The Role of Mathematics in Francis Bacon's Natural Philosophy

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Abstract

In this study, I discuss the role of mathematics in Francis Bacon's natural philosophy. Bacon was one of the important figures of early modern philosophy and has been accepted as one of the frontier philosophers of modern science. The increasing role of mathematics in natural philosophy was an important development of this period of time, which raises the question of whether Bacon approved of the new role of mathematics in natural philosophy. The new role of mathematics in natural philosophy was mainly developed by astronomers such as Copernicus, Galileo, and Kepler, and can be defined as 'making natural philosophical claims through mathematics'.

I will examine the role of mathematics in Baconian natural philosophy by considering the following questions:

Can Bacon's attitude towards the role of mathematics be accepted as Aristotelian?

Were there similarities between Bacon and al–Bitruji in their ideas of how an astronomical model should be established?

Is there any difference in Bacon's attitude towards mathematics between his earlier and later works?

Can we use Bacon's approach to arithmetical quantification to refute the claim that he was against the new role of mathematics?

Was there any similarity between the attitude of Bacon and neo-Platonist chemical philosophers towards mathematics?

Is there any relation between the non–mechanical character of Bacon's philosophy and his attitude towards mathematics?

Is there any relation between his matter theory and his attitude towards mathematics?

Throughout this thesis, I emphasise that Bacon attached importance to applying mathematics to natural philosophy, however, was against the idea of making natural philosophical claims through mathematics. I argue that he had two fundamental commitments for being distrustful towards mathematics' ability in making natural philosophical claims; his first being the consistency between the human mind and the course of logic and mathematics, and the second being the inconsistency between the course of nature (matter) and the course of logic and mathematics.

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Introduction

Bacon's attitude towards the role of mathematics in natural philosophy is an ongoing debate among scholars. Some researchers have argued that Bacon neglected the role of mathematics in sciences. For example, John William Draper, in his *A History of the Intellectual Development of Europe* states:

> Ignorant himself of every branch of mathematics, he presumed that they were useless in science, but a few years before Newton achieved by their aid his immortal discoveries (Draper, 1875, p. 233).

Another example can be given from Lynn Thorndike:

> He [Bacon] complained that Aristotle had mixed it [natural philosophy] with logic; Plato, with natural theology; and the Neo–Platonists, with mathematics. This suggests what from the standpoint of modern science was his chief defect, his total disregard of mathematical method. He spoke of pure mathematics as, like the game of tennis, of no use in itself but as good exercise to cure intellectual defects (Thorndike, 1958, pp. 66–7).[1]

However, there are other more recent scholars who have argued against this view. Graham Rees was the most important scholar, whose works has been important in improving our understanding of Bacon. More recently, Peter Urbach's (1987), Stephen Gaukroger's (2001), Mary Domski's (2013) and

1. For similar views on Bacon and mathematics, see also Hochberg (1953, p. 322).

Dana Jalobeanu's (2016b) works have extended our views regarding Bacon's attitude towards mathematics' role in natural philosophy. All of these scholars are in agreement that Bacon gave an auxiliary role to mathematics in natural inquiries, and this agreement has come about due to Bacon's statement in the *De Augmentis Scientiarum* (1623):

> I have thought it better to designate Mathematics, seeing that they are of so much importance both in Physics and Metaphysics, and Mechanics and Magic, as appendices and auxiliaries to them all (Bacon, *De augmentis*, SEH IV, p. 370).

In this thesis, I argue that the auxiliary role of mathematics in natural philosophy is defined as not making natural philosophical claims through mathematics. Making natural philosophical claims through mathematics was the new role of mathematics, which was given by mathematical physicists such as Copernicus, Galileo and Kepler.

Bacon's attitude towards making natural philosophical claims through mathematics could be seen as him undervaluing the role of mathematics in sciences. However, for Bacon, except for his disagreement with the role of mathematics in making natural philosophical claims, he still believed mathematics was a useful and necessary application for natural philosophical inquiries. I believe, therefore, that Bacon's affirmative ideas about the application of mathematics in natural philosophical inquiries, and his attitude towards making claims of natural philosophy through mathematics should be cautiously separated. We must accept that Bacon's disapproval of mathematics' ability to make natural philosophical claims can be interpreted as his belittlement of the role of mathematics in sciences. Galileo, for example, argued that mathematics gives us the ability to discover the truth of nature. He would have believed that Bacon belittled the role of mathematics in natural philosophy because he did not believe natural philosophical claims could be made through mathematics.

Before I summarize what I have tried to contribute to the discussions on Bacon and mathematics in this dissertation, let me first present a brief account of the works I will mention and their relation to Bacon's views about mathematics and natural philosophy.[2]

Valerius terminus: Of the interpretation of nature, which Bacon wrote in 1603, outlines the limits and impediments of knowledge. Bacon also covers these themes in his *Advancement of learning* and *Novum organum* (1620). In these works, he examines what we need to do to improve sciences by considering natural philosophy and its relationship to morality and religion. I mention *Valerius terminus* in Chapter 3 to show Bacon's ideas about the relation between astronomy and natural philosophy. They are also covered in the *Advancement of learning*. The A*dvancement of learning*, *Novum organum* and *De Augmentis Scientiarum* are three important books of Bacon that I mention throughout my thesis.

In his *Cogitationes de natura rerum* (Thoughts on the nature of things), written in 1604, we see Bacon's thoughts on atoms or matter theory. For Bacon, atoms (i.e. seeds) are the way to look for the principles of motion in matter, but not beyond matter, such as the forms of Aristotle or the mystical numbers of Pythagoras. It is important to understand Bacon's attitude towards mathematics and logic. According to Bacon, if you look for the principles of motion beyond nature, then you will use logic and mathematics more than experiment[3] in your natural philosophical method. I have discussed this work

2. For the chronology of Bacon's works, see Peltonen (1996, pp. xiii-xv).

3. For Bacon, experience and experiment have different meanings. Experience happens by itself, while experiments are sought out deliberately (see Bacon, *Novum*, OFB XI, Book One, §. 82, p. 131). However, in Renaissance terminology, experiment and experience have almost the same meaning and they had been used interchangeably. See Jardine, (1974, p. 137). For a discussion regarding experience and experiment in Zabarella's and Galileo's writings, see Schmitt (1969). See also Rusu (2013, pp. 37–9).

of Bacon in the second and fifth chapter of this dissertation.

In 1605, Bacon published the *Advancement of learning*, the full title of which was *Of Proficience and Advancement of Learning Divine and Human*. In this book, Bacon classifies human understanding into three categories: memory, imagination and reason, which correspond to history, poetry and philosophy respectively. Bacon divided philosophy into the divine, human and natural. Natural philosophy has three aspects: natural history, physics and metaphysics. In this book, Bacon makes an important distinction between pure and mixed mathematics and explains the role of mathematics in natural philosophy, which he calls 'auxiliary'. I have used this work of Bacon throughout this dissertation.

Bacon also wrote his main ideas about mathematics in the revised version of the *Advancement of learning,* which is *De Augmentis Scientiarum* (1623). In these two books, he defines what pure and mixed mathematics are and what role they have in natural philosophy. Bacon writes that mathematics plays a role auxiliary to that of natural philosophy. However, it is important to further understand what he meant by an 'auxiliary role', and why he gave this role to mathematics.

A difficult but essential text for understanding the properties of Bacon's matter theory is the ancient Greek fable of *Cupid and Coelum*. This fable was placed in *De sapientia veterum* (The wisdom of the ancients), published in 1609. In 1612, Bacon's *De principiis atque originibus* (On principles and origins according to the fables of Cupid and Coelum) was also written. In this book, Bacon also explains his matter theory by interpreting the ancient Greek fable 'Cupid and Coelum', the same fable he discusses in the *De sapientia veterum* (The wisdom of the ancients). In his 1612 version of the fable, we can see that Bacon interprets it in a more detailed way. Bacon's matter theory from the fable of *Cupid and Coelum* is particularly important for chapters two and six.

A description of the intellectual globe and *Theory of the heaven* were written in 1612 and published in 1653.[4] I have cited these two books to explain Bacon's thoughts about the relation between astronomy and natural philosophy, which give us an opportunity to understand what Bacon means by the 'auxiliary role' of mathematics in natural philosophy. Unlike *Theory of the heaven*, *A description of the intellectual globe* is about the division of human learning into history, poesy, and philosophy. Bacon made this division according to the three faculties of the mind, however, in this book, Bacon also discusses the relation between astronomy and natural philosophy. For Bacon, astronomy (as a mathematical science) should be based on physics. In *Theory of the heaven*, Bacon explains his astronomical theory by considering the physical statements of the heavens instead of the 'dialectical and mathematical subtleties' of the astronomers, which for him should be left aside. I discuss these two works of Bacon in Chapter 3.

In 1620, two important works of Bacon had been published, *Parasceve ad historiam natvralem et experimentalem* (Description of a natural and experimental history), and *Novum organum*. I discuss *Parasceve* and *Novum organum* in the fourth chapter of my thesis, where I examine his usage of arithmetical quantification in natural historical works. In *Parasceve*, we learn that for Bacon, the union of physics and mathematics produces practice. We can also see a similar idea in *Novum organum*. In 1622, Bacon had written *Abecedarium novum naturae*. I used these works in the fourth chapter when regarding Bacon's quantitative works. Bacon also emphasises the importance of mathematics to produce practice in these writings.

4. See Peltonen (1996, p. XIV) and Bacon (OFB VI, p. XVII).

In *Novum organum*—which plays an important role in several sections of this dissertation — Bacon explains his new kind of inductive logic. He states that a natural philosopher should proceed from lower axioms to higher axioms,[5] step by step through his eliminative, inductive experimental method. Bacon discusses all aspects of his natural philosophy in this work, including his view on the role of mathematics in natural philosophy. He says in *Novum organum* that we should not use mathematics to procreate natural philosophy, that is, we should not make natural philosophical claims through mathematics.

Now, let me summarize my arguments chapter-by-chapter in the dissertation.

In Chapter 1, I outline the place of mathematics in Baconian natural philosophy by considering it within the place of mathematics in the Aristotelian schema. I explain Bacon's views regarding the Aristotelian disciplinary boundary between mathematical sciences (mixed mathematics)

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5. In Baconian terminology, *axiom* has double meaning. First, for the common principles which belong to several sciences, Bacon classifies this kind of axioms or principles as *Philosophia Prima* (or *summary philosophy*). Such as:

> "The nature of everything is best seen in its smallest portions," is a rule in Physics of such force that it produced the atoms of Democritus; and yet Aristotle made good use of it in his Politics, where he commences his inquiry of the nature of a commonwealth with a family (Bacon, *De augmentis*, SEH IV, pp. 337–8).

Second, for the physical and metaphysical causes, which are material, and efficient causes for physics; formal, and final causes for metaphysics. We can see this in Bacon's division of natural philosophy into speculative and operative parts:

> Why therefore should we not divide Natural Philosophy into two parts, the mine and the furnace … the Inquisition of Causes, and the Production of Effects; Speculative and Operative … all true and fruitful Natural Philosophy has a double scale or ladder, ascendent and descendent, ascending from experiments to axioms [causes], and descending from axioms to the invention of new experiments (Bacon, *De augmentis*, SEH IV, p. 343).

Mary Horton seems to confine axioms to forms (laws of nature or hypotheses, theories). See Horton, (1973, pp. 247–248). However, Bacon calls not only formal causes, but material and efficient causes axioms because the ladder (or double scale) includes material, efficient, and formal causes.

Bacon also divides axioms into the ones which are to be determined through old (syllogistic) logic, and the ones which are discovered through Bacon's new inductive logic. See Bacon (*Novum,* OFB XI, Book One, §. 24, p. 73).

For further reading about Bacon's classification of natural philosophy, see Section 1.2.

and natural philosophy, and I argue that in some senses, Bacon was loyal to the Aristotelian disciplinary boundary.

In Chapter 2, I examine the reasons Bacon did not approve of the new role of mathematics in natural sciences. I argue that Bacon had two fundamental commitments to refuse the idea of making natural philosophical claims through mathematics. First, the consistency between the human mind and the course of logic and mathematics; and second, the inconsistency between the course of nature and the course of logic and mathematics. Bacon surmises that the unaided human mind cannot deal with the subtlety of matter. I will make further explanations about the subtlety of matter in Section 2.2.

In Chapter 3, I examine the role of mathematics in Baconian natural philosophy through his ideas regarding astronomy. When we examine the history of astronomy up to the seventeenth century, I separate three different thoughts regarding the role of mathematics in establishing an astronomical theory. First, there were those who held that mathematics should only save the phenomena. For them, this role was enough for a geometrical explanation of the heavens, and it did not have to provide us with the real motions of the heavenly bodies. This group are called 'instrumentalists' by Pierre Duhem. I have labelled the second group *mathematical realists*. They believed in the explanatory power of mathematics in developing an astronomical theory, and that mathematics can provide us with the real (physical) structure of the heavens. The third group argued that mathematics could not give us the real structure of the heavens, but saving the phenomena should not also be seen as enough for a geometrical (mathematical) model of the heavens. They then stated that a geometrical (mathematical) model should be established according to physics. I call the third group *physical realists*, and argue that Bacon should be accepted as a physical realist.

In Chapter 4, I examine the quantitative works of Bacon. Graham Rees argues that when we turn our attention from Bacon's attitude towards geometrical abstraction to his arithmetical quantitative works, we can see Bacon was more affirming of mathematical methods. However, I argue that the arithmetical quantifications in Bacon's natural historical works cannot be used to refute the argument that he did not approve of the new role of mathematics in natural philosophical inquiries, or that the method of geometry could be used to make natural philosophical claims.

I have argued that there is a correlation between the use of excessive logic and passive matter and experimental method and active matter in the second chapter. Bacon shows this by comparing Democritus' philosophy (or ancient wisdom) and rationalist philosophies such as Aristotle's philosophy. In Chapter 5, I attempt to demonstrate a correlation between mechanical philosophy and passive matter, and vitalist philosophy (neo-Platonist chemical philosophy) and active matter. Showing this correlation will clarify Bacon's attitude towards mathematics and its relation with his matter theory.

In Chapter 6, I argue that, for Bacon, mathematical models such as the geometrical models of the heavens, are mechanics, and I call this kind of mechanics *external mechanics*. Mathematical models (external mechanics) are different from mathematically–oriented models of machinery (systems of machinery) because legitimate mathematical models must be based on the axioms of physics to avoid producing systems of machinery.[6]

6. What is meant by a mathematical model here is a mathematical demonstration regarding natural phenomena. I use this term to emphasise the difference between physical accounts of a natural phenomenon, which should be considered as a result of natural philosophical inquiries, and mathematical demonstrations regarding the same phenomenon.

Chapter 1

The Relation between the Mathematical Sciences and Natural Philosophy, and the Aristotelian Facet of Francis Bacon

The role of mathematics in Francis Bacon's natural philosophy and the reform he wanted to fulfil in natural philosophy strictly hinges on his reservations about the current philosophy of his day, which was largely based on Aristotelian philosophy. In this chapter, I argue that Bacon cannot be interpreted as someone who was hostile to the application of mathematics in sciences, but that he was averse to the new application of mathematics in sciences. What I mean by the new application of mathematics in sciences is mathematics that can be used to make natural philosophical claims. Even though Bacon violates the Aristotelian disciplinary boundary between mathematical sciences and natural philosophy by placing mathematical sciences in natural philosophy, he still separates the objects of mathematical sciences and natural philosophy, which, indeed, can be interpreted as having a loyalty to the disciplinary boundary between mathematical sciences and natural philosophy. When we consider this, the discussion regarding Bacon's attitude towards the role of mathematics in sciences becomes clearer.

In section 1.1, I will outline the reasons Aristotle separated natural philosophy from mathematical sciences. In section 1.2, I will discuss the various mathematical sciences and their place in the Baconian schema, and argue that

Bacon separates the object of mathematical sciences and natural philosophy, showing his loyalty to the disciplinary boundary between mathematical sciences and natural philosophy. In section 1.3, I will discuss Bacon's loyalty to the disciplinary boundary through his anti-Copernicanism.

1.1 The development of the distinction between mathematical sciences and natural philosophy

Aristotle divides mathematics into pure mathematics and mathematical sciences (in Baconian terminology, 'mixed mathematics').[7] Arithmetic and geometry can be given as examples of pure mathematics; and mixed mathematics are those mathematical sciences whose objects are natural phenomena, such as light for optics, celestial phenomena for astronomy, sound for acoustics, and spatial and dimensional attributes of bodies for perspective.

To explain the difference between mixed and pure mathematical sciences, Aristotle states the following:

> Further clarification comes from the branches of mathematics which are closest to natural science (such as optics, harmonics, and astronomy), since they are in a sense the converse of geometry: where geometry studies naturally occurring lines, but not as they occur in nature, optics studies mathematical lines, but as they occur in nature rather than as purely mathematical entities (Aristotle, 2008,

7. The term 'mixed mathematics' corresponds with the Aristotelian mathematical sciences, which was located by Aristotle as falling somewhere between pure mathematics and physics. Gary Brown argues that "the term 'mixed mathematics' can be traced back at least as far as Francis Bacon" (Brown, 1991, p. 81). Mathematical sciences were also called 'middle sciences'. See Grant (2007, p. 158).

> p. 37; book 2, 194a 7).

It follows to ask what the difference is between mathematical sciences and natural philosophy? While natural philosophy examines a natural phenomenon by considering it in terms of matter, mathematics does not have the ability to do that.[8]

Aristotle distinguishes 'generation, or coming–to–be' from 'corruption, or alteration', stating that the properties of the perceptible substratum of a body undergo change, while the imperceptible substratum of the same body continues to exist. Then, the object of mathematics is form (perceptible substratum) which undergoes change in the sense of alteration, but the objects of natural philosophy do not undergo change. 'Generation, or coming–to–be' can only be true of the objects of natural philosophy. Aristotle says the following when discussing the difference between the objects of mathematics and natural philosophy:

> the bronze is now round, now a thing with corners, but remains the same (Aristotle, 1982, p. 14; 319b 15).

This example is saying that while the shape of bronze changes, the substratum

8. John Schuster answers the question well:

> A natural philosophical account of something was an explanation in terms of matter and cause, but for Aristotle, mathematics could not provide that. The mixed mathematical sciences, such as optics, mechanics, astronomy, or music theory, used mathematics not to provide explanations, but instrumentally to present physical things and processes mathematically in ways that might be useful but certainly were not true to reality as defined by natural philosophical explanation stories of matter and cause. For example, for Aristotelians, the investigation of the physical nature of light would fall straightforwardly under natural philosophizing, an issue of invoking appropriate principles of matter and cause. In contrast, the mixed mathematical science of geometrical optics studied ray diagrams, in which geometrical lines represented rays of light, and phenomena such as the reflection and refraction of light were dealt with in a descriptive, mathematical manner. This might be useful, but it was, according to Aristotle, incapable of providing proper explanations, dealing with the physical nature, properties and causal behavior of light (Schuster, 2013, p. 51).

or underlying subject does not, showing that for Aristotle, mathematics deals with forms.[9] He further states this opinion in *Posterior Analytics,* saying that "mathematics is concerned with forms" (Aristotle, 1994, p. 21; 1:13, 79a 5–10).

According to Aristotle, geometrical shapes of natural bodies are the objects of mathematical sciences, but the composition of the sun and moon are what should be studied by natural scientists. Mathematical properties of natural bodies can be separated or abstracted from the world of change, that is, from matter; however, for a natural philosopher, an inquiry into nature should include both matter and form, while for a mathematician, it should include only mathematical properties which can be abstracted from matter.[10]

In *Posterior Analytics* 1.13, Aristotle presents two types of syllogistic demonstration. One of them is known as 'demonstration of the reasoned fact', and the other one is 'demonstration of the fact'.[11] In Latin, the first one is translated as 'demonstratio propter quid', and the latter as 'demonstratio quia'. Mancosu, when explaining the difference between them, states: "The former proceeds from effects to their causes, whereas the latter explains

9. It has mostly been thought that Aristotle did not believe there are perfect geometrical objects in the physical world. According to Aristotle, the claim that the straight line cannot touch the bronze sphere at a point was used by Protagoras to refute geometers. Contrary to general belief, Jonathan Lear argues in his *Aristotle's Philosophy of Mathematics* (1982) that the objects in the physical world instantiate mathematical properties. However, Theokritos Kouremenos argues that "*de An*. 403a 10–6 does not commit Aristotle to the perfect instantiation of geometric properties in the physical world because the two objects assumed to touch each other at a point in this passage are not physical, as Lear takes it, but geometric: consequently, *de An*. 403a 10–6 cannot be taken as evidence that geometric properties are perfectly instantiated in physical objects, from which geometric objects are abstracted" (Kouremenos, 2003, p. 463). In Aristotelian cosmology, perfect geometrical objects can be seen in the superlunar realm of the cosmos, because this part of the cosmos is composed of imperishable aether.

10. On the objects of mathematics and physics, see also Zvi (2008, pp. 24–34).

11. Aristotle calls pure mathematical sciences 'superior or higher sciences', and mathematical sciences 'subordinate sciences'. The superior sciences, such as arithmetic and geometry, can make reasoned fact explanations for the subordinate sciences, such as harmonics and optic. For example, harmonics is a subordinate science of arithmetic; mechanics is a subordinate science of geometry, see McKirahan (1978).

effects through their causes" (Mancosu, 1999, p. 11). Aristotle argues that mathematics uses the first type of syllogism (demonstration of the reasoned fact) to perform its proofs. He states, in *Posterior Analytics*:

> Of the figures, the first is especially scientific [the first syllogistic figure]. The mathematical sciences carry out their demonstrations through it – e.g. arithmetic and geometry and optics – and so do almost all those sciences which inquire into the reason why. For deductions giving the reason why are carried out, either in general or for the most part and in most cases, through this figure. For this reason, then, it is especially scientific; for study of the reason why has most importance for knowledge (Aristotle, 1994, p. 22; 79a 15–25).[12]

With regard to mathematics as syllogism, Orna Harari writes that Aristotle's successors also tried to reformulate the mathematical proofs in syllogistic form (see Harari, 2004, p. 91). One of them was Alexander of Aphrodisias, a Greek commentator on Aristotle, who attempted to put mathematical proofs into syllogistic form. Harari also says that the most elaborate example she knows as an attempt to reformulate mathematical proofs into syllogistic form was *Analyseis Geometricae Sex Librum Euclidis* (1566) by Herlinus and Dasypodius (see Harari, 2004, p. 91, fn. 8). Jean van Heijenoort also mentions an Italian mathematician and logician, Giuseppe Peano (1858–1932), whose work, Fromulaire, "is an attempt to reduce all of mathematics to syllogisms (in the Aristotelian–Scholastic sense)" (Heijenoort, 1999, p. 187). Christopher Clavius, a mathematician and astronomer who was contemporary of Bacon, also tried to apply syllogistic reasoning to mathematics, as he states:

> "all other propositions, both Euclid's and those of all other

12. For an argument on Aristotle's claim regarding mathematics as syllogistic being false, see Jonathan Barnes' translation of Aristotle's *Posterior Analytics* (1994, p. 162), and McKirahan (1992, p. 150). See also Kouremenos (1998).

> mathematicians, can be solved in this way [syllogistic method].” But “mathematicians disregard this solution [by syllogism] in their demonstrations because proofs are quicker and easier without it.”[13]

Rees also believes that Paracelsians “tended to equate mathematics with logic, and to damn both as impious instruments of the detested, heathenish philosophers Aristotle and Galen” (Rees, 1986, 425).[14] As to Francis Bacon, he also argues mathematics is syllogistic. He states in his letter to Father Redemptus Baranzano in 1622:

> In the Mathematics there is no reason why it [syllogism] should not be employed (Bacon, *Letter*, SEH VII, p. 377).

The following example is important to explain the difference between the objects of natural philosophy and mathematical sciences – whether the earth turns around the sun or vice versa. This question is a natural philosophical question because, in Aristotelian natural philosophy, every element has its own natural motion. The celestial bodies are made of aether, which is an imperishable element; and, as aether is imperishable, its natural motion is perfect (continual) motion, that is, circular motion. So, the earth cannot move around the sun because the sublunar elements are perishable elements and their natural motions are straightforward. Fire and air move upwards, and water and earth move downwards to the centre of the earth.[15] As is seen, the motion of sublunar and superlunar bodies are related to the properties of their materials, and this is the reason that questions regarding the motions of celestial bodies are the objects of natural philosophical inquiries rather than astronomy as a mathematical science. So, making claims related to the motions of the celestial bodies by mathematicians was a violation of the

13. Quoted from Lattis (1994, p. 35).
14. See also Debus (1973).
15. See Aristotle (1939).

disciplinary boundary between natural philosophy and mathematical sciences.[16] I have given this example because it was the main matter of debate between mathematical physicists[17] such as Copernicus, Galileo, Kepler, and natural philosophers in the sixteenth and seventeenth centuries.

Baconian forms are completely different from Aristotelian forms. For Bacon, forms are a part of metaphysics and metaphysics is a part of natural philosophy. I will make detailed explanations about the different meaning of Baconian form later (see pp. 24–5; fn. 30, 31), but for now, I want to emphasise that, even though Baconian forms are different than Aristotelian forms, Bacon also separated the objects of mathematical sciences and natural philosophy and argued that a mathematician cannot make natural philosophical claims. A mathematician should only deal with the object of mathematical sciences, and this means that Bacon was loyal to the disciplinary boundary between mathematical sciences and natural philosophy. When we consider the motions of the celestial bodies, Bacon also argued that the kind of motions celestial bodies had was a natural philosophical inquiry, but not an astronomical inquiry. I will talk about this in detail in Section 3.5.

1.2 The place of mixed mathematics in Baconian natural philosophy

The speculative (theoretical) part of natural philosophy has three parts in Baconian natural philosophy: natural history, physics, and metaphysics.[18] A

16. For the disciplinary boundary between natural philosophy and mathematics, see Westman (1980).

17. By mathematical–physicists, I refer to those who made claims of natural philosophy through mathematics.

18. For detailed explanations regarding the classification of natural philosophy in Baconian schema, see Anstey (2012), and Kusukawa (1996). On Francis Bacon’s conception of natural

natural inquiry begins with natural history, then proceeds to physics, and finally to metaphysics.

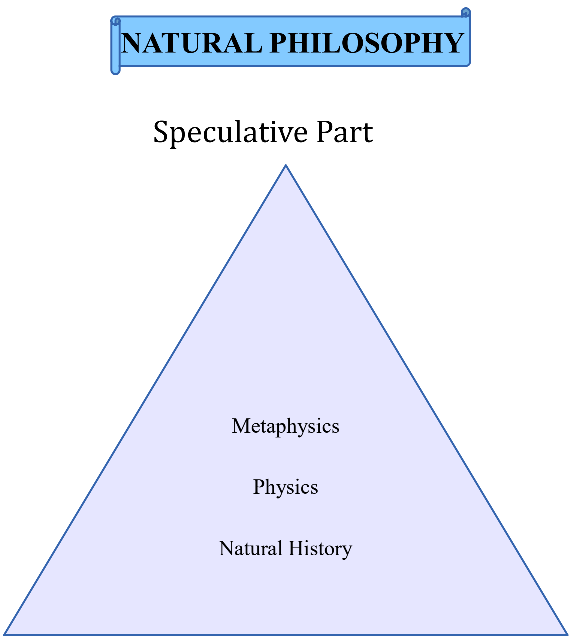

Figure 1

However, Bacon gave a different meaning to 'metaphysics' and 'formal causes' than Aristotle, and as mentioned above, he places metaphysics as a part of natural philosophy. According to Bacon, while physics is the inquiry into material and efficient causes, metaphysics examines formal and final causes. However, natural philosophy does not include inquiries into final causes because, for Bacon, even though final causes are real, they are barren and beyond human comprehension.[19] Bacon believed nature bears God's will, but it is not the business of a natural philosopher. So, we can conclude that in Baconian natural philosophy, in practice, metaphysics only includes inquiries into formal causes.[20]

history as a foundation of true natural philosophy, see Manzo (2009); Jalobeanu (2015b) and (2016a). On Bacon's natural history and testimony, see Serjeantson (1999).

19. On rejection of inquiries into final causes in Baconian natural philosophy, see also Pérez-Ramos (1988, p. 162) and Quinton (1993, p. 160).

20. For more explanations regarding Baconian forms see Whitaker (1970), and Horton

Bacon did not classify pure mathematics; however, he placed mixed mathematics as a branch of metaphysics, and metaphysics as a part of natural philosophy. That is, for Bacon, mathematical sciences are a part of natural philosophy.

The reason Bacon placed mixed mathematics as a branch of metaphysics, as you will see below, is that it is 'one of the *essentiall forms* of things', so it 'is causatiue in Nature of a number of Effects', that is, it has some axioms of nature.[21] As Bacon states:

> Neuerthelesse there remaineth yet another part of NATVRALL PHILOSOPHIE, which is commonly made a principall part, and holdeth ranke with PHISICKE speciall and METAPHISICKE: which is [Mixed] *Mathematicke*, but I think it more agreable to the Nature of things, and to the light of order, to place it as a Branch of *Metaphisicke*: for the subiect of it being *Quantitie*, not *Quantitie Indefinite*: which is but a *Relatiue*, and belongeth to *Philosophia Prima* (as hath beene said,) but *Quantitie determined, or proportionable*, it appeareth to bee one of the *essentiall forms* of things; as that, that is causatiue in Nature of a number of Effects … MIXT (mathematics) hath for subiect some Axiomes or parts of Naturall Philosophie: and considereth Quantitie determined, as it is auxiliarie and incident vnto them (Bacon, *The Advancement*, OFB IV, pp. 87–8, underlinings

(1973, pp. 243–4).

