REGULA SOCRATIS:

THE REDISCOVERY OF ANCIENT INDUCTION

IN EARLY MODERN ENGLAND

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Abstract

The influence of Sir Francis Bacon on early modern science is widely recognized. His ideas regarding the utility of knowledge, value of observation, and benefits of cooperative research were widely adopted in the seventeenth century. But Bacon believed his chief contribution to the reform of knowledge was not these, but rather his proposal for a new kind of inductive reasoning. His theory of induction, however, is generally not thought to have had significant direct influence on subsequent developments in science. I argue in this dissertation, based on close reading of the relevant texts, that the conventional assessment is hampered by an inadequate understanding of Baconian induction, and that this misunderstanding can be corrected by considering Bacon's proposal in the historical context in which it was presented.

Bacon's treatise on induction, the *Novum Organum*, was meant as an alternative to Aristotle's *Organon*. The dissertation therefore begins by examining Aristotle's views on induction. I propose a significant revision to the received interpretation of Aristotle's position. I then argue that my interpretation was conventional until late antiquity when it was altered by Neoplatonic writers. The dissertation traces the transmission of the Neoplatonic interpretation through the major Islamic and Latin commentators. During the Renaissance, some humanist

scholars realized that the scholastic interpretation of induction differed from that common in antiquity, and a debate ensued about its nature. One chapter here examines the contributions to that debate by four late sixteenth-century thinkers, Jacopo Zabarella, Everard Digby, William Temple, and John Case. Bacon's proposal for a new kind of induction is then examined in the context of the contemporary and historical background. I argue that although Bacon's theory of induction is more systematic than any that had gone before, it was in a sense a return to induction as it was understood in antiquity. In the final chapter, I argue that the work of William Harvey and Robert Boyle were good examples of Baconian induction in practice.

I conclude that Bacon's induction, and not only his general vision for reform, was well understood and in fact used by important seventeenth century scientists.

Acknowledgements

It is right that the last words written on this project should appear not at the end but at the beginning. Only in hindsight can one fully appreciate the help that others have given—how an early comment yielded late dividends, how mistakes and misdirections that could have been embarrassing were corrected with timeliness and grace, how someone doing a job better than it needed to be done saved months of research, how daily enthusiasm and support made a long-term difference. Considering the project from this vantage point, it is clear that thanking those who have helped is a matter of urgency.

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The ability and willingness of Lynn Kaiser and Linda Huynh to keep me on the road, help me over speed bumps, and get me around obstacles is greatly appreciated as is the assistance and courtesies I have received from rare-book librarians at the Huntington Library, Stanford University, University of Cambridge, the University of Oxford, the University of Newcastle upon Tyne, Yale University, Claremont Colleges, the University of Texas at Austin, and Bryn Athyn College.

Loving thanks go to my wife, Char. Since she first stoked my interest in history years ago, Char's enthusiasm for my study in the field has been unwavering. I particularly appreciate the support she gave me when writing of the dissertation

must have appeared oddly bereft of any actual writing and was taking longer than I suggested it might. Char constantly inspired me to keep the pace and has been understanding when that required time apart. That time apart has been one unenjoyable part of the project.

Notes on Typography, Translations, and Terminology

This project relies heavily on a close, careful, and contextualized reading of texts, and presentation of its argument demands typographical care. American style guidelines allow the use of quotation marks and italics for multiple purposes, and following these guidelines can lead to important and misleading ambiguities. Consequently, the following practices have been adopted.

Besides the names of journal articles and book sections, double quotation marks are used only for verbatim excerpts or translations thereof. All double-quoted material has its source cited. Citations are primarily to original publications, rather than later collected editions, especially in the case of books published in England before 1700, as these are now readily available on-line.[1] Translators and alterations of translations are identified in footnotes. Original-language source material is reproduced in footnotes, except for Greek passages from Aristotle and Plato for which Greek texts are readily available, for Arabic passages, and for a few other passages. Bekker numbers are provided for Aristotelian passages, Stephanus numbers for Plato. With Aristotle and Plato, I have taken the liberty of using

[1] *Early English Books Online*, http://eebo.chadwyck.com.

different translations for different passages, choosing the one I believe presents the relevant idea most clearly for a given context.

Single quotation marks are used for terms or phrases that have a technical or distinctive use by an author or authors but for which no specific passage is being cited. For example,

> Digby deduced his conclusion from a 'clear and distinct' idea.
>
> Bacon discussed four types of 'idols.'

In such uses, the marks indicate that the author under discussion is using the term (or the term from which the quoted term is a translation) in a distinctive way, not that I am. I do not introduce any scare quotes (single or double) of my own. Single quotation marks are also used for definitions (unless being quoted verbatim from a cited dictionary or a cited author). For example,

> The term came to mean 'the essence of.'

In these, cases, the definitions are my own. (If not, they are set in double quotation marks and cited.) Single quotations marks are also used for quotations within quotations, according to standard practice.

Italics are used when a word or phrase is functioning as a term or concept.

> We seek to understand what is meant by *induction*.

This may be read

> We seek to understand what is meant by the term *induction*.

or

> We seek to understand what is meant by the concept *induction*.

