems to have its own set of laws of motion.⁹²

7.3 Explanatory Mechanisms for Universal Attraction What Is (the Cause of) Gravitation?

At various stages in his life, Newton proposed different devices for explaining the cause of gravitation. As several authors already pointed out, although the most enduring mechanism in Newton’s attempts to explain gravitation was ether, there are several meanings Newton used for ether during his life.⁹³ Some other hypotheses were connected with alchemy. In chronological order, they are:

1. Condensed alchemical spirit (early alchemical drafts).
2. Mechanical ether (*Questions, Waste Book*, and, after an apparent break in 1668, again in manuscripts connected with *Principia* or in drafts of optical *Queries*).

3. Ethereal spirits (*Hypothesis on Light*, and manuscripts from the same period).
4. Mechanical ether and some active principle(s) (*Opticks*).
5. Unknown spiritual agent mediating God's direct interventions (*Letters to Bentley*).
6. Active principles (*Opticks*).

What all these have in common is a "source of activity" separated from the passive matter. The ultimate source of this activity is God, acting in the world through some mediators. I think it is relevant that although all these explanations are dependent on God's creation and "maintenance", none of them postulate the direct divine intervention in Descartes' way, for example. Newton's God is always manifesting his actions through mediators, and as we shall see, this is one of Newton's "principles of philosophy" (and theology, as a matter of fact).

7.3.1 Condensed Alchemical Spirit (1660s?)

Several early alchemical manuscripts refer to a vital agent, a mercurial spirit, universal and active. This is a spirit which penetrates through the entire Universe, regardless of the presence of matter. It seems to have a cosmological role, and is also responsible for all the creation and preservation of matter.

The vital agent diffused through everything in the earth is one and the same.

And it is a mercurial spirit, extremely subtle and supremely volatile, which is dispersed through every place...

This agent has the same general method of operating in all things, namely, excited to action by a moderate heat, it is put to flight by a great one, and once an aggregate has been formed, the agent's first action is to putrefy the aggregate and confound into chaos. Then it proceeds to generation.

And the particularities of this method are many, according to the nature of the subject in which it operates. For it accommodates itself to every nature. From metallic semen it generates gold, from human semen men, etc.

And it puts on various forms according to the nature of the subject. In metals is not distinguished from the metallic substance, in men, not from the human substance, etc.

In the metallic form it is found most plentifully in Magnesia. And from this one root come all species of metals. And that in this order: mercury, lead, tin, silver, copper, gold.⁹⁴

Or:

The vapor of the elements... is very pure and almost insensible and contains in it the spirit of fire or light, which is the form of the universe... And in descending and becoming sensible it first puts on the body of the air which we breathe and becomes enclosed in it to nourish and vivify all nature. And that it may act more easily upon the grosser bodies of vegetables and minerals, it becomes still denser and insinuates itself into the water.⁹⁵

However, the “alchemical spirit” will not last as an explanatory device for Newton. As soon as the 1660s he is searching other mechanical or non/mechanical causal agents. As an interesting difference, although he will talk about “spirit” in later writings, there is not a unique cosmological spirit at work anymore, but several different spirits.

7.3.2 Mechanical Ether (1660s, mechanical philosophy)

(*Waste Book, Questions, etc.*)

It is interesting that mechanical explanations using ether are contemporary with Newton’s “Cartesian” period of his early student years in Cambridge (see *Questions*). Soon enough Newton will abandon the mechanical ether. Apparently, he changed his mind somewhere around 1668, when, in *De Gravitatione*, he criticizes Descartes’ ether, and replaces it with the absolute space. If this is indeed so, then by 1672 he changed his mind again, this time in favor of a universal ethereal spirit with alchemical connotations.

I think it is fairly clear that mechanical ether as an explanatory device for gravitation is abandoned and replaced with a combination of mechanical ether and active principle(s), as in *Opticks*, or a material and a spiritual ether in a more alchemical or Neoplatonic tradition.⁹⁶

7.3.3 Ethereal Spirit(s) (1670s, 1710?)

Not only in Newton's alchemical manuscripts but also in his published works, ethereal spirits play an important role. From this point of view, one of the most interesting texts is Newton's second published paper, *A Hypothesis Explaining the Properties of Light* (1675), in which terms belonging to alchemy and natural philosophy coexist in a sort of "alchemical cosmology".⁹⁷ The general basis of explanation in *A Hypothesis...* is an ethereal medium, compounded of "the main phlegmatic body of aether" and various ethereal spirits.

All things are generated from ether, in a general process of continuous transmutation:

Perhaps the whole frame of nature may be nothing but various contextures of some certain aethereal spirits, or vapours, condensed as it were precipitation, much after the same manner, that vapours are condensed into water, or exhalations into grosser substances, thought not so easily condensable; and after condensation wrought into various forms; at first by the immediate hand of the Creator; and ever since by the **power of nature**; which, by virtue of the command increase and multiply, became a complete imitator of the copies set her by the protoplast. Thus perhaps may all things be originated from aether.

