FRANCIS BACON ON AXIOMS, LAWS, RULES AND PRINCIPLES: AN OVERVIEW

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Abstract. Francis Bacon is rarely mentioned in the histories of the emergence of the concept of laws of nature. His philosophy does not seem to contain a conception of laws as regularities; but he does treat the subject and has a very rich vocabulary to refer to it. The trouble is that he talks, sometimes indistinguishably, of laws, forms, principles and axioms, precepts, maxims and rules. My purpose in this article is to review and clarify some of this vocabulary and to show that Bacon's terminological struggles are philosophically interesting. I show that we can find in Bacon's works a change and evolution of this vocabulary of axioms, rules and laws; and that significant changes are happening in significant contexts, such as his attempts to define the elements of a *scientia* or the outlines of a proper inquiry. I claim that Bacon's attempts to put some order in this philosophical vocabulary read as attempts to develop a new concept of order compatible with a certain kind of conception of laws of nature.

Keywords: Francis Bacon; laws; axioms; rules; principles.

1. AXIOMS AND RULES: FIRST ATTEMPTS OF CLARIFICATION

Francis Bacon's views on the architecture of the sciences have long time puzzled his interpreters. Bacon left many unfinished works and projects; so many felt the need to systematize and "methodize" his writings. Such was the eighteenth-century chemist and natural philosopher Peter Shaw (1694–1793). In 1733, Shaw published a three-volume set of Bacon's *Philosophical works*, translated into English, "abridged and methodized". In his preface to the English translation of the *Novum organum*, Shaw claims that Bacon's aphorisms are imperfect axioms. And that *this* is the sense in which the *Novum organum* is unfinished. Shaw claims that

> […] aphoristical writings are rich and pregnant things, capable of being unfolded, explained, illustrated, and reduced into great variety. Yet and aphorism differs from an axiom; as a true and perfect axiom is incapable of farther improvement,

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> but an Aphorism is still improvable. So that Aphorisms as a kind of imperfect Axioms, that ought to point and lead up to the perfect. And as Aphorisms thus approach to Axioms, we should not despair or raising an Axiomatical Philosophy upon the following set.[1]

This is, in many ways, a puzzling statement; and makes one wonder about its sources and context. In this paper, I try to make sense of it and reconstruct its meaning. I show that we can indeed see Bacon as engaged in something of this sort, i.e., a way of extracting, from historical experience and physical experiments theoretical propositions of increasing degrees precision and generality out of which his projected new science, the *scientia activa* would have been build.

This process of successive generalizations is something that many of Bacon's interpreters took to be one of the characteristic features of his work. However, if one looks a bit more carefully, it is precisely in connection with this process of successive generalizations and the production of axioms, that Bacon's writings are a terminological mess. Bacon refers, sometimes indistinctively to axioms, principles, rules and maxims. In doing this, he follows the contemporary custom, so familiar to the seventeenth century, of treating axioms and maxims indistinctly. As Brian Vickers has shown, this is rather the rule than the exception in late sixteenth century[2]. Axioms, maxims, principles, even aphorisms, are sentences of brevity and authority which may play a role in the construction of a certain science. But they can also stand on their own, in philosophy and law, where collections of maxims are highly appreciated and often used. We have clearly such a use in Bacon, who often emphasized the pithy, authoritative and heuristic character of his axioms[3]. Axioms can be "seeds of knowledge", which means that they can inflame the imagination, or that they can generate new ideas, new conjectures, observations, new experiments. They are also said to generate light[4]. There are many kinds of axioms; throughout his works Bacon mentions axioms of maturation, axioms for the production of gold, axioms referring to the ways in which plants can influence and change each other properties if they extract their nutriments from the same piece of soil[5], axioms of vivification, but also the "great axiom" stating the impossibility of annihilation, for example[6]. In some cases, axioms are clearly formulated as rules to guide a particular experimental procedure, as in the case of the axioms for the production of

[1] Francis Bacon and Peter Shaw, *Novum Organum Scientiarum: containing rules for conducting the understanding in the search of truth … Translated from the Latin, by Peter Shaw, M.D.* (London, 1818).

[2] Brian Vickers, *Francis Bacon and Renaissance Prose* (Cambridge, 1968).

[3] On Bacon's maxims of law and the relationship of the maxims of law with his axioms see for example Silvia Manzo, "Francis Bacon: Freedom, Authority and Science", in *British Journal for the History of Philosophy*, 14 (2006): 245–273; Julian Martin, *Francis Bacon, the state, and the reform of natural philosophy* (Cambridge, 1992).

[4] See for example *Sylva Sylvarum*, experiment 2. See also Dana Jalobeanu, "*Sylva Sylvarum*: Retorica științei și pedagogia experimentului. Studiu introductiv," in Francis Bacon, *Opere filosofice* (Bucharest, 2017), ed. by Dana Jalobeanu, pp. 11–52.

[5] *Sylva Sylvarum*, experiments 483, 490. For a discussion, see Doina–Cristina Rusu, *From Natural History to Natural Magic: Francis Bacon's Sylva Sylvarum* (Radboud University, 2013).