21. Lisa Jardine believes that the object of mathematics in Baconian natural philosophy is not the essential form as it is in Aristotelian philosophy. In Aristotelian schema, quantity is accidental attributes of bodies, not essential, and she thinks that the same idea goes for Bacon. She argues that the reason Bacon offered a subsidiary role for mathematics in natural philosophy resulted from an accidental character of quantity, see Jardine, (1974, p. 78). However, Bacon clearly says that, "For Quantity (which is the subject of Mathematic), when applied to matter, is as it were the dose of Nature, and is the cause of a number of effects in things natural; and therefore it must be reckoned as one of the Essential Forms of things" (Bacon, *De augmentis*, SEH IV, pp. 369–70).

added).

As to pure mathematics, it deals with quantity, which is completely severed from matter, and from axioms of natural philosophy:[22]

> To the PVRE MATHEMATICKS are those Scie*n*ces belonging, which handle *Quantitie determinate* merely seuered from any Axiomes of NATVRALL PHILOSOPHY: and these are two, GEOMETRY and ARITHMETICKE (Bacon, *The Advancement*, OFB IV, p. 88).[23]

For Bacon, 'quantity proportionable', which is the object of mixed mathematics, is a form, but it is the most abstracted form from matter compared to other forms which are more immersed into matter.[24] As Bacon states:

> …it is true also that of all other formes (as wee vnderstand formes) it [quantity proportionable] is <u>the most abstracted, and separable from matter</u> and therefore most proper to *Metaphisicke*; which hath likewise beene the cause, why it hath beene better laboured, and enquired, <u>then any of the other *formes*, which are more immersed into Matter</u>. (Bacon, *The Advancement*, OFB IV, p. 87, underlining added).

22. Nobuo Kawajiri argues that Bacon gave the handmaiden role to pure mathematics. See Kawajiri, (1979, p. 17). However, I argue that Bacon did not give any role to pure mathematics in natural philosophy. As Bacon states, 'To Pure Mathematic belong those sciences which handle Quantity entirely severed from matter and from axioms of natural philosophy.' So, for Bacon, pure mathematics does not have any axioms of natural philosophy, but mixed mathematics does, because he says 'Mixed Mathematic has for its subject some axioms and parts of natural philosophy.' For the full quotation, see p. 20 in this dissertation.

23. In *De Augmentis Scientiarum*, Bacon says similar things:

> Mathematic is either Pure or Mixed. To Pure Mathematic belong those sciences which handle Quantity entirely severed from matter and from axioms of natural philosophy. These are two, Geometry and Arithmetic; the one handling quantity continued, and the other dissevered (Bacon, *De augmentis*, SEH IV, p. 370).

24. Graham Rees calls these two kinds of forms 'mathematical forms' and 'non-mathematical forms'. See Rees (1986, pp. 406–7).

These arguments can be expressed below in diagrammatic form:

	Pure Mathematics	**Mixed Mathematics**
Its object	Quantity Indefinite It is not a form Fully separated from matter	Quantity Proportionable It is one of the essential forms The most abstracted form from matter
Its relation with Natural philosophy	(–)	A part of natural philosophy (A branch of metaphysics)
Its role in natural philosophy	(–)	Auxiliary
Sorts	Geometry, Arithmetic	Perspective, Harmony, Astronomy, Cosmography, Architecture, Machinery, etc.

Figure 2

The diagram below shows the two parts of Baconian natural philosophy and the place of the object of mathematical sciences (quantity determined) in it:

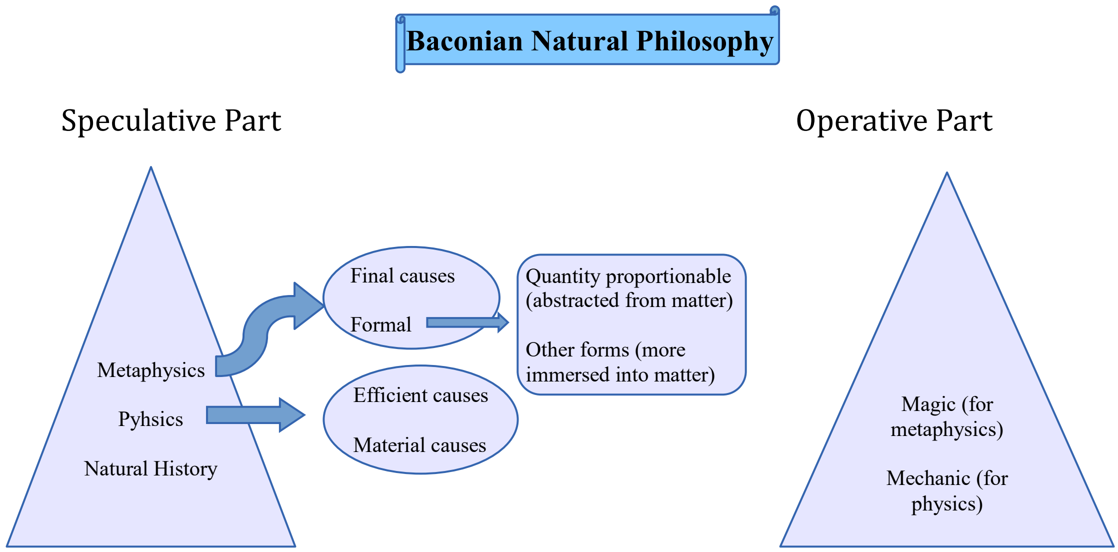

Figure 3

Related to the object of mixed mathematics, Nobuo Kawajiri argues that 'quantity proportionable', as it was used in the *Advancement of Learning,* and 'dose of nature', as it was used in the *De Augmentis Scientiarum,* have different meanings (see Kawajiri, 1979, p. 18). However, I argue that both 'quantity proportionable' and 'dose of nature' lays stress on quantity, which is determined in matter and both terms express the object of mixed mathematics. I believe we can conclude that these two terms do not have different meanings and that Bacon uses both these terms synonymously. Bacon calls both 'quantity proportionable' and 'dose of nature' one of the essential forms of things:

> For Quantity (which is <u>the subject of Mathematic</u>), when applied to matter, is as it were the <u>dose of Nature</u>, and is the cause of a number of effects in things natural; and therefore it must be reckoned as one of <u>the Essential Forms of things</u> (Bacon, *De augmentis*, SEH IV, pp. 369–70).[25]

When Bacon says <u>the subject of Mathematic</u> above, he means the subject of mixed mathematics because, as mentioned before, only the subject of mixed mathematics is 'causatiue in Nature of a number of Effects', which means that mixed mathematics has some axioms of natural philosophy. As Bacon states:

> Mixed Mathematic has for its subject some axioms and parts of natural philosophy (Bacon, *De augmentis*, SEH IV, p. 371).

Bacon also states:

> <u>Quantitie determined</u>, or proportionable, it appeareth to bee one of

25. See also fn. 21.

the essentiall formes of things (Bacon, *The Advancement*, OFB IV, p. 87, underlinings added).

As is seen, Bacon uses 'quantity determined' and 'dose of nature' synonymously.

1.3 Bacon's loyalty to the Aristotelian disciplinary boundary between mathematical sciences and natural philosophy

As mentioned, Bacon gave an auxiliary role to mathematics in natural philosophy. However, when studying the auxiliary role of mathematics in natural inquiries, Rees and Kawajiri argue that Bacon started to see mathematics' role as an auxiliary to natural philosophy in the *De Augmentis Scientiarum* (1623).[26] However, I argue we can also see the same attitude in Bacon's *Advancement of Learning* (1605):

> MIXT (mathematics) hath for subiect some Axiomes or parts of Naturall Philosophie: and considereth Quantitie determined [the object of mixed mathematics], as it is auxiliarie and incident vnto them (see p. 17 for the full quotation).

The same statement can be seen in the *De Augmentis Scientiarum* as follows:

> Mixed Mathematic has for its subject some axioms and parts of natural philosophy, and considers quantity [quantity determined] in so far as it assists to explain, demonstrate, and actuate these (Bacon,

26. See Rees (1985, p. 27), (1986, p. 412), and Kawajiri (1979, p. 17).

De augmentis, SEH IV, p. 371).[27]

I believe these two statements show Bacon's attitude towards the auxiliary role of mathematics does not change between the *Advancement of Learning* and the *De Augmentis Scientiarum.*

Rees present two reasons why he believes Bacon gave the auxiliary role to mathematics in his later work. First, Bacon developed his qualitative philosophy in the later stages of his life, and as a result, he holds a subsidiary role for mathematics in his later work, *De Augmentis Scientiarum* (1623). Second, Bacon had a *special anxiety* about the effect of mathematics on physics.[28] Kawajiri argues the reason for this difference is the progress of mathematical physics.[29]

Even though I believe the above statements of Bacon from his two works clearly show that his attitudes towards the auxiliary role of mathematics did not change, I do want to discuss Bacon's anxiety about the effect of mathematics on physics, and how it can be seen as a reason for Bacon's attitude towards the auxiliary role for mathematics.

Bacon had a special anxiety about the effect of mathematics on physics, and the reason for this was that there were mathematicians who made natural philosophical claims through mathematics, such as Copernicus, Galileo and Kepler. He was concerned about this because he did not trust mathematics'

27. My argument concerns mixed mathematics specifically, or the role of (mixed) mathematics in natural philosophy. I have argued that mixed mathematics does not change from the *Advancement of Learning* to the *De Augmentis Scientiarum.* My concern with logic is limited to its role in natural philosophy. Logic may have changed, as argued in Anstey (2015), but Bacon's conception of the auxiliary role of logic in natural philosophy, at least, did not change. We can also see this in the following words of Bacon written in the *De Augmentis Scientiarum,* 'For it has come to pass, I know not how, that Mathematic and Logic, which ought to be but the handmaids of Physic.' For the full quotation, see p. 23.

28. See Rees (1985, p. 28).

29. See Kawajiri (1979, p. 17).

ability to discover the objects of natural philosophy. If Bacon had trust in mathematics' explanatory power for the objects of natural philosophy, then he would not have separated the objects of mathematics and natural philosophy.

For Bacon, a mathematician should not make natural philosophical claims through mathematics, and this shows us Bacon's loyalty to the Aristotelian disciplinary boundary. If there had not been mathematicians who violated the disciplinary boundary, or who made natural philosophical claims through mathematics, Bacon would not have compelled to give an auxiliary role to mathematics:

> Which indeed I am in a manner compelled to do, by reason of the daintiness and pride of mathematicians, who will needs have this science almost domineer over Physic. For it has come to pass, I know not how, that Mathematic and Logic, which ought to be but the handmaids of Physic, nevertheless presume on the strength of the certainty which they possess to exercise dominion over it (Bacon, *De augmentis*, SEH IV, p. 370).

In the above words, we can surmise that 'being domineer over physics' comes to mean making natural philosophical claims through mathematics. So, we can say that Bacon suggested a handmaid's role for mathematics in natural inquiries, and this role comes to mean 'not making natural philosophical claims through mathematics'.

Now, I will argue that there is a correlation between the hierarchy of the natural axioms and the course that should be followed in natural inquiries. First, let's see how Bacon defines both physical and metaphysical causes in the *De Augmentis Scientiarum* (1623) as follows:

> And herein without prejudice to truth I may preserve thus much of

> the conceit of antiquity, that Physic handles that which is most inherent in matter and therefore transitory, and Metaphysic that which is more abstracted and fixed. And again, that Physic supposes in nature only a being and moving and natural necessity; whereas Metaphysic supposes also a mind and idea … Physic inquires and handles the Material and Efficient Causes, Metaphysic the Formal and Final.
>
> Physic then comprehends causes vague, variable, and respective; but does not aspire to the constant (Bacon, *De augmentis*, SEH IV, p. 346).[30]

Let me say two things regarding the above quotes. First, for Bacon, only final causes, a part of metaphysics, supposes a mind and idea, not formal causes.[31] Also, as mentioned above, final causes are not the objects of natural

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30. In the *Advancement of Learning* (1605), he states a similar idea, see Bacon (The Advancement, OFB IV, pp. 82–3).

What does Bacon mean by 'transitory' in the above quotation? The answer was quoted by Bacon from Virgil as follows:

> As the same fire which makes the soft clay hard
> Makes hard wax soft (Bacon, *De augmentis*, SEH IV, p. 346).

This quotation was translated by Fairclough as follows: "As this clay hardens, and as this wax melts in one and the same flame." See Virgil (1999, Book VIII, p. 81).

The variable or transitory nature of lower axioms (causes) means that lower axioms can have more than one effect. As is seen in the above example, fire is the cause of the hardening of soft clay, and the same fire is the cause of softening hard wax.

As to constant and fixed axioms such as formal axioms (causes), the fixed and constant nature of these axioms means that they always have the same effect. Bacon gives an example in his *Novum organum,* when he inquiries into the form of heat. At the end of his inquiry, he comes to the conclusion through his inductive method that the form of heat is motion, which means that motion produces heat in every situation. So, forms or formal causes are the causes of motion, but in contrast to variable causes, they are fixed and constant causes of motion in nature. Cf. Rusu (2013, pp. 192–7). Rusu argues that Baconian form is motion. On Baconian forms, see also fn. 20 and 21 in this dissertation.

31. Baconian formal causes cannot be considered as teleological causes. However, Aristotelian forms also function as efficient and final causes, which means that forms can be considered as teleological causes. This point is well put by Lynn Joy. See Joy (2006, p. 76).

For how Aristotle accepts forms as the real causes of motion in matter, see Aristotle (1982, p. 53, book 2, 9.335b 25–35).

philosophers, but formal causes are. For Bacon, natural philosophers should only deal with material, efficient, and (immersed) formal causes.

Second, for Bacon, lower axioms are variable, while general axioms (forms) are fixed and constant, and this is the hierarchy in nature.

Now, let's read the following words of Bacon:

> Nor need anyone shrink from this subtlety as something beyond disentangling; on the contrary, the more the investigation touches on simple natures, the more will all things be put out in the open and plain view; the matter being converted from the manifold to the simple, from the incommensurable to the commensurable, from the irrational to the computable, from the infinite and vague to the definite and certain, as happens in letters in writing, and notes sung in unison. Thus investigation of nature turns out best when physics is given definition by mathematics (Bacon, *Novum*, OFB XI, Book Two, §. 8, p. 213).

When we interpret the above quotations, we can say that the course of the natural axioms is from the variable (manifold) nature of the lower axioms to the constant (simple) nature of general axioms. And, for Bacon, we should follow the same course and start our natural inquiry with the lower axioms, then we should proceed to simpler (general) axioms.

As mentioned before, among formal axioms, 'quantity determined' is the most abstracted form, which means that it is the most general and simple axiom among formal axioms. So, the object of mixed mathematics is the most certain and simplest axiom, and, for Bacon, this is also the reason why 'quantity', the object of mixed mathematics, "hath beene better laboured, and enquired, then any of the other *formes*, which are more immersed into Matter" (Bacon, *The*

Advancement, OFB IV, p. 87).

Now, let me explain what Bacon means, in the above quotation, by arguing that 'investigation of nature turns out best when physics is given definition by mathematics.' We can interpret these words in two ways. First, it refers to the quantification processes in natural history, so we can provide accuracy for the physical inquiries, and can also produce practice. As Bacon states:

> This is why we must get closer to the mathematics or measures and scales of motions, without which, well counted and weighed and defined, the doctrine of motions may falter and not be reliably translated into practice (Bacon, *Abecedarium*, OFB, XIII, p. 211).[32]

Second, as you remember, Bacon discusses that there is a hierarchy among natural axioms, from the variable (manifold) to the fixed (simple), that is, from the axioms which are more immersed into matter to the axioms which are less immersed into matter, and the object of mathematics are the least immersed forms into matter or the most abstracted forms from matter. So, we should start our natural inquiries with the discovery of the lowest axioms, and we should ascend to the higher axioms. The highest axioms we can discover are the most abstracted forms from matter, and those axioms are the objects of mathematicians, not the objects of natural philosophers. Therefore, we can say that when Bacon says 'investigation of nature turns out best when physics is given definition by mathematics', he means the last step status of mathematics in a natural inquiry, which shows Bacon's distrust of mathematics to discover the other axioms which are more immersed in matter. The discovery of the objects of mathematics (quantity) depends on the discovery of the more immersed axioms into matter because, in the Baconian inductive method, we cannot leap up to the higher axioms. The last step

32. On quantitative approach in Baconian natural history, see also Rees (1985); Pastorino (2011a) and (2011b); Jalobeanu (2016b), and Chapter 4 in this dissertation.

status of mathematics refers to the priority of the inquiries into the objects of natural philosophy, and this was also pointed out by Rees as the 'priority of physics' (see Rees, 1986, pp. 414–416). However, by the last step status of mathematics, I do not mean that mathematics cannot be applied before or during the discovery of the axioms of natural philosophy at all. What I mean is that before the discovery of the axioms of natural philosophy, we should not develop mathematical models regarding the natural phenomenon, such as the al-Bitrujian geometrical model for the motions of the celestial bodies.[33]

We should not also fail to notice the following words of Bacon:

> mathematics … ought to round off natural philosophy and not generate or procreate it (Bacon, *Novum*, OFB XI, Book One, §. 96, p. 155).

By rounding off natural philosophy, Bacon also means the last step status of mathematics in a natural inquiry, and by saying 'not generate or procreate natural philosophy', he means that we should not try to discover the objects of natural philosophy through mathematics.

1.4 Summary

The accepted division between natural philosophy and mathematical sciences refers to the epistemic division between them. Making claims of natural philosophy by a mathematician was a violation of this division. Even though Bacon placed mathematical sciences in natural philosophy, he aimed to make his new inductive experimental method sovereign over mathematics, but not

33. For mathematical models, see fn. 6. See also Chapter 3 and Chapter 6.

to make mathematics dominant over natural philosophy.

Bacon did not approve of the new role of mathematics in sciences, and the new role was making natural philosophical claims through mathematics. Bacon's separation of the objects of mathematical sciences and natural philosophy shows us his loyalty to the Aristotelian disciplinary boundary between mathematical sciences and natural philosophy; however, Copernicus, Galileo, Kepler were mathematical physicists who made such claims. The important thing that separates these mathematical physicists from Bacon is their belief that natural philosophical claims could be made through premises of geometry. Making natural philosophical claims through mathematics was possible by equating the objects of mathematics and natural philosophy.[34] I will also discuss this disciplinary boundary in the third chapter regarding its influence on Bacon's view of how an astronomical theory should be developed.

In the next section, I will discuss the two fundamental commitments Bacon held that caused his mistrust in mathematics' ability to discover the objects of natural philosophy.

34. For the equation of the objects of mathematics and natural philosophy see Goldenbaum (2016).

Chapter 2

Two Reasons Bacon Disapproved of Making Natural Philosophical Claims through Mathematics

In this chapter, I will discuss the reasons why Bacon did not approve of making claims of natural philosophy through mathematics. I argue that he had two fundamental commitments which caused his disapproval. First, the consistency between human understanding and the course of logic and mathematics and second, the inconsistency between the course of nature (matter) and the course of logic and mathematics. I examine the first commitment in section 2.1, and in section 2.2, I examine the second commitment. In section 2.3, I discuss the relation between Bacon's inductive method and the errors of the human mind. Thorough this chapter, I also discuss Bacon's description of rationalist philosophy as an idolization of the human mind and the results of the mentioned errors of the human mind.

2.1 Rational method, the errors of the human mind and the properties of matter

2.1.1 Searching for the properties of matter beyond nature

Bacon mostly took his views related to the properties of matter from the pre-

Socratics, especially Democritus, and Greek mythology. Let's examine Bacon's views on what those pre-Socratics thought about the properties of primary (first) matter:

> almost all the ancients, *Empedocles*, *Anaxagoras*, *Anaximenes*, *Heraclitus* and *Democritus*, though differing in other respects about primary matter, were as one in maintaining that matter was active, had some form and imparted its form, and had the principle of motion within itself. Nor would it be possible for anyone to think otherwise, unless he wanted to abandon experience altogether. Thus all these latter [the above-mentioned pre-Socratics] submitted their minds to the nature of things (Bacon, *On principles*, OFB VI, p. 209).

Bacon thought that those who did not approve of the principle of motion in primary matter, and of (primary) form which is united with primary matter, created abstract matter:

> This abstract matter is the matter of disputations, not of the universe. But one who philosophizes rightly and in an orderly manner must dissect nature and not abstract from it (for those who will not dissect it are forced to abstract), and he must wholly maintain that primary matter is united with the primary form, and also with the first principle of motion, as we find it (Bacon, *On principles*, OFB VI, p. 209).

He also states in his *Novum organum*:

> it happens that men do not stop abstracting from nature until they arrive at potential and uninformed matter (Bacon, *Novum*, OFB XI, Book One, §. 66, p. 107).

Regarding the properties of matter, that is, the principle of motion and form, Bacon shares the view of the above-mentioned pre-Socratics and we can see this in his interpretation of the fable of Cupid. Bacon interpreted Cupid (Eros) as primary matter, and believed this fable reveals the purest truth about primary matter. He argued it shows us the belief of the ancients towards the qualities of primary matter:[35]

> For nothing has corrupted philosophy as much as this inquiry about *Cupid's* parents, i.e. philosophers have not accepted the principles of things as they are found in nature and embraced them as a positive doctrine and as if they were articles of experimental faith, but they have rather deduced them from the laws of discourse, the piddling conclusions of dialectic and mathematics, from common notions, and from suchlike excursions of the mind beyond the bounds of nature. <u>Therefore a philosopher should always be telling himself that *Cupid* has no parents, in case his mind wanders off into the realms of emptiness</u>; because the human intellect gets carried away with these high generalities, it abuses both the nature of things and itself, and while straining towards things further off, it falls back on things closer to hand (Bacon, *On principles*, OFB VI, pp. 199–201, underlining added).[36]

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35. For Cupid as natural appetite, see Giglioni (2016b). For Cupid and its presence within English culture, see Kingsley-Smith (2013).

36. At this juncture, I should point out that when Bacon says 'the piddling conclusions of dialectic and mathematics', he means the Pythagorean application of mathematics, because Pythagoras was the one who found the principles of things in numbers. This argument can be supported with the following words of Bacon related to the second school of Plato (neo-Platonists) and Proclus who adopted the Pythagorean application of mathematics:

> So hath *Plato* intermingled his Philosophie with Theologie, and *Aristotle* with Logicke, and the second Schoole of *Plato*, *Proclus*, and the rest, with the Mathematiques (Bacon, *The Advancement*, OFB IV, p. 30).

Proclus "assimilated the Pythagorean view that numerical relationships revealed the universe's order" see notes of M. Kiernan in Bacon (*The Advancement*, OFB IV, p. 231). See also Bacon (*Novum*, OFB XI, Book One, §. 96, p. 155). According to Rees, when Bacon says that Proclus and the rest intermingled their philosophy with mathematics, "the kind of mathematics Bacon has in mind here is well represented in Agrippa, De occulta philosophia, For Bacon, the ancients believed that Cupid (primary matter) has no parents, and parents of primary matter refer to the principles of things found beyond nature. This means the ancients approved of the principles of motion in matter and that primary matter is united with a (primary) form. The parents of Cupid come to mean the properties of matter which are beyond nature. If the properties of matter are in matter, then we cannot talk about Cupid's parents. By arguing Cupid has no parents, Bacon is stating that the properties of matter are in matter itself, and we should not search for them beyond nature.

This analogy of Cupid also shows us that the ancients took the principles of things as they are found in matter, not beyond matter. We can say that searching for the principles of matter beyond matter is searching for the parents of Cupid or (primary) matter. For Bacon, searching for the principles of things beyond nature is one of the errors of the human mind:

> The human mind swells and cannot stay still or rest <u>but aspires to go further</u>, but in vain. It cannot therefore conceive of <u>any end or limit to the world</u>, but always compulsively hankers after <u>something beyond</u> (Bacon, *Novum*, OFB XI, Book One, §. 48, p. 85, underlinings added).

Then, Bacon comes to a conclusion that 'a philosopher should always be telling himself that *Cupid* has no parents, in case his mind wanders off into the realms of emptiness' (see p. 31).

Taking the principles of things as they are found in matter means that matter itself contains those principles or properties of matter such as the principles

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pp. 249 ff" (Bacon, *Novum*, p. 529). It is known that Agrippa used the Pythagorean application of mathematics in his occult philosophy. For a discussion of the mystical mathematics of the Paracelsians and Fludd, see Debus, (1972a) and (1972b).

of motion (change) and form. The principles of motion are active or vital forces in matter, and this notion is contrary to potential or passive matter, which was argued by Aristotle.

We can mention here a distinction between the Aristotelian sense of matter (as in “prime matter”) and the “matter” of everyday experience. For example, the Aristotelian sense of prime matter is destitude of form while the “matter” of everyday experience coexists with form.

Bacon criticised the matter theory of Aristotle because he believed matter should be conceived as active and of having some form. However, Aristotle conceived matter as potential or passive, and what causes the change in matter as not something in matter, but forms. As mentioned above, Bacon calls this kind of matter ‘abstract matter’.

In Baconian terminology, ‘abstraction of matter’ refers to the rational method, and ‘dissection of nature’ refers to the experimental method. Bacon argues that ‘those who will not dissect it are forced to abstract’, that is, those who do not use an experimental method are forced to use a rational method, or logical and mathematical methods. And a philosopher who wants to dissect nature ‘must wholly maintain that <u>primary matter is united with the primary form</u>, and also with <u>the first principle of motion</u>’ (see p. 30 in this dissertation, underlining added). As is seen, Bacon establishes a clear correlation between the approving of ‘form’ and ‘the principle of motion’ (or activity) to matter and the experimental method. As mentioned before, contrary to rationalists, for Bacon, pre-Socratics approved of activity and primary form to prime matter (see p. 30). Bacon also attributed form (primary form) to prime matter. However, Aristotle did not attribute form to prime matter, instead attributing it to ‘matter of everyday experience’, because he used forms to explain the causes of change (motion) in ‘matter of everyday experience’. For Bacon, however, explaining the change in ‘matter of everyday experience’ through forms is something which can be defined as not submitting our minds to the nature of things. Instead, he believed we should submit our minds to the nature of things, or the real causes of motion in matter; and he emphasised that we should find the principles of motion in matter not beyond matter such as (Aristotelian) forms. Bacon accepted this as the base of experimental philosophy (or dissecting of nature).[37]

For Bacon, some philosophers did not accept the principles of things as they are found in nature, and they deduced them from the conclusions of logic and mathematics. For example, Bacon believed Aristotle deduced the principles from syllogistic logic and Pythagoras deduced those principles from mathematics. Pythagoras found the principles in numbers, while Aristotle found them in forms. According to Bacon, the forms of Aristotle and the numbers of Pythagoras are things that do not rest on experience.

For Bacon, if a philosopher does not accept the principles of things as they are found in matter, it is expected that s/he will also not rest on experience when it comes to the method of natural philosophy, and Aristotle was one of these. Now, let us read the following words of Bacon to see his complaint about how Aristotle forsook experience:

> And no one should be impressed by the fact that in his books on Animals, in his Problems, and in other tracts of his he often deals in experiments. For he had made up his mind beforehand, and did not take experience into due account when he framed his decrees and axioms but, having made up his mind to suit himself, he bends experience to his opinions and drags it about in chains, so that in this respect too he is more blameworthy than his modern followers (the family of scholastic philosophers) who have abandoned experience

37. On Aristotelian primary matter, form and the principles of change in matter, see Bostock (2006a), (2006b) and (2006c).

> altogether (Bacon, *Novum*, OFB XI, Book One, §. 63, p. 101).[38]

Bacon also says that:

> And again Aristotle's school, which giveth the due to the sense in assertion, denieth it in practice much more than that of Plato (Bacon, *Filium labyrinthi*, SEH III, p. 504).

Bacon argued there are three kinds of false philosophy; sophistical, empirical, and superstitious.[39] He puts Aristotle in the first category, namely, sophistical, and says that "the most obvious example of the first family is Aristotle who with his dialectic corrupted natural philosophy when he fashioned the world from categories" (Bacon, *Novum*, OFB XI, Book One, §. 63, p. 99). However, by sophistical philosophy, Bacon actually means rationalist philosophy because, when he explains the errors of sophistical philosophy, he uses the term 'rational family'.[40]

Then, we should ask: why did Bacon believe Aristotle was a rationalist? I can

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38. In Galileo's *Dialogue concerning the two chief world systems*, we can see a similar approach of using experience by Aristotle as follows: "Aristotle first laid the basis of his argument a priori, showing the necessity of the inalterability of heaven by means of natural, evident, and clear principles. He afterward supported the same a posteriori, by the senses and by the traditions of the ancients" Galilei (1967, p. 50).

39. Bacon mentions empirical philosophy among false philosophies too, but by considering this, no one should come to a conclusion that Bacon is not an empiricist. Bacon criticises empirical philosophers for making a philosophy after they have done just few experiments. As to the errors of the supporters of superstitious philosophy, Bacon means those who mix their philosophy with theology and traditions.