This peculiar ether is the cause of gravitation, as of whatever else exists in the Universe. His action is a cosmological one. Interesting enough, this all-pervasive ethereal spirit is responsible for the continuous creation of matter, under God command, and after God's model. There are plenty of alchemical terms here.⁹⁸ It is also worth noticing that besides the alchemy, an important theological aspect might be involved. The word of God is in Newton's case the power of nature and its ethereal manifestation.

Apart from this, it is extremely interesting that Newton combines theological or alchemical explanations with natural philosophy. For example, for expressing the fact that the ethereal spirits are responsible for whatever exists in the world, he gives a familiar example, an analogy with an experiment: an electrically charged piece of glass and small pieces of paper.

And as this condensed matter by rarefaction into an aethereal wind (for by its easy penetrating and circulating through glass I esteem it aethereal) may cause these odd motions, and by condensing again may cause

electrical attraction with its returning to the glass to succeed in the place of what is continually recondensed; so may the gravitating attraction of the earth be caused by the continual condensation of some other such like aethereal spirit, but of something very thinly and subtilly diffused through it, perhaps of an unctuous or gummy, tenacious and springy nature, and bearing much the same relation to aether which the vital aethereal spirit, requisite for the conservation of flame and vital motions, does to air.

It is worth noting that we have all the elements of an alchemical cosmology. Ether and ethereal spirits are responsible for a global process of transformation labeled "condensation" by which everything was formed. What we have here is the continuous creation, taking place in Nature according with God's commandments and to his initial plan. Newton is manipulating the traditional story of the alchemical cosmology: Nature is alive and fallen (because of human original sin) and should be redeemed by Art. There is a continuous process of transformation and transmutation taking place at the cosmic scale and the role of the alchemist is just to speed up this process.

For nature is a perpetual worker, generating fluids out of solids and solids out of fluids, fixed things out of volatile and volatile out of fixed, subtle out of gross and gross out of subtle...

The same ethereal spirits can be found in many other manuscripts. Here is an example:

For if such an aethereal Spirit may be condensed in fermenting or burning bodies (or otherwise inspissated in ye pores of ye earth to a tender matter which may be as it were ye succus nutritious of ye earth or primary substance out of which things generable grow) [or kind of a humid active matter for the continuall uses of nature, adhering to the sides of those pores after the manner that vapours condense on the sides of a Vessell subtly set]; **the vast body of the Earth, who may be every where to the very center in perpetual working, may continually condense so much of this Spirit as to cause it from above to descend with great celerity for a supply.**⁹⁹

7.3.4 Mechanical Ether and Some Active Principles

(*Opticks* 1704, *Opticks*, 1718 [*Queries*])

Basically this means only a reformulation of the same problem by adding another mediator, the mechanical ether.

7.3.5 Unknown Spiritual Agent Mediating God's Direct Interventions

(*Letters to Bentley*)

Much has been said about Newton's celebrated correspondence with Bentley,¹⁰⁰ especially in connection with Newton's alleged distaste for action at a distance. It seems to me that John Henry argued convincingly against the common interpretation, showing that Newton (and Bentley, for that matter) were rather in favor of the action at a distance, provided that the power of attraction is not an essential quality of matter. According to Henry, God endowed matter with a non-essential but universal property in the beginning. Since the moment of creation, God is acting into the world only by his *potentia ordinata*. Henry's main argument is that God is acting on the bodies through a "material or immaterial spirit", therefore through an intermediary. But, as it was pointed out several times (Oakley, Osler, etc.), the distinction between *potentia absoluta* and *potentia ordinata* stands on a rather different ground than mediation. God is acting according to the very rules he established in the first place, or against them — according to the laws of nature or against them. Accordingly, and taking into consideration Newton's voluntarism, God's actions into the world can be done through his absolute power¹⁰¹ (therefore, a special theory on miracles), but also through the mediation of active principles.¹⁰² At stake here are special issues concerning causality: is the Universe causally closed? Can matter be created after the initial creation (by the powers of nature or by the art of the alchemist)? Can matter be created without gravity?

7.3.6 Active Principles

As a partial conclusion in this point of my survey, I suggest that there is an additional common feature of all previous 4 devices for explaining the gravity. All of them are in the last instance "active principles" or can be reduced to active principle(s). You might say that this is not making the things more clear, since it is rather confusing what Newton meant by active principles. I do suggest that an analysis of this Newtonian term will

bring us to the meaning Newton attached to the concept of the laws of nature.

Of course, the problem of understanding of what are the active principles is not an easy one and involves a considerable detour to the seventeenth century natural philosophy. There is no place here for such a digression. Suffice to say that the term is a common one in the seventeenth century and, as such, it is often used by mechanical philosophers to explain why sources of activity do exist in the world.¹⁰³ It was often pointed out that one of the main failures of mechanical philosophy was that by throwing away Aristotelian forms and prime matter, it lost all the natural sources of activity in the world.¹⁰⁴ The natural world of the mechanical philosopher is purely passive.¹⁰⁵ The way out of this difficulty is either the reintroduction of some active principles,¹⁰⁶ or some extreme form of voluntarism (occasionalism).