[6] See for example *Sylva Sylvarum*, experiment 100.

gold[7]. In this, Bacon seems to follow his own precept, clearly stated in the *Novum organum*, according to which

> Human knowledge and power come to the same thing, for ignorance of the cause puts the effect beyond reach. For nature is not conquered save by obeying it; and that which in thought is equivalent to a cause, is in operation equivalent to a rule.[8]

Thus, axioms and principles are theoretical statements, expressing causal connections; while rules are operative precepts. But they are not separated entities; they are more like the two sides of the same coin. One can express the axioms of maturation with the intention of spelling out the causal connections which explains the process of concoction[9]. But one can also make these sentences operational and give them a practical value so that the investigator of nature can learn how to control this process: accelerating or retarding, through experiments, the maturation of fruits, for example[10].

Thus, a first attempt to clarify Bacon's vocabulary is to follow his own distinctions: theoretical, causal explicative on the one side, to be complemented by the practical, operative, applicative. The problem with this approach, and the problem with the aphorism 3 of the *Novum organum* quoted above, is that this clearly does not hold for all axioms and for all rules. It might hold for the more general of them, for the principles of sciences. The general axiom of the conservation of matter can be also formulated as a rule (no annihilation is possible; or "in each instance, the sum of what goes in and what goes out of a closed system must be constant" or in other ways). But there are also rules of operation which come before one has causal explanations. As Bacon already states in the *Novum organum*, when it comes to works "a man can do nothing except bring natural bodies together or put them asunder; nature does the rest from within"[11]. And often the investigator of nature does not know how nature does a certain thing. But this does not mean one cannot establish some rules of practice which would guide the investigation. For example, Bacon suggests rules "for the opening of bodies" in a very tentative manner

> From this the best rule governing the opening and solution of bodies is derived. For, leaving aside corrosive substances and strong waters which blaze a trail for themselves, if you can find a body proportioned and both more consentient and friendly to some solid body other than the one with which the solid is mixed as if by necessity, the solid instantly relaxes and opens itself […][12]

[7] *Sylva Sylvarum*, century IV, experiments 327–328. See also Dana Jalobeanu, "*Sylva Sylvarum* și științele baconiene ale naturii", in Francis Bacon, *Opere filosofice* (Bucharest, 2017), ed. by Dana Jalobeanu, pp. 699–710.

[8] *Novum organum*, I. 3.

[9] Dana Jalobeanu,"Spirits Coming Alive: The Subtle Alchemy of Francis Bacon's *Sylva Sylvarum*", in *Early Science and Medicine*, 23, no. 5–6 (2018): 459–486.

[10] Dana Jalobeanu,"Bacon's Apples: a Case-Study in Baconian Experimentation", in *Motion and Power in Francis Bacon's Philosophy*, eds. Guido Giglioni, et al. (Dordrecht, 2016), pp. 83–113.

[11] *Novum organum* I. 4., in Francis Bacon, *The Instauratio magna. Part 2: Novum organum and Associated Texts*, vol. XI (Oxford, 2004), pp. 64–65. Hereafter OFB XI.

[12] *Novum organum*, OFB XI 390–1.

In this case, it is clear that the rule regards the experimental procedure. It is a rule of selection – it helps us to select, from all the substances, those who have a high chance to produce the "opening" (dilatation, dissolution) of a particular body. Such substances are, on the one hand, those generally corrosive; but also those "friendly" with the body that needs to be opened and can activate its motion of consent. We do not have an axiom yet; merely a set of preliminary educated guesses on the basis of which we can conduct investigations. Eventually, some of these investigations will result in the formulation of axioms.

Axioms come in all sorts of shapes and forms; some are more specific, or "intermediate", others are more general. More puzzling, some axioms are said to be more exact than others; while some are "imperfect" and provisional, subject to corrections. In fact, one of the most puzzling characteristics of Bacon's discourse of axioms is that he specifies clearly that axioms are neither self–evident (since they are obtained from experiments, by forms of inductive generalizations) or necessary true. Axioms can be false and have to be rejected; more precisely, one can discover false axioms among one's corpus of theoretical knowledge. And this, according to Bacon, can happen quite often. More than that, axioms are provisional; and mostly imperfect, subject to further corrections. As Bacon stated in the *Norma abecedarium* (a set of rules of his *Abecedarium novum naturae*).

> I also establish rules (though only provisional ones) and imperfect axioms (*axiomata inchoate*) such as crop up in the course of inquiry, and not with the intention of laying down the law. For they are useful if not altogether true.[13]

This is a very good example of an instance where Bacon uses all the terms we are investigating here: axioms, rules and laws. The translation is a bit misleading, a more correct one would be, probably

> I establish rules (though only provisional ones) and imperfect axioms, such as crop up in the course of inquiry, without the intention of setting out a solution/pronouncing a sentence (*non pronunciantibus*).