40. See Bacon (*Novum*, OFB XI, Book One, §. 62, p. 99). However, Bacon does not mean rationalist in the post–Kantian sense, as Alberto Vanzo states:

> Like empiricists in the modern sense, Bacon's empirics rely on experience – not, however, in their reflections on the origins and sources of knowledge, but in their attempts to attain knowledge. They do not deny that we have innate concepts or substantive *a priori* knowledge, nor do they claim that all of our knowledge derives from experience. Nevertheless, they do seek *scientia* – understood as general, firmly established knowledge that can ground conclusions about, intervention upon, and production of particular things – within the realm of experience (Vanzo, 2014, p. 520). See also Selcer (2014).

say that the above-mentioned answer regarding the attitude of Aristotle towards experience is partly correct. My claim is that the answer springs from the attitude of Aristotle to the properties of matter. As mentioned above, Bacon names Aristotle's view of matter as abstract matter, and abstract matter, as you remember, is a kind of matter whose active properties (and its form) are isolated from it. It is a passive or potential matter.

Bacon calls abstract matter the matter of disputations (see p. 30); however, to philosophise correctly, someone must dissect nature, but not abstract from it (see p. 30). As stated previously, dissection of nature refers to the experimental method, while abstracting from it refers to rational philosophies. Now, let's see how Aristotle finds the causes of motion (change) in forms instead of matter itself:

> If, on the other hand, someone were to say that it was the matter which generated things on account of movement, what he said would be more scientific than that just described. For that which alters a thing, or changes its shape, is more truly the cause of generation; and generally we are accustomed to describe as the producer, both in the case of things which occur in nature and of those which result from skill, that thing, whatever it may be, which has to do with movement. Nevertheless, what these people have to say is also incorrect. For it is the property of matter to be acted upon and to be moved, whereas causing movement and acting belongs to another capacity. This is obviously the case with things which come to be through skill and those which come to be through nature: the water does not itself produce an animal out of itself, nor the wood a bed — it is skill which does this. So these people are for this reason incorrect in their account, and because they leave aside what is more strictly the cause; for they take away the essence and the form (Aristotle, 1982, p. 53; book 2, 9.335b 25–35).

In Aristotelian natural philosophy, forms also function as efficient and final causes, which means that forms can be considered as teleological causes, and we know that Bacon was strictly against the intermingling of teleological causes with natural inquiries.[41]

As mentioned before, Bacon argued that not taking the principles of things as they are found in nature causes philosophers to deduce them from the premises of logic and mathematics. If you do not attribute the principles of motion (change) to matter, you do not have a chance to rest on experience in your method. However, even though Plato approved of eternal action to matter, he made another mistake. Aristotle discusses Plato and eternal action in his *metaphysics*:

> This is why some have posited an eternal action, for example, Leucippus and Plato; for they declare that movement is eternal (Aristotle, 1952, p. 257, 1071b 30).

The terms 'eternal action' and 'eternal movement' mean that matter has always been active. Bacon does not mention Plato's name among those who attribute active powers (the ability of action) to matter, but he does not say that Plato did not think movement was eternal. Let us read Bacon's words about Plato's mistake:

> But it is manifest, that *Plato* in his opinion of *Ideas*, as one that had a wit of eleuation scituate as vpon a Cliffe, did descry, *that formes were*

41. Bacon says the following about the harm which is caused by intermingling final causes with natural inquiries:

> For the handling of *finall causes* mixed with the rest in *Phisicall enquiries*, hath intercepted the seuere and diligent enquirie of all *real and phisicall causes*, and giuen men the occasion, to stay vpon these *satisfactorie and specious causes*, to the great arrest and preiudice of furder discouerie (Bacon, *The Advancement*, OFB IV, p. 86). See also fn. 19.

> *the true obiect of knowledge*; but lost the real fruite of his opinion by considering of formes, as absolutely abstracted from Matter, & not confined and determined by Matter: and so turning his opinion vpon *Theologie*, wherewith all his Naturall Philosophy is infected (Bacon, *The Advancement*, OFB IV, pp. 83–4).

As is seen, Bacon believed Plato's mistake was that he did not attribute form to matter; remembering that when Bacon mentions the properties of primary matter, he also says that primary matter has some (primary) form (see pp. 30–3).

Therefore, we can conclude that, for Bacon, the rationalist philosophers did not approve of the principles of motion or form in (primary) matter, but they found them beyond nature. In doing this, they made the objects of knowledge fantastic, fictional principles, such as the abstracted forms of Plato or the numbers of Pythagoras; instead of the real principles of matter. For Bacon, rationalism means deducing the principles of motion from conclusions of dialectic and mathematics. He believed rational philosophies use excessive logic and mathematics instead of experiment in natural inquiries.

Aristotle did not abstract forms from matter. Instead, he abstracted the principles of motion from matter. However, Bacon argued that even though Aristotle defined forms in matter, he ignored matter and its properties, which are the real causes of motion in matter. Instead, Aristotle approved of forms as the causes of motion (change) in matter.

2.1.2 Finding rest among the general axioms

Now, I will discuss the desire of the human mind to find rest among the general axioms, without being concerned sufficiently with particulars. Before talking about this error of the human mind, the following shows the difference Bacon held between his new method and the method that was in fashion in his day:

> There are and can only be two ways of investigating and discovering truth. The one rushes up from the sense and particulars to axioms of the highest generality and, from these principles and their indubitable truth, goes on to infer and discover middle axioms; and this is the way in current use. The other way draws axioms from the sense and particulars by climbing steadily and by degrees so that it reaches the ones of highest generality last of all; and this is the true but still untrodden way (Bacon, *Novum*, OFB XI, Book One, §. 19, p. 71).

Flying from particulars to axioms of the highest generality causes middle axioms to be deduced from those axioms. This is the method of rationalistic philosophy. However, Bacon also criticises experimentalists of his day for flying from particulars to the most general axioms, because they deduce general axioms from just a few experiments. Both the rationalistic method and the experimental method, which fly from particulars to the most general axioms without being concerned with particulars, have a strong connection with the mentioned error of the human mind, as Bacon states, "For the mind longs to leap up to higher generalities to find rest there; and after a short while scorns experience" (Bacon, *Novum*, OFB XI, Book One, §. 20, p. 71).

If we consider rationalistic philosophy, we can say that both errors of the human mind resulted in putting more emphasis on logic than on experiment and can conclude that the method of rationalistic philosophy is the result of the errors of the human mind. To remove these errors, Bacon holds the instruments of human understanding (his new method) as a precaution, in order to prevent the mind from flying to general axioms without appealing enough to experiment. This precaution, he believes, will work for both the first and second error of the mind. In regards to the first error, which is looking for the properties of matter beyond nature, Bacon explicitly warns philosophers not to look for the parents of primary matter (Cupid), and accept the principles of things as they are found in nature.

The above-mentioned second error of the human mind – that is, leaping up to general axioms without considering lower axioms sufficiently – follows the same course as with logic and mathematics. Bacon argues that mathematics satisfies the mentioned tendency of the (unaided) human mind to find rest among general axioms, and states:

> For it being plainly the nature of the human mind, certainly to the extreme prejudice of knowledge, to delight in the open plains (as it were) of generalities rather than in the woods and inclosures of particulars, the mathematics of all other knowledge were the goodliest fields to satisfy that appetite for expatiation and meditation (Bacon, *De augmentis*, SEH IV, p. 370).[42]

2.1.3 Mathematics as a way to attribute excessive orderliness to nature

Now, I will discuss the third error; attributing excessive orderliness to nature. Bacon states:

> The human intellect is constitutionally prone to supposing that there is more order and equality in things than it actually finds. For though

42. See also Bacon (*The Advancement*, OFB IV, p. 116).

> there are many things monadic in nature and quite unlike anything else, the intellect nevertheless counterfeits parallels, correspondences and relatives which do not exist. Hence the fiction that *In the heavens everything moves in perfect circles*, with spiral lines and dragons absolutely rejected in all but name (Bacon, *Novum*, OFB XI, Book One, §. 45, p. 83).

Why were perfect circles ascribed to the movement of celestial bodies? Because, for Bacon, human understanding tends to suppose more orderliness in nature than it actually finds. Later on, in the same paragraph, Bacon states:

> Hence the element of fire with its orb is brought in to make up a quaternion with the other three which sense detects. Hence again people arbitrarily impose on the elements (as they call them) the theory that one element is ten times more or less rare than another, and suchlike dreams. And this nonsense holds sway not just in dogmas but also in simple notions (Bacon, *Novum*, OFB XI, Book One, §. 45, p. 83).

The element of fire makes up a square with other three elements, and the ratio of density of these elements is fixed at ten to one. In these examples, we can see that human understanding attributes excessive orderliness in nature and this orderliness can be defined as mathematical orderliness. The last two examples, in particular, which are about the element of fire and the ratio of density of the elements, are called mystical mathematics by Bacon, which was supported by Pythagoras and neo-Platonic philosophers. The first example of perfect circles of the motion of the celestial bodies, however, was also supported by some astronomers who were not Pythagoreans, such as Claudius Ptolemy (100–170 AD) and Copernicus.

Another example can be found in Bacon's comparison of Democritus' idea concerning the shapes of atoms, with the idea of Pythagoras:

> For there are two opinions, nor can there be more, with respect to atoms or the seeds of things; the one that of Democritus, which attributed to atoms inequality and configuration, and by configuration position; the other perhaps that of Pythagoras, which asserted that they were altogether equal and similar. For he who assigns equality to atoms necessarily places all things in numbers; but he who allows other attributes has the benefit of the primitive natures of separate atoms, besides the numbers or proportions of their conjunctions (Bacon, *Cogitationes*, SEH V, p. 422).

The error of Pythagoras, for Bacon, was placing all things in numbers, and it was sourced from Pythagoras' belief in the equality and similarity of atoms. If every atom is similar and equal to the other, nature becomes more expressible with mathematics; but when someone thinks that atoms have different shapes, he has the benefit of the primitive natures of separate atoms.

As to the common fault, which all these examples share, it is their attribution of excessive orderliness to nature. And, this belief in excessive orderliness in nature is the result of an error of human understanding.

I should also emphasise that the human understanding's tendency to suppose the availability of more regularity in nature than it has is enhanced and sustained by mathematics:

> *That the spirite of man, beeing of an equall and vnifourme substance, doth vsually suppose and faine in Nature a greater equalitie and vniformitie, than is in truth*; Hence it commeth, that the *Mathematitians* cannot satisfie themselues, except they reduce the Motions of the Celestiall bodyes, to perfect Circles, reiecting spirall

> lynes, and laboring to be discharged of Eccentriques (Bacon, *The Advancement*, OFB IV, p. 116).

Attributing excessive orderliness to nature can be defined as a belief that nature can be explained mathematically. However, by saying nature does not have a mathematical structure, Bacon does not mean we cannot apply mathematics to nature at all. Except for making natural philosophical claims, Bacon did not set bounds to mathematicians, but as stated before, this limit comes to mean that he did not approve of the new role of mathematics in sciences.

2.2 The human mind and the subtlety of matter

The subtlety of matter refers to the inconsistency between the course of logic and mathematics and the course of nature. For example, Galileo believed the language of nature is mathematics, and the human and God's intellect are equal qualitatively. The human intellect can understand nature through mathematics because nature (matter) is considered by Galileo to be constructed mathematically. However, nature is not considered by Bacon to be constructed mathematically. For Bacon, the way the human mind works and the way nature works are different because there is an inconsistency between the human mind and the subtlety (or obscurity) of matter.

Let me make an analogy to explain the subtlety of matter. Imagine we have a kind of matter which consists of triangles, circles, squares and other mathematical figures, and that we have a filter which has mathematical figures on its surface, and this filter represents mathematics as a tool for natural inquiries. Now, when we apply the filter (mathematics) to matter, the filter will work. Also, imagine we have a kind of matter which consists of some complicated figures, figures like stones or leaves. When we apply the same filter (mathematics) to this kind of matter, we will see that it will not work, that is, our mind will not discover the truth of nature. Bacon also mentions the subtlety of words, arguments, notions, and the senses; he believes that all of them are rude and gross in comparison to the subtlety of matter (see Bacon, *Valerius*, SEH III, p. 242). If the way the human mind and nature works was similar, then there would not be the subtlety of matter.

Now, imagine there is another filter which refers to Bacon's new inductive experimental method. When we apply that filter to matter, it will work, because its subtlety is thin and elegant enough in comparison to the subtlety of matter. We can therefore say that because the aim of natural philosophy is the discovery of the desires and appetites of matter (vital forces in matter, the causes of motion or Baconian forms), the discovery of these forces is possible through the inductive experimental method, and not through logic and mathematics. I should also emphasise that when I say matter is more elegant in comparison to the human mind and the senses, I do not mean thin matter such as pneumatic matter in Baconian terminology.[43] What I mean is that the objects of natural philosophy cannot be discovered though logic and mathematics, but it can be discovered through the inductive experimental method, because the inductive method has the ability or it is subtle enough to discover the objects of natural philosophy.

The following words of Bacon shows his belief that the subtlety of matter requires the inductive method instead of (syllogistic) logic and mathematics:

> I do not propose to give up syllogism altogether. Syllogism is incompetent for the principal things rather than useless for the generality.

43. On pneumatic matter in Bacon's natural philosophy, see Rees (1975).

> In the Mathematics there is no reason why it should not be employed. It is the flux of matter and the inconstancy of the physical body which requires induction; that thereby it may be fixed, as it were, and allow the formation of notions well defined. (Bacon, *Letter to*, SEH VII, p. 377).

Bacon emphasises that the reason mathematics and syllogistic logic cannot be applied to matter (to discover the object of natural philosophy) is the flux of matter or the inconstancy of the physical body. He offers the inductive method for natural inquiries because it can compete with the flux of matter (the subtlety of matter or the obscure nature of things). These three terms refer to the same thing: the inconsistency between the course of logic and mathematics and the course of nature. As mentioned before, these vital forces require an inductive experimental method to be discovered. As we see in the above quotation, the flux of matter is the reason why we should apply induction instead of syllogistic logic and mathematics.

Now, let me show how these three terms have the same meaning. You already read the flux of matter in the above quotation. Let's also read the following words of Bacon to see how the term 'obscurity of things' has the same meaning with the flux of matter:

> The intellect without direction and help is an unequal thing and simply not up to the job of mastering <u>the obscurity of things</u> (Bacon, *Novum*, OFB XI, Book One, §. 21, p. 73, underlining added).

As is seen, Bacon argues that <u>the obscurity of things</u> cannot be mastered by the intellect which is destitute of direction and help; and by direction and help Bacon means the inductive experimental method. Now, let's read further in regards to the subtlety of nature (matter):

> In no way can it come about that axioms established by argumentation can contribute to the discovery of new works, for the subtlety of nature far surpasses the subtleties of argumentation. But axioms abstracted from particulars in a proper and systematic way readily point out and specify new particulars, and so render the sciences active (Bacon, *Novum*, OFB XI, Book One, §. 24, p. 73).

I should emphasise that the axioms (causes) established by argumentation mean the axioms established by syllogistic logic and mathematics. As is seen, these axioms cannot contribute to the discovery of new works. Bacon's new method includes two processes: ascending from experiments to axioms, and descending from these axioms to new experiments or new works (see Section 2.3 for further explanations). For Bacon, the discovery of new works depends on the discovery of the real axioms, and the argumentation or syllogistic logic and mathematics cannot do this because the subtlety of nature far surpasses the subtleties of syllogistic logic and mathematics.

So, as shown above, the obscurity of things, the flux of matter and the subtlety of matter refer to the same thing: the inability of logic and mathematics to discover the objects of natural philosophy.

The point which should be emphasized is that Bacon finds compatibility between the human mind and logic, and states, "The unaided intellect takes the same way (i.e. the former) which it takes when directed by dialectic" (Bacon, *Novum*, OFB XI, Book One, §. 20, p. 71). Now, let me requote Bacon to show the inconsistency between the human mind and the subtlety of matter: 'The intellect without direction and help is an unequal thing and simply not up to the job of mastering the obscurity of things.' As is seen, the unaided intellect or the intellect without direction, which means the intellect without the proper method for natural inquiries, cannot master the obscurity of things while it takes the same way with dialectic. In other words, the understanding, unless directed by its instruments, is in accordance with dialectic, and is ill-suited to contend with the obscurity of things. As a result, the obscurity (or subtlety) of things refers to the inconsistency between how the human mind works and how nature works; the understanding should be assisted and directed by its instruments to increase its ability to compete with the subtlety of matter.

As mentioned before, for Bacon, because of the subtlety of matter, mathematics and logic are not useful methods for the discovery of the truth of nature; that is, we cannot make claims of natural philosophy through mathematics and logic. This does not mean, however, that mathematics is not useful at all. As long as a mathematician does not make natural philosophical claims through mathematics, Bacon does not set bounds to the application of mathematics to natural phenomena. However, it should not be forgotten that his attitude towards making natural philosophical claims through mathematics shows us his disapproval of the new role of mathematics in sciences.

In conclusion, this section has attempted to show the inconsistency between the course of nature and the course of logic and mathematics; and the consistency between the human mind and the course of mathematics and logic. Bacon argued that the inductive experimental method is required because of the flux of matter (or the subtlety of matter). Logic and mathematics does not work well for inquiries into the axioms (causes) of natural philosophy because those axioms are more subtle than logic and mathematics.

2.3 Bacon's inductive experimental method and the errors of the human mind

The scope of this thesis does not include a detailed discussion on Bacon's inductive method, but it is important to show the reader the inductive method when associated with the errors of the human mind.

First of all, Bacon's new inductive method was developed by considering the above-mentioned errors of the human mind. For him, the real method should be in bonding with nature. Bonding with nature is possible by applying the right method to natural inquiries. The right method was designed by considering how to get rid of the above-mentioned errors of the human mind.

We can see below how Bacon defines his new method:

> in dealing with the nature of things I use induction throughout, and that in the minor propositions as well as the major. For I consider induction to be that form of demonstration which upholds the sense, and closes with nature, and comes to the very brink of operation (Bacon, *The great*, SEH IV, pp. 24–5).

Bacon's new inductive experimental method starts with bare experiments and moves to the higher axioms of nature step by step. As he writes:

> we should hope for better things from the sciences only when we ascend the proper ladder by successive, uninterrupted or unbroken steps, from particulars to lower axioms, then to middle ones, each

> higher than the last until eventually we come to the most general. For the lowest axioms barely differ from naked experience (Bacon, *Novum*, OFB XI, Book One, §. 104, p. 161).

Bacon argued that the art of logic (dialectic) "does more to entrench errors than to reveal the truth" (Bacon, *Novum*, OFB XI, p. 55), because of how late it comes into play. The mind is already full of common notions or certain doctrines when logic comes to fix errors. Therefore, Bacon held that the human mind should be guided in every phase. He defined his plan for his new method as follows:

> Now my plan is as easy to describe as it is difficult to effect. For it is to establish degrees of certainty, take care of the sense by a kind of reduction, but to reject for the most part the work of the mind that follows upon sense; in fact I mean to open up and lay down a new and certain pathway from the perceptions of the senses themselves to the mind (Bacon, *Novum*, OFB XI, p. 53).

I should emphasise that Bacon uses the terms 'method', 'art', and 'invention' interchangeably.[44] For Bacon, method means (inductive) logic or art of discovery or invention.

Bacon's new method or art for the discovery of scientific truth is defined as new logic when we compare it with Aristotle's old method or syllogistic logic. Bacon called this new method or logic 'interpretation of nature', and he called the old logic of Aristotle 'anticipation of nature'. Indeed, in his *Advancement of Learning* Bacon presents four subdivisions of logic:

a) Art of inquiry or invention

44. On Francis Bacon's conception of natural inquiry, see Pérez-Ramos (1988).

b) Art of examination or judgement

c) Art of custody or memory

d) Art of elocution or tradition

Bacon divided 'art of inquiry or invention' into 'invention of art and sciences' and 'invention of arguments'. He further divided 'invention of art and sciences' into 'experientia literata' (learned experience)[45] and 'interpretatio naturae' (interpretation of nature).[46] While 'learned experience' is only a degree and rudiment of 'interpretation of nature', the discovery of the natural axioms (causes) is only possible by 'interpretation of nature' (see Bacon, *The Advancement*, OFB IV, p. 111).

The interpretation of nature is the inductive method (logic) of Bacon, and it has two major steps: ascending to axioms from experiments, and descending to new experiments or new works from those axioms. In this new method, we must first prepare a complete natural history regarding the natural phenomena we search for. When we consider heat, for example, we should collect all the known instances of heat.[47] Secondly, we should collect the negative instances. Negative instances refer to the instances which are destitute of heat. We should make observations and experiments to prepare tables for instances. We should also prepare another table (the third table) for the instances which include heat in a lesser or greater degree. For example, motion increases heat.

After preparing these three tables, we can then apply Baconian induction.

45. For further reading for 'experientia literata', see Jardine (1990); Weeks (2008); Georgescu (2011); Georgescu and Giurgea (2012); Stewart (2012); Giglioni (2013b); Jalobeanu (2011), (2013), (2016a).

46. On 'interpretation of nature', see Serjeantson (2014).

47. Bacon explains his inductive method regarding heat in his *Novum organum*, see Bacon (*Novum*, OFB XI, Book Two, §. 8, pp. 217–81).

Baconian induction is a rejection of instances in the prepared tables which are not the form of heat. In his example regarding heat, Bacon found motion as the form of heat.[48]

If we look at the relationship between Baconian induction and the modern problem of induction, however, we surmise that if there are more instances than those we have collected, the inductive process will not work. Bacon assumed it was possible to collect all instances before applying induction, but this seems unjustified.

Consequently, Bacon likens understanding to a naked hand, and just as a naked hand cannot be very useful and needs instruments to be more effective, understanding also needs instruments to be more effective. The instruments of understanding, which can be defined as suggestions and cautions, are useful for us to see the difference between the old rationalistic method and the new inductive method of Bacon. The new method can be described as the same thing, but with the instruments of the human understanding, and it should take the place of the old logic (or method), which was defined by Bacon as the idolization of the human mind. Those who supported the old method, Bacon says, have neglected the instruments of the understanding by admiring the human mind excessively, namely, by falling into the above-mentioned errors of the human mind. Excessive admiration of the human mind is the same thing as using syllogistic logic and mathematics excessively in natural philosophical inquiries. By saying this, I mean making natural philosophical claims through syllogistic logic and mathematics. In using syllogistic logic and mathematics more than experiment, Bacon believed that the scientific inquiries of those philosophers were not helpful enough to discover the axioms of natural philosophy.

48. For further reading for the inductive method (or logic) of Bacon, see Horton (1973); Hesse (1968); Vickers (1992); Malherbe (1996); McCaskey (2006). On the role of memory and imagination in the practice of Baconian science, see Jacquet (2010).

Baconian induction is different from the rational method, and also from the experimental method of his day because the new method was designed by Bacon to get rid of the above-mentioned errors of the human mind.

2.4 Summary

In this chapter, I have argued that Bacon criticised the method of the rationalists as one that, following natural tendencies of the human mind, relied inappropriately upon logic and mathematics instead of experimentation as a means of understanding nature.

Bacon argued that there is a consistency between the understanding and the course of logic and mathematics, while the course of logic and mathematics are inconsistent with the course of nature. So, Bacon offered his new inductive experimental method as an instrument for understanding, to increase its subtlety to contend with the subtlety of matter.

For Bacon, logic and mathematics are certain disciplines, but when it comes to contending with the subtlety of matter, they are not subtle enough to compete with the subtlety of matter. As a result, according to Bacon, we cannot discover the axioms of natural philosophy by applying syllogistic logic or mathematics to natural phenomena.

The inconsistency between logic and mathematics (the human mind) and the course of nature (the subtlety of matter) is the reason why logic and mathematics, as Bacon states, 'ought to be but the handmaids of Physics' (see p. 23). Those who make natural philosophical claims through mathematics are those who ignore the mentioned errors of the human mind and think that they can discover the truth of nature through syllogistic logic and mathematics. However, through Bacon's new method, we can discover the truth of nature by progressing step by step, from particulars to generalities, because Bacon developed his new method by considering the mentioned errors of the human mind.

Now, let me remind you how the above-mentioned three errors of the human mind are related to logic and mathematics: Those who fell into the first error, for Bacon, 'deduced them [properties of matter] from the laws of discourse, the piddling conclusions of dialectic and mathematics.' As to the second error, Bacon accepts that 'the mathematics of all other knowledge were the goodliest fields to satisfy that appetite', that is, the desire of the human mind to find rest among general axioms. Finally, regarding the third error, which is the human mind's tendency to find more orderliness in nature than it finds, the following words of Bacon can express to us the role of mathematicians in it: 'the *Mathematitians* cannot satisfie themselues, except they reduce the Motions of the Celestiall bodyes, to perfect Circles, reiecting spirall lynes, and laboring to be discharged of Eccentriques' (see p. 42).

As to the subtlety of matter, it refers to the inconsistency between the course of logic and mathematics and the course of nature, that is, the inability of logic and mathematics to discover the axioms of natural philosophy. Instead, those axioms require the inductive method to be discovered, because the new method of Bacon is subtle enough to discover these axioms. The new method is more subtle because it was designated by Bacon to get rid of the mentioned errors of the human mind.

Chapter 3

Francis Bacon: A Physical Realist

When we examine the history of astronomy up to the seventeenth century, it has been argued that there were two groups of philosophers and astronomers: instrumentalists and realists. However, when we consider the attitudes towards the explanatory power of mathematics in determining astronomical theories, we can add a third group. The first group, *instrumentalists*, includes those who believe mathematics should only 'save the phenomena'. I label the second group *mathematical realists*, and this includes those who think mathematics can provide the real motions of celestial bodies, such as Copernicus and Galileo. As to the third group, which includes Ibn Rushd (Averroes) and al–Bitruji (Alpetragius), they think mathematics cannot provide us with the real structure of the heavens, but in contrast to the first group, they emphasise there should not be any contradiction between the mathematical model and the physical model of the heavens. To avoid any contradiction between the physical and mathematical models, the third group holds that the mathematical model of the heavens should be designed by considering physics, so I call them *physical realists*. I argue, in this chapter, that Bacon can be considered as a *physical realist*.

In section 3.1, I attempt to clarify the difference between the terms *physical realist* and *mathematical realist*. In section 3.2, I discuss the quarrel between physics and mathematics by considering the Arabic opposition to Ptolemaic astronomy. In section 3.3, I discuss how Bacon's idea of the priority of physics is similar to al-Bitruji's and Averroes' ideas, and argue that Bacon can be placed among physical realists. In section 3.4, I discuss Rees' argument, which claims Bacon had a physical model before he adopted al–Bitruji's (12^{th} century) geometrical (mathematical) model, and I argue that his claim is problematic. Finally, in section 3.5, I discuss Bacon's physical arguments through which he explains the motions of celestial bodies.

3.1 Physical realists vs. mathematical realists

There was a debate in the history of astronomy (as a mathematical science) about its ability to provide the real motions of the heavenly bodies. When astronomers had tried to find an answer to explain apparent motions of the celestial bodies, they reached two different explanations, known as the eccentric and epicyclic models, which were developed by Apollonius of Perga (262–190 BC) and Hipparchus of Nicaea (190–120 BC). Interestingly, these two different geometrical models are almost equivalent in terms of their success in explaining the apparent motions of the celestial bodies. Geminos informs us of the idea of Herakleides of Pontos[49], which is that "even if the Earth moves in a certain way and the Sun is in a certain way at rest, the apparent irregularity with regard to the Sun can be saved" (Geminos, 2006, p. 254). The question to be asked then, is if two different models (eccentric and epicyclic models) can save the apparent irregularity, how can we decide which one is the real structure of the heavens? Pierre Duhem discusses this problem in his book titled, '*To Save the Phenomena*', published in 1908.

49. Indeed, it was Aristarchos of Samos who offered Sun-centred explanation, see Geminos (2006, p. 254, fn. 18).

According to Duhem, all Greek astronomy is instrumentalist,[50] and this instrumentalist tradition begins with Plato, because Simplicius, in his commentary on Aristotle's *De Coelo*, says the following:

> Plato without hesitation assigned to the heavenly motions circularity, uniformity, and order and put forward to the mathematicians this problem: by making what hypotheses about uniform, circular, and ordered motions will it be possible to preserve the phenomena involving the planets? (Simplicius, 2005, p. 33; 493, 1).

According to the ancients, the motions of the celestial bodies are circular and uniform; however, later observations revealed that there are anomalies in their motions. There anomalies, therefore, cannot be real, and astronomers should provide geometrical models to remove these anomalies. Simplicius believed this was the astronomers' role, which was given to them by Plato. Duhem interprets this as an instrumentalist view, because those who supported the mentioned role for astronomers believed that the geometrical (mathematical) models of the heavens do not have to reflect the real structure of it. Indeed, for instrumentalists, geometrical (mathematical) models of the heavens are fictitious, made up to save appearances. However, there were others who thought astronomical theories could reflect the physical structure of the heavens, and these are named by Duhem as realists.

In order to reveal the relationship between astronomy as a mathematical science and physics, I will discuss the debate between realists and instrumentalists within the context of their belief in the explanatory power of mathematics in determining the real motions of the celestial bodies. If we

50. Similar views about the instrumentalist interpretation of ancient Greek astronomy can be found in Dreyer (1906); Dijksterhuis (1964); Sambursky (1962) and Koestler (1989).