7.4 Newton's Active Principles

The key passages concerning active principles and the laws of nature are to be found in Newton's *Opticks*. But, before considering them, it would be interesting to emphasize their place in Newton's works. We have seen already that the term "law of nature" was suppressed from Newton's *General Scholium*, and that we cannot find it in any of the works connected with celestial mechanics. And now we find it in *Query 31* with a very clear-cut meaning: laws of nature are active principles or results of active principles.

It seems to me, further, that these particles have not only a *vis inertiae*, accompanied with such passive laws of motion as naturally result from that force, but also that they are moved by certain active principles, such as is that of gravity, and that which causes fermentation, and the cohesion of bodies. **These principles I consider, not as occult qualities, supposed to result from the specific forms of things, but as general laws of nature, by which the things themselves are formed; their truth appearing to us by phenomena, though their causes be not yet discovered.**¹⁰⁷

I consider this definition and the place in which it was written as highly meaningful. If the laws of nature are active principles, they stand beyond mechanical explanation (or beyond the mechanical explanation Newton was able to offer). They are active and creative and they are obviously

connected with the microscopic level. If the law of universal attraction has something to do with the laws of nature (active principle) this could be only at the microscopically level of some intermediary device, which is responsible for its production. I would suggest that we have here a possible delimitation between two separate realms of being: the macroscopical and mechanical world of the celestial mechanics in which the existence of gravitation is enough for us to make sense of the order and design of the Universe, and the microscopic world of continuous creation and active principles, an alchemical laboratory of Nature.

Let us summarize the properties of active principles for Newton.

7.5 Properties of Active Principles

Principles of motion and conserving the motion

According to Newton, the quantity of motion in the world as a whole is not conserved. As in the case of matter, which seems to be continually produced and annihilated, motion is produced by active principles.¹⁰⁸

The *vis inertiae* is a Passive principle by which bodies persist in their Motion or Rest, receive Motion in proportion to the Force impressing it, and resist as much as they are resisted. By this Principle alone there never could have been any motion in the world. **Some other Principle was necessary for putting Bodies into Motion; and now they are in Motion, some other Principle is necessary for conserving the Motion.**

For we meet with very little motion in the world besides what is owing to these active principles & therefore we ought to enquire diligently into the general Rules or Laws observed by nature in the preservation or production of motion by these principles as the Laws of motion on which the frame of Nature depends & the genuine principles of the Mechanical Philosophy.

Causal agents acting according to certain laws

Active principles are clearly causal agents.

Gravity must be caused by an agent acting constantly according to certain laws: but whether this agent is material or immaterial, I have left to the consideration of my readers.¹⁰⁹

As for rejecting such a medium (*aether*) we have the authority of the oldest and most celebrated Philosophers of Greece and Phoenicia, who made a vacuum, and Atoms, the first principles of their Philosophy tacitly attributing gravity to some other cause than dense matter.¹¹⁰

Agents responsible for the cohesion and formation of bodies

There are therefore agents in Nature able to make the particles of bodies stick together by very strong attractions. And it is the business of experimental philosophy to find them out.¹¹¹

Have not the small particles of bodies certain powers, virtue or forces, by which they act at a distance, not only upon the rays of light for reflecting, refracting and inflecting them, but also upon one another for producing a great part of the of the phenomena of Nature? For it is well known that bodies act upon one another by the attractions of gravity, magnetism and electricity; and these instances show the tenor and course of Nature, and make it not improbable but that there may be more attractive powers than these. For Nature is very consonant and conformable to herself.¹¹²

Mediators of the divine interventions

(Letters to Bentley, Principles of Philosophy)

One of the key problems concerning Newton's natural philosophy and theology is his constant use of mediation and mediators.¹¹³ The subject is far too vast for us to discuss it here; suffices to say that for Newton God's actions into the world take place through a continuous process of mediation. There might be "mediators", but for sure active principles are such devices connected with mediation. In his third letter to Bentley¹¹⁴ Newton says:

It is inconceivable that inanimate brute Matter should, without the Mediation of something else, which is not material, operate upon, and affect other Matter without mutual Contact, as it must be, if Gravitation in the sense of Epicures were essential and inherent in it.¹¹⁵

The mediation is done by "an Agent acting according to certain Laws" and through this mediation distant bodies act upon each other.¹¹⁶

7.6 Active Principles and the Cause of Gravity

Putting together excerpts from the letters to Bentley and later optical *Queries*, the picture becomes complete. An active principle is the cause of gravity;¹¹⁷ therefore active principles must be “material or immaterial” Agents, through which the mediation is done. They act according to “certain laws” imposed by God in the beginning and as such they are the laws of nature. It is not clear if there is one active principle causing gravity or there are many active principles acting undifferentiating as divine Agents through the Creation. What can we say, though, is that for Newton there are many active principles, and some of them concern vegetation, fermentation, life, i.e. the “continuous creation of matter”,¹¹⁸ the cohesion of bodies, and so on. I think there is still an open question if the active principle concerning gravity is of the same kind or not. A further exploration of these issues will involve the *potentia absoluta/potentia ordinata* discussion, but it might prove itself extremely valuable for coming to terms with Newton’s cosmological picture.