Bacon uses here as in many other places a legal vocabulary; and the contrast is between formulating theoretical statements that help the inquiry to move further and theoretical statements that sort–out, and close the inquiry, the equivalent of a positive sentence/pronouncement which closes a case. So what Bacon is saying is that in order to complete the kind of inquiry required to establish the *abecedarium* of nature, one needs both *provisional rules* and *imperfect axioms* which help the inquiry. The terms introduced here are significant: Bacon uses a term borrowed from the classical tradition – *canones mobiles* for the provisional rules. It is a term we can only find in his late writings, post 1620[14]. In the *Novum organum* he only uses the term *regulae* to designate the operative aspect of axioms.

[13] Francis Bacon, *The Instauratio magna. Part 3: Historia naturalis et experimentalis: Historia ventorum and Historia vitæ & mortis*, vol. XII (Oxford; New York, 2007), pp. 222–223. Hereafter OFB XIII.

[14] On the structure of Bacon's natural histories see Dana Jalobeanu, *The Art of Experimental Natural History: Francis Bacon in Context* (Bucharest, 2015); Rusu, *From Natural History to Natural Magic*.

It is tempting to say that the introduction of the term canon is an attempt to distinguish cases when rules and axioms are not merely the two sides of a coin, but are statements with quite different contents and different purposes. Rules are guiding the experimental procedure, while axioms continue to express causal connexions, although, in some cases, they are merely tentative and provisional causal connexions, as in the examples mentioned above.

It is, of course, not to simple. Canons do not merely express operational rules. In fact, Bacon uses another term for designating rules of experimenting – he calls them *modes of experimentation*[15]. *Cannones mobiles* are more general, theoretical statements; in fact, their content is till still highly similar, in some cases, with the axioms and principles. For example, the conservation of matter is said to be a principle, a fundamental axiom[16]. Meanwhile, in the *Historia densi et rari*, the conservation of matter is one of the *canones mobiles*. In the investigation of sounds, in the *Sylva Sylvarum*, we have a very general rule stating that sounds are propagated in straight lines. Is this also an axiom? The *Sylva Sylvarum* claims that it is, but clearly this rule is not formulated as a causal connection. Sounds travel in straight lines is a *regulative* statement of the kind which, to the modern eye, looks very much like a law of nature. How are we supposed to read it and how does it fit in Bacon's scheme?

In order to be able to answer this question we need to take a detour and inquire into the uses of axioms in Bacon's writings. From the beginning, Bacon uses axioms in multiple ways. They are not only pieces from which future sciences will be constructed. They are also vehicles of teaching and learning as we shall see in the next section of this paper.

2. A THEORY OF TEACHING AND LEARNING

What seems to be for Bacon a major characteristic of an axiom or maxim relates again to teaching and learning. Axioms and maxims are seeds of knowledge: they have a sort of "generative power" once sowed into the mind of men. Moreover, if we look at Bacon's specific examples of axioms, their main characteristic seems to be their "productivity": axioms are said to uncover new particulars, or new classes of phenomena.

> In no way can 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.[17]

[15] Dana Jalobeanu,"Disciplining Experience: Francis Bacon's Experimental Series and the Art of Experimentation.", in *Perspectives on Science*, 24, no. 3 (2016): 324–342.

[16] Silvia Manzo,"Holy Writ, Mythology, and the Foundations of Francis Bacon's Principle of the Constancy of Matter", in *Early Science and Medicine*, no. 4 (1996): 116–126.

[17] OFB XI 72–73. See also: "The axioms in current use flow from a handful of slender experiences and from a few particulars which crop up often, and are pretty much made and tailored to fit them, so that it is no

There are several ways in which axioms are vehicles of teaching and learning. The most basic is because they share with aphorisms and other pithy sayings the capacity of striking the imagination. But axioms are more than that. They illuminate hidden connexions between domains of knowledge, tracing the very footsteps of nature. Thus, Bacon claims that the *philosophia prima* contains principles and axioms with a high level of generality which are valid in all sciences, principles which have, according to Bacon, a "primitive force and efficacy in all sciences", and so conduce the mind to the contemplation of the unity of Nature. And this is, Bacon claims in *De augmentis scientiarum* the very "office and use of Philosophia Prima"[18].

The problem is how to read such claims. We tend, too often, to read them in a foundational manner – but this is not, I think, what Bacon had in mind. An important and rather bewildering feature of the *philosophia prima* is its un–systematic or, rather anti-systematic character. Such higher–level axioms are, Bacon claims, necessarily disconnected. They do not form a (logical) system. Their truth is not guaranteed by any internal syntactic coherence. Philosophia prima is simply a

> […] receptacle for all such profitable observations and Axioms as fall not within the compasse of any of the speciall parts of philosophie, or sciences, but are more common and of a higher stage.[19]