For the falsity of the instrumentalist interpretation of the ancient Greek astronomy, see Musgrave (1991) and Evans (1998, pp. 216–9).

separate these three mentioned groups according to their belief in the explanatory power of mathematics for natural phenomena, their differences become clearer. As mentioned above, the third group of philosophers or astronomers hold that the mathematical model should follow the physical model. We cannot label the third group as instrumentalist because they do not find saving the appearances enough for a mathematical model. Neither can we call them mathematical realists, because they do not believe mathematics has enough explanatory power to explain the physical structure of the heavens. According to the third group, a geometrical (mathematical) model of the heavens should be based on a physical model, because mathematics does not have the ability to reflect the real model of the heavens, but physics (natural philosophy) does. This is why I call them physical realists.[51]

What should be emphasised is that when a mathematical model and a physical model are in harmony, we cannot see any contradiction between these two models, and so we can defend the same model on both mathematical and physical grounds; however, this does not make the third group mathematical realists. For mathematical realists, the mathematical model reflects the physical model; however, physical realists deduce the mathematical model from the physical model, and this is the result of their disbelief in the explanatory power of mathematics in determining the real structure of the heavens.

3.2 Arabic opposition to Ptolemy

One of the important figures of Arabic philosophy and the most important

51. James Lattis calls the third group *skeptical realists*, see Lattis (1994, p. 134), but I prefer to call them physical realists because they gave priority to physics to determine their astronomical theory.

figure among the Arabic philosophers who were against Ptolemaic astronomy was Ibn Rushd (Averroes) (1126–1198 AD). Others who opposed Ptolemy were Ibn al–Haytham, Ibn Bajja and Jabir ibn Aflah; however, according to Abdelhamid Sabra, these men should be separated from Ibn Tufayl, Averroes and al–Bitruji because they had only a partial criticism of Ptolemaic astronomy, whereas Ibn Tufayl, Averroes and al–Bitruji radically rejected it (see Sabra, 2002, p. 135).

I will focus primarily on Averroes and al–Bitruji, as they are the more important figures in the critical reaction against Ptolemy. Averroes keenly criticised Ptolemy and demanded a new astronomy, and al–Bitruji made the Ptolemaic model more accordant with Aristotelian physics.

Averroes was an influential philosopher in the Latin West and became famous in Italy in the sixteenth century. His commentaries on Aristotle were read by many Italian philosophers, and he became especially famous in Italy in the second half of the sixteenth century (see Cozzoli, 2007, p. 157). For Averroes, the problem was the contradiction between Ptolemy's geometrical (mathematical) model of the heavens and Aristotelian physics, because Ptolemy assumed the existence of epicyclic and eccentric models, which is contrary to nature and so impossible. As mentioned above, Averroes' objection to Ptolemy's astronomical model was shown by his attitude to mathematics' explanatory ability in astronomy. This leads us to ask what can astronomers (mathematicians) and natural philosophers provide? When we take the answers to this question into consideration, it becomes possible to see the quarrel between physics and mathematics. Averroes himself answers this question as follows:

> what the astronomer mainly gives is based only on those things that appear to the senses ... the natural philosopher, however, endeavours

> to give the cause why this is so.[52]

As is seen, astronomy is not capable of giving causes, so Averroes thought that real astronomy should use natural philosophical principles as its foundation. For Averroes, the Ptolemaic model, even though it agrees with calculations, should be rejected because it offers the existence of epicyclic and eccentric models which is not physically possible. The new astronomy must be possible from the standpoint of physical principles, as Averroes puts it:

> For to assert the existence of an eccentric sphere or an epicyclic sphere is contrary to nature. As for the epicyclic sphere, this is not at all possible; for a body that moves in a circle must move about the center of the universe (*al–kull*), not aside from it … It is similarly the case with the eccentric sphere proposed (*yada'uhu*) by Ptolemy. For if many centers existed, we should have a multitude of heavy bodies outside the place of the earth, and the center would cease to be unique, and it would be extended and divisible. But all this is not possible …
>
> It may be possible to replace these two things by the spiral motions (*al–harakät al–lawlabiyya*) assumed by Aristotle in this astronomy (*hädhihi l–hay'a*) in imitation of (*hikäyatan 'an*) those who came before him. For it appears that astronomers before Hipparchus and Ptolemy assumed no epicyclic or eccentric spheres. Ptolemy stated this in his book on *Planetary Hypotheses*, and he claimed that Aristotle and his predecessors had assumed instead spiral motions, thereby increasing, as he claimed, the number of motions … But when people came to believe that this [new] astronomy was simpler and easier for [explaining] the revolutions (*'awd al–harakät*) now recorded in

52. Quoted from Endress (1995, p. 42).

> Ptolemy's book, they neglected the ancient astronomy until it became so obsolete that people are not now able to understand what Aristotle says in this place [in the *Metaphysics*] about those [ancient] people.
>
> We should therefore embark on a new search for this ancient astronomy, for it is the true astronomy that is possible from the standpoint of physical principles. It is in my view based on the motion of one and the same sphere about one center and different poles, which may be two or more in accordance with the phenomena. For such motions can give rise to the acceleration, retardation, accession, and recession [*iqbäl wa idbär*] of a planet, and other motions for which Ptolemy failed to produce an arrangement [*hay'a*]. Such motions would also be the approaching and receding of a planet, as in the case of the moon. In my youth [*fi shabäbi*] I had hoped to accomplish this investigation, but now in my old age [*fi shaykhûkhati*] I have despaired of that, having been impeded by obstacles. But let this discourse spur someone else to inquire into these matters [further]. For nothing of the [true] science of astronomy exists in our time, the astronomy of our time being only in agreement with calculations [*al–husbän*] and not with what exists.[53]

Averroes spent his life trying to establish an astronomical hypothesis that is possible from the standpoint of physical principles because he believed that unless guided by physics, astronomy could easily go off track. He ran out of time to achieve his aim but hoped someone else would achieve his mission, and it was eventually carried out by al–Bitruji, known in the Latin West as Alpetragius.

Al–Bitruji is the most important figure of the Arabic opposition against

53. Quoted from Sabra's translation, see Sabra (2002, pp. 141–42).

Ptolemy because he did what Averroes hoped to do during his life, which was develop a new astronomy based on Aristotelian physics. In his book, *The Principles of Astronomy*, he makes a new hypothesis about the motions of the celestial bodies by using concentric spheres instead of the eccentrics and epicycles of Ptolemaic astronomy.[54] What al–Bitruji did with this new astronomy was a revision of Eudoxus' homocentric models.[55]

As a member of the Andalusian school, al–Bitruji was averse to the mathematical character of Ptolemaic astronomy, but in comparison to others from this school of thought, he was the only one who established a new astronomical model based on Aristotelian physics. Like Averroes, al–Bitruji believed that an astronomical model should be established on the principles derived from physics.[56] He explained his goal to explain the physical principles which account for the motions of celestial bodies as follows:

> Indeed, the remainder of my life would not possibly suffice for this project. The goal of these remarks was (to explain) the quality of the truly necessary motion (which underlies) the many diverse motions and to expose astronomical principles [physical principles] by which it is possible to account for the motions of the heavens (al–Bitruji, 1971, p. 154).

We can also see Bacon's belief evidenced in the name of one of his treatises,

54. For al–Bitruji's explanations about Ptolemy's model, see al–Bitruji (1971, p. 61).

55. As Mohammed Abattouy puts it: "with the innovation that the inclinations of the axes of the planetary spheres were made variable, the movement of each sphere being governed by that of its pole, which described a small epicycle in the neighbourhood of the pole of the equator" Abattouy (2012, p. 194).

56. The idea of the priority of physics in establishing an astronomical theory can also be found among the Averroist philosophers who lived in Italy in the sixteenth century, such as Agostino Nifo, Alessandro Achillini, Girolamo Fracastoro, Agostino Nifo and the most famous one, Alessandro Piccolomini. They argued that mathematics cannot provide us with the real motions of the celestial bodies, see Jardine (1988, pp. 231–2); Lattis (1994, pp. 34–6, 109–10) and Omodeo (2014, pp. 76–85).

'*The Theory of the Planets Proved by Physical Arguments*' (see Duhem, 1969, p. 32). Al–Bitruji believed astronomical models should be led by physics; otherwise, an astronomer can only be a mathematician who establishes fictional models of planetary trajectory. So, like Averroes, al–Bitruji's attitude towards mathematical astronomy shows his belief in mathematics' inability to provide the real motions of the celestial bodies.

According to al–Bitruji, the celestial spheres desire to reproduce the motion of the prime mover, and the closer spheres to the prime mover move faster than those further from the prime mover (see al–Bitruji, 1971, p. 75, 77).[57]

In conclusion, the geometrical model of al–Bitruji, which was set against the Ptolemaic one, was established on these kinds of qualitative physical arguments (see Hockey, 2007, pp. 133–4).

Below, I will show how Bacon's idea of the priority of physics in developing a mathematical model is similar to al–Bitruji's and Averroes' ideas.

3.3 The hide of an ox: astronomy which presents only the exterior part of the heavens

In his *De Augmentis Scientiarum,* Bacon tries to explain the lack of natural philosophy in astronomy by likening it to the hide of an ox. As Bacon puts it:

> For in all these Natural History investigates and relates the fact, whereas Physic likewise examines the causes; I mean the variable causes, that is, the Material and Efficient. Among these parts of Physic

57. For further reading on transmission of energy from prime mover to the other celestial bodies, see Francis Carmody's analysis for al-Bitruji's *De Motibus Celorum* (1952, pp. 44–46).

> that which inquiries concerning the heavenly bodies, is altogether imperfect and defective, though by reason of the dignity of the subject it deserves special consideration. Astronomy has indeed a good foundation in phenomena, yet it is weak, and by no means sound; but astrology is in most parts without foundation even. Certainly astronomy offers to the human intellect a victim like that which Prometheus offered in deceit to Jupiter. Prometheus, in the place of a real ox, brought to the altar the hide of an ox of great size and beauty, stuffed with straw and leaves and twigs. In like manner astronomy presents only the exterior of the heavenly bodies (I mean the number of the stars, their positions, motions, and periods), as it were the hide of the heavens; beautiful indeed and skilfully arranged into systems; but the interior (namely the physical reasons) is wanting, out of which (with the help of astronomical hypotheses) a theory might be devised which would not merely satisfy the phenomena (of which kind many might with a little ingenuity be contrived), but which would set forth the substance, motion, and influence of the heavenly bodies as they really are ... but all the labour is spent in mathematical observations and demonstrations. Such demonstrations however only show how all these things may be ingeniously made out and disentangled, not how they may truly subsist in nature; and indicate the apparent motions only, and a system of machinery arbitrarily devised and arranged to produce them, not the very causes and truth of things. Wherefore astronomy, as it now is, is fairly enough ranked among the mathematical arts, not without disparagement to its dignity; seeing that, if it chose to maintain its proper office, it ought rather to be accounted as the noblest part of Physics (Bacon, *De augmentis*, SEH IV, pp. 347–9).

The hide of an ox analogy says that mathematical demonstrations of the celestial bodies, such as calculations of their positions, are the hide of an ox;

while physical studies, such as studies on the substance of the celestial bodies and the causes of their motions, are the interior part of an ox. We can also see from this quote that Bacon was familiar with the concept of 'saving the phenomena' because he says that 'a theory might be devised which would not merely satisfy the phenomena'. In another work, *Descriptio Globi Intellectualis* (*A Description of the Intellectual Globe*), Bacon also explains his aim concerning astronomy as follows:

> I am nevertheless starting a far greater project; for I do not merely have calculations or predictions in mind, but philosophy; that is, that which can inform the human intellect not only about celestial motion and its periods but also about the substance of the heavenly bodies and every sort of quality, power and influx, according to natural and incontrovertible reasons and without the superstition and frivolity of traditions; and again that can discover and unfold in the very motion not just what saves the phenomena, but what is found in the bowels of nature and is actually and really true (Bacon, *A description*, OFB VI, p. 111).

When Bacon states that 'not what is accordant with the phenomena', we can again see his familiarity with the concept of 'saving the phenomena'. Bacon does not find saving the phenomena enough for a geometrical (mathematical) model. He also emphasises that an astronomical theory should 'set forth the substance, motion, and influence of the heavenly bodies as they really are'. So, this lack in astronomy for setting forth the substance of the heavenly bodies, their qualities and influences, and their real motions as they are found in nature, can only be satisfied by natural philosophy.

The lack of natural philosophy in mathematical sciences was seen by Bacon as a major problem for the development of these sciences. Bacon complained that 'all the labour is spent in mathematical demonstrations.' I do not conclude from these words that Bacon believed we should not spend time in mathematical demonstrations regarding natural phenomena, but rather we should also perform natural philosophical inquiries. The important thing to note is that mathematical demonstrations should come after we have done physics, because the priority of physics was seen by Bacon as the protector for natural philosophy to avoid establishing incorrect models for the celestial motions, such as Copernican astronomy.

I do not believe, however, that Bacon was against the application of geometry to physics, but rather he was against the application of geometry to physics to make natural philosophical claims through the premises of geometry, which was done by mathematical realists, such as Copernicus, Galileo, and Kepler. However, al-Bitruji designated his geometrical model by considering physics. This difference between mathematical realists and physical realists should not go unnoticed.

As for instrumentalists, Osiander wrote an anonymous preface for Copernicus' *De Revolutionibus* (On the Revolutions) and claimed that astronomy could not provide the real motions of the celestial bodies. In his preface, Osiander suggests that saving the phenomena is enough for a geometrical model, and he argues that geometrical models do not have to reflect reality. So, we can say that Osiander supports the astronomer's role as 'saving the phenomena'. Let's read some parts of his preface:

> Since the newness of the hypotheses of this work — which sets the earth in motion and puts an immovable sun at the centre of the universe — has already received a great deal of publicity, I have no doubt that certain of the savants have taken grave offense and think it wrong to raise any disturbance among liberal disciplines which have had the right set–up for a long time now. If, however, they are willing to weigh the matter scrupulously, they will find that the author of this

> work has done nothing which merits blame. For it is the job of the astronomer to use painstaking and skilled observation in gathering together the history of the celestial movements, and then — since he cannot by any line of reasoning reach the true causes of these movements — to think up or construct whatever causes or hypotheses he pleases such that, by the assumptions of these causes, those same movements can be calculated from the principles of geometry for the past and for the future too. This artist is markedly outstanding in both of these respects: for it is not necessary that these hypotheses should be true, or even probably; but it is enough if they provide a calculus which fits the observations... For it is sufficiently clear that this art is absolutely and profoundly ignorant of the causes of the apparent irregular movements. And if it constructs and thinks up causes — and it has certainly thought up a good many — nevertheless it does not think them up in order to persuade anyone of their truth but only in order that they may provide a correct basis for calculation. But since for one and the same movement varying hypotheses are proposed from time to time, as eccentricity or epicycle for the movement of the sun, the astronomer much prefers to take the one which is easiest to grasp. Maybe the philosopher demands probability instead; but neither of them will grasp anything certain or hand it on, unless it has been divinely revealed to him. (Copernicus, 1995, pp. 3–4).

After Kepler revealed in his *Astronomia Nova* (New Astronomy) that the preface of Copernicus' *De Revolutionibus* was written by Osiander, we learned that he tried to save Copernicus from the Church's accusation. Osiander holds that astronomical hypotheses are not supposed to reflect the real model of the heavens. For him, if these geometrical models ensure the correct basis for calculations, it is fair enough.

However, Barker and Goldstein argue that Osiander's preface to Copernicus is not instrumentalist. Indeed, for them, Osiander's preface is neither instrumentalist nor realist, because Osiander argued that the causes of the celestial motions are unattainable for both astronomers and philosophers unless the causes are divinely revealed to them (see Barker and Goldstein, 1998). However, I think that since Osiander argued that for an astronomer it is enough to choose a hypothesis which fits in best with the calculation, he should be accepted as an instrumentalist; Osiander's argument regarding a philosopher's disability in providing the real motions of the celestial bodies is beside the point.

As to Copernicus, he believed the rotation of the earth around the motionless sun was a reality and not a mathematical fiction to save the phenomena. Copernicus thought that mathematics should have pre-eminence in natural philosophy. His emphasis on mathematics rather than physics can be seen in the following words:

> And though all these things are difficult, almost inconceivable, and quite contrary to the opinion of the multitude, nevertheless in what follows we will with God's help make them clearer than day – at least for those who are not ignorant of the art of mathematics (Copernicus, 1995, p. 24).

However, for Averroes and his followers, and also for Bacon, the idea of 'saving the phenomena' cannot be accepted, because astronomical models should be in harmony with physical models, and the harmony between the geometrical (mathematical) model and physical model can be ensured by the guidance of natural philosophy. So, we can define Osiander's preface as an example of the instrumentalist view, and Copernicus' own claim as an example of a mathematical realist view.[58]

Now, let's read the following words of Bacon to see how he places importance on natural philosophy for the sciences:

> So we see *Cicero* the Orator complained of *Socrates* and his Schoole, that he was the first that separated Philosophy, and Rhetoricke, whereupon Rhetorick became an emptie & verball Art. So wee may see that the opinion of *Copernicus* touching the rotation of the earth, which Astronomie it self ca*n*not correct, because it is not repugnant to any of the *Phainomena*, yet Naturall Philosophy may correct. So we see also that the Science of *Medicine*, if it be destituted & forsaken by *Natural Philosophy*, it is not much better then an Empeirical practise (Bacon, *The Advancement*, OFB IV, p. 93).[59]

In this quotation, we can see that Bacon likens the separation of philosophy from rhetoric to the separation of philosophy from astronomy. Just as rhetoric, after it was separated from philosophy, became an empty verbal art, in the same way, lack of philosophy in astronomy caused the same thing to happen to astronomy. For Bacon, medicine also needs natural philosophy to abstain from becoming only an empirical practice.

He also states:

> And this great mother of the sciences has, with wonderful indignity,

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58. The difference between al-Bitruji (or Bacon), who I call a physical realist, and Copernicus, who I call a mathematical realist, is explained by Pietro D. Omodeo as follows:

> the rejection or the reaffirmation of the pre-eminence of physics over mathematics, and the choice between a mathematical approach to nature and a causal one (Omodeo, 2014, p. 85).

For an instrumentalist interpretation of Copernicus, see Gingerich (1973). For a realist interpretation of Copernicus, see Gardner, (1983).

59. See also Bacon (*Valerius*, SEH III, p. 229).

> been forced into the role of a servant, dancing attendance on the business of medicine and mathematics (Bacon, *Novum*, OFB XI, Book One, §. 80, p. 127).

Just as natural philosophy had been used as a servant, other sciences were separated from their root, and this separation led to a loss of their ability to grow well. Astronomy is one of these sciences, as is optics, music, a number of mechanical arts, and medicine (see Bacon, *Novum*, OFB XI, Book One, §. 80, p. 127). Why then does Bacon give medicine and mathematics as particular examples of using natural philosophy as a servant? Indeed, it is clear that by medicine, Bacon means Paracelsus and Paracelsians, and by mathematics, he means those who had used mainly mathematics but not natural philosophy in their natural inquiries, such as Copernicus, Kepler, and Galileo. Bacon argued those who had been studying these mathematical sciences had neglected natural philosophy.

Bacon believed astronomy and physics should come together to create one body of science:

> Now astronomy and philosophy ought to have arranged things so that astronomy would prefer hypotheses which are most useful for cutting short calculation, philosophy those which come closest to the truth of nature; and, further, that the hypotheses which astronomy uses for its own convenience should not be prejudicial to the truth of the matter, and in turn that the determinations of philosophy should be such as to be wholly reconcilable with the phenomena of astronomy. But at present the opposite happens, namely that the fictions of astronomy have been introduced into philosophy and have debauched it, while the speculations of the philosophers concerning the heavenly bodies please only themselves and almost desert astronomy, looking at the heavenly bodies generally but in no way applying themselves to

> particular phenomena and their causes. Therefore since both sciences (as they stand now) are frivolous and perfunctory, our footing must be fixed altogether more firmly, and we must treat the two of them as one and the same and combined into a single body of science, which because of men's narrow meditations and the practice of professors have been used to separation for so many ages (Bacon, *A description*, OFB VI, p. 135).

Holding that astronomy and physics should be one body of science constructed out of physics and mathematics does not, however, mean that Bacon treats these sciences equally. To achieve a harmony between the results of physics and astronomy, a physical model should first be developed; then a mathematical model should be established on this physical ground. When this is done, Bacon believes there cannot be a contradiction between the physical model and the geometrical (mathematical) model of the heavens, and this shows us his unbelief in the explanatory power of mathematics in determining the real motions of the celestial bodies.

Bacon was not against the application of mathematics in astronomy; however, he thought that a geometrical model should follow physics. The reason for this, as I mentioned above, is Bacon's lack of confidence in mathematics' explanatory power regarding the objects of natural philosophy. This is the main difference which should be borne in mind between mathematical realists, such as Copernicus, Galileo, Kepler, and physical realists, such as Bacon and the Averroists.

In her 'A natural history of the heavens: Francis Bacon's anti-Copernicanism', Jalobeanu emphasises the collection of measurements of the celestial motions and states:

> In fact, much of Bacon's proposal for a novel and 'living astronomy',

> which would replace the 'stuffed ox' of the received mathematical astronomy, was based on the same project of constructing a well regulated and well organised data-base of phenomena, a natural history of the heavens (Jalobeanu, 2015a, p. 78).

In this chapter, however, instead of the collection of measurements for a natural history of the heavens,[60] I emphasise a later step in the Baconian schema – which comes after establishing a natural history of the heavens – and it is developing a physical model of the celestial motions. As to developing a mathematical model, it comes after developing physical model. This attitude of Bacon towards a mathematical model of the heavens is related to his attitude towards the new role for mathematics as making natural philosophical claims through the premises of geometry, which was indeed a violation of the Aristotelian disciplinary boundary between mathematical sciences and natural philosophy (see Chapter 1 for the disciplinary boundary).

Bacon suggested establishing an astronomical theory by considering physics first and then developing a geometrical model to beget practice. I will discuss what those physical statements are in Section 3,5. However, mathematical realists ignore physics and apply the rules of geometry on the history of the observations and measurements regarding the celestial bodies to establish a geometrical model of the heavens, which, for them, reflects the physical model of the heavens.

60. On quantitative approach in Baconian natural history, see fn. 32.

3.4 Did Bacon adopt al–Bitruji's mathematical model of the heavens before he developed his physical model?

In this section, I discuss one of Rees' claims that Bacon adopted al–Bitruji's geometrical model before he developed his physical model, and that Bacon's idea of the priority of physics in developing an astronomical theory was a later development in Bacon's career.[61] As Rees states:

> However, the relationship between the Baconian physical system and the Alpetragian kinematic principles looks very different when it is seen from the point of view of the system's origins and growth. Indeed, Bacon adopted the Alpetragian principles at least twenty years *before* he developed the physical cosmology. In fact, Alpetragian geometry served as an armature about which he moulded the physical system. The history of the speculative system manifests a *reversal* of what Bacon subsequently held to be the proper sequential relationship between physical and mathematical endeavours in the field of natural philosophy. In the development of speculative philosophy, a sketchy geometrical structure preceded the physical flesh that was to clothe it – although Bacon was later to represent the geometry as a consequence of the physics (Rees, 1985, p. 30).[62]

Rees also states:

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61. For the similarities of Bacon's and al-Bitruji's astronomical models, see p. 77 in this dissertation.

62. See also Rees (1986, p. 424).

> Paradoxically kinematics exerted a crucial influence on the shaping of his [Bacon] own substantive natural philosophy, an influence that implicitly contradicted the cardinal principle of the priority of physics (Rees, 1985, p. 31).

First, al-Bitruji rejected epicyclic and eccentric models of Ptolemy and offered spiral lines for the motions of celestial bodies because of natural philosophical reasons, but not because of the requirement of the premises of geometry. Al-Bitruji offered a model for the celestial motions by considering physics, then he developed a geometrical model which is in harmony with the physical model. This is what Rees failed to notice. Rees thought that the astronomical model of al-Bitruji regarding the celestial motions was derived from geometry, but indeed, it was derived from physics. What Bacon adopted from al-Bitruji was a physical model for the celestial motions. The geometrical model of al-Bitruji was developed out of this physical model. For Rees, what Bacon adopted from al-Bitruji was the kinematic principles of al-Bitruji, that is, geometry; however, what Bacon adopted from al-Bitruji was a physical model. Bacon's and al-Bitruji's explanations regarding spiral lines for the motions of the celestial bodies and the geocentric model of the heavens were natural philosophical explanations.

In other words, if we believe we can discover the physical model of the heavens through mathematics, we should be called mathematical realists. This leads us to ask, was al–Bitruji a mathematical realist? The answer is no. As mentioned above, he made an offer according to which a geometrical model of the heavens should be based on physical principles. So, we can say that the Alpetragian model for the motions of the celestial bodies was derived from the principles of physics. Therefore, Rees' mistake again was ignoring al–Bitruji's priority for physics in the development of an astronomical theory. We can also question whether Bacon was a mathematical realist. The answer is no because, like al–Bitruji, Bacon also thought that a mathematical model of the heavens should be based on a physical model. This is why Bacon adopted the Alpetragian account of the celestial motions. Rees was surprised by the Baconian adoption of the Alpetragian account of the celestial motions:

> It is not entirely clear why Bacon was attracted to the Alpetragian scheme for it was not taken seriously by any of his contemporaries even though it was part of the small change of astronomical discourse in the early seventeenth century Rees (1986, pp. 422–3).

As mentioned before, the Alpetragian model was derived from the principles of physics, and this is the reason why Bacon was attracted to the Alpetragian model. So, we cannot claim that in the system of Bacon, the geometrical model of the celestial motions preceded physical model. The following quote from Rees shows us that even he might be aware that his claim is problematic:

> However, one should perhaps not make too much of this reversal … It is possible that these outline principles were chosen because they accorded with deep–seated physical or metaphysical intuitions that Bacon had arrived at before 1592. It is possible that, in this sense, such intuitions governed his outlook throughout his career Rees (1986, p. 424).

Below, I will discuss Bacon's physical statements regarding the motions of celestial bodies.

3.5 Bacon's physical statements and his astronomical theory

In this section, examples will be given to show how Bacon explains the motions of the celestial bodies with physical arguments. These physical arguments primarily concern the matter of the heavenly bodies. Bacon explained the celestial motions according to their substance because, for him, by considering the substance of the heavenly bodies "their motion and construction may be better understood" (Bacon, *Theory*, OFB VI, p. 173). As is seen, Bacon established his astronomical theory by considering physics, such as the substance of the heavenly bodies, and he discarded mathematical (or logical) subtleties (see Bacon, *Theory*, OFB VI, p. 179).

In his physical model, the relation between the speed of the celestial motions and the immobility of the Earth is explained as follows:

> the rapidity and speeds of the heavenly motions abate by degrees, as if about to end in something immovable, and that in respect of the poles even the heavenly bodies participate in rest; and that if immobility be excluded, the System comes apart and disperses. Now if there be any concentration and mass of the immovable nature, it seems that we need inquire no further to show that this is the globe of the Earth (Bacon, *Theory*, OFB VI, p. 179).

Bacon claimed rest cannot be excluded from nature, and if celestial bodies are closer to the Earth, they are slower, because the Earth is immovable (see Bacon, *Theory*, OFB VI, pp. 181–2). If we do not consider immobility, Bacon's system dissolves. The spherical, finite cosmos of Bacon requires an immutable centre; while the celestial region consists of a flamy substance, the Earth consists of tangible matter.[63] Bacon explained the different motions of the celestial bodies with reference to their material substance:

> For dense and tight packing together of matter induces a tendency

63. For Bacon's Paracelsian cosmology, see Rees (1975).

> torpid and antipathetic to motion, just as on the other hand loose unfolding induces a tendency ready or apt (Bacon, *Theory*, OFB VI, p. 179).

Accepting rest in nature requires an acceptance of motion without limit (perfect mobility). Like Aristotle, Bacon finds this perfect (limitless) motion in the circular motion of the starry heaven (see Bacon, *Theory*, OFB VI, p. 181).

The important thing for us is that Bacon did not rest upon mathematics when he enquired into the motions of the celestial bodies. He declares:

> Now when I explain these things [the motions of the celestial bodies], I shall banish to calculations and tables the fancy mathematics (that motions be reduced to perfect circles, either eccentric or concentric), and the empty talk (that the Earth is in comparison to the heaven like a point, not like a quantity), and many other fictitious devices of the astronomers (Bacon, *Theory*, OFB VI, pp. 179–81).

For Bacon, there are two kinds of heavenly motions: cosmical and mutual. Of the first sort of motion, Bacon writes:

> Now this motion seems truly cosmical and for that reason singular except in so far as it admits both diminutions and deviations according to which this motion echoes through the universe of movable things, and penetrates from the stellar heaven all the way to the bowels and insides of the Earth, not by some violent or vexatious compulsion, but by constant consent. Now this motion is also perfect and complete in the stellar heaven, both in just measure of time and in full restitution of place. But the further we depart from the upper regions, the less perfect is this motion in respect of its slowness and also in respect of deviation from circular motion (Bacon, *Theory*, OFB

VI, p. 181).