To conclude for the moment, we have seen that the laws of nature are active principles and the active principles are God’s Agents into the world. This suggests that we shall look to Newton for a hierarchy of laws of which the laws of nature constitute only one level. A still active and causal level, as opposed to the passive level represented by the laws of motion.

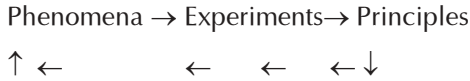
There are, however, several important questions that need to concern us here. What is the connection between the laws of nature and the laws of motion? Can we discover the laws of nature? And, most important of all for the understanding of Newton’s *Principia*, what is gravitation?

7.7 Newton’s Principles of Philosophy

In order to answer these questions we need an epistemological detour. I think that a relevant text for this epistemological counterpart of the previous analysis is the manuscript labeled (by McGuire) as *Newton’s Principles of Philosophy*. We can find here that Newton is listing gravity among the Principles of his natural philosophy,¹¹⁹ together with God, the impenetrability of bodies and the existence of atoms. This might be an interesting hint, and if we reconstruct the previous analysis from an epistemological point of view, we will get a very different picture.

Newton’s methodological approach in the principles of philosophy is coherent with his Rules of reasoning in *Principia*. We should proceed

from experiments to theoretical conclusions, which, in turn, should be amended by further experiments.

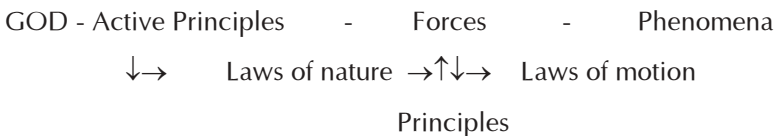


In this way, our domain of study is extended. But eventually we have to stop. We will do this only when we will be able to delimitate a complete domain of phenomena.

And there is no other way of doing any thing with certainty than by drawing conclusions from experiments & phenomena until you come at (such) general Principles (as are) & then from those Principles giving an account of Nature. Whatever is certain in Philosophy is owing to this method & nothing can be done without it.¹²⁰

We can recognize here Newton's general research program¹²¹. We can also understand in which way is gravitation a principle. The principles are neither laws of nature, nor laws of motion, but epistemological devices, which allow an end point for our quest. They might have unknown causes, and they cannot be tested directly, but they are considered in virtue of their unifying power.

In other words, Newton's general scheme is:



God is always acting into the world through active principles, but we see only forces and the phenomena they are producing. The mathematical relations between the forces and the produced phenomena are the laws of motion. The laws of nature are, presumably, the relations between the active principles and what we perceive as forces. The domain of our certain knowledge is limited. We don't know the laws of nature and we cannot see the active principles. God's actions into the world are invisible and unknowable. What we can see and discover are forces of different kind and, through Newton's method, we can delimitate with accuracy their

actions and the corresponding laws. What we would call today the main interactions, are Principles: they define and delimitate a special domain of activity. As a matter of fact, gravity is the only discovered “principle”. Newton’s schema provides a place for other principles also, as the last paragraph of the *General Scholium* is showing.

7.8 Conclusions

1. God acts always through the mediation of active principles.
2. He is not subject to the laws of nature, but acts always through *potentia absoluta*, i.e. “creating” through the mediation of active principles, matter, bodies, at the microscopic level.
3. Active principles are able to create much more than we can imagine (Nature might be alive), but they are subject to the laws (divine commandments). Active principles are the expression of divine activity in the world.
4. The laws of nature are regulating the secondary actions of creation. The result of these actions is not only matter but also forces. We cannot know or we do not know the laws of nature.
5. What we can do is to discover sources of activity/forces and describe the interactions through laws of motion. Because we don’t know the causes of these “fundamental interactions” they are called Principles (of philosophy). They are tested through experiments and appreciated according with their unifying power.