Examples comprise: "If you add unequal quantities to equals, we obtain unequals" – said to be an axiom in mathematics, but also in the law. Or, again, the conservation of the total quantity of matter is a principle in natural philosophy but also a maxim in theology. And Bacon gives quite diverse and disconnected examples of the principles of *philosophia prima*. How are we to understand their disjoint character? There are two possible explanations. One is to say that we do not have the *philosophia prima*, properly speaking; it is one of the parts of knowledge that needs to be reconstructed. We merely infer its existence from the existence of such disconnected, very general axioms which happen to be true in more than one science. We can even say (as Silvia Manzo has done) that, for Bacon, the maxims, principles and axioms belonging to *philosophia prima* are remains of a former knowledge, now lost, a "natural" form of wisdom once existent (the Persian magic)[20]. Another way of reading the disjoint character of the axioms and principles of *philosophia prima* is to insist upon their function of seeds of knowledge, i.e., vehicles of learning. They are not axioms because once they belonged to a complete science (and might be the same again), but because they are generating knowledge in the minds of the reader. And

wonder if they do not lead to new particulars. But if by chance some instance never known or seen before presents itself, an axiom is saved by some silly distinction, when it would have been better to put right the axiom itself." (OFB XI 74–75).

[18] Francis Bacon, *Of the Advancement and Proficience of Learning, or the Partitions of Sciences IX bookes … Interpreted by Gilbert Wats* (London, 1674), p. 135.

[19] *Ibid*.

[20] Silvia Manzo, "Holy Writ, Mythology, and the Foundations of Francis Bacon's Principle of the Constancy of Matter", in *Early Science and Medicine*, 4 (1996): 116–126.

Bacon seems to claim sometimes that only disjoint axioms and principles can do that. Once they are nicely arranged and methodised they lose their generative character.

There are many places where Bacon insist upon this heuristic power of individual aphorisms; perhaps one of the most interesting is in his unfinished and posthumous *Maxims of law* where he explicitly states

> Whereas I could have digested these rules into a certain method or order, which, I know, would have been more admired, as that which would have made every particular rule, through his coherence and relation unto other rules, seem more cunning and more deep; yet I have avoided to do so, because this delivering of knowledge in distinct and disjoined aphorisms doth leave the wit of man more free to turn and toss, and to make use of that which is so delivered to more several purposes and applications. For we see all the ancient wisdom and science was wont to be delivered in that form; as may be seen by the parables of Solomon, and by the aphorisms of Hippocrates, and the moral verses of Theogonis and Phocylides: but chiefly the precedent of the civil law, which hath taken the same course with their rules, did confirm me in my opinion.[21]

3. GENERATIVE POWER OF AXIOMS AND THE THEORY OF TRUTH

The other important thing about *philosophia prima* is the way in which we are to understand Bacon's claim that it is the "mother of all sciences", a universal wisdom, or sapience, from where all other sciences spring like branches from a tree.

> *[…] constituatur una Scientia Universalia, quae sit mater reliquarium, et habeatur in progressu doctrinarum tanquam portie viae communis antequam viae se separent et disjugant. Hanc Scientiam Philosophiae Primae, sive etiam Sapientiae (quae olim rerum divinarum atque humanarum scientia definiebatur nomine insignimus).*[22]

Bacon understands here the tree model quite literally: he claims that there is an organic unity of knowledge, an inseparability of domains, again, from the perspective of the inquirer of nature who is searching for the truth of the sciences[23]. It is not a merely methodological, but also a metaphysical unity; the tree of the sciences corresponds to a similar order pattern of nature. Sciences are said to communicate and corroborate each other, to feed from each other and be in a permanent, true communion with each other. There are "true communities" between sciences[24], "affinity and

[21] Francis Bacon, *The Works of Francis Bacon*, 14 vols. (London, 1859–1874), VII, 321. Hereafter SEH.

[22] *De augmentis scientiarum*, SEH I, 540.

[23] "And, generally let this be a rule, that all partitions of knowledges be accepted rather for lines and veins, than for sections and separations; and that the continuance and entireness of knowledge be preserved. For the contrary hereof hath made particular sciences to become barren, shallow and erroneous; while they have not been nourished from the common fountain." (Bacon, *Of the Advancement and Proficience of Learning, or the Partitions of Sciences IX bookes … Interpreted by Gilbert Wats*. This is incidentally a quotation of Seneca's *Epistle 89*, as clearly identified by Gilbert Wats, *Ibid*., p. 178).

[24] *Valerius Terminus*, SEH III, 234.

consent"[25] between sciences, due to the fact that all knowledge bears the marks of common "seals of nature"[26]:

> Neither are all these whereof we have spoken, and others like nature mere similitudes only, as men of narrow observation perchance may conceive; *but one and the very same footsteps, and seales of nature, printed upon severall subjects or matters*.[27]

Thus, determining common axioms of the sciences is equivalent with determining common laws of nature. To continue in Bacon's terms, the axioms/principles/laws will be the intersections of the branches, points from which secondary branches are growing, equivalent to the footsteps & seals of Nature. This way of looking at things was, according to Bacon, a feature of the "Persian magic":

> And indeed, the Persian Magique, so much celebrated, consists chiefly in this; to observe the respondency in the architectures, and Fabriques of things Naturall, and of things Civile.[28]

The Persian magic, according to Bacon, had the special skill to determine the inflexion points and the generative points in the two architectonics: the structure of axioms, rules and principles constitutive for the sciences and the "architecture" and fabric of nature, including its laws[29]. Similarly, the experimental inquirer has to observe such points of generation from which sciences can grow (hoping that they correspond to generative principles and laws of nature). By extension, the generative relation is ascribed to sciences per se. Thus, philosophia prima is the root, or the mother of all sciences.