Bacon argued that the motion of opposition from west to east (which was attributed to the planets) is just an appearance, not a real motion. As the starry heaven moves faster, it leaves the planets behind, and this was assumed by others as a motion from west to east (Bacon, *Theory*, OFB VI, p. 181). The planets' velocity is different, and they do not return to the same point of trajectory because their trajectory is not a perfect circle. Bacon argued, like al–Bitruji, that the planets move in spiral lines (see al–Bitruji, 1971, pp. 100–4). Al-Bitruji calls this spiral motion *idära lawlabiya* (see al–Bitruji, 1971, p. 101). According to Bacon, admitting spiral lines for planetary motions is closest to sense and fact (Bacon, *Theory*, OFB VI, p. 183). Let me summarise the similarities of Bacon's and al-Bitruji's astronomical models as follows:

- These two models are geocentric.
- Both models are against the existence of eccentric and epicyclic models.
- Both offer the idea of spiral motion for the celestial bodies.
- Both propose that the motion of celestial bodies becomes slower when they get nearer to the Earth.

For Bacon, these views are better than the astronomers' views, such as, "Compulsion and Repugnance of motions, different polarity of the zodiac, the reversed order of speed and the like" (Bacon, *Theory*, OFB VI, p. 185). The astronomer's views have nothing to do with nature of things, but "they keep the peace, such as it is, with the calculations" (Bacon, *Theory*, OFB VI, p. 185). Namely, astronomers' views save the phenomena, even though they do not reflect reality. The faults of astronomers are expressed by Bacon as follows:

> Nor did the better astronomers fail to see these things, but being attentive to their art, mad on perfect circles, straining for subtleties,

> and indulgent of bad philosophy, they disdained to follow nature. But this imperious disposition of wise men towards nature is worse even than the simplicity and credulity of the crowd, if a man disdains plain things because they are plain. And yet it is a prodigious and very widespread evil that the human intellect, since it cannot be on a level with things, prefers to be above them (Bacon, *Theory*, OFB VI, p. 185).

As we can see, the main reason why Bacon is against astronomers' views is that they did not follow nature. The reason for this failure is intellectual. For Bacon, when the human wit (i.e. understanding) is not able to match nature, it puts itself above nature. So, Bacon believed the ideas of astronomers, such as perfect circles, are results of unaided intellect. According to Bacon, as quoted in Section 2.2, 'The unaided intellect takes the same way (i.e. the former) which it takes when directed by dialectic' (see p. 46). When human understanding is left alone, it ignores nature and creates ideas through logic and mathematics, which are beyond nature. To avoid these kinds of false ideas, we should follow nature when we try to develop an astronomical theory.

3.6 Summary

In this chapter, I have argued that Bacon should be accepted as a physical realist along with others such as al–Bitruji, Averroes, and the aforementioned Italian Averroists (see fn. 56). I have argued they should be labelled physical realists because they held that a geometrical model of the heavens should be derived from physics. Those who believed their geometrical model of the heavens reflected the physical model should be labelled as mathematical realists, to divide them from physical realists. As to instrumentalists, like physical realists, they also did not believe mathematics could provide us with a physical model of the heavens; however, they believed that if a geometrical model saves the phenomena, it should be enough for us, even though it does not reflect the real motions of the celestial bodies.

What al–Bitruji himself offered was, as an astronomer, establishing an astronomical model which is in accord with physics. Therefore, what Bacon adopted from al–Bitruji was an astronomical theory which was developed out of physics, but not out of the premises of geometry. This is an attitude which gives priority to physics but not mathematics. It is the same attitude which was shared by Bacon himself. Therefore, I call both al–Bitruji and Bacon physical realists. Al–Bitruji and Bacon argued that a geometrical model could reflect reality only if it is derived from physics.

Chapter 4

Geometrical Abstraction vs. Arithmetical Quantification

Rees argues that when we turn our attention from Bacon's attitude towards geometrical abstraction to his arithmetical, quantitative works, we can see that he was more affirming of mathematical methods (see Rees, 1985, p. 31). Rees evaluates both the quantification process and geometrical abstraction as mathematical methods, which blurs Bacon's attitude towards the application of mathematics in natural philosophy because the mathematical method has been known as a geometrical method. These two aspects of Baconian natural philosophy should not be compared, and those who criticise Bacon for his disagreement of making natural philosophical claims through the premises of geometry cannot be refuted through his use of arithmetical quantification or the collection of measurements in natural history.

Section 4.1 addresses the arithmetical quantitative works of Bacon. In section 4.2, I argue that the arithmetical quantitative works of Bacon cannot be used to refute the claims of those who argued that Bacon did not approve of the new role of mathematics in modern science. Section 4.3 will address Thomas Kuhn's charge that Bacon mistrusted the entire quasi–deductive structure of the mathematical sciences.

4.1 Arithmetical quantification in Bacon’s natural historical works

Bacon attaches importance to measuring and weighing bodies or virtues of natural phenomena in his natural historical works. We can say that his quantitative approach to natural phenomena represents one side of his approach to mathematics. We can see some examples of this in his natural histories; including history of the winds, history of life and death, history of dense and rare, history of heavy and light, history of the sympathy and antipathy of things; and history of sulphur, mercury, and salt (see Bacon, *Historia*, OFB XII, p. 7). The first three of these were published, but the others are only short prefaces. Bacon’s *Sylva Sylvarum* (1626) can also be presented as a good example of his quantitative approach.[64]

As to the relation between his quantitative approach in his natural historical works and his attitude towards mathematics, Bacon himself explains it, saying:

> In addition I demand that everything to do with natural phenomena, be they bodies or virtues, should (as far as possible) be set down, counted, weighed, measured and defined. For we are after works not speculations, and, indeed, a good marriage of Physics and Mathematics begets Practice. And for this reason we should investigate in detail and thoroughly record, in the History of Heavenly Bodies, the precise returns and distances of the planets; in the History of Earth and Sea, the extent of the land and how much of the surface it

64. Rees informs this account of Bacon’s works, see Rees (1985, p. 34).

> occupies compared with the waters; in the History of Air, how much compression air will put up without strong resistance; in the History of Metals, how far one may outweigh another; and countless other instances of this kind. But where precise proportions are not available to us we must for sure fall back on rough estimates and comparisons, as, for instance, (if we happen to distrust the astronomers' calculations of distances) that the Moon stands within the Earth's shadow; that Mercury is above the Moon, and the like (Bacon, *Parasceve*, OFB XI, §. 7, pp. 465–7).

Also, in his *Novum organum* Bacon says,

> Now the *Operative Part* has two vices and, in general, two instances with special rank to match them. For operation either lets you down or gives you too much trouble. For the most part operation lets you down (especially after careful investigation of natures) by inaccurate determination and measurement of the powers and actions of bodies. Now the powers and actions of bodies are circumscribed and measured either by point in space, moment of time, concentration of quantity, or ascendancy of virtue, and unless these four have been well and carefully weighed up, the sciences will perhaps be pretty as speculation, but fall flat in practice (Bacon, *Novum*, OFB XI, Book Two, §. 44, p. 367).

As you see, for Bacon, 'a good marriage of Physics and Mathematics begets Practice,' and we should know that practice can provide to humanity Bacon's dominant, prelapsarian position over nature, which was lost after the Fall. So, this divine goal of natural philosophy can be fulfilled through technological achievements, and these achievements cannot be possible without the speculative (theoretical) knowledge of natural philosophy. Speculative, or theoretical knowledge of the causes can produce practice when combined with mathematics, so the application of mathematics in natural philosophy is important for Bacon, as it is helpful to fulfil the goal of a natural inquiry.

I should emphasise that 'a good marriage of Physics and Mathematics begets Practice' also refers to the measuring and weighing processes in natural history, which functions, as Jalobeanu states, as a "prerequisite to the emergence of a quantitative science of nature" (Jalobeanu, 2016b, p. 69). But, we should separate the measuring and weighing processes in his natural historical works from the application of geometry. The measuring and weighing processes in natural history come before physics, while the application of geometry comes after physics. By 'application of geometry', I mean developing geometrical models such as a geometrical model of the heavens (see Chapter 3 and Chapter 6).

4.1.1 Examples of quantification from the writings of Bacon

For Bacon, quantity of matter and its distribution in bodies is important in natural inquiries. It is well known that quantity of matter in the universe is fixed. In his *Historia densi at rari*, Bacon tried to explain the phenomena of expansion and contraction by cube and bladder experiments. To learn the densities of some liquids and solids, he measured their weight by applying the same volume for all of them. He explains one of the results of his experiment as follows:

> since the gold cube weighs one ounce and the cube of myrrh one pennyweight, it is evident that the bulk of myrrh compared with the bulk of the body of gold is as twenty to one; so that in the same space there are twenty times more matter in gold than in myrrh, or

> contrariwise that myrrh has twenty times the bulk of the same weight of gold (Bacon, *Historia densi*, OFB XIII, pp. 45–7).

By using his cube experiment, Bacon was able to refute the well–known claim that everything in the world is composed of four elements:

> The opinion that sublunary things are made up of the four elements does not come well out of this. For the gold in the vessel weighed in at 20 pennyweight; common earth at little more than 2; water at 1 dwt. and three grains; air [and] fire, much more tenuous and less materiate, weigh nothing at all (Bacon, *Historia densi*, OFB XIII, p. 49).

Another example of his quantitative experimentation can be given as follows. Bacon takes a phial and pours certain amount of wine into it. He inserts the neck of the phial into the mouth of a bladder, which was prepared for this experiment. Then, he heats the phial and reports:

> Not long after that the breath of the spirit of wine rose up into the bladder and gradually blew it up quite strongly all round. When that had happened I took the glass from the fire forthwith and punctured the top of the bladder with a needle to let the breath out rather than let it revert to drops. Then I took the bladder from the phial, and with the scales I showed how much of that half ounce of spirit of wine had been lost and turned into a breath. Now by weight the loss amounted to not more than six pennyweights, so that the six pennyweights spirit of wine, which in a body did not (as I recall) fill a fortieth of a pint, filled a space amounting to eight pints when turned into breath (Bacon, *Historia densi*, OFB XIII, p. 69).

These quantitative experiments of Bacon provided a basis for his pneumatic theory of matter. Bacon believed these quantitative experimental inquiries should be performed in natural historical works, which he suggests are the proper basis for further inquiries into nature. These natural historical works should be a basis for inquiries into physics. So, it can be easily seen that quantitative experimental works in his natural histories are not just for practical goals, but they provide a basis for Bacon's theoretical inquiries.[65]

4.1.2 Mathematical instances (instances of measurement)

For the operative part of his natural philosophy, Bacon mentions seven instances and calls them *Practical Instances*. Four of them are mathematical instances or instances of measurement:

A) Instances of the Rod or Rule

B) Instances of the Course

C) Instances of Strife

D) Instances of Quantity

For our inquiry, 'instances of quantity' are the most important; and Bacon also defines 'instances of quantity' as 'doses of nature', which is 'quantity proportionable'. As previously mentioned, Bacon calls the object of mixed mathematics 'quantity proportionable' or 'dose of nature' synonymously (see pp. 20–1). Below, I mention these four mathematical instances to see how we

65. Rees explains this side of Bacon's philosophy well by saying:

> There can be no doubt that he regarded the collecting of quantified data as essential to the successful accomplishment of his programme. He complained that in natural history nothing had been "duly investigated, nothing verified, nothing counted, weighed or measured." In the Novum Organum he stressed the absolute necessity of using measuring instruments to the full in order to overcome the deficiencies of the senses … It is perfectly plain that in principle Bacon believed that quantified data should form a major part of the new natural history—not least because such data would help to generate a productive philosophy (Rees, 1985, pp. 32–3). See also Jalobeanu's recent work (2016b).

can quantify nature by measuring and weighing bodies and virtues, which helps us apply further applications of mathematics to natural phenomena.

A) Instances of the rod or rule

Bacon places the first kind of mathematical instances (the instances of the rod or rule, that is, instances of range or limitation) as the twenty-first place of *Prerogative Instances*. These instances are about the powers and the motions of things, and they are not accidental, but fixed; not indefinite, but finite. Some of these powers act by visible contact such as medicines, which we cannot discover their virtues without touching the body.

There are also powers which act at a distance, for example, amber attracts straws. We can observe magnetic powers when a piece of iron and a magnet or two magnets are approaching each other. In this example, the action between a piece of iron and magnet or the action between two magnets happen at a small distance; but the magnetic virtue which moves the needle of a compass operates at much more of a distance if we compare it with the magnetic virtue among two magnets. Bacon surmises then that the following magnetic powers also act at great distances:

1) The power between the globe of the Earth and heavy bodies.

2) The magnetic power between the globe of the moon and the waters of the sea.

3) The magnetic power between the starry sphere and the planets.

Among other instances of action at a distance, we can mention perfumes, light, and sound.

The important thing is that even with these instances of action at small or great distances, there is a certain limit which cannot be exceeded. This limit, for Bacon, "varies according to the mass or quantity of bodies, or the strength and weakness of virtues, or the helps and hindrances of the media, all of which ought to come into the reckoning and to be noted down" (Bacon, *Novum*, OFB XI, Book Two, §. 45, p. 371). Not only are the natural motions caused by natural powers, but because of having fixed limits, the measurements regarding the instances of violent motions should also be observed and computed, such as projectiles, guns, wheels (see Bacon, *Novum*, OFB XI, Book Two, §. 45, p. 371).

Another kind of motion is spherical motion, which is the expansion or contraction of bodies. Bacon believed it is important to measure the degree of expansion and contraction of bodies. He observed that rare bodies allow contraction more than tangible bodies. To learn about these kinds of motions, he conducted the following experiment:

> I had a hollow globe made from lead, whose volume amounted to two wine pints, and which had sides thick enough to withstand considerable force. I poured water into it through a hole made for the purpose, and when the globe was full, I stopped the hole with molten lead to make the globe quite solid. Then I flattened the globe on opposite sides with a great hammer, whence it followed of necessity that, since a sphere is of all shapes the amplest, the water was driven into a smaller space. Then, when the hammering stopped making the water withdraw further, I resorted to a mill or press until the water, impatient of further pressure, oozed (like a fine dew) through the solid lead. Then I worked out how much space had been lost by compression, and gathered that the water had endured that much compression (but only when worked on with great violence) (Bacon, *Novum*, OFB XI, Book Two, §. 45, p. 375).

B) Instances of the course (instances of the water)

While the previous instances of the rod are measurements of degrees of space, instances of the course, which was put in twenty–second place, are the measurements of the periods of time. Bacon says that he borrowed the term *instances of water* from the hourglasses of the ancients. All motions in natural bodies happen in a period of time; for example, celestial bodies revolve in a certain period of time. Ebb and flow also happen periodically. The falling of bodies and the expansions and compressions of bodies happen in a certain time frame that can be measured. Among other examples of these kind of instances, Bacon counts the following:

> when ships set sail, animals move, and missiles fly, all these are likewise accomplished in times which can (as far as their sums are concerned) be reckoned … Moreover when several artillery pieces are fired together, which are sometimes audible thirty miles off, people near the guns hear the bang sooner than those a long way off (Bacon, *Novum*, OFB XI, Book Two, §. 46, p. 377).

However, Bacon warns us that we should not only measure the time period of motions of bodies, but we should compare their motions. For example, when we compare the motion of sound and the motion of light, we can see that the motion of light is faster than the motion of sound because the fire of a gun can be seen before its sound can be heard (see Bacon, *Novum*, OFB XI, Book Two, §. 46, p. 379). Bacon accepts this phenomenon as the inequality of motions, and gives some other examples such as how the strings of a violin seem doubled or tripled when they are struck by a finger; or, when we turn a ring it seems that it becomes a globe. The reason for this is that "visible species are picked up by sight more quickly than they are set aside … because new species are picked up before the old are set aside" (Bacon, *Novum*, OFB XI, Book Two,

§. 46, p. 379). Bacon believed that even Galileo founded his theory of ebb and flow upon the mentioned inequality of velocities of motion. Galileo supposed that the world turns faster than the flow of water, which, according to Bacon, is a wrong assumption.

C) Instances of strife (instances of predominance)

Bacon calls the twenty–fourth prerogative instance, or the third of the mathematical instances, *instances of strife* or *instances of predominance.* According to Bacon, these instances "draw attention to the ascendancy of virtues over each other or their submission to each other, and which of them is the stronger and gets the upper hand and which the weaker and goes under. For the motions and exertions of bodies are no less composed, decomposed and intermixed than the bodies themselves" (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 383).

Bacon gives 'resistance in matter' as an example for instances of strife. Resistance is a kind of virtue in matter which resists being destroyed. So, we can say that nothing can reduce any portion of matter. The Schoolmen denote this motion by an axiom, which is "two bodies cannot be in the same place", or they call it motion "to prevent penetration of dimensions" (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 385).

The second motion of this kind of instance is the *motion of connexion*. The Schoolmen called this motion a 'motion to prevent a vacuum' (see Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 385). It is a kind of resistance to the separation of bodies.

The third motion is the *motion of liberty*. This motion refers to a body's struggle to escape unusual pressure and to return its natural size. Bacon gives the following examples of these kinds of motions:

- The motion of water in swimming
- The motion of air in flying
- The motion of water in rowing
- The motion of air in the undulations of winds
- The motion of springs in clocks (see Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 385)

Bacon also gives examples of the motion of bodies which escape from pressure. This kind of motion can be seen "in the air left in glass eggs after they have been sucked out, and in strings, leather, and cloth which spring back after stretching, unless the stretching last long enough to stay put, etc" (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 387). This motion is evidenced not only in fire and air but even solid bodies such as wood, lead and iron.

The fourth motion is the *motion of matter*. Contrary to the motion of liberty, which is the struggle of bodies to return to their old size after pressure, the motion of matter is the desire of bodies for a new dimension. For instance, when air is heated, it expands and longs for a new dimension, and without applying cold, it does not want to regain its earlier dimension.

The fifth motion is the *motion of continuity*, that is, the self–continuity of a certain body. All bodies resist discontinuity, and some bodies have a stronger resistance than other bodies. For example, when we consider steel, we can say that it has a strong resistance to discontinuity.

The sixth motion is the *motion of gain* or *motion of want*. When bodies are placed among other, hostile bodies; if these bodies find an opportunity, they try to unite with allied bodies. For example, paper and cloth imbibe water but expel air. For Bacon, electricity can be given as an example of this kind of motion, as he states:

> For the operation of electric bodies (about which Gilbert and others since have turned out so many tales) is nothing other than an appetite of a body excited by gentle rubbing, an appetite which does not put up well with air but prefers another tangible body if one can be found close by (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 391).

The seventh motion is the *motion of the greater congregation*. This motion was named 'natural motion' by the Schoolmen. Bodies have a tendency to gather with other bodies which are of a like nature. Heavy bodies move towards the Earth, while light bodies move towards the heavens.

The eighth motion is the *motion of the lesser congregation*. Homogeneous parts of a body have a desire to separate themselves from the heterogeneous parts, and both parts of a body come together with each other. For example, when a glass of milk is left awhile, the creamy part of it gathers on the top; and when we consider a glass of wine, we can see that the dregs gather in the bottom of the glass.

The ninth motion is the *motion of magnetic*. Bacon thinks that magnetic motion might seem similar to the motion of lesser congregation, but argues that in fact, it is a different kind of motion. The moon raises the waters; the starry heaven attracts planets to their highest points of their orbits, and so we can see that these motions are different from both greater and lesser congregation.

The tenth motion is the *motion of flight*. This motion is the opposite of the motion of lesser congregation. Some bodies have an antipathy to other hostile bodies, and they desire to flee from them and refuse to mix with them.

The eleventh motion is the *motion of assimilation* or *self–multiplication*. Two examples of this kind of motion can be seen as follows: "flame multiples itself and generates new flame over vapours and oily bodies ... air multiplies itself and generates new air over water and watery bodies" (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 401).

The twelfth motion is the *motion of excitation*. This motion is in a similar class to the motion of assimilation. It is a diffusive, multiplicative, and transitive motion. While the motion of assimilation multiplies and transforms bodies and substances, the motion of excitation multiplies and transforms virtues only. For example, more heat causes more magnetic power and more putrefaction. The important thing to note is that this kind of motion is the form of heat, as Bacon states,

> this motion is especially conspicuous in heat and cold. For in heating the heat does not spread itself by communication of the initial heat, but only by *Excitation* of the parts of the body to that motion which is the form of heat, a motion of which I spoke in the *First Vintage concerning the Form of Heat* (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 405).

As we can see, the motion of excitation, which is one of the mathematical instances, is the form of heat. In *Novum organum*, Bacon, after an inquiry, concludes that motion is the form of heat (see Bacon, *Novum*, OFB XI, Book Two, §. 11), and again in *Novum organum,* we learn that one of the mathematical instances, motion of excitation, is the form of heat. Measuring this motion refers to the operative part of natural philosophy, which is a process defined by Bacon as descending to new experiments or works from axioms of physics or forms. I will discuss this in the next chapter in detail.

The thirteenth motion is the *motion of impression*. This motion is the same kind of motion as the motion of assimilation, and it is the most subtle among those diffusive motions. Bacon explains the difference between the motion of assimilation and the motion of impression as follows:

> For simple motion of *Assimilation* transforms the bodies themselves such that if you take away the initial mover, it makes no difference to the effects that follow (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 405).

As an example, when we consider magnetised iron, even though we move the magnet, iron continues to magnetise other metals. However, when we consider the motion of impression, according to Bacon, it depends on the mover. For example, when we take the magnet away from a non–magnetised piece of iron, the effect of the magnet on iron ceases in a stroke. This motion can be seen in three things: in percussions of sound, in rays of light, and in magnetism. When we take away light, vision is gone; when we take away percussion, the sound dies away, and when we take the magnet away, the iron drops.

The fourteenth motion is the *motion of configuration* or *position*. This motion is not about the desire of union or separation of bodies, but about the desire of position and collocation of bodies with reference to other bodies. For example, the heavens revolve from east to west rather than from west to east, and we do not know the reason for it, but there must be a cause for it. Bacon thinks that there are certain positions and configuration of parts in bodies that cause these kinds of motions, and without knowing these configurations, it is impossible to manage and to control these bodies.

The fifteenth motion is the *motion of transition*. This motion refers to the promotion or prevention of virtues of bodies through their medium. While one medium fits to light, another medium might fit to magnetic virtues. For example, the medium of iron fits to magnetism, but the medium of a piece of wood does not; or the medium of wood does not fit to light, but the medium of water or glass does.

The sixteenth motion is the *royal* or *political motion*. This motion refers to motions caused by the predominant parts of bodies over other parts. The predominant parts of bodies may regulate the other parts of bodies; they may force them to separate or unite or move, so we can say that Bacon likens the position of predominant parts of bodies over other parts to a sort of government. When we consider quicksilver and vitriol, for example, the thicker parts are the predominant parts of them.

The seventeenth motion is the *spontaneous motion of rotation*. This motion is the motion of the heavens and the heavenly bodies. When we consider the Earth, the motion of missiles and arrows are defined Bacon as the motion of liberty, and I should emphasise that as Bacon thought the Earth stands still, we can say this motion is related to astronomy. Bacon holds there are nine differences regarding this motion, which are caused from the following properties:

> the first relates to the centres that bodies move round; the second to the poles which they move on; the third to the circumference or confines according as they lie distant from the centre; the fourth to their speed according as they rotate faster or slower; the fifth to their consecutions, as from east to west or west to east; the sixth to their divergence from a perfect circle by spirals nearer to or further from the centre; the seventh to their divergence from a perfect circle by spirals nearer to or further from their poles; the eighth to the smaller or greater distances of their spirals from each other; the ninth and last to the variability of their poles if they are mobile, though the variability has nothing to do with rotation unless it moves in a circle (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 411).

The eighteenth motion is the *motion of trepidation*. This motion is indeed an astronomical motion. It is “a backward and forward motion of the equinoctial points” (Brummelen, 2014, p. 116). However, Bacon does not attach much credit to this claim as it is understood by astronomers. For Bacon, “Now this motion is a kind of life imprisonment, i.e. where bodies not altogether well situated in terms of their nature and yet not absolutely uncomfortable, are all aquiver and fretful, neither content with their lot nor daring to change it” (Bacon, *Novum*, OFB XI, Book Two, §. 48, p. 411). The motion of the heart and pulses of the animals can be given as examples of this kind of motion.

The nineteenth motion is the *motion of repose* or the *motion of aversion to move*. This motion is the reason why the Earth stands still, but its extremities move towards the centre. Bacon argued that bodies which have considerable density abhor motion. If these bodies are forced to move, they have the desire to recover their position and not to move any further.

D) Instances of quantity (doses of nature)

The twenty–third of the prerogative instances, and the third of the mathematical instances, are the instances of quantity.[66] Bacon explains he borrowed the term ‘doses of nature’ from medicine. Instances of quantity or ‘doses of nature’ are important, because, as we saw in the first chapter (see pp. 20–1), that ‘dose of nature’ or ‘quantity determined’ is the object of mixed mathematics, which was also placed by Bacon as a branch of metaphysics. Bacon defines ‘instances of quantity’ or ‘doses of nature’ as follows:

66. Bacon also discusses measure of quantity in his *Abecedarium novum naturae*, but it seems that his explanations regarding mathematical instances in *Novum organum* are more comprehensive. However, his attitude towards the quantification process in natural history seems similar to *Novum organum* because he says, “This is why we must get closer to the mathematics or measures and scales of motions, without which, well counted and weighed and defined, the doctrine of motions may falter and not be reliably translated into practice” (Bacon, *Abecedarium*, OFB XIII, p. 211).

> These are the ones which measure virtues according to the *Quantum* of bodies, and show what the *Quantum of a Body* does to influence the *Mode of the Virtue*. Now in the first place there are certain virtues which subsist only in *Cosmic Quantity*, i.e. in a *Quantity* acting in consent with the configuration and structure of the universe … In the second place, practically all particular virtues work by a body's *Much* or *Little*" (Bacon, *Novum*, OFB XI, Book Two, §. 47, pp. 381–3).

For the first virtues mentioned above, which exist in cosmical quantity, Bacon gives the following examples: "The Earth stands still but its parts fall. The waters of the sea ebb and flow, but those of rivers do not do it at all other than when the sea comes in" (Bacon, *Novum*, OFB XI, Book Two, §. 47, p. 383).

For the second virtues, we can say that a large quantity of water corrupts slowly, while small quantities of water quickly. When we consider casks, which can have a larger quantity of wine and beer in them than bottles, these liquids ripen more quickly than they do in bottles. Also, we can see that a large quantity of magnets can draw more iron than a small quantity.

Next, Bacon talks about freely falling bodies, and says that the Aristotelian idea that a bullet whose weight is two ounces falls two times more quickly than a bullet whose weight is an ounce is false, and that the real measures of freely falling bodies must be searched through experiment, "not from likelihoods or conjectures" (Bacon, *Novum*, OFB XI, Book Two, §. 47, p. 383). Bacon also thought that all effects which are caused by a 'dose of nature', that is, one of the essential forms, must be observed and recorded.

As mentioned in the first chapter, Bacon says that 'dose of nature' or 'quantity proportionable' is the object of mixed mathematics, which is a branch of metaphysics. We also know that metaphysics is a speculative (theoretical) part of natural philosophy, and natural philosophy also has an operative part which includes magic and mechanics. Bacon thinks that mathematical instances are among practical instances, which are pre–eminently useful for the operative part of natural philosophy (see Bacon, *Novum*, OFB XI, Book Two, §. 44, p. 367). The instances have three roles in the operative part of natural philosophy: pointing out, measuring, and facilitating. The role of mathematical instances is measuring; they measure practice. But, even though these instances are mostly useful for the operative part of philosophy, they are also useful for the speculative part, as the causes which should be inquired into for the speculative part are supposed to be based on the result of natural histories. All inquiries into instances are natural historical works.

To recap, Bacon says that all effects which are caused by a 'dose of nature' must be set down. But, in his speculative (theoretical) part of natural philosophy, the object of mixed mathematics, that is, 'dose of nature' is placed as one of the essential forms of natural bodies — 'dose of nature' is also the cause of many effects in nature. Therefore, in natural history, the effects should be measured and observed. The quantitative data of the effects can be used for the operative and theoretical parts of natural philosophy. Mathematics can also be used as an assistant in the discovery of the axioms. As Bacon states:

> For many parts of nature can neither be invented with sufficient subtlety, nor demonstrated with sufficient perspicuity, nor accommodated to use with sufficient dexterity, without the aid and intervention of Mathematic: of which sort are Perspective, Music, Astronomy, Cosmography, Architecture, Machinery, and some others (Bacon, *De augmentis*, SEH IV, p. 371).

So, because the object of mixed mathematics, which is 'quantity determined' (dose of nature), is one of the essential forms, mixed mathematics is different from pure mathematics and is a part of natural philosophy. Bacon holds that mixed mathematics should be an assistant to natural philosophy because mixed mathematics, as mentioned above, 'considers quantity in so far as it assists to explain, demonstrate, and actuate these (i.e. axioms of natural philosophy)' (see p. 21).

Bacon holds that some natural philosophical demonstrations are impossible without the help of mathematics. However, I should point out that the main method for a natural inquiry is still the Baconian experimental inductive method. More than this, we can say that Bacon does not accept mathematical sciences as sciences which are distinct from natural philosophy. By accepting mixed mathematics as a branch of mathematics, Bacon made those sciences a part of physics (natural philosophy), leading us to conclude that every mathematical science becomes a part of natural philosophy in Baconian schema.