NOTES

- 1 Examples for this point of view, which can be considered the “classical” one for historiography: Dijsterhuis (1961), Koyre (1957), Copenhaver and Schmitt (1992), etc.
- 2 See Garber (1995), Garber, Joy, Henry, Gabbey (1998), etc.
- 3 There are many conceptual and historical problems involved in using this term, despite its brilliant career in the last half of the century. See I.F. Cohen, (1994), I.B. Cohen, (1985), and my paper, KRISIS (1999).
- 4 Stephen Menn (1998), p. 34, Copenhaver, Schmidt, (1992) pp. 303-328. In most of the seventeenth century works on natural philosophy, metaphysics or even theology there is an increasing emphasis on the “new” as opposed to an “old” philosophy. The meaning of this “new” and “old” is not always straightforward: “new” philosophy does not mean usually more than “different” from traditional Aristotelianism. In this way Hermeticism, Neoplatonism and all brands of *prisca theologia* can be related to the “new philosophy” as in Bacon, More, Newton. See for example Gaukroger (1991), Yates (1964).
- 5 See, for example, Jolley (1989), p. 363, Cunningham (1991), Osler (1995), Osler (1994).
- 6 Marsilio Ficino, Pico, the Padovan school, and even Kepler, in *Epitome*, were engaged in such a task.
- 7 Grant (1982), Grant (1994), Sorabji (1991), etc.
- 8 See Descartes’ critique of the void in the second part of the *Principles of Philosophy* for a standard account of the seventeenth century “fear” of void.
- 9 See M.B. Hall, *Matter*, pp. 345-346.
- 10 J. Henry (1986), M.B. Hall (1963), etc.
- 11 See Garber, Henry, Joy, Gabbey, (1998).
- 12 Daniel Sennert, Jacoppo Zabarella, etc. See Garber, Henry, Joy, Gabbey (1998).
- 13 The most famous being Descartes, who postulates the existence of three kinds of physical particles, insisting on the same time upon the indefinite divisibility of matter. See *Principles of Philosophy*, part II and III.
- 14 As, for example Galileo. See Bechler (1991), Garber et. al. (1998).
- 15 Cambridge Platonists, Warner, Harriot, Hill. See Henry (1982), Garber et al. (1998).
- 16 This demonstration is the subject of one of the chapters of my Ph.D. thesis.
- 17 Henry (1982), Osler (1994), etc.
- 18 See Copenhaver and Schmidt (1992), p. 305.
- 19 J. Fitzgerald (1963), at p. 97 emphasized the importance of the concepts of matter and forms in a convincing manner. “In the first two books of *Physics*, Aristotle is concerned with the discovery and formulation of those primitive concepts, form and matter, which, in his view, are entailed in the very possibility of such existing things as confront, everywhere and always, the

human observer. Their discernment and formulation do not, in his view, constitute in any sense a 'science' of nature, but rather the most general preconditions of any science of nature, both with respect to the existence and the scientific cognition of nature. Accordingly, they are said to be 'principles' precisely in the sense that there is nothing in nature prior to them in being or in concept, and they are entailed in everything else in nature and our knowledge of nature."

20 See Bechler (1991) about the Aristotelian structure of what counts as a "scientific" explanation.

21 Oakley, (1961), p. 433.

22 Zilsel (1942), Needham (1956), vol II, pp. 518-583.

23 See Whitehead (1937), (1993), Crombie (1996), Oakley (1961), etc.

24 Whitehead (1937), p. 142.

25 For example, Funkenstein (1986)) emphasizes the importance of "secularizing" natural theology, which became a domain of study for non-theologians, to be almost identifiable with natural philosophy. Oakley (1998) points to the radicalization of the seventeenth century theology and its constraints. On the other hand, Osler (1994) proposes a different interpretation, focusing on the differences in the historical questions. Although theology continues to provide "boundary conditions" (p. 35) for natural philosophy, the main concern of natural philosophers is epistemological and concerning the foundations of a sound mechanical philosophy.

26 Hutchinson (1983), pp. 297-334.

27 See Hutchinson (1983), p. 299. "So, if the mechanical philosophy is right in stripping matter of its Aristotelian qualities, and leaving motion as the sole remaining principle of corporeal activity, God must be intimately involved with every event in the material universe."

28 Newton, *General Scholium*; Boyle, *An Inquiry*; Descartes' king metaphor, etc.

29 Boyle (1996), pp. 24-25, pp. 38-39, etc. For example (p. 25) "And it is intelligible to me that God should at the beginning impress determinate motions upon the parts of matter, and guide them as he thought requisite for the primordial constitution of things; and that ever since, he should by his ordinary and general concourse maintain those powers which he gave the parts of matter to transmit their motion thus and thus to one another. But I cannot conceive how a body devoid of understanding and sense, truly so called, can moderate and determine its own motions, especially so as to make them conformable to laws that it has no knowledge and apprehension of." See also Descartes, *Principles*, Part I, 21. "And nothing can obscure the clarity of this proof, at least if we consider the nature of time or the duration of things; which is such that its parts do not depend upon one another, or ever exist simultaneously; and that, accordingly, from the fact that we now exist, it does not follow that we shall also exist a

moment from now, unless some cause (that is, the same one as that which first produced us) continually produces us, as it were, anew; that is, conserves us. For we easily understand that there is in us no power by which we may conserve ourselves; and that He in whom there is so much power that he can conserve us separately from himself, must also conserve himself all the more, or, rather, must require no conservation by anyone and finally, must be God."

30 Bacon, *Novum Organum*, I, 14.

31 Ibid, I, 15.

32 Ibid., I, 51.

33 Ibid., II, 2.

34 The term "law of nature", Bacon's famous "supreme and summary law of nature" does not appear in the *Novum Organum*, but only in *The Advancement of Learning* and in its Latin version *De Augmentis Scientiarum*. See *The Advancement of Learning*, part II, VII, 6, p. 44.