But because the distributions and partitions of knowledge are not like several lines that meet in one angle, and so touch but in a point; but are like branches of a tree that meet in a stem, which hath a dimension and quantity of entireness and continuance, before it come to discontinue and break itself into arms and bought; therefore it is good, before we enter into the former distribution, to erect and constitute one universal science, by the name of *philosophia prima*, primitive or summary philosophy, as the main and common way, before we come to the ways part and divide themselves[30].

[25] Bacon's favourite example is Persian magic: "an observation of the contemplation of nature and the application thereof to a sense politic; taking the fundamental laws of nature, with the branches and passages of them, as an original and first model, whence to take and describe a copy and imitation for government", WFB, 10, 90. The possibility of founding a government mirroring the government of the natural world is founded on the imprints of a fundamental "law of nature", SEH X, 91.

[26] Also, NO, II, 27. OFB XI 290–291.

[27] Bacon, *Of the Advancement and Proficience of Learning, or the Partitions of Sciences IX bookes … Interpreted by Gilbert Wats*, p. 135.

[28] *Ibid*.

[29] It is worth noting that in the passages on the Persian magic we find most of the occurrence of the term law of nature. See "Persian magic": "an observation of the contemplation of nature and the application thereof to a sense politic; taking the fundamental laws of nature, with the branches and passages of them, as an original and first model, whence to take and describe a copy and imitation for government" (SEH, 10, 90).

[30] *Valerius Terminus*, SEH III, 363.

On the other hand, in the *Novum Organum*, the same generative metaphor is applied to natural philosophy. This time, natural philosophy is said to be "the great mother of the sciences" and the very root of the tree. The uninterrupted flow of axioms from it towards the particular sciences is seen as the very key to the advancement of knowledge; namely that

> […] natural philosophy be carried on and applied to particular sciences, and particular sciences be carried back again to natural philosophy[31].

In *Valerius Terminus*, for explaining this continuous dependency of sciences one upon another and their relations with philosophia prima, Bacon borrows and redefines a traditional phrase, the "circle learning". The circle learning is more than the chains of sciences linked together.

> For I mean not that use which one science hath of another for ornament or help in practice, as the orator hath of knowledge of affections for moving, or as military science may have use of geometry for fortifications; but I mean it directly of that use by way of supply of light and information which the particulars and instances of one science in their very truth and notion.[32]

In fact, as it becomes clear from Bacon's examples, there are two instances of this "circle learning"; one involves checking the sciences one against the other so that we can falsify theories that do not stand the check. In *Valerius Terminus* Bacon points to moral and natural philosophy: the moral philosophers have used all their skills in debating all sorts of definitions of highest good and virtue instead of using natural philosophy to understand the natural tendencies of all bodies whatsoever and define their notions in accordance with the truth of things[33]. The other instance is the appeal to axioms, maxims and principles of higher generality, common to all sciences, like those that are part of philosophia prima. In both cases, however, what we have is a claim that no science can gain autonomy; the internal coherence is no standard of truth. Instead, at all steps, theories should look back not only to "facts" and the nature of things but to the higher generality maxims and axioms (the best example: the principle of "constancy of matter", or conservation) in order to check their possible deviations and errors.

What are these higher order maxims, axioms and principles that are subject to a philosophia prima? In more than one place, Bacon claims that they are scattered fragments of a lost wisdom. We can dig up in ancient fables or indeed in the ancient philosophies (Democritus' philosophy being Bacon's favourite example) elements of this lost wisdom under the format of principles, maxims and axioms of high generality like,

[31] NO, I, 80. OFB XI 126–27.

[32] *Valerius Terminus*, SEH III, 229.

[33] *Valerius Terminus*, SEH III, 234. A similar suggestion in the *De augmentis scientiarum*, book VII, that a culture of the mind should be based on the natural constitution of the mind, on a "theory of mind". See also Stephen Gaukroger, *Francis Bacon and the Transformation of Early Modern Natural Philosophy*, (Cambridge, 2001).

for example, the principle of constancy of matter[34]. We can corroborate them using the Scriptures. But how do we know they are true? Here, I think, is the most interesting aspect of Bacon's organisation of knowledge and to this I will turn in the last section of my paper.

4. SIGNS, PRODUCTIVITY AND A NEW THEORY OF TRUTH

My suggestion is to pause a bit and inquire more seriously on the meaning of Bacon's claim that axioms have a generative power. One can say this in more sense than one. In fact, I would claim that there are three meanings of "generative" at work here.