However, we can still say that in some sciences, mathematics can have more of a role to play than in others, but as an assistant to the rightful method. This means that mathematics cannot be applied to deduce axioms of natural philosophy; it can only be used as an assistant to the experimental method. However, when we consider the four mathematical instances, just one of them is defined by Bacon as 'dose of nature', that is, the object of mixed mathematics. We may ask, therefore, does the object of mixed mathematics include only the instances of quantity (dose of nature)? According to Bacon, the answer is yes, because he only holds that 'quantity determined' (i.e. 'dose of nature') is the object of mixed mathematics. However, when we consider the instances of the course, we can give the revolving period of the celestial bodies as an example, and it is clear the revolutions of celestial bodies should also be calculated. So, if we accept that the object of mixed mathematics is only the instances of quantity, then how can we explain the instances of the course? More clearly, while all these mathematical instances are things that should be measured and weighed, why did Bacon only hold 'dose of nature' or 'quantity determined' as an object of mixed mathematics?

Bacon did not give a clear answer to this question, but I believe the reason he placed 'dose of nature' as an object of mixed mathematics is that he wanted to find a physical, concrete reason to place mathematical sciences in natural philosophy. Recall Bacon stated that even though 'dose of nature' is the most abstracted form, it is not fully separated from matter, and it is indeed one of the essential forms of matter. Therefore, we can conclude that Bacon chose only 'instances of quantity' or 'doses of nature' as the objects of mixed mathematics to place mathematical sciences as parts of natural philosophy because 'doses of nature' is determined in matter. However, we should not forget that all four mathematical instances can and should be measured and weighed to prevent sciences from falling flat in practice.

4.2 Can we use Bacon's arithmetical quantitative works to refute the argument that he denied the new role of mathematics in the sciences?

According to Rees, if we consider Bacon's quantitative works in his natural histories, we can see that his application of arithmetical quantification "will finally destroy the notion that he was somehow congenitally innumerate or implicitly hostile to mathematical methods" (Rees, 1985, p. 31).[67] In the first chapter, I gave some examples of those who criticised Bacon's attitude towards mathematics. Some of them criticise Bacon for not appreciating the

67. Rees also says that "it is rash to assume that Bacon was entirely ignorant of mathematics or that one can pretend that mathematics need not figure in modern historical accounts of his work. The validity of these conclusions seems all the stronger when another aspect of the question is examined, when one turns from Bacon's attitude to *geometrical abstraction* to the role of *arithmetical quantity* in his scientific work" (Rees, 1985, p. 31).

new role of mathematics in sciences, and what they mean by the new role is geometrical abstraction, not arithmetical quantification.

As mentioned before, there are also other researchers who wrongly believed that Bacon belittled mathematics. Some of Bacon's writings indeed may cause others to think that he belittled the application of mathematics in sciences, for example, his words regarding pure mathematics:

> In the Mathematicks, I can report noe deficience, except it be that men doe not sufficiently vnderstand the excellent vse of *the pure Mathematicks*, in that they doe remedie and cure many defects in the Wit, and Faculties Intellectuall. For, if the wit bee too dull, they sharpen it: if too wandring, they fix it: if to inherent in the sense, they abstract it. So that, as Tennis is a game of noe vse in itselfe, but of great vse, in respect it maketh a quicke Eye, and a bodie readie to put itselfe into all Postures: So in the Mathematickes, that vse which is collateral and interuenient, is no lesse worthy, then that which is principall and intended (Bacon, *The Advancement*, OFB IV, p. 88).

As mentioned in the first chapter, the part of mathematics that was given a role in natural inquiries is mixed mathematics, not pure mathematics (see pp. 17–8). Also, Bacon places mixed mathematics as a branch of metaphysics because the objects of mixed mathematics, that is, 'quantity proportionable', is one of the essential forms of natural bodies. However, it seems that because Bacon thought that pure mathematics was useful to cure the defects of the intellectual faculties of the human being, some researchers concluded that he belittled the application of mathematics in sciences.

The handmaid role Bacon gave to mathematics for natural philosophical inquiries is another reason researchers could conclude he belittled mathematics. However, it should be emphasised that the handmaid, or the subsidiary role of mathematics in natural philosophical inquiries, refers to Bacon's belief that mathematics should not be used to discover the objects of natural philosophy.

Now, let us examine the development of the term mathematical (geometrical) abstraction. Mathematical abstraction means, in an Aristotelian sense, "the merely mental existence of mathematical objects" (Mueller, 1970, p. 157). As Aristotle states:

> So geometry, though its subject matters happen to be sensible, does not deal with them as sensible beings, and the mathematical sciences are therefore not sciences of sensible things; but neither are they therefore sciences of things that are separate from sensible things. So there are many traits that things have because they are what they are: a living being has the peculiar attributes of being female or male, yet there is no female or male being separate from living beings; thus, there are peculiar attributes that things have when taken only as lengths or as planes (Aristotle, 1952, p. 275; 1078a, 1–10).

In the fourteenth century, certain mathematicians such as Thomas Bradwardine, Richard Swineshead, and Nicole Oresme extended the application of mathematics in natural philosophy by representing qualities geometrically, which can also be defined as mathematical abstraction. For example, Oresme (1323–1382) wrote an important book called *Treatise on the Configuration of Qualities and Motions* discussing the intention and remission of forms and qualities. What Oresme did was give a quantitative character to intentions and remission of qualities. He symbolised variable qualities as geometrical figures, and he found the geometrical proof of the mean speed theorem (see Grant, 2007, p. 212). Oresme expressed the change in time with horizontal lines, and variable velocity with vertical lines. This kind of representation was a geometrical representation of qualities; it shows the change of velocity through time geometrically.[68] Different types of velocity represented geometrically by Oresme can be seen below in Figure four.

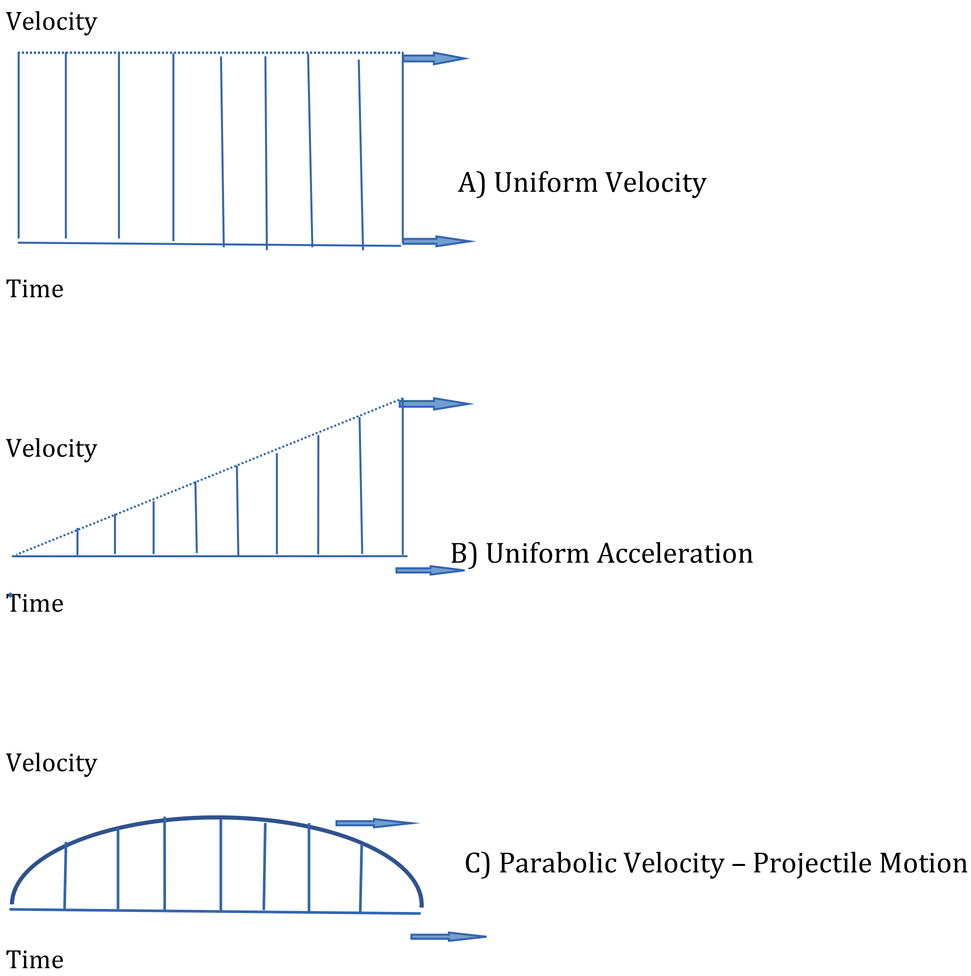

Figure 4

Crosby states that Oresme and other members of Merton College "prefigured Kepler and Galileo with their glorification of geometry" (Crosby, 1997, p. 110). One of the titles of the works of Nicole Oresme shows the role of geometry in his natural inquiries, which is 'The Geometry of Qualities and Motions' (see Crosby, 1997, p. 110).

68. For detailed explanations, see Oresme (1968).

The role of geometry in natural philosophy had increased, and in the dawn of modern science, mathematicians (astronomers) began to make natural philosophical claims through the premises of geometry; that is, they rejected the accepted Aristotelian disciplinary boundary between mathematical sciences and natural philosophy (see Chapter 1). Copernicus blames Peripatetics for falling into error through ignorance of geometry (see Copernicus, 1995, p. 10). Newton named the new inquirers of nature as 'geometrical philosophers' or 'philosophical geometers' and states, "I therefore urge geometers to investigate nature more rigorously, and those devoted to natural science to learn geometry first" (Newton, 2010, p. 87). In his letter to Marin Mersenne, René Descartes states that "my entire physics is nothing but geometry" (Descartes, 1997, p. 119). Mark Peterson summarises the situation well by saying that "all geometry became, potentially at least, a metaphor for nature, promising that nature could be understood as geometry could be understood" (Peterson, 2011, p. 28).

Galileo's words also show us a similar belief in geometry:

> Philosophy is written in this grand book, the universe, which stands continually open to our gaze, but the book cannot be understood unless one first learns to comprehend the language and read the letters in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth (Galilei, 1957, pp. 237–8).

After mathematicians, such as Copernicus, Galileo, and Kepler, had begun to make natural philosophical claims through mathematics (geometry), we can say that mathematical or geometrical abstraction also came to mean making natural philosophical claims through mathematics. We can see this well in the neo-Platonic Paracelsians' attitude towards mathematical abstraction; they accepted mathematical abstraction as the logical method of Scholastics (see also Chapter 5). When Rees mentions geometrical abstraction, he also meant making natural philosophical claims through mathematics (see Rees, 1985, 31).

Mathematical abstraction is also known as the mathematization of nature or natural philosophy, and the mathematization of nature should not be confused with the quantification process in natural history. Quantification is a process to collect quantified data before the application of more advanced mathematics. Mathematization of nature, however, refers to a belief that nature can be understood as geometry can be understood, that is, the course of nature and the course of geometry are the same. Edmund Husserl explains Galileo's mathematization of nature as follows: "*nature itself* is idealized under the guidance of the new mathematics; nature itself becomes — to express it in a modern way — a mathematical manifold" (Husserl, 1970, p. 23).[69]

For Bacon, as mentioned before, the mathematization of nature is the result of the desire of mathematicians who want to be dominant over natural philosophy. But I should also reemphasise that I do not claim that Bacon was against the application of mathematics to natural inquiries. I can make Bacon's position clear regarding the application of mathematics to natural phenomena as follows: Bacon accepted the application of geometry to natural phenomena as long as one does not make natural philosophical claims through mathematics. As you remember, this is because Bacon separated the objects of mathematical sciences and natural philosophy (see Chapter 1).

Bacon explicitly says that mathematics can be applied to both the theoretical and operative parts of natural philosophy as an auxiliary to them. What I want

69. For mathematization of nature, see also Henry (2002, pp. 14–30).

to emphasise is that the quantitative works of Bacon for natural history and his approach to the new role of mathematics should not be mistaken for each other.

As mentioned earlier, quantification is a necessary process to have quantified data to apply mathematics. By arguing “there is a great difference between Bacon the natural historian and Bacon the cosmologist” (Rees, 1985, p. 32), Rees shows us that he believes the attitude of Bacon towards the role of mathematics in natural philosophy is different in his natural historical works (arithmetical quantification) than in his astronomical works (mathematical abstraction), but this is not true. Indeed, quantification includes cosmological studies too, such as histories of astronomical observations.[70] By holding ‘a great difference between Bacon the natural historian and Bacon the cosmologist’, I believe Rees causes confusion, and he gives an impression that Bacon has different attitudes towards mathematical methods in his cosmology than in his natural history.

Arithmetical quantification and mathematical abstraction are not two different approaches to the application of mathematics in natural philosophy, but the former is a necessary process for the latter. The main question is what Bacon’s attitude towards mathematical abstraction or the application of geometry to natural phenomena was. If we do not make natural philosophical claims through geometry, but only develop a model which saves the phenomena and, at the same time, is in accord with physics, then we can say that Bacon would approve.

70. As Bacon states: “And for this reason we should investigate in detail and thoroughly record, in the History of Heavenly Bodies, the precise returns and distances of the planets” Bacon, *Parasceve*, OFB XI, §. 7, p. 465). See also Jalobeanu (2015a).

4.3 Do the arithmetical quantitative works of Bacon call his distrust of the entire quasi–deductive structure of mathematical sciences into question?

In his ‘Mathematical vs. Experimental traditions in the development of physical science’, Kuhn makes a distinction between Baconian experimental sciences and mathematical sciences:

> If Baconianism contributed little to the development of the classical sciences [mathematical sciences], it did give rise to a large number of scientific fields, often with their roots in prior crafts. The study of magnetism, which derived its early data from prior experience with the mariner’s compass, is a case in point. Electricity was spawned by efforts to find the relation of the magnet’s attraction for iron to that of rubbed amber for chaff. Both these fields, furthermore, were dependent for their subsequent development upon the elaboration of new, more powerful, and more refined instruments. They are typical new Baconian sciences. Very nearly the same generalization applies to the study of heat (Kuhn, 1976, pp. 14–5).

Apart from Baconian sciences, Kuhn holds that there are other sciences that cannot be classified as Baconian. These include astronomy, harmonics, mathematics, optics and statistics. Kuhn calls these classical sciences. The important property classical sciences share is that they are mathematical.[71]

71. Kuhn says that, “Practiced by a single group and participating in a shared mathematical tradition, astronomy, harmonics, mathematics, optics, and statics are therefore grouped together here as the classical physical sciences or, more simply, as the classical sciences” (Kuhn, 1976, p. 6).

Kuhn explains why Bacon was against the mathematical nature of classical sciences. He writes:

> Bacon himself was distrustful, not only of mathematics, but of the entire quasi–deductive structure of classical science. Those critics who ridicule him for failing to recognize the best science of his day have missed the point. He did not reject Copernicanism because he preferred the Ptolemaic system. Rather, he rejected both because he thought that no system so complex, abstract, and mathematical could contribute to either the understanding or the control of nature. His followers in the experimental tradition, though they accepted Copernican cosmology, seldom even attempted to acquire the mathematical skill and sophistication required to understand or pursue the classical science. (Kuhn, 1976, pp. 16–7).

As mentioned in the third chapter, Bacon complained that the mathematical sciences of his day had a lack of physics or natural philosophy, and what mathematicians of his day had done in these classical (mathematical) sciences was only mathematical demonstrations. For Bacon, those mathematicians ignored natural philosophy (see Bacon, *De augmentis*, SEH IV, p. 348). Therefore, Bacon did not deny mathematical sciences, or what Kuhn called classical sciences; he only denied the method of mathematical sciences of his day, which were destitute of natural philosophy.

What Kuhn has ignored is that even though Bacon rejects making natural philosophical claims through mathematics, he gives a role to mathematics as an auxiliary to his experimental method. Further, Bacon says that "for as Physic advances farther and farther every day and develops new axioms, it will require fresh assistance from Mathematic in many things, and so the parts of Mixed Mathematics will be more numerous" (Bacon, *De augmentis*, SEH IV,

p. 371).[72] So, we can say that Bacon did not make a severe distinction between some sciences as experimental and others as mathematical. And we should not forget that the concept of mathematical sciences (mixed mathematics) was a common idea in Bacon's day, and as mentioned before, by placing mathematical sciences in natural philosophy, Bacon took a revolutionary step which refutes Kuhn's claim.

Bacon did not deny the application of mathematics to natural phenomena, but he denied making claims of natural philosophy through mathematics, which had been done by some mathematicians such as Copernicus and Galileo. Therefore, we cannot say that Bacon made a distinction between mathematical sciences and empirical sciences as Kuhn suggested. However, Bacon denied the mathematical or geometrical abstraction for two reasons: first, he did not accept making claims of natural philosophy through mathematics; and second, he complained of the ignorance of physics (natural philosophy) by mathematicians who were concentrating only on mathematical demonstrations.

As it is stated well by Pastorino, the arithmetical quantification of Bacon in his natural historical works is a precondition for the possible employment of mathematics, and so it definitely calls into question the Kuhnian dichotomy between mathematical and experimental sciences.[73] However, we should not

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72. These words of Bacon show us that even though he puts mixed mathematical sciences in natural philosophy, he still makes a distinction between mathematical sciences and natural philosophy (see Chapter 1).

73. As Pastorino states:

> It is then possible that Bacon's program of data quantification for natural histories was also preliminary to the use of mathematics as envisaged in De Augmentis. In fact, mathematics can fully operate only on experimental results that are suitably organized in quantitative form: in this case, quantification of data is a precondition not just for operation, but for the possible employment of mathematics—and these two aims possibly overlap, or are indeed identical. Bacon never fully elaborated these points, and in any case it seems that this reassessment of the role of mathematics can be considered an view to which he came late in his work. However that be, this reconsideration of the role of quantification and of mathematics in Francis Bacon seriously calls into question

forget that Kuhn was also right in saying that Bacon denied the quasi–deductive structure of classical (mathematical) sciences.

4.4 Summary

In this chapter, I have argued that the quantitative approach of Bacon in natural history and his attitude to geometrical abstraction should not be compared, and that Rees' approach to quantification blurs Bacon's attitude towards the application of mathematics in natural philosophy.

Quantification in Bacon's natural historical works cannot be used to refute those who criticised him of not appreciating the new role of mathematics. The new role of mathematics requires making claims of natural philosophy through mathematics, but for Bacon, mathematics cannot be used to make claims of natural philosophy. He believed its role was limited to an assistant to his inductive experimental method. As mentioned before, the goal of Bacon's natural philosophy was to discover the objects of natural philosophy. However, through mathematics or premises of geometry, we are not able to discover any of these causes.

There are some scholars who argued that Bacon underestimated the role of mathematics in sciences, such as John William Draper and Lynn Thorndike (see p. 1). Bacon's approach towards quantification in natural history can be used to refute them, but there are other scholars who argued that Bacon underestimated the role of mathematics in sciences. They used Bacon's disapproval of mathematics' ability in making natural philosophical claims to

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the strong Kuhnian dichotomy between a mathematical and an experimental tradition in seventeenth–century science (Pastorino, 2011a, pp. 569–70).

assert this, for example, Eduard Dijksterhuis:

> Bacon lacks all understanding of the importance of the mathematical treatment of science, which has already beginning to score such great triumphs during his lifetime (Dijksterhuis, 1964, p. 401).[74]

I can say that the second group of scholars' claim cannot be refuted by using a quantitative approach in natural history.

What Rees does by using the quantitative works of Bacon to refute others who claimed that Bacon did not approve of the new role of mathematics in modern science can be likened to the following example. Robert Fludd supported the Pythagorean application of mystical mathematics, but he was against the geometrical abstraction of Kepler. If someone accuses Fludd of not appreciating the real significance of mathematics in natural philosophy, refuting him by giving an example of Fludd's attitude towards Pythagorean mathematics would be beside the point.

Similarly, I argue that the quantitative approach of Bacon in his natural history cannot be used to refute the claims of those who argued that he did not approve of the new role of mathematics in sciences, because the new role of mathematics was related to the application of geometry to natural phenomena to make natural philosophical claims.

74. For similar views, see also Carre (1949, p. 245) and Quinton (1990, p. 47).

Chapter 5

Clarification of the Role of Mathematics in Baconian Natural Philosophy by Considering Active and Passive Matter Theories

In this chapter, I discuss Bacon's attitude towards mathematics in relation to active and passive matter theories. As you remember, Bacon compared the philosophy of the pre-Socratics with Aristotle's philosophy. He argued that the philosophy of the pre-Socratics (see Chapter 2) favoured active matter, and as a result of this, their method was experimental (dissection of nature). As to Aristotle, Bacon argued Aristotle did not approve of the principles of motion in matter (passive matter), so he abstracted matter and used excessive logic in his method.

We can see similar ideas in the struggle between mechanistic philosophy, which favoured inert or non-self-determined matter, and neo-Platonist chemical philosophy, which held to an active matter theory. In the second chapter, I discussed Bacon's comparison of Democritus' philosophy with rationalistic philosophies, especially with Aristotle. The comparison was related to active matter and passive matter. We can make a similar comparison between mechanical philosophy and neo-Platonist chemical philosophy. Of course, I do not mean a complete mutuality between them; however, the main difference between them is whether matter should be conceived as active or passive.

I should emphasise that by active (vitalist) matter theories, I mean those which approve of the principles of motion in matter, but not beyond matter. Here, I should also point out that I limit the definition of 'mechanical philosophy' to the motion of particles only by touching each other, which refers to its conceiving matter as a passive entity, and is a counter-argument of a belief in the ability of particles to move without collision, that is, act at a distance, which refers to active matter.[75]

In section 5.1, I will discuss Bacon's attitude towards mathematics in natural philosophy by considering the relation between his active matter theory and his rejection of the Aristotelian idea of the unmoved mover. In section 5.2, I argue that Bacon's vitalistic view regarding the motion of smallest particles is contrary to a mechanical view regarding the motion of these particles, which is more accordant with a mathematical approach to nature.[76]

5.1 The chemical philosophy on the unmoved mover and mathematics

The empiricist philosophers who affected the intellectual world of Bacon were the chemical and natural magical philosophers of the Renaissance. Even though Bacon was an idiosyncratic philosopher, there are some characteristics

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75. Marina Paola Banchetti–Robino expresses the transition between vitalistic and mechanical philosophy as follows:

> The sixteenth and seventeenth centuries marked a period of transition between the vitalistic ontology that had dominated Renaissance natural philosophy and the early modern mechanistic paradigm that was endorsed by Cartesian natural philosophers, among others. However, even with the dawning of the eighteenth century Chemical Revolution, chemistry remained resistant to the mechanical philosophy (Banchetti–Robino, 2011, pp. 173–4).

76. For those who also argue that Bacon was not a mechanical philosopher, see Weeks, (2008), Klein (2008) and Giglioni (2012).

in his philosophy which show impressions left by other philosophies. It is widely accepted that the alchemical and natural magical philosophies affected his natural philosophy. However, even though he was affected by them in some respects, he also criticised them.[77]

These chemical philosophers agreed partly with Pythagorean mystical mathematics, however, they were against the mathematical abstraction of Copernicus, Kepler, and Galileo. As mentioned in the second chapter, even though Bacon was against the mystical mathematics (number mysticism) of neo-Platonist philosophers, he did agree with them in his refusal to apply mathematical abstraction to natural phenomena; and I should also point out that when the neo-Platonist chemical philosophers of the Renaissance used the term 'mathematical abstraction', they did not only mean what Copernicus and Galileo did, but also the syllogistic method of Aristotle used in his physical inquiries. Regarding the neo-Platonist chemical philosophers' attitudes towards mathematics, Debus writes:

> In contrast with the traditional emphasis on logic, or what they frequently termed "mathematical demonstration," they insisted that their chemical philosophy would have its fundamental tenets firmly based in the two irrefutable books prepared for us by the Creator–the Holy Scripture and the Book of Nature (Debus, 1973, p. 5).

Debus shows that the neo-Platonist chemical philosophers were against the application of syllogistic logic to natural philosophical inquiries and they accepted a logical demonstration as a mathematical demonstration. As we saw in his letter to Father Redemptus Baranzano, Bacon also discusses mathematics as a syllogistic discipline that is not suitable for natural inquiries. This is because natural inquiries require the inductive experimental method

77. For how magic and alchemy affected Bacon's thoughts, see Henry (2003), Weeks (2007b), and Rusu (2013).

(see Chapter 2). Of course, these remarks do not show that Bacon was hostile to mathematics in general, but rather that he was opposed to making claims of natural philosophy through mathematics and logic.

Debus gives an example from the influential Paracelsist, Petrus Severinus, who explained how medicine was damaged in the hands of Galen. The reason for this was Galen's attempt to organise the medicine within, as Debus says, "the mathematical or geometrical system of Aristotle."[78] We can see this in the following words of Galen:

> So in the demonstration regarding the triangle – for there is no need for us to resile from the example since we have already expelled the uneducated Methodics from the discussion – the proposition itself was reached from these two premises: the first is that the area enclosed by the five feet and the twelve feet is sixty feet, and the second is the claim that the triangle is half that are, and showing that it is. However, each of these again requires certain other premises for demonstration, then those others again, until we come to those premises that are primary, which no longer have their proof from one another or from demonstration, but from themselves. The same applies too, I think, in the case of demonstrations in the medical craft. In all instances, there must be reduction to certain primary and undemonstrable premises, and from these all things must draw their proof. Indeed, if everyone attempted to say something about the therapeutic method in this way, they would be in harmony with each other in every respect, just like the arithmeticians, geometers, and

78. Debus informs us that he achieved the ideas of Severinus by annotating the following source: "Petrus Severinus, Idea medicinae philosophicae (3rd ed., Hagae–Comitis: Adrian Vlacq, 1660), pp. 2–3, 21. The first edition of this work appeared in 1571." (see Debus, 1973, p. 6, fn. 7). Severinus accepted the writings of Paracelsus as true medicine based on experiment (see Debus, 1968, p. 22).

logicians.[79]

These examples show us that, as mentioned in the first chapter, some philosophers believed in the equality of geometrical and syllogistic demonstration; which is why these chemical philosophers spoke of the method of Scholastics as geometrical or mathematical when they put forward their contrary ideas towards applying syllogism to natural philosophy or medicine.

As to mystical mathematics or number mysticism, while Bacon was against the application of this kind of mathematics to natural phenomena (see p. 113), the chemical philosophers generally embraced it as a way to comprehend the essence of nature, that is, the mathematical structure of it. However, one of these chemical philosophers, Jan Baptist van Helmont, was also against number mysticism as well as mathematical abstraction, similar to Bacon.

Van Helmont's view regarding the logical method of Aristotle and Galen is similar to Severinus' ideas about the same subject. According to van Helmont, the Aristotelian interpretation of nature "is a Paganish Doctrine drawn from Science Mathematical, which necessitates the first Mover to a perpetual unmoveablenesse of himself, that without ceasing he may move all things ... Therefore let the Schooles know, that the Rules of the Mathematicks, or Learning by Demonstration do ill square to Nature. For man doth not measure Nature; but she him."[80]

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79. Galen (2011, Book One, pp. 53–5). We can also read the following from Ben Morisonto regarding how Galen applied logic to medicine:

> Because Galen put heavy emphasis on the use of logic in demonstrating medical truths, he had much to criticize in the way other ancient logicians operated. Galen thought that logic is primarily a tool for extending our knowledge of medicine, geometry, and etc. (Morison, 2008, p. 74).

80. Quoted from the translation of Debus. See Debus (1973, p. 14).

Van Helmont believed that the prime mover is a false notion which was drawn from mathematics, and when he says 'Science Mathematical', he must mean mathematics as a syllogistic discipline (on mathematics as syllogistic, see pp. 12–4). So, if the prime mover, which is the cause of motion in nature, is a false idea, then what did van Helmont offer as a cause of motion in nature? He answers this question as follows:

> there is something in sublunary things which can move it self locally, and alteratively, without the Blas of the Heavens, and an unmoveable natural mover. The will especially, is the first of that sort of movers, and moveth it self; also a seminal Being, as well in seeds, as in the things constituted of these. Moreover as God would, so all things were made: Therefore from a will they were at first moved: For from hence whatsoever unsensitive things are moved, they are moved as it were by a certain will and pleasure or precept of nature, and have their own natural necessities, and ends even as is seen in the beating of the Heart, Arteries, expelling of many superfluities, & C.[81]

As seen, van Helmont attributed activity to nature by arguing that there is something which can move itself locally without an unmoved mover, which is 'will'. Van Helmont thought that matter was endowed with the ability to move by itself in creation. This contrasts with Aristotle, who attributed passivity or potentiality to matter. Also, the unmoved (prime) mover was seen by van Helmont as a result of logical and mathematical thinking. The idea of the unmoved mover is unacceptable for him because this idea makes the creator motionless. As noted below, the ideas of van Helmont regarding the activity of matter, the unmoved mover of Aristotle, and Aristotle's logical approach to nature are similar to Bacon's ideas about the same subjects.

In examining what Bacon thought about the unmoved mover, he states in his

81. Quoted from the translation of Debus. See Debus (1973, pp. 13–4).

Novum organum (1620):

> *Idols* imposed on the intellect by words are of two kinds: for they are either the names of things which do not exist (for just as there are objects which through inadvertence lack a name, so there are names which through flights of fancy lack an object), or names of things which do exist but are muddled, ill–defined, and rashly and roughly abstracted from the facts. Of the first sort are fortune, first mover, planetary orbs, the element of fire, and fictions of that kind whose origins lie in vain and deceitful theories (Bacon, *Novum*, OFB XI, Book One, §. 60, pp. 93–5; underlinings added).