35 The Aphorisms, *The Works*, vol. 3, 345-360 and in an electronic version at <http://history.hanover.edu/texts/bacon/aphor.htm>. The quoted fragment is at p. 346.

36 Bacon's Preface to the "Novum Organum", *The Works*, vol. 3, p. 343.

37 See also, *Novum Organum*, I, 97.

38 Ibid, p. 348-349.

39 See II. 8, and also II. 3: "... he who is acquainted with forms comprehends the unity of nature in substances apparently most distinct from each other. He can disclose and bring forward, therefore (though it has never yet been done), things which neither the vicissitudes of nature, nor the industry of experiment, nor chance itself, would ever have brought about, and which would forever have escaped man's thoughts; from the discovery of forms, therefore, results genuine theory and free practice..."

40 II. 4: "... for the form of any nature is such, that when it is assigned the particular nature infallibly follows. It is, therefore, absent, whenever the nature is absent, and perpetually testifies such absence, and exists in no other nature. Lastly, the true form is such that it deduces the particular nature from some source of essence existing in many subjects, and better known to nature, than the form itself."

41 Example: gold as composed of yellow, heavy, of a certain weight, malleable, ductile, melts in a particular manner, etc. Of course, there is the possibility of transforming bodies one into another by superinducing all the simple natures. II 5. Therefore, Bacon acknowledges the possibility of transmutation. See Bacon, *The Making of Gold*.

42 II. 5: "For all these investigations relate to concrete or associated natures artificially brought together, and take into consideration certain particular and special habits of nature and not those fundamental and general laws which constitute forms. It must, however, be plainly owned, that this method

appears more promptly and easy, and of greater promise than the primary one."

43 *The Advancement of Learning*, II, VII, 5.

44 There is, of course, a wide range of "spirits" in natural philosophy and also in Bacon's writings. There are at least several respects in which they are said to be material, and, apart from Descartes, the vast majority of natural philosophers saw them as mediators between God and his creation.

45 Descartes, at XI, p. 32; Descartes (1985), vol. I p. 90.

46 Descartes, at XI, pp. 34-35, (1985) vol. 1, pp. 90-91.

47 Descartes (1931), pp. 106-109.

48 Woolhouse, (1993) argues that the presence of two distinct definitions of motion in *The World* and *Principles of Philosophy* may account for the existence of a kinematical and a dynamical definition. The difference between the two passages he quotes (p. 87) consists in the presence of the "place" as a referential of movement in the so-called "dynamical definition" which states that the movement is a sort of action by which bodies pass from one place to another occupying in between all the intermediary positions. In fact, the only action involved here is an infinite number of collisions (some of them macroscopic, the other microscopic) in a fluid-type model (theoretically without pressure). See also Shea (1981), pp. 33-34: "Cartesian motion is neither dynamic (involving consideration of force) nor kinematical (involving consideration of space and time), but merely diagrammatic (involving only considerations of space)."

49 The texts with the two definitions of motion are: in *The World*, chap. 7, at XI, 37-46, in *Principles of Philosophy* the main passage is II 25 with an obviously circular definition.

50 Descartes (1985), at XI, 18, vol. 1, p. 86.

51 *Ibid*, p. 84.

52 At XI, 41.

53 At XI, p. 20

54 Descartes, at XI, 41. See *Principles...*

55 *The World*, Chap. 7, at XI, 37, Cottingham, I, 93.

56 At VII, p. 49.

57 At VII, p. 50.

58 At IX B, p. 62. "For He always preserves the motion in the precise form in which is occurring at the very moment when he preserves it, without taking any account of the motion which was occurring a little earlier."

59 "For it follows of necessity, from the mere fact that he continues thus to preserve it, that there must be many changes in its parts which cannot, it seems to me, properly be attributed to the action of God (because that action never changes), and which therefore I attribute to nature. The rules by which these changes take place I call the 'laws of nature'."