The first sense in which we can talk about the generative power of axioms is that already discussed, in connection with a theory of teaching and learning. This is a weak sense in which we can say, simply, that principles, maxims and axioms act as seeds or sparks of knowledge, starting a reaction in our mind: it begins with a sense of wonder, continues with curiosity and the desire to learn more, to test and experiment and extend the knowledge so acquired[35].

A second, stronger sense in which we can say that a principle or an axiom has generative power is that in which we see the axiom as generating, by itself, "new particulars"[36] and suggesting new experiments, pointing the way to the emergence of new inquiries, or different domains of knowledge. And this is how I think Bacon means this second sense of "generation". Axioms properly formed/discovered emerge from a serious experimental investigation[37]. And somehow the very sign that we have a "good axiom" is "productivity" – its possibility to engender new experiments and to generate new knowledge. There are places where Bacon seems to affirm that once a good axiom is established, one can begin a new field of inquiry, open the possibility for a new branch of knowledge to grow in the tree of the sciences. This is, for example, the model of the multiplication of mixed mathematics. Bacon claims that once more and

[34] Silvia Manzo has shown how Bacon uses ancient myths and fables and theological interpretation to "uncover" and sustain a principle of constancy of matter. Manzo, "Holy Writ, Mythology, and the Foundations of Francis Bacon's Principle of the Constancy of Matter". On the meaning of Bacon's fables see also G. Giglioni, "*Historia* and *Materia*: The Philosophical Implications of Francis Bacon's Natural History.", in *Early Science and Medicine*, 17, no. 1-2 (2012): 62-86; Guido Giglioni, "Francis Bacon," in *The Oxford Handbook of Brtish Philosophy in the Seventeenth Century*, ed. by Peter Anstey (Oxford, 2013), pp. 41–73.

[35] "But the first and most ancient seekers after truth were wont, with better faith and better fortune, too, to throw the knowledge which they gathered from the contemplation of things, and which they meant to store up for use, into aphorisms: that is, into short and scattered sentences, not linked together by an artificial method; and did not pretend or profess to embrace the entire art.", NO, I, 76. OFB XI 120–21.

[36] "axioms duly and orderly formed from particulars easily discover the way to new particulars, and thus render the sciences active", NO, I, 24, OFB XI 72–73.

[37] *Valerius Terminus*, SEH III, 237; see also *De augmentis scientiarum*, book 3, chapter 4 for the example of formulating the axiom concerning the relation between the mixture of two substances having parts and the production of whiteness; the axiom is formulated after formulating and testing six "directions" and "out of this assertion are satisfied a multitude of effects and observations".

more axioms of natural philosophy will receive quantitative clothes, one can imagine the emergence of new mixed mathematics[38].

In this way, many axioms can be seen as the starting point of new fields of inquiry. From the axioms stating rules for the propagation of sounds one can construct, by analogy with optics (a mixed mathematical science) one can construct a science of sounds (another mixed mathematical science). Or, again, starting from the axiom which affirms that

> […] there is no difference between the consents or sympathies of bodies endowed with sensation and those of inanimate bodies without sensation, except that in the former an animal spirit is added to the body so disposed, but is wanting in the latter.

It follows a whole new field of inquiry – or perhaps even two such inquiries, one into the new senses one can discover in the animal world, and another one on the "perceptive" capacities of inanimate bodies[39].

A third sense of generative is, I think, even more interesting and relates to Bacon's interesting "theory of signs" and the formulation of a new criterion of truth. In one brief paragraph of the *Valerius Terminus*, Bacon sums up all the accepted criteria of truth proposed by philosophers[40], only to reject all of them on the basis that they cannot stand by themselves as the absolute criterion of truth. Instead, he proposes a new criterion of truth

> That the discovery of new works and active directions not known before, is the only trial to be accepted of; and yet not that neither, in case where one particular giveth light to another; but where particulars induce an axiom or observation, which axiom found out discovered and designed new particulars.

What does this mean? This paragraph has been usually interpreted in utilitarian terms[41], usually on the basis of another paragraph of the *Novum organum* where Bacon seems to claim that truth and utility are the same thing[42]. But, in the *Valerius Terminus* Bacon claims explicitly that this is not about utility, or about axioms being profitable.

[38] Dana Jalobeanu,"The marriage of Physics with Mathematics: Francis Bacon on Measurement, Mathematics and the construction of Mathematical Physics", in *The Language of Nature: Reassessing the Mathematization of Natural Philosophy in the Seventeenth century*, eds. Geoffrey Gorham, et al., (2016), pp. 51–81.

[39] NO, II, 25 OFB XI 72–73.

[40] That in deciding and determining the truth of knowledge, men have put themselves upon trials not competent. That Antiquity and authority; common and confessed notions; the natural and yielding consent of the mind; the harmony and coherence of a knowledge in itself; the establishing of principles with the touch and reduction of other propositions unto them; inductions without instances contradictory; and the reports of the sense; are none of them absolute and infallible evidence of truth, and bring no security sufficient for effects and operations. (*Valerius Terminus*, SEH III, 242).