Here, Bacon separates the idols of the human mind into two kinds, and he places the concept of the prime (unmoved) mover among the first kind; for Bacon, the first mover is the name of a thing which does not exist.

In the second chapter, I mentioned the differences between the views of empiricists and rationalists on the activity and passivity of matter and the relationship between their views with their methods. Recall that passive matter is the result of looking for the principles of motion and form beyond matter. As Aristotle did not believe that matter had the principles of motion in itself, he created the notion of the prime mover as a source of motion in matter, which is pure form. Thus, we can draw a conclusion that the idea of the unmoved mover as the cause of motion beyond matter is the result of the human mind's propensity for searching for the principles of motion beyond matter; and as you remember for Bacon, the human mind, left to itself, follows the same course as logic and mathematics (see p. 46). We can conclude that, like chemical philosophers, Bacon believed the prime mover was the result of a logical and mathematical way of thinking.

5.2 Active matter as the reason for being against logical and mathematical methods in natural inquiries

Similar to the neo-Platonist philosophers such as Giordano Bruno, Paracelsus, Marsilio Ficino, Tommaso Campanella and Cornelius Agrippa, Bacon's matter theory was also vitalistic.[82] As Banchetti–Robino states, "Vitalism has been generally regarded as the view that claims that 'vital forces' or 'vital spirits' are causally operative in nature" (Banchetti–Robino, 2011, p. 174).[83] As for Bacon, his references to matter's activity show that for him, matter has the principles of motion in itself. As discussed in the second chapter, the activity of matter is the basis of Bacon's experimental method, and the assumption that matter is passive and that principles of motion must be found beyond nature is, for Bacon, the hallmark of rationalist philosophy or the logical and mathematical approach to nature. Such a mistake is the result of the human mind's tendency to believe there is always something beyond nature.

For Bacon, the unmoved mover of Aristotle's cosmology was the result of seeing matter as passive or as a potential entity; and seeing the unmoved

82. On Bacon's theory of matter, see Rees (1975); Weeks (2007a); Rusu (2012), (2013, pp. 51–7) and Giglioni (2013a), (2016a), (2016b), (2016c).

83. 'Vital forces' or 'vital spirits' refer to the principles of motion (or change). According to vitalist view, these principles do not stem from something beyond matter, such as forms of Aristotle or numbers of Pythagoras. So, what I mean by vitalism is a kind of matter which includes the principles of motion, and whether these principles are considered as spirits or anything else does not matter.

Banchetti–Robino states: "Vitalism dominated natural philosophy during the fifteenth and sixteenth centuries as a result of the Neoplatonic and hermetic traditions that informed Renaissance culture. It infused the work of such thinkers as Marsilio Ficino, Tommaso Campanella, Cornelius Agrippa, and Giordano Bruno and continued to dominate natural philosophy well into the seventeenth century" (Banchetti–Robino, 2011, p. 175).

mover as the result of a logical and mathematical approach to nature also shows us the relationship established by Bacon between active matter and experimentalism, as well as passive matter theory and rationalism.

Bacon compares passive matter or the *fantastical matter* of Aristotle with the active matter of the ancients as follows:

> the ancients laid down that primary matter (such as can be a principle of things) had form and properties, and was not abstract, potential and unformed. Certainly that despoiled and passive matter seems to be nothing more than a figment, arising from the fact that as far as the human intellect is concerned, those things seem to have most reality which the intellect takes in most readily, and which affect it most. So it follows that forms (as they call them) seem to have more reality than either matter or action, because the former is hidden, and the latter fluctuates; the one does not strike so forcibly, the other does not fix itself so firmly. Those other images, by contrast, are thought to be both manifest and firm, such that primary and common matter seems to be like an accessory and substrate; and action of whatever kind seems to be little more than an emanation of form, and forms are given all the best parts. And it is from here that the reign of forms and ideas in essences seems to have originated, namely with the addition of a kind of fantasy matter (Bacon, *On principles*, OFB VI, p. 207).

Clearly, Bacon believed that by designing this kind of fictional matter, Aristotle "did proceede in such a Spirit of difference & contradiction towards all Antiquitie, vndertaking not only to frame new wordes of Science at pleasure: but to confound and extinguish all ancient wisedome" (Bacon, *The Advancement*, OFB IV, p. 81).

Bacon argued that Democritus approved of active matter because he did not look for the principles of matter beyond nature, which means he found the principles of matter as they are found in matter. For Bacon then, Democritus approved of active matter. Bacon's idea of Democritus regarding his approval of active matter may seem strange when we consider the modern mechanical interpretation of Democritean atomism, however, as you remember, Bacon mentions Democritus' name alongside some other pre-Socratics who approved of the principles of motion in matter (see p. 30). So, if the principles of motion are found in matter but not beyond matter, then we must accept that, for Bacon, Democritus' matter theory is active.[84] The important thing is that while mechanical philosophers approved of mathematics for natural inquiries, neo-Platonist chemical philosophers accepted mathematics as the logical method of the Scholastics and rejected it. What they rejected was making natural philosophical claims through mathematics, but in contrast to Bacon, as we mentioned before, they approved of the mystical mathematics of Pythagoras.

We can say, therefore, that the reason for the struggle between vitalistic and mechanical philosophy is a result of their conceiving of matter. According to mechanical philosophy, as Antonio Clericuzio states, "matter is inert and all interactions in nature are produced by the impact of particles" (Clericuzio, 2000, p. 7). This view is an acceptance that all qualities can be explained through shape, size, and motion, which are indeed quantitative properties (see Henry, 2002, p. 69).[85] The increasing role of mathematics in natural philosophy became a tool for mechanical philosophy to support its argument

84. For Bacon, Democritus was important because the philosophy of Democritus mostly agrees with the ancient wisdom, which is represented in the fable Cupid. On the role of Democritus in early modern English philosophy, see Levitin (2015).

85. Paolo Rossi also states that mechanical philosophy had the following assumptions:

> (1) nature is not the manifestation of a living principle but is a system of matter in motion that follows laws; (2) the laws of nature are mathematically precise; (3) relatively few such laws suffice to explain the universe; and (4) the explanation of natural phenomena excludes all reference to *vital forces* or *final causes* (Rossi, 2001, p. 125).

against vitalist philosophy. The term I refer to here as vitalist experimental philosophy refers to the philosophy of the above–mentioned neo-Platonist chemical philosophers, but not the philosophy of mechanical experimentalist philosophers such as John Locke.

As for Bacon, we can see the influence of his vitalistic view of matter in his attitude towards the role of mathematics in natural philosophy. For both Bacon and the neo-Platonist chemical philosophers, the qualitative properties of matter, such as desires or appetites of matter, are properties that cannot be represented mathematically. For them, these qualities can only be discovered through experiment (see fn. 86). However, mechanical philosophers did not favour such qualitative properties of matter and action at a distance; instead, they held to motion by collision of particles and assumed that qualities are reducible to quantitative properties that can be defined according to the laws of geometry (see also p. 125).

Chemical natural philosophers not only tried to discover those appetites of matter or vital forces through experiments but also applied their knowledge to control or alter natural phenomena. For one of the most important chemical philosophers, Paracelsus, nature can be understood as chemical processes are understood (see Debus, 2002, p. 87). When we consider neo-Platonist chemical philosophers, who saw chemical processes as the key to understanding nature; and mechanical philosophers, who saw mathematics as the key to understanding it, there is a remarkable difference between them. While mechanical philosophers did not favour experiments, they found different explanations for how nature works, and what method should be mainly applied for the discovery of the truth of natural phenomena.

Mechanical philosophers did not deny the experimental method, but chemical philosophers denied the logical and mathematical methods. The reason chemical philosophers favoured only the experimental method, instead of logical and mathematical methods (except the mystical mathematics of Pythagoras), was their views regarding the properties of matter. For chemical natural philosophers, the appetites and desires of matter, which refer to the vital forces in matter, are the proper objects of natural philosophy which can be discovered through experimental method.[86] Also, for Bacon, "the principles, fountains, causes, and forms of motions, that is, the appetites and passions of every kind of matter, are the proper objects of philosophy" (Bacon, *Cogitationes*, SEH V, p. 426). So, we can say that as the appetites and desires of matter can be discovered empirically, there was a relation between active matter and the experimental methods of chemical philosophers and Bacon. The aim of the neo-Platonist chemical philosophers was to control nature to produce practice, and controlling nature by discovering the hidden powers of nature was possible through the experimental method.

In this context, I should also mention 'natural magic' and the 'natural magician'. Magic was the violation of natural laws, while natural magic was nothing but the application of natural laws to beget practice. According to Della Porta, magical operations seem miraculous because the spectators do not understand how those operations happen (see Rossi, 2009, p. 19).[87] There

86. The relation between active matter theory and the experimental method is also well stated in the following words of John Henry:

> As soon as Bacon turned to magic he could hardly fail to notice that its principal method was experimental (Henry, 2003, p. 53).

Magic is the operation to produce practice from the discovered (hidden) properties of matter; for Bacon, these properties are forms. Henry also states the followings about the same issue:

> Since magic was chiefly concerned with exploiting the sympathies and antipathies between corresponding things in the Great Chain of Being, and since the assumption was that these powers of agreement and disagreement were hidden or occult, the magician could only discover the powers of things empirically (Henry, 2003, p. 55).

On appetites of matter in Baconian natural philosophy, see Giglioni (2010).

87. Cornelius Agrippa's following words show us the relation of natural magicians with natural philosophy. A natural magician was an explorer of these hidden or secret powers of nature, as he states:

> Therefore natural magic is that which having contemplated the virtues of all natural and celestial things and carefully studied their order proceeds to make

is a strong relation between discovering the hidden powers of nature and its operations to produce practice. We can also see this well in Bacon's work. For him, magic is placed in the operative part of natural philosophy (see Figure 3 on p. 19), and it corresponds to formal axioms (causes) in the speculative part of natural philosophy. According to Bacon, magic is "the science which applies the knowledge of hidden forms to the production of wonderful operations; and by uniting (as they say) actives with passives, displays the wonderful works of nature" (Bacon, *Cogitationes*, SEH V, p. 426).[88]

I have discussed above the similarities between Baconian natural magic and the natural magic of others. We should next ask whether there was a difference between Baconian natural magic and traditional natural magic. As I mentioned, magic corresponds to forms in Baconian schema, and for Bacon, forms are the most important part of natural philosophy to be discovered for the advance of sciences:

> known the hidden and secret powers of nature in such a way that inferior and superior things are joined by an interchanging application of each to each; thus incredible miracles are often accomplished not so much by art as by nature, to whom this art is as a servant when working at these things. For this reason magicians are like careful explorers of nature only directing what nature has formerly prepared, uniting actives to passives and often succeeding in anticipating results so that these things are popularly held to be miracles when they are realy no more than anticipations of natural operations; as if someone made roses flower in March or grapes ripen, or even more remarkable things such as clouds, rain, thunder, various species of animals and an infinite transformations of things … therefore those who believe the operations of magic to be above or against nature are mistaken because they are only derived from nature and in harmony with it. Quoted from Rossi (2009, p. 19).

On how Francis Bacon use Della Porta's natural magic, see Rusu (2016).

88. Rossi also discusses the operative role of magic:

> Campanella writes that the aim of magic is to 'imitate and assist nature'. For him magic is the ruling science for it is a practical activity operating on reality; certain inventions had been described as magic until they were understood, when they became common knowledge; such were gunpowder, the magnet, and the printing press … For Paracelsus alchemy fulfils and perfects nature: 'the achemist is he who helps to develop to the extreme limits intended by nature that which nature produces for the benefit of mankind'. Thus the weaver, the baker, the cultivater, are alchemists and the difference between the saint and the alchemist is that the operations of the one proceed from God whereas the other employs only natural powers (Rossi, 2009, pp. 19–20).

> For it seems to me there can hardly be discovered any radical or fundamental alterations and innovations of nature, either by accidents or essays of experiments, or from the light and direction of physical causes; but only by the discovery of forms (Bacon, *De augmentis*, SEH IV, p. 366).

Since the discovery that forms are the most important thing for the advance of sciences, magic also shares the same importance because it can only be applied after the discovery of the forms.[89] So, the proper method in discovering forms is also important for magic. Then, the difference between the traditional natural magic and Baconian natural magic results from the methods they had applied. Yes, both methods were experimental, but as you remember, Bacon also criticised the experimental method of his day (see p. 52). For Bacon, the experimental philosophers of his day deduced general axioms from just a few experiments. However, he suggested his new inductive method which proceeds step by step from particulars to general axioms (see Section 2.3 for Baconian inductive method).

5.2.1 Action at a distance, motion through the impact of particles, and the role of mathematics in natural philosophy

Another aspect of Bacon's matter theory is his views about the motion of

89. Rees also states:

> just as metaphysics provides the most abstract and powerful scientific knowledge attainable by human beings, so magic (not to be confused with what Bacon regarded as the superstitious impostures sometimes associated with magic) endows mankind with mastery over nature, with the power to prolong life almost indefinitely, transform base metal into gold, produce new plants and animals, and generally obviate the material disabilities incurred by the Fall (Rees, 1986, p. 405).

atoms (or seeds or smallest particles). In this section, I want to discuss one aspect of these views. My concern, as mentioned in the title, is whether the smallest particles can act at a distance or can act only through touching each other. Therefore, in this study, I describe mechanical philosophy as a philosophy which considers that 'matter is inert and all interactions in nature are produced by the impact of particles' (see p. 120), and I describe vitalist philosophy as a philosophy which attributes vitality to matter. Vitalist chemical philosophers accepted the ability of seeds to act at a distance as something which shows the activity in matter.

Bacon was a vitalist. He believed that matter is an active entity which is different from the passive matter of Aristotle and mechanical philosophy. For Bacon, atoms or smallest particles were endowed by God with appetites and desires which give them a chance to move intrinsically. This ability of the smallest particles or, in Bacon's own words 'seeds', are the reason for action in matter.

This active matter is different from the passive matter of mechanical philosophy. The important question I want to emphasise is whether motion is an innate quality of particles. As to a mechanical account of the motion of particles (motion by collision of particles), we can see that it had been used as a justification for the explanatory power of mathematics in natural inquiries. As Christopher Kaiser rightly says, particles which can move by touching each other (an account such as that we have found in Descartes) "meant that matter was entirely receptive to the mathematical laws imposed on it by God" (Kaiser, 1997, pp. 215–6). According to this idea, qualities are reducible to quantitative properties of size, shape and motion. The idea that qualities can be reducible to quantitative properties is also a justification for the application of mathematics to natural phenomena.

Now, let us look at Bacon's attitude towards the motion of seeds (atoms). *On*

Principles and origins according to the fables of Cupid and Coelum is one of Bacon's important texts in which he mentioned his ideas about atoms and Democritus. Bacon believed this fable shows the ancient doctrine regarding the principles of things, and this doctrine was mainly held by Democritus. As I mentioned in the second chapter, Cupid represents primary matter, and primary matter was conceived by ancients as owning principles of motion in itself, which refers to the activity of matter.

Now, let us read Bacon's words showing he agrees with Democritus:

> *Democritus* made the admirable claim that atoms or seeds, and their virtue, were quite different from anything subject to the senses, but that they were remarkable for being things whose nature was entirely dark and secret. Therefore he proclaimed concerning them, that
>
> *they do not resemble fire or anything else*
> *besides that which can send bodies*
> *to our senses or be felt by our sense of touch*,
>
> and again concerning their virtue,
>
> *But in giving birth to things the first beginnings ought*
> *to hold to a secret and dark nature,*
> *lest something should rise up to fight against and oppose them.*
>
> Thus atoms are not like fiery sparks, drops of water, bubbles of air, specks of dust, not tiny amounts of spirit or ether. Nor is their power and form something heavy or light, hot or cold, dense or rare, hard or soft, such as are found in larger bodies, since these virtues and others of the kind are products of composition and combination (Bacon, *On principles*, OFB VI, pp. 201–3).

However, Bacon thinks differently from Democritus regarding the motion of atoms. He states:

> Nor, similarly, is the natural motion of the atom either that motion of falling bodies which is called natural, or the motion opposite to it (percussion), or the motion of expansion and contraction, or of impulse and connection, or the motion of expansion and contraction, or of impulse and connection, or of the rotation of the heavenly bodies, or any of the other motions of larger bodies simply. None the less in the atoms' body exist the elements of all bodies, and in the atom's motion and virtue exist the beginnings of all motions and virtues. But yet in this very matter, namely the atom's motion compared with that of larger bodies, the philosophy of parable [the fable of Cupid] seems to differ from the philosophy of *Democritus*. For we find that *Democritus* is not only quite at odds with the parable, but also at odds and virtually in contradiction with himself in the other things he says on the matter. For he ought to have attributed a heterogeneous motion to the atom no less than a heterogeneous body and a heterogeneous virtue. But he chose from among the motions of larger bodies the two motions of descent of the heavy and ascent of the light (which he explained by the striking or percussion of the heavier driving the lighter upwards), and attributed them to the atom as primitive motions. The parable, however, preserves the heterogeneity and exclusion throughout, in both substance and motion (Bacon, *On principles*, OFB VI, p. 203).

Bacon did not accept reducing the motion of atoms into descending and ascending, and he agreed with the ancient doctrine of the motion of atoms being heterogeneous. I believe the Democritean idea of ascending and descending motions of atoms according to their weight should not be seen as a proof of passive matter or mechanical accounts of the motion of atoms. Bacon especially emphasised that Democritus was one of the pre-Socratics who attributed the principles of motion (or activity) to matter (see Bacon, *On principles*, OFB VI, p. 209. See also Chapter 2).

As you remember, for Bacon, Plato and Aristotle abstracted nature, that is, Plato did not attribute form to matter, and Aristotle did not attribute activity to matter. By doing this, they created a fantastical matter which can be seen as the end result of their abstractions, as Bacon states in his *Novum organum*, 'it happens that men do not stop abstracting from nature until they arrive at potential and uninformed matter' (see p. 30).

The other thing which Bacon did not accept was dissecting nature until you arrive at atoms:

> Hence it happens that men … do not stop dissecting nature until they arrive at the atom — ideas which however true they may be, can do little for the good of mankind (Bacon, *Novum*, OFB XI, Book One, §. 66, p. 107).

What Bacon meant by 'abstracting from nature until they arrive at potential and uninformed matter' was the creation of fantastical matter by finding the principles of motion beyond matter. However, dissecting nature until we arrive at atoms also does not give us anything, because atoms are beyond our senses and we can only speculate about them. What we can do, however, is search for the appetite and desires of matter which arises from the motion of atoms or seeds. We can only sense the effect of their forces, and from these effects, we can deduce causes or axioms of nature.

In the *Novum organum*, Bacon explains that he does not accept the Democritean doctrine of atoms:

> Now this business will not be brought down to the atom, which presupposes a vacuum and invariable matter (both false assumptions), but to real particles as we actually find them (Bacon, *Novum*, OFB XI, Book Two, §. 8, p. 213).

Bacon believed the doctrine of atoms to be false because the ideas of vacuum and invariable matter, which are required by the doctrine, are false assumptions.[90] However, Bacon still thought that there are particles in matter; the real particles, which do not presuppose a vacuum, and invariable matter.

5.2.2 Did Bacon think that Democritus' doctrine of atoms was a mechanical account of motion in matter?

In his *Cogitationes de Natura Rerum* (Thoughts on the Nature of Things – 1604), Bacon says the following about Democritus and his doctrine of atoms:

> THE doctrine of Democritus concerning atoms is either true or useful for demonstration. For it is not easy either to grasp in thought or to express in words the genuine subtlety of nature, such as it is found in things, without supposing an atom. Now the word atom is used in two senses, not very different from one another. For it is either taken for the last term or smallest portion of the division or fraction of bodies, or else for a body without vacuity (Bacon, *Cogitationes*, SEH V, p. 419).

For Bacon, Democritus' doctrine of atoms is useful for demonstration. As you

90. For further reading regarding atoms and void in Bacon's natural philosophy, see Kargon (1966); Rees (1980) and Manzo (2001). Guido Giglioni has argued more recently that Baconian atoms are indeed actual appetitive motions of matter, not forms, atoms and minima naturalia. See Giglioni (2016a, pp. 63–7) and (2016b, p. 165).

remember, Bacon's conception of Democritus was that he was one of the pre-Socratics who thought matter has the principles of motion in it; that is, he did not look for these principles beyond matter. So, by accepting atoms as the principles of motion, Democritus did not fall into the error defined by Bacon as looking for the principles of motion beyond matter (see Chapter 2). It is clear that the reason why Bacon approved of Democritus' doctrine of atoms was that Democritus saw matter as the object of his natural philosophy by accepting atoms as the principles of motion in matter. So, the main reason Bacon supported the philosophy of Democritus was because of its search for the principles of motion in matter, which refers to an agreement with ancients' theory of matter, as told in the fable of Cupid. Even though Bacon was against some Democritean ideas regarding atoms, he still approved of Democritus because Democritus agreed with ancient wisdom and his theory of atoms was the closest philosophy to ancient wisdom. As you remember, the most important part of ancient wisdom to Bacon was its ascribing form and the principles of motion to matter, which refers to the ability of action in matter (see p. 30).

In his '*Atomism in England from Hariot to Newton*', Robert Kargon separated Baconian philosophy into two parts. He thought that in his earlier works, Bacon was an atomist and a mechanical philosopher, then later gave up the doctrine of atomism and adopted pneumatic matter theory. However, Kargon accepted that Bacon's atom is endowed with form, appetite, and motion (see Kargon, 1966, p. 46). Kargon thought that after Bacon adopted pneumatic matter theory he gave up atomism and he positioned pneumatism against atomism. For Kargon, pneumatism refers to the vitalist character of Bacon's matter theory, while atomism refers to the mechanist character of it.

Related to Kargon's argument, I agree with him in arguing that Bacon's atoms (or seeds) are endowed with appetite and motion. But Kargon attributed problematically the vitalist character of Bacon's matter theory to Bacon's pneumatism, not to his atoms. Indeed, because atoms are endowed with appetite and motion, we should call Bacon's atomism 'vitalist'.

As for Rees, he did not accept that Bacon had accepted the doctrine of atoms in any of his works, and for him, Bacon cannot be seen as a mechanical philosopher. The main reason for this was explained by Rees as follows:

> Bacon's rejection of the classical atom is all too plain. He explained that minute portions of spirit were not the same as the atomists' ultimate particles and since spirit and tangible matter were convertible, it must follow that tangible matter did not consist of the atomists' indivisible particles either (Rees, 1980, p. 563).

Rees based this argument on the following words of Bacon: 'atoms are not like fiery sparks, drops of water, bubbles of air, specks of dust, nor tiny amounts of spirit or ether' (see p. 126). As seen, atoms are different from the particles of spirit or pneumatic matter. As a result, Rees argues that Bacon never became an atomist and a mechanical philosopher and that, for Bacon, atomism was only a useful tool to explain the subtlety of nature (see Rees, 1980, p. 562).

However, Silvia Manzo rightly argues that Rees' argument is problematic because it rests on the idea that pneumatic matter and atoms are incompatible. As quoted above, Bacon says, 'Thus atoms are not like fiery sparks, drops of water, bubbles of air, specks of dust, not tiny amounts of spirit or ether' (see p. 126). Rees interprets Bacon's words as an incompatibility between atoms and spirits, but, as Manzo rightly argues, we cannot interpret these words as such. Manzo explains her argument as follows:

> In order to argue for the imperceptibility of atoms, Bacon deals with a relation of external similitude (*similes*), not with a relation of ontological identity. And even if he had meant a relation of identity,

> Rees' conclusion would still not follow, because from "*A* is not identical to *B*," it does not necessarily follow that *A* is incompatible with *B*, nor that *B* is not composed of *A* (Manzo, 2001, p. 224, fn. 71).

For Manzo, the alchemical and mechanical approaches are interwoven in Bacon's works, especially in his later works. She accepts Bacon's explanations regarding the processes of separation and alteration as mechanical explanations, while she accepts the appetites of Cupid as an animistic approach. However, while I agree with Manzo that separation and alteration can be seen as mechanical explanations in Baconian natural philosophy, I still label Bacon as a non–mechanical philosopher because of his belief in activity in matter, or particles' intrinsic ability to move. Bacon's mechanical explanations regarding alteration and separation are not an obstacle in labelling him as a non–mechanist philosopher. Also, I do not believe that Manzo labels Bacon as a mechanical philosopher, she just rightly argues that Bacon's explanations regarding the processes of separation and alteration are mechanical explanations.

To sum up, Kargon's aforementioned argument is problematic because, as I argued in the second chapter, attributing the appetite and motion to atoms refers to vitalistic matter theory. Rees' argument is also problematic because it rests on the incompatibility between pneumatic matter and atoms. The desires and appetites of Cupid, which refers to the activity of particles bestowed by God on them, should be determinative for us because, as mentioned above, Bacon defined the difference between rationalist philosophies and empiricist philosophies by considering whether they attributed activity to matter. Further, the close interest of rationalist philosophies to mathematical abstraction in natural philosophy was seen both by Bacon and the neo-Platonist chemical philosophers as a result of their abstraction of the principles of motion from matter.

5.3 Summary

It is evident that Bacon accepted there are particles endowed by God in the creation, with the ability to move intrinsically. So, for Bacon, 'the principles, fountains, causes, and forms of motions, that is, the appetites and passions of every kind of matter, are the proper objects of philosophy' (see p. 122). These appetites and passions of matter are the results of motions of seeds or smallest particles, which have the ability to act at a distance. However, when we consider mechanical philosophy, it does not attribute any qualitative appetite to particles.

Vitalist philosophers had a tendency to consider qualitative changes in natural processes, while mechanical philosophers were satisfied to reduce these qualitative properties to quantitative properties, such as shape, size and motion. As you would appreciate, these quantitative properties justified the application of mathematics to natural phenomena in the sense of making natural philosophical claims through mathematics. As discussed above, the quarrel between chemical and mechanical philosophers regarding the application of mathematics to natural phenomena was related to their differing beliefs and methods in active or passive matter theory.[91]

In Chapter 2 I argued that the activity of matter is the basis of Bacon's experimental method, and the assumption that matter is passive and that

91. As Debus states: "the Scientific Revolution was not simply the forward march of a new experimental method coupled with the powerful tool of mathematical abstraction. For some the two were incompatible" (Debus, 1968, p. 32). I should again emphasise that I do not say that mechanical philosophers who approved of mathematical abstraction did not pay attention to the experimental method, but that those neo-Platonist chemical philosophers did not approve of mathematical abstraction (see also p. 113).

principles of motion must be found beyond nature is, for Bacon, the hallmark of rationalist philosophy or of the logical and mathematical approach to nature. For Bacon, such a mistake is the result of the desire of the human mind, because the human mind has a tendency to believe there is always something beyond nature. So, for Bacon, there is a correlation between the activity of matter and the experimental method and between passive matter and rational philosophy (see Chapter 2).

Can we see the same relationship between active matter theory and experimental method in neo-Platonist chemical philosophers? In this chapter, I have argued that similarly to neo-Platonist chemical philosophers, Bacon saw the idea of the unmoved mover as the cause of motion in nature as the result of the logical and mathematical method of the Scholastics. So, neo-Platonist philosophers were against the passive matter of Aristotle because they were against the unmoved mover (pure form) as the cause of motion in matter, and they argued that it was the result of logical and mathematical thinking. So, the relationship which was found by them between passive matter and logical and mathematical method requires us to accept that they also found a relationship between active matter and the experimental method.

We know that neo-Platonist chemical philosophers approved of active matter and they applied the experimental method for their inquiries. They were also known as natural magicians, and a natural magician was an explorer of the hidden or secret powers of nature. Cornelius Agrippa states:

> magicians are like careful explorers of nature only directing what nature has formerly prepared, uniting actives to passives and often succeeding in anticipating results so that these things are popularly held to be miracles when they are realy no more than anticipations of natural operations; as if someone made roses flower in March or grapes ripen, or even more remarkable things such as clouds, rain,

> thunder, various species of animals and an infinite transformations of things.[92]

As natural magicians search also for desires and appetites of matter, their method had to be experimental. As John Henry states:

> Since magic was chiefly concerned with exploiting the sympathies and antipathies between corresponding things in the Great Chain of Being, and since the assumption was that these powers of agreement and disagreement were hidden or occult, the magician could only discover the powers of things empirically (Henry, 2003, p. 55).

When we consider Bacon, Henry argues a similar thing and states: “As soon as Bacon turned to magic he could hardly fail to notice that its principal method was experimental” (Henry, 2003, p. 53).

The neo-Platonist vitalist philosophers were experimental, and they accepted mechanical philosophy as a rational philosophy because a mechanical philosopher’s application of mathematics to natural phenomena was seen by chemical philosophers as the logical and mathematical approach of the Scholastics to nature. So, when we consider Bacon, the reason he did not approve of making natural philosophical claims through mathematics was that he, like chemical (neo-Platonist) philosophers, saw mathematics as a logical method of Scholastics (see p. 104).