- 60 The first problem is that no specific claim about any individual part of the universe follows deductively from a global conservation law. This problem has been widely discussed. See for example Barbour (1990); S.Gaukroger, *Descartes*; Zev Bechler, *Newton's Physics*; D. Garber, *Descartes' Metaphysical Physics*.
- 61 Another connected problem is the status and the object of the laws of nature. What is the subject of Descartes' laws of nature? Bodies? They don't exist. Arbitrarily delimited parts of matter? The Universe as a whole? God imposing rules for the intelligibility of the world? On the status of Descartes' laws of nature see P. McLaughlin, *Descartes on Mind-Body Interaction*; D. Garber, *Descartes and Occasionalism*, pp. 105-133; E. Slowick, *Perfect Solidity*.
- 62 Jalobeanu, Brading, (forthcoming).
- 63 The problem of what shape is and its relation to extension according to Descartes is problematic. He discusses this in his account of rarefaction and condensation, which is found in *Principles of Philosophy* II, 6-7. He associated a measure (that is, extension) to shape in *Principles of Philosophy* II, 8, and he equated it with quantity in *Principles of Philosophy* II, 9.
- 64 In *The World* Descartes seems to leave open the possibility of multiple worlds, and on this account if God puts a different total quantity of motion into the world this would suffice to make it a distinct world. In the *Principles of Philosophy* (II, 39) he insists that God preserves the quantity of motion, as it is at that very instant.
- 65 I will not discuss the problem of having a well-defined quantity of motion for the Universe as a whole when that Universe is indefinitely extended.
- 66 There is an interesting comparison to be made here between Descartes' use of analogy and Newton's analogy of nature. Discussion of this is deferred to a separate paper.
- 67 Maybe in some connection with the fact that Descartes' laws of nature were similar. But of course, Descartes was wrong. His law of inertia is one of the few valid things that Newton knew to pick up and develop. In this respect, as others, Newton was right; although, afraid of a comparison with Descartes' metaphysics and trying to keep out of philosophical grounds, he avoided the term in *Principia*... All along this line are several influential interpretations of Cohen and Koyre.
- 68 It is interesting enough that we might mention at this point Kant's discussion of the laws of nature, where the law of gravitation *a posteriori*, as opposed to the law of inertia, which is *a priori*, and therefore, the "real" law of nature. See Michael Friedman, *Kant and the Exact Sciences*.
- 69 *Sir Isaac Newton's Mathematical Principles of Natural Philosophy and his System of the World*, translated by Andrew Motte in 1729 and revised by Florian Cajori, Univ. of California Press, 1934 - referred therefore as *Principia*
- 70 *Ibid.*, p. XXII.
- 71 *Ibid.*, p. XXXII.

- ⁷² See A. Funkenstein, *Theology and Scientific Imagination*; M. Osler, *Divine Will and Mechanical Philosophy*, especially Chap.5; F. Oakley, *The Absolute and Ordained Power of God*.
- ⁷³ "The business of true philosophy is to derive the natures of things from causes truly existent, and to inquire after those laws on which the Great Creator actually chose to found this most beautiful Frame of the World, not those by which he might have done the same, had he so pleased." (*Sir Isaac Newton's Mathematical Principles*, p. XXVII).
- ⁷⁴ A description that strikingly resemble Francis Bacon's three pyramids of knowledge from *The Advancement of Learning*. For Bacon, in the top of these pyramids stands the supreme and summary law of nature. As a matter of fact, MacLaurin quotes Bacon's imaginative description (see p.57).
- ⁷⁵ C. MacLaurin, *An Account of Sir Isaac Newton's Philosophical Discoveries*, p. 22.
- ⁷⁶ "It is of utmost importance in philosophy to establish a few general powers in nature, upon unquestionable evidence, to determine their laws, and trace their consequences, however obscure the causes of those powers may be." (Ibid. p. 111)
- ⁷⁷ R. Bentley, *A Confutation of Atheism from the Origin and Frame of the World*, London, pp.317-318.
 "... yet, unless they [Atheists] will affirm that the inanimate Matter (which is what we would bring them to) they must still leave their Atoms to their mechanical affections; not able to make one step toward the production of a World beyond the necessary Laws of Motion."
- ⁷⁸ See J. Henry's discussion in *Pray do not Ascribe this Notion to me*, p. 123-147.
- ⁷⁹ Koyre's Newtonian Studies, Koyre, *La gravitation universelle de Kepler a Newton*.
- ⁸⁰ I..B. Cohen, *Newton's Third Law*.
- ⁸¹ De Gandt, *Force and Geometry in Newton's "Principia"*.
- ⁸² See especially I..B. Cohen, op. cit.
- ⁸³ De Ghand, op. cit., pp. 269-272.
- ⁸⁴ As, for example, in *A Treatise of the System of the World*, the original concluding book of the *Principia*, published in English translation in 1728, where it is stated that gravity "arises from the universal nature of matter". See Koyre-Cohen, p. 571. For a discussion, see Westfall, *Never at Rest*, p. 431. See also *Conclusio*, in Hall & Hall, for several statements concerning attractions between particles. But, most impressing of all is the manuscript called "The elements of mechaniks", MS Ass 4005, fols. 23-25, in Hall & Hall, pp. 165-169.
- ⁸⁵ See Cohen, op. cit; A. Koyre, *La gravitation universelle*, pp. 638-653; Westfall, *Never at Rest*, pp.382-390, etc. For a discussion about different influential interpretations concerning Newton's gravitation see J. Henry,

Pray do not Ascribe that Notion to Me. See also J.E.McGuire, *Force, Active Principles and Newton's Invisible Realm.*

86 As a matter of fact there are more than one problematic steps. As it was pointed out by Z. Bechler (in op. cit., pp. 355-356), Newton's use of the Law III (for example in Proposition V) is possible only if gravitation is a direct action. If attraction is transmitted to some mechanical ether, the central body does not act directly on its satellites and, therefore, does not gravitate towards them. Bechler also emphasizes the fact that the continental critics of Newton were directed along these lines.

87 *The Elements of Mechanics*, MS Add 4005, fols. 23-35, p. 167.