[41] Stephen Gaukroger, *The emergence of a scientific culture: science and the shaping of modernity, 1210–1685*, (Oxford; New York, 2006), pp. 166–167.

[42] As Rossi has shown, the common utilitarian interpretation of truth is based mainly on a stretched (mistaken) translation of NO I, 124. Paolo Rossi, "Bacon's idea of science," in *The Cambridge Companion to Bacon*, ed. by Markku Peltonen (Cambridge, 1996), pp. 25–47. The paragraph is also connected with the productive character of true knowledge: the difference between building up a true model of the universe and

> That the nature of this trial is not only upon the point, whether the knowledge be profitable or no, but even upon the point whether the knowledge be true or no; not because you may always conclude that the Axiom which discovers new instances is true, but contrariwise you may safely conclude that if it discovers not any new instance it is in vain and untrue.[43]

Thus, at least in the *Valerius Terminus*, "productive" does not equal "useful," is "generative" in the sense explained above. And here is where the "doctrine of signs" can help us understand what all this means. The doctrine of signs is introduced quite early by Bacon; it figures prominently in *The Advancement of Learning*; and it is further developed in *Novum organum*. In *AL* "signs" are "signposts" we have to look for when navigating in our search for knowledge. They help us understand (1) why it happened that science and philosophy has not progressed so far; (2) recognizing those fields in which such progress did happen; (3) connect truth, productivity and progress together (as part of a providential history of mankind). The doctrine of sings is said to be useful for two reasons: (a) it leads to and informed assent; (2) helps eradicating the idols. In the *Novum organum*, the doctrine of signs is further developed to give a semiology of types of historical knowledge. Bacon talks much more general of "the signs of truth and soundness in the received philosophies and the sciences" (*vera et sanitatis Philosophiarum & Scientiarum*)[44]. In this context, one of the signs is productivity, an important sign to construct arguments of hope – here the "signs" are taken to be indications that we are on the right track – not only in formulating global theories and maps of knowledge, but also locally, in assessing the power or perfection of an axiom. And this is the context in which productivity is reassessed

> Among the signs none is more certain or noble than that derived from fruits. For the discovery of fruits and works as it were guarantees and underwrites the truth of philosophies [*Fructus enim & Opera inventa, pro veritate Philosophiarum velut sponsores & fideiussores sunt*].[45]

Few interpreters dealt with Bacon's doctrine of signs, and they merely treated it in connection with a psychology of knowledge[46]. But the doctrine of signs is more

building up theories and systems of our own minds (apish images). (The passage in question is the following: "For I am building in the human understanding a true model of the world, such as it is in fact, not such as man's own reason would have it to be; a thing which cannot be done without a very diligent dissection and anatomy of the world. But I say that those foolish and apish images of worlds which the fancies of men have created in philosophical systems, must be utterly scattered to the winds. Be it known then how a vast difference there is between the Idols of the human mind and the Idols of the divine. The former are nothing more than arbitrary abstractions; the later are the creator's own stamp upon creation, impressed and defined in matter by true and exquisite lies. Truth therefore and utility are here the very same things: and works themselves are of a greater value as pledges of truth than as contributing to the comforts of life.", OFB XI 186–7).

[43] SEH III, 242.

[44] NO I 77, OFB XI 122–23.

[45] OFB XI 117.

[46] Stephen Gaukroger, *Francis Bacon and the Transformation of Early Modern Natural Philosophy* (Cambridge, 2001). For a discussion, see Dana Jalobeanu,"Francis Bacon on Sophists, Poets and Other Forms of Self–Deceit (Or, What Can the Experimental Philosopher Learn from a Theoretically Informed

elaborated than that, and can help us understand some of the things we have discussed so far. This is what I think Bacon claims:

(1) That there are seeds of wisdom spread in the world – attainable through the natural exercise of reason. Even animals can sometimes perform good chains of reasoning, reaching to a discovery. Bacon refers repeatedly to the "chance" and "animal instinct" (*instinctum animalium*) as being at the origin of discoveries (and performing much better in producing axioms than the received sciences)[47].
(2) We can recognize these seeds/true axioms by their productivity; a historical investigation of knowledge becomes thus a hunt for true axioms. Bacon contrasts the productivity of axioms with the bareness of speculative sciences and philosophy (books in the libraries)[48].
(3) By way of consequence, we can understand why some philosophies have not progressed – they remained bare (Bacon's favourite examples being the bareness of the speculative philosophers of Greece)[49].

But the most interesting part of this theory of signs is that it helps us understand how literally does Bacon understand the equivalence between truth and productivity and the requirement that axioms are not merely true but also "living" (*Axiomata illa vera & solida & viva* – true, solid and living axioms[50]). It also helps us understand how important is the role of historian to determine the starting points of inquiry; the natural historian has to identify such promising starting points among his observations and experiments; the civil historian or the intellectual historian can also identify such true and living axioms in the works of past philosophers and can make the elements of new experimental inquiries.