92. For the full quotation, see fn. 87.

Chapter 6

External Mechanics and Mathematics

As mentioned in the previous chapter, Bacon was not a mechanical philosopher. He used the term ‘mechanics’ in a different sense, and he discussed three kinds of mechanics. First, he discussed the mechanics of the artisan; a sort of mechanic which does not depend on physics, and which is empirical and operative only.[93] Bacon places this kind of mechanics in natural history. Second, ‘experientia literata’, that is, learned experience; which refers to the inventions which are found by intentional experiments and is different from the inventions of artisans found by chance (see Bacon, *De augmentis*, SEH IV, p. 366).[94] Third, the kind of mechanics which depends on physics and is placed by Bacon in natural philosophy (see Bacon, *De augmentis*, SEH IV, p. 366). Sophie Weeks calls this kind of mechanics which depends on physical causes ‘philosophical mechanics’ to avoid confusion with the other two types of Baconian mechanics (Weeks, 2008, p. 134, fn. 3).[95] When we consider mathematical sciences, however, I believe we need another kind of mechanics.

93. As Bacon states:

> I know that there is also a kind of Mechanic often merely empirical and operative, which does not depend on Physic; but this I have remitted to Natural History, taking it away from Natural Philosophy (Bacon, *De augmentis*, SEH IV, pp. 365–6).

94. For ‘experientia literata’, see also fn. 45.

95. For an example of ‘philosophical mechanics’ regarding maturation, see Weeks (2008, pp. 185–186).

In this chapter, I will argue that Bacon had another type of mechanics which can be listed as the fourth type.[96] Similar to 'philosophical mechanics', the fourth kind of mechanics is also based on the axioms of physics, and to avoid confusion with the other types of mechanics, I call it 'external mechanics'.[97] This type of mechanics can be seen in the following words of Bacon: "ARISTOTLE has well remarked that <u>Physic and Mathematic produce Practice or Mechanic</u>" (Bacon, *De augmentis*, SEH IV, p. 369; underlining added). What Bacon means by mechanics here is different to the three other kinds of mechanics attributed to him. As mentioned previously, the operative part of Baconian natural philosophy includes mechanics and magic (see Figure 3 on p. 19). This mechanics refers to both philosophical mechanics and external mechanics, however there are differences between them, and I will discuss these below.

In section 6.1, I will discuss the difference between *philosophical mechanics* and *external mechanics*, and I will argue that *external mechanics* is also based on the axioms of physics which makes it separate from the mechanics of mathematicians, that is, the system of machinery. In section 6.2, I will discuss the difference between the Baconian labyrinth–like nature and the mathematically structured cosmos of mathematicians. This will give us a chance to examine the difference between a Baconian definition of external mechanics and mathematicians' systems of machinery. In this section, I will also discuss the relation between external mechanics and its role in producing practice.

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96. Sophie Weeks discussed this topic with me in correspondence. I thank her for many helpful suggestions.

97. The term 'external mechanics' is mine; Bacon did not use this term. However, as he used the term 'systems of machinery' for the geometrical models of mathematicians who developed their models by ignoring physics, and as he thought that when "Physic and Mathematic produce Practice or Mechanic" (Bacon, *De augmentis*, SEH IV, p. 369), I argue we can call the mathematical models of mathematicians who base their models on physics, such as al-Bitruji, 'external mechanics'. It is 'external' because it refers to the hide of the ox (for al-Bitruji and the hide of the ox analogy see Chapter 3).

6.1 External mechanics and philosophical mechanics

External mechanics is based on the axioms of physics, so it is important to explain clearly the difference between external and philosophical mechanics. First, external mechanics is characterised by mathematical sciences (mixed mathematics), while philosophical mechanics is characterised by natural philosophy and it refers to the descending part of Baconian natural philosophy (see Figure 5 on p. 139). When we inquire into a natural phenomenon by applying the Baconian inductive method, we should ascend to new axioms until we reach to the highest axiom, that is, the form of the phenomenon we search for. This ascending process is possible through descending to new experiments or works. New experiments are necessary for us to leap up to a higher axiom. However, even though external mechanics also depends on the axioms of physics, there are differences between them. External mechanics (or mathematical models) should be performed by mathematicians, not natural philosophers. External mechanics refers to mathematical demonstrations which should be performed after natural philosophical inquiries have been done, such as the mathematical models of the heavens (see Chapter 3). For example, when we consider optics or sound, a natural philosopher should complete her/his inquiries into the axioms of the mentioned phenomenon by applying the ascending and descending processes, then a mathematician should start her/his mathematical demonstrations, and those demonstrations should be in harmony with the discovered axioms of physics. So, while inquiries into the axioms of natural philosophy (through ascending and descending processes) refers to the internal part of the inquiry (internal part of the ox), mathematical demonstrations refer to the external part of it, which is why I call it 'external mechanics'. Philosophical mechanics is one of the internal parts of natural inquiries; however, external mechanics is the external part of natural inquiries for the mathematical sciences. As you remember from Chapter 3, Bacon likens natural philosophy to the ox and separates the interior and exterior parts of it. The interior part of the ox refers to inquiries into the objects of natural philosophy while the exterior part or the hide refers to the mathematical demonstrations. For further clarification on this concept, please see Figure 5.

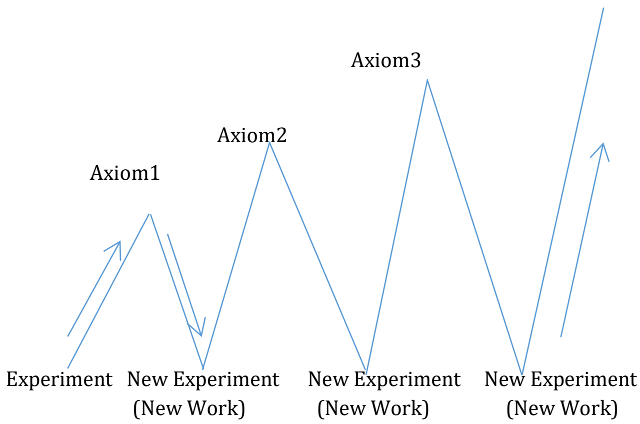

Figure 5[98]

Bacon defines the mathematical model of the mathematicians who ignore natural philosophy as a 'system of machinery' (see p. 63). This definition shows us that Bacon sees mathematical models as a kind of mechanics. However, mathematical models which were developed by considering physics, such as al-Bitrujian's geometrical model of the heavens (see Chapter 3), are different from 'systems of machinery', and I call them (external) mechanics. The difference between them is that while 'system of machinery' does not depend on the axioms of physics, external mechanics depends on these axioms. For example, Copernicus' mathematical model of the heavens, which offers a heliocentric model, is incorrect in Bacon's view because it ignores physics. Copernicus' and Ptolemaios' models were established to save

98. For Weeks' similar and detailed figure regarding the ascending and descending parts of Baconian natural philosophy, see Weeks (2008, p. 181).

the apparent motions, and this is why Bacon calls them 'systems of machinery'. However, al-Bitruji's model reflects the real motions of the celestial bodies because he developed his geometrical model by considering physics. To emphasise the difference between these two models, I call the latter 'external mechanics'.[99]

When you look at the above figure, every descending part refers to philosophical mechanics. As you see, there are several ascending and descending parts which give us a chance to rise to the higher axioms step by step without leaping up to the next step. This is the internal part of natural philosophy. When we consider mathematical sciences, however, we cannot say that every descending part also refers to external mechanics. If every descending part included external mechanics or mathematical models, for Bacon, a natural philosopher would also be a mathematician.

As mentioned in the first chapter, Bacon did not classify mathematical sciences and natural philosophy separately, but even though he approved of mathematical sciences as a part of natural philosophy, he separated the objects of mathematical sciences and natural philosophy, so we cannot say that, for Bacon, a natural philosopher must be a mathematician. Bacon never said something like this. However, when we consider Copernicus or Galileo, they believed that a natural philosopher must be a mathematician. Also, as mentioned before, Newton called new inquirers of nature 'geometrical philosophers' or 'philosophical geometers' (see p. 103).[100]

As I have discussed in the first chapter, Bacon's loyalty to the disciplinary boundary between mathematical sciences and natural philosophy does not

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99. Please see Chapter 3 for further discussion about Bacon's conceiving of the al-Bitrujian and Copernican models.

100. In her 'Observation and Mathematics' (2013) Mary Domski defends an interpretation of Newton on which Newton can in fact be understood to follow in the tradition of Bacon. Cf. Smeenk (2016) and Goldenbaum (2016).

require natural philosophers to be mathematicians. When the objects of natural philosophy and mathematics were equated by mathematical physicists, being a mathematician became a necessity for a natural philosopher.

If we accept that external mechanics should be developed in descending parts from the axioms of physics to new experiments during natural inquiries, then we must accept that a natural philosopher must also be a mathematician. However, mathematicians should use steps to make their demonstrations or to develop mathematical models after natural philosophers discover the natural philosophical axioms. As I mentioned in the third chapter, Bacon developed a physical model for the heavens as a natural philosopher, and he argues that a mathematical model (or external mechanics) should be developed by a mathematician which is in harmony with the physical model, which means that the mathematical model should be derived from the physical model. As you remember, this was the priority of physics in natural inquiries.

As mentioned before regarding the celestial motions, Bacon emphasises that he 'shall banish to calculations and tables the fancy mathematics (that motions be reduced to perfect circles, either eccentric or concentric), and the empty talk (that the Earth is in comparison to the heaven like a point, not like a quantity), and many other fictitious devices of the astronomers' (see p. 76). And, indeed, when we consider astronomy, we cannot see any ascending and descending processes in Bacon's explanations regarding the motions of celestial bodies. Bacon's explanations regarding the celestial motions are more similar to Aristotle's explanations. As mentioned in Section 3.5, Bacon explains the motions of the celestial bodies according to the materials of these bodies.

When we compare inquiries into the axioms of natural philosophy and mathematical demonstrations, Bacon gave priority to the former for two reasons. First, he believed it was the proper order which should be followed in natural inquiries, and I have discussed this in Chapter 2. Second, a priority of physics stops us reaching the wrong conclusions, such as in Copernican astronomy. Mathematicians should consider the results of natural philosophy before they make their demonstrations, so these two parts (internal and external) can be in harmony with each other to establish one body of science (see p. 70). As a result, Bacon saw the priority of physics as a precaution for mathematicians to prevent them making natural philosophical claims through mathematics.

Before I finish this section, let me requote the following words of Bacon which also show us the external status of mathematical models (the last step status of mathematics, see pp. 26–7), which covers the inquiries into natural causes; these words also show us the auxiliary role of mathematics which refers to its inability to make natural philosophical claims:

> mathematics … ought to round off natural philosophy and not generate or procreate it (see p. 27).

6.2 The Baconian labyrinth–like nature, geometrically structured nature, and their relation with external mechanics and the system of machinery

In his *De Sapientia Veterum* (Wisdom of the Ancients) published in 1609, Bacon interprets the mythological figure, Daedalus, as 'the mechanic'. Daedalus is a genius, but interestingly he is a bad character. According to Bacon, "the ancients drew a picture of mechanical skill and industry, together with its unlawful artifices and depraved applications" (Bacon, *De sapientia*, SEH VI, p. 734). The reason for Daedalus' bad reputation is that he made an artificial cow for Pasiphae, the wife of King Minos of Crete. In the story, the God Poseidon gives a bull to King Minos to sacrifice, but King Minos saves the bull for himself, and this makes Poseidon angry. Poseidon takes revenge by making Pasiphae desire the bull. To satisfy her desire, the artisan Daedalus makes an artificial cow for Pasiphae so she can mate with the bull. This act results in Pasiphae giving birth to a strange creature, the Minotaur. Daedalus later built a labyrinth to hide this monster. For Bacon, this is "a work wicked in its end and destination, but in respect of art and contrivance excellent and admirable" (Bacon, *De sapientia*, SEH VI, p. 734). Bacon believed this story reveals two faces of mechanical arts or technology; the fountain of arts can produce both the instruments of wellbeing and the instruments of disaster and death.

For Bacon, the labyrinth which was made by Daedalus represents nature. To find the exit from the labyrinth, Daedalus also designates a clue, and Bacon likens the clue to experiment. In his preface to Bacon's *Inquisitio legitima de motu*, James Spedding defines the clue as the true method for natural philosophy (see Spedding, *Preface to*, SEH III, p. 624). As the essence of the true method is experiment, the clue can be defined as both experiment and the true method. Daedalus is the same man who designed the labyrinth and who invented the clue to find the exit from the labyrinth. What matters most in the present context is the analogy of the relationship between the labyrinth and the clue on the one hand, and nature and experiment on the other.

It is important to point out that Bacon likened nature to a labyrinth, in contrast to others who likened nature to a mathematically designated structure. Bacon did so because he wanted to emphasise nature's subtlety and that nature cannot be cast in a rational mould (that is, we cannot understand nature through the rules of geometry or logic). As mentioned before, Bacon believed there is a tendency of the human mind to suppose 'that there is more order and equality in things than it actually finds' (see p. 40), an error of the mind which makes us think that nature is more explainable through mathematics. However, the mentioned supposition of the human mind is not real, that is, there is not as much order and equality in nature as we suppose.

Bacon quotes from Democritus the following words which imply nature's obscurity: "That the truth of nature lies hid in certain deep mines and caves" (Bacon, *De augmentis*, SEH IV, p. 343). Again, in his *De Augmentis Scientiarum*, Bacon says that "For Physic carries men in narrow and restrained ways, imitating the ordinary flexuous courses of Nature" (Bacon, *De augmentis*, SEH IV, p. 362). To overcome this obscurity of matter (see also Chapter 2), experiment (or mechanics) is seen by Bacon as an important tool (see Bacon, *De augmentis*, SEH IV, pp. 365–366).

We know that Bacon emphasises the difference between 'nature free' and 'nature constrained'. Nature can only be constrained by mechanics or art to reveal its truth.[101] This is why mechanics was seen by Bacon as the clue to find the way out from the labyrinth. As you remember, Bacon interpreted Daedalus as the 'mechanic' and the clue, which was invented by Daedalus the mechanic, as experiment.[102]

In the hidden maze of the labyrinth, mathematics is not as strong a tool as the inductive experimental method.[103] The Baconian labyrinth-like nature is

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101. On nature which is constrained by experiment (or mechanics) to reveal its truth, see Pesic (1999). On Bacon's theory of experimentation, see Jalobeanu (2013).

102. On mechanics as experiment, see Rossi (1970) and Weeks (2008).

103. Rossi compares a mathematical image of the world with Baconian image that is labyrinthical, and says:

> The typically Platonic images of a world of mathematical and rational structures created by a geometer God who composed the world out of *numero, pondere, etmensura* doubtlessly were to be more fruitful to the development of modern science than the Baconian image of nature as a "forest" and a "labyrinth." The so-called Baconian "incomprehension" of mathematics which led Bacon to appreciate "mechanics" such as Agricola more than "theorists" such as Copernicus and Galileo was deeply bound up with his appraisal of logic as a "labyrinthian thread" as a means for ordering the natural forest (Rossi, 1970, p. 117).

contrary to the geometrically structured nature of mathematicians.

At this point, the claim that a bronze sphere cannot touch a straight plate at a point is important to mention. This is an old claim. According to Aristotle, Protagoras used this claim in his rebuttal to geometers (see p. 12, fn. 9). This claim was interpreted, especially by the Peripatetics, as one of the reasons why mathematics should not be applied to physics. In his *Dialogue Concerning the Two Chief World System,* Galileo made Simplicio — an imaginary peripatetic — say that "these mathematical subtleties do very well in the abstract, but they do not work out when applied to sensible and physical matters" (Galilei, 1967, p. 203). Again, in his other dialogue, *Dialogues Concerning Two New Sciences*, Galileo puts Aristotelian thought about the same subject into the mouth of Simplicio as follows: "The arguments and demonstrations which you have advanced are mathematical, abstract, and far removed from concrete matter; and I do not believe that when applied to the physical and natural world these laws will hold" (Galilei, 1914, p. 52).

As the imperfection of matter does not allow mathematics to be applied to physics, the Peripatetics believed that, in contrast to geometrical spheres, physical spheres cannot touch each other at a point. The reason is explained by the Peripatetic spokesman of Galileo, Simplicio, by saying that "it is the imperfection of matter which prevents things taken concretely from corresponding to those considered in the abstract" (Galilei, 1967, p. 207). However, Galileo tried to demonstrate that two physical spheres can touch each other at a point. Indeed, if geometrical spheres were not perfect, they could not touch each other at a point even in the abstract. In a similar way, if physical spheres were perfect enough, then they could touch each other at a point. Galileo's writings show us that things work both in the abstract and in

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We cannot say that Copernicus or Galileo believed in Platonian kinds of abstract forms, but without thinking about Platonian forms it is also possible to believe that the cosmos has a mathematical structure.

the concrete, in the same way. The errors, according to Galileo, come from the calculator, not from abstractness or concreteness or from physics or geometry. The important thing in Galileo's words is his belief that, both in the abstract and in the concrete, mathematics works in the same way. This idea must depend on his idea of the unchangeability of matter; because instead of the belief of Aristotle and the Peripatetics in changeability and perishability of matter, Galileo assumes that matter is unchangeable. His spokesman Salviati says that "Since I assume matter to be unchangeable and always the same, it is clear that we are no less able to treat this constant and invariable property in a rigid manner than if it belonged to simple and pure mathematics" (Galilei, 1914, p. 3).

As one at the frontier of mathematical physics,[104] and probably the best in the early modern period, Galileo was against the idea that the abstractness of mathematical objects causes mathematics to fall into error in physics, and this idea is related to the unchangeability of matter. We know that Aristotle thought that only heavenly bodies have perfect geometrical shapes (see fn. 9). Accordingly, the superlunar realm of the cosmos has the advantage of unchangeableness and imperishableness, because this part of the cosmos is composed of aether. However, what Galileo means is that matter can be defined mathematically, and the abstractness of mathematical objects does not cause any errors in mathematical demonstration related to physics, so motion and change in matter can mathematically be defined.

We can see that those who thought mathematics could be used to make natural philosophical claims had a propensity to interpret the cosmos as something geometrically structured.[105] However, when we consider the

104. On the birth of mathematical physics, see Zvi (2008, pp. 9–11).

105. Rossi discusses this relation between mechanics and mathematics well:

> The assumption of the model machine, the integral explanation of physical and biological reality in terms of matter and motion, entailed a very profound

labyrinth–like universe of Bacon, which has so many ambiguous ways, the difference between it and a geometrically structured universe can be easily seen.

The labyrinth-like nature of Bacon refers to the subtlety of matter, and as you remember from the second chapter, the subtlety of matter requires the experimental method, not logical or mathematical methods. So, Bacon likening experiment to the clue which helps us to find the exit from the labyrinth is understandable.

As to the relationship a labyrinth-like nature and a geometrically structured one between external mechanics and the system of machinery, even though experiment was seen by Bacon as the clue to find out the truth of nature, we also need mathematical demonstrations, especially when we consider mathematical sciences. As mentioned, physics and mathematics should form one body of science. Bacon gives the ox as an example to explain what he means by one body of science formed out of physics and mathematics. The interior part of the ox represents the inquiries into the objects of natural philosophy, and the exterior part of it or the hide of the ox represents mathematical demonstrations or external mechanics. Then, we can mention a difference between the mathematical demonstrations of mathematicians who ignored natural philosophy and those who considered the axioms of natural philosophy, as mentioned above, such as the geometrical model of al-Bitruji. Bacon calls the former 'system of machinery', and I call the latter 'external

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modification of the concept of nature. Nature no longer appeared as a context of forms and essences in which "qualities" inhere, but of phenomena which are quantitatively measurable. All qualities not translatable in mathematical and quantitative terms were excluded from the world of physics. It was declared that there were no "hierarchies" in nature and the world no longer appeared as constructed for man or to the measure of man. All phenomena, like all the component parts of a machine, were declared to have the same value. Knowledge of reality implied an awareness of how the machine of the world functions, and that machine (at least theoretically) could be broken down into its single components and put together again piece by piece (Rossi, 1970, p. 142).

mechanics'.

External mechanics should cover the labyrinth-like nature of Bacon, like the hide of the ox covers the interior part of it, that is, mathematical demonstrations (mathematical models or external mechanics) should follow the inquiries into the axioms of natural philosophy because the main method for a labyrinth-like nature is experiment, however those who thought nature is geometrically structured gave the main role for their natural inquiries to mathematics, and for Bacon, they ignored natural philosophy. So, Bacon defined their mathematical demonstrations as 'systems of machinery' to emphasise their lack of natural philosophy. When we consider astronomy, mathematical demonstrations regarding the motions of the heavenly bodies indicate a 'system of machinery' which is established on apparent motions only, that is, a system which is devised to produce apparent motions only, not the causes of things (see Bacon, *De augmentis*, SEH IV, pp. 348–9).

It should also be considered that without external mechanics, mathematical sciences cannot be put into practice. For mathematical sciences, putting theory into practice is mostly possible through external mechanics (mathematical models). For Bacon, we can use a geometrical model (external mechanics) of the heavens, for example, to navigate our ships on the open seas; or we can use the external mechanics of projectile motion, for instance, to design cannons which can hit their targets with a better approximation.[106] External mechanics (mathematical models) is not a study regarding the causes of nature but rather descriptive studies which should be developed out

106. For further reading on the application of geometry to develop instruments such as devices for the art of warfare, see Bennett (2002) and (2011). On a discussion in sixteenth century on whether astronomical instruments could represent the cosmos, see Mosley (2006). Thomas Tenison (1636–1705) informs us in his *Baconiana* that Bacon also made a mechanical device representing the planetary motions, see Tenison (1679, pp. 17–8). I thank Sophie Weeks for letting me know about this invention of Bacon. On the status of the mechanical arts in sixteenth century, see Heikki (1999). On mathematical practitioners and their role in adoption the language of mathematics in natural philosophy, see Cormack (2016).

of physics. For example, we can say that Galileo should have made causal explanations regarding natural and violent motions before he made his descriptive explanations. Bacon gave some causal explanations regarding the motions of the celestial bodies by considering their substance (see Section 3.5). For Bacon, the causal knowledge of the motions of the celestial bodies cannot produce practice unless it meets mathematics. Bacon thought that sciences could advance if we work on the axioms (causes) of natural philosophy. Working on mathematical demonstrations and ignoring natural philosophy was an obstacle for the advancement of sciences because, as mentioned before, Bacon thought new works could be deduced from the axioms of natural philosophy.

6.3 Summary

I want to point out that unlike philosophical mechanics and the other two mentioned mechanics, external mechanics itself is not an experiment but a mathematical model based on the axioms of physics, which should be developed by mathematicians. Exterior mechanics is exclusively for mathematically characterised sciences (mixed mathematics); and while philosophical mechanics is the descending from the axioms of physics to new experiments, we should wait until we discover the axioms of a certain phenomenon through ascending and descending processes to develop the mathematical model (external mechanics). Al-Bitrujian's geometrical model for the celestial motions is a good example of external mechanics (see also Chapter 3).

Bacon calls the mathematical models of mathematicians who ignore physics in developing their model 'systems of machinery'. For Bacon, Copernicus' or Galileo's mathematical models were not derived from a physical description of the mechanisms involved. However, I should emphasise that this is Bacon's point of view. For Copernicus and Galileo, their mathematical model reflects the physical model. Bacon thought that Copernicus' model ignores physics because it is in conflict with, for example, the stability of the earth at the centre of the universe. So, we can say that while al-Bitruji's exterior mechanics regarding the motions of the celestial bodies is an example of a mathematical model which is based on physics, Copernicus' model is an example of a mathematical model (system of machinery) which was not derived from a physical description of the mechanisms involved.

Conclusion

In this study, I have argued that Bacon did not approve of the new role of mathematics, which can be defined as making natural philosophical claims through mathematics. I have argued that Bacon had two fundamental commitments which caused him to disapprove of the new role of mathematics. First, the inconsistency between the course of nature (matter) and the course of logic and mathematics. Second, the consistency between human understanding and the course of logic and mathematics.

The inductive experimental method of Bacon consists of the instruments of the human mind and senses, which make them more able to deal with the subtlety of matter. So, Bacon defined the role of mathematics in natural philosophy as an assistant his inductive experimental method, and this subsidiary role refers to mathematics' inability to be used to make natural philosophical claims. For Bacon, those who used mathematics to make natural philosophical claims tried to make mathematics dominant over physics.

The idea of not making natural philosophical claims through mathematics was an Aristotelian notion and was the result of Aristotle's disciplinary division between mathematical sciences and natural philosophy. When we consider this aspect of disciplinary division, I have argued that Bacon remained an Aristotelian. However, I have also argued that Bacon rejected a disciplinary division between mathematical sciences and natural philosophy because he took the mathematical sciences to be a branch of metaphysics, which in turn, he makes them a part of natural philosophy. I argue this because, as mentioned in the first chapter, Aristotle's disciplinary division rests on the separation of mathematical sciences and natural philosophy, so we cannot make natural philosophical claims through mathematics. In contrast to Aristotle, Bacon placed mathematical sciences as a branch of natural philosophy, but agrees with Aristotle on the rejection of making natural philosophical claims through mathematics. We can say that placing mathematical sciences in natural philosophy was a revolutionary act, but rejecting the ability of mathematics in making natural philosophical claims was a counter–revolutionary attitude. These two attitudes of Bacon should not be confused with each other.

Bacon's attitude towards mathematics is similar to the attitudes of the neo-Platonic chemical philosophers. They both accepted that making natural philosophical claims through mathematics was the logical and mathematical approach of the Scholastics to nature, and they also both accepted the idea of the unmoved mover as an unwelcome result of the logical and mathematical approach to nature. While these chemical philosophers applied an experimental method, Aristotle and Scholastics chose to use excessive logic in natural inquiries. I have argued that these similarities between chemical philosophers and Bacon resulted from their belief in active matter, which was contrary to the Aristotelian and scholastic view of passive or potential matter. For Bacon, those who did not approve of the active properties of matter must search for them beyond matter, and finding these principles beyond matter forces them to apply excessive logic and mathematics in natural inquiries. For Bacon, when the human mind is unaided, it follows the same route as logic and mathematics.

What Bacon held true for the role of mathematics for natural inquiries can be well seen in his attitude towards designing a mathematical model of the heavens. For him, such a model should be established by considering the axioms of natural philosophy. This attitude was a precaution to avoid making physical claims through mathematics. Bacon believed the axioms of natural philosophy should be discovered through his inductive method. Mathematical models (external mechanics) of the heavens or any mathematical models for any natural phenomena should be established by considering axioms of natural philosophy.

Now, let me make an analogy by comparing the relationship between mathematics and natural philosophy in the early modern period with social sciences in the twentieth century. Eugene Wigner tells a story between two friends in his famous paper, '*The Unreasonable Effectiveness of Mathematics in the Natural Sciences',* written in 1960:

> There is a story about two friends, who were classmates in high school, talking about their jobs. One of them became a statistician and was working on population trends. He showed a reprint to his former classmate. The reprint started, as usual, with the Gaussian distribution and the statistician explained to his former classmate the meaning of the symbols for the actual population, for the average population, and so on. His classmate was a bit incredulous and was not quite sure whether the statistician was pulling his leg. "How can you know that?" was his query. "And what is this symbol here?" "Oh," said the statistician, "this is π." "What is that?" "The ratio of the circumference of the circle to its diameter." "Well, now you are pushing your joke too far," said the classmate, "surely the population has nothing to do with the circumference of the circle" (Wigner, 1960, p. 1).

As we can see, the statistician's classmate objects to the idea that the population can be represented by the ratio of the circumference of the circle to its diameter. Now, I want to remind the readers of Bacon's objection to the representation of the Earth with a point, but not a quantity, in comparison to the heavens (see p. 76).

The following words of Stephan Hartmann and Jan Sprenger make the above analogy clearer:

> Over the years, mathematics and statistics have become increasingly important in the social sciences. A look at the history quickly confirms this claim. At the beginning of the 20th century most theories in the social sciences were formulated in qualitative terms while quantitative methods did not play a substantial role in the formulation and establishment of them. Moreover, many practitioners considered mathematical methods to be inappropriate and simply not suited to foster our understanding of the social domain … All this changed by the end of the century. By then, mathematical and especially statistical methods were standardly used and it became relatively uncontested that they are of much value in the social sciences (Hartmann and Sprenger, 2011, p. 594).[107]

The possibility of making natural philosophical claims through mathematics is related to the idea that mathematics, as a creation of the human mind, can explain the objects of natural philosophy.[108] Bacon's answer to this is 'no', and in this thesis, I have attempted to show two reasons why he disagreed with this statement (see Chapter 2).

The Baconian labyrinth–like nature cannot be cast into a logical or mathematical mould. This does not mean that Bacon was against the application of mathematics, but that he had no trust in mathematics for

107. I should point out that the definition of social science in Hartmann and Sprenger's paper includes anthropology, political science, sociology, economics, and parts of linguistics and psychology. See Hartmann and Sprenger (2011, p. 609, fn. 1).

108. In a more recent paper, physicist Max Tegmark argues that our physical world is an abstract mathematical structure. See Tegmark (2008).

the explanation of the objects of natural philosophy. He believed it is useful as an assistant, and being an assistant for natural philosophy means that we should not make natural philosophical claims through mathematics. As long as we do not make natural philosophical claims through mathematics, Bacon had no issue with the application of mathematics to natural philosophy, and as mentioned before, we should not fail to notice that making natural philosophical claims through mathematics was the new role for mathematics. The new role of mathematics was a violation of the disciplinary boundary between mathematical sciences and natural philosophy by equating the objects of mathematics and natural philosophy.

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