"1. All bodies are impenetrable & have a force of gravity towards them proportional to their matter & this force in receding from the body decreases in the same proportion that the square of the distance increases & by means of this force the Earth, Sun, Planets and Comets are round."

"2. The Sun is a fixt star & the fixt stars are scattered throughout all the heavens at very great distances from one another & rest in their several regions being great round bodies vehemently hot and lucid & by reason of the great quantity of their matter **they are endured with a very strong gravitating power.**" (p.167).

88 *Never at Rest*, esp. pp. 388-389, pp. 420-423, p. 462.

89 Hall & Hall, p. 353, Draft A, MS Add 3965 fols. 357-358.

90 See especially Book I Section IX, Book one, Definitions, Definition VIII: "I likewise call attraction and impulses, in the same sense, accelerative and motive; and use the words attraction, impulse or propensity of any sort toward a center promiscuously, and indifferently, one for another; *considering those forces not physically, but mathematically...*" See also, "The System of the World", in *Principia*, p. 559.

91 See, for example, *Letters to Bentley*, Letter IV, Cohen, p. 310, draft for Query 23, UCL Add 3970 fol. 619r, cited by McGuire (in *Force, Active Principles* 15, p.171): "Whence it seems to have been an ancient opinion that matter depends upon a Deity for its (laws of) motion as well as for its existence. The Cartesians make God the author of all motion & it is as reasonable to make him the author of the laws of motion. Matter is a passive principle & cannot move itself. It continues in its state of moving or resisting unless disturbed. It receives motion proportional to the force impressing it, and resists as much as it is resisted. These are passive laws & to affirm that there is no other is to speak against experience. For we find in ourselves a power of moving our bodies by our thought. Life and will (thinking) are active Principles by which we move our bodies & thence arise other laws of motion unknown to us."

92 See especially the Queries of *Opticks* (23, 31), the projected Conclusion of the *Principia*. See my *Representing the Invisible: Descartes' and Newton's Theories of Everything*.

- 93 See especially A.R. Hall, *All Was Light*; L. Rosenfeld, *Newton's Views*. L. Rosenfeld strongly emphasizes the difference: "This superficial resemblance should not mislead us to any facile conclusion, for the ether of Newton's later years, such as he describes it in the *Queries*, is radically different from the medium bearing the same name, to which, in his youthful speculations, he assigned such a prominent role in the economy of the universe." (p. 30).
- 94 Keynes MSS 12A, quoted in BJT Dobbs, *The Foundations*, p. 25; R.S. Westfall, *Never at Rest*, p. 308.
- 95 Yahuda MS Var I, Newton MS 30 f 2v.
- 96 See J. Henry, op. cit., p.123, for a summary of the accepted Newtonian devices for explaining gravity.
- 97 See BJT Dobbs, *The Janus Face of Genius* for an extended discussion of this alchemical cosmology.
- 98 See BJT Dobbs, for example, pp. 106-108 for a discussion of the term "protoplast".
- 99 *Correspondence*, vol.1. pp. 365-6.
- 100 See especially J. Henry, op. cit..
- 101 J.E. McGuire, *Force, Active Principles*.
- 102 God is (almost) always acting through mediators.
De Gravitatione:
"...if any think impossible that God may produce some intellectual creatures so perfect that he could, by divine accord, in turn produce creatures of a lower order, this so far from detracting from the divine power enhances it; for the power which can bring forth creature not only directly but through the mediation of other creatures is exceedingly, not to say infinitely greater."
Yahuda MS Var I:
"That God the father is an infinite, eternal, omniscient, immortal & invisible spirit whom no eye hath seen nor can see... & God does nothing by himself, which he can do by another..."
- 103 J. Henry, *Active Principles*.
- 104 Van Ruler (1996), *The Crisis of Causality*.
- 105 See K. Hutchinson, *Supernaturalism and Mechanical Philosophy*; M. Osler, *Divine Will*.
- 106 See J. Henry, *Occult Qualities*.
- 107 Query 31, *Opticks*.
- 108 Drafts of Query 31 and Query 31.
- 109 Letter III to Bentley.
- 110 Query 28.
- 111 *Opticks*, 1717, p. 369.
- 112 *Opticks*, Query 31.
- 113 *Principles of Philosophy*, McGuire for the theological bit, *Letters to Bentley* for Gravitation (III), etc. Dobbs, McGuire (active principles). Emanationist theories (Wesman, McGuire for the Neo-Platonism).
- 114 Letter III, p. 301, p. 303.

- 115 And the continuation of the fragment!
- 116 Letter III, p. 301. Newton's definition for attraction is: "Any force by which distant Bodies endeavor to come together without mechanical Impulse". See also J. Henry, *Pray do not...*
- 117 Query 31.
- 118 Query 31, etc.
- 119 "A third principle is that all (the great) bodies in the Universe have a tendency towards one another proportional to the quantity of matter contained in them & that this tendency in receding from the body decreases & is reciprocally proportional to the square of the distance from the body..."
- 120 Op. cit.
- 121 *My Representing the invisible...*

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