5. HOW DO WE TEST PRODUCTIVITY? PROVISIONAL RULES, IMPERFECT AXIOMS AND BACON'S NATURAL HISTORY

But, if all this is so, then the inquirer has the following problem: how to test productivity? One way is to look for past sciences, and consider them to have emerged

History of Philosophy?)", in *Experiment, Speculation and Religion in Early Modern Philosophy*, eds. Alberto Vanzo and Peter R. Anstey (London, 2019), pp. 8–36.

[47] OFB XI 165, 167 for the list of discoveries such as mariner's compass, gunpowder, silk which "were not discovered by philosophy or the rational arts, but by chance and circumstance". In the literature, this was only discussed in relation with Bacon's *sagacitas*. See Rhodri Lewis, "A Kind of Sagacity: Francis Bacon, the *ars memoriae* and the Pursuit of Natural Knowledge", in *Intellectual History Review*, 19 (2009): 155–177.

[48] OFB XI 137. See also Dana Jalobeanu, "Francis Bacon on Sophists, Poets and Other Forms of Self-Deceit (Or, What Can the Experimental Philosopher Learn from a Theoretically Informed History of Philosophy?)".

[49] Francis Bacon and Benjamin Farrington, *The Philosophy of Francis Bacon. An essay on its development from 1603 to 1609 with new translations of fundamental texts* (Liverpool, 1964); Dana Jalobeanu, "Francis Bacon on Sophists, Poets and Other Forms of Self-Deceit (Or, What Can the Experimental Philosopher Learn from a Theoretically Informed History of Philosophy?)".

[50] OFB XI 161.

from productive axioms. How about new sciences? Or lost sciences? This is the sense in which, I think, Bacon developed in his late works a whole theory of imperfect axioms and provisional rules, together with the new vocabulary we have already seen. However, it is not easy to say when an axiom is productive in experimental context. And it is also clear that productivity does not have a yes/no answer but comes in degree – some of our provisional axioms (hypotheses) are more productive, some are less. In this sense, Bacon's concept of imperfect axioms makes sense. And, so does the idea that some of our axioms are simply wrong; and those that are right (or perhaps true?) are only partial. One can imagine ways of perfecting the axioms at the end of more experimental investigations. One can also think of a criterion to arrange axioms in a system in terms of their productivity. The more general, more productive axioms are those which generate more experiments, or experiments in many different fields, advancing the inquiry. The less general, less productive are the more specific axioms, governing a particular class of phenomena. But this is just a provisional classification, like all Bacon's attempts to classify the elements of the sciences.

CONCLUSION

One of the principal causes of confusion when one reads Bacon comes from the fact that the two stages in the development of science are not always clearly distinguished in his works. We need to imagine, each time when Bacon talks about *scientia* and *knowledge* that there are two kinds of science. An initial, provisional and historical stage of the development of *scientia* – and this is the stage in which we all are. In this stage the inquirer is an explorer of nature, works by *indicia* and attempts to find and test potentially productive imperfect axioms[51]. Progress in this stage depends on adopting good provisional rules and organizing properly the resulting natural histories. A second stage is that (not achieved so far) in which some sciences reach completitude, axioms and terms are properly formed and sciences are deductively arranged, starting from first principles. In this stage, the criterion of generative power does not matter anymore – which makes one wonder whether in this stage, and by analysing the corpus of axioms constitutive for a science, it is not the moment when the natural philosopher can start spotting a particular type of axiom/rule which is very much like some of the modern laws of nature. These are the axioms governing the collaboration, ascendency and hierarchy of powers and virtues in Bacon's universe.

We do find in Bacon sentences which seem to substantiate such an interpretation. Such is, for example,

> That everything in nature, although it has his private and particular affection and appetite, and doth follow and pursue the same in small moments, and when it is

[51] See also Dana Jalobeanu, "Francis Bacon on Sophists, Poets and Other Forms of Self–Deceit (Or, What Can the Experimental Philosopher Learn from a Theoretically Informed History of Philosophy?)".

> delivered and free from more general and common respects, yet nevertheless when there is in question or case for sustaining of the more general, they forsake their own particularities and proprieties, and attend and conspire to uphold the public.[52]

This is an expression of a very general rule or axiom or law of the common good. We can find it introduced among the fundamental principles of the *philosophia prima*, in the *De augmentis scientiarum*. We can also find it in action here and there where Bacon has to estimate the relative power of different virtues and the ways they "come together" in particular cases.

Thus

> *Quod conservativum est Formae majoris, id activitate potentius* [Whatever is preservative of a greater Form is more powerful in action],
>
> or
>
> *Augetur vis agentis per antiperistasin contrarii* [The force of an agent is increased by a reaction to the contrary].

Such rules are saying something interesting both about the *scientia* Bacon aims to construct and about the kind of universe he is investigating. And in this sense, they also seem to prefigure a modern concept of laws of nature.

[52] SEH X 91.