When both italics and single quotations marks could be justified by these rules, only the italics will be used.

> Cicero used the term *inductio* for Aristotle's *epagōgē*.

Italics are also used occasionally for emphasis and, of course, for book titles.

Non-English words are not by virtue of being non-English typographically distinguished, but are frequently set in single quotation marks for reasons above. For example

> For Nifo, induction is a manner of speaking (oratio).
>
> A principle true per se is also true de omni.

but

> Bacon surveyed four types of 'idols,' or 'idola.'
>
> Aristotle believed the 'archai' of science are developed from experience.

As here and above, Greek is transliterated into Latin characters unless quoted from Latin sources in which the Greek was printed as such.

I do not consider *natural philosophy* and *science* (and their corresponding derivatives) interchangeable. One is not simply the old term and the other the new. Francis Bacon used both terms, and so will I. Without trying to state definitions for each that apply across all periods (which I am not convinced is possible), I will simply try to use the term I think appropriate for the context. By that rule, *natural philosophy* will be the much more common term.

Contents

Introduction

Yes, We Use Induction:

A Problem of Meaning

In 1654, John Webster, a provincial English minister and schoolmaster with no known university experience, published an attack on university teaching. He called on the faculties of Cambridge and Oxford to reject centuries-old scholasticism and begin teaching the method of induction proposed earlier in the century by Sir Francis Bacon.[1] Webster's attack drew a sharp response from two Oxford faculty members, John Wilkins, Warden of Wadham College, and Seth Ward, Savilian Professor of Astronomy.[2] Unlike Webster, both were active members in England's major scientific, academic, religious, and political communities. Both were accomplished natural philosophers, and both would later be founders of the Royal

[1] John Webster, *Academiarum examen, or, The examination of academies wherein is discussed and examined the matter, method and customes of academick and scholastick learning, and the insufficiency thereof discovered and laid open.* (London: Giles Calvert, 1654), 32–40.

[2] The relevant documents with an introductory essay that cites previous discussions on this debate appear in Allen G. Debus, *Science and Education in the Seventeenth Century: The Webster-Ward Debate* (New York: Neale Watson Academic Publications, 1970).

Society. The theme and tone of their rebuttal were that Webster did not know what he was talking about, regarding what was indeed taught at Oxford and even regarding how to properly use the inductive method. They insisted that Baconian induction was taught at Oxford and that they and their colleagues—and not this provincial schoolteacher—were on the forefront of Baconian inductive science.[3]

We would like to know if Wilkins' and Ward's claim was true. Were students in Oxford learning Bacon's induction? We would like to know because Wilkins, Ward, and their colleagues and students went on to exert such remarkable influence on early modern natural philosophy in England. Were they using Bacon's induction? They certainly claimed they were, but there are reasons to doubt that they meant that literally. Bacon's *Advancement of Learning* had inspired a generation of reformers. At a time in England when reforms of secular learning were still held in suspicion, he defended such reforms against those who saw a threat to king and country. Webster, Wilkins, and Ward were all members of that generation and

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[3] Seth Ward and John Wilkins, *Vindiciae academiarum containing briefe animadversions upon Mr Websters book.* (Oxford: Leonard Lichfield for Thomas Robinson, 1654), 25, 45, 46, 49. On Wilkins's remarkable influence and career—in science, academia, religion, and politics—see Barbara J. Shapiro, *John Wilkins, 1614–1672: An Intellectual Biography* (Berkeley and Los Angeles: University of California Press, 1969). Ward was an accomplished mathematician and astronomer, the first to teach the Copernican system at Oxford. He made influential advances on Kepler's laws. He was elected president of Trinity College in 1659. He resigned his astronomy post in 1660 and became Bishop of Exeter in 1662. Though an active member of the Royal Society in the 1660s, he made no more major scientific contributions and spent the rest of his career as a very capable church administrator. There is no full treatment of his life. John Henry, "Ward, Seth (1617–1689)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

shared an enthusiasm for new learning. But academics such as Wilkins and Ward need not have extended that enthusiasm to Bacon's whole methodological proposal.

Though Bacon had written a proposal for a new kind of induction, he was not after all an accomplished natural philosopher or trained academic. Wilkins and Ward, on the other hand, were establishment academicians, reared in the scholastic culture of university disputations and trained in the technical details of Aristotelian logic. Of course they would say that they taught induction. Any professor of logic anywhere in Europe would have said the same, for induction had been a stock part of the Aristotelian natural philosophy curriculum for centuries. It appeared in all introductory logic textbooks right after discussion of the syllogism. Did Wilkins and Ward really mean that they taught *Bacon's* induction? One of their colleagues, Savilian Professor of Geometry at Oxford, perhaps the most talented English mathematician before Isaac Newton, and one of the central figures of the early Royal Society, John Wallis, wrote a thoroughly conventional, non-Baconian treatment of induction in a logic textbook he published in 1687.[4] Did his colleagues in the Royal Society really mean by induction the procedure that Bacon advanced in his treatise on the subject?

One reason to doubt it is that Wallis and his fellows were remarkably successful natural philosophers, and as modern philosophers of science regularly point out, Bacon's induction—in all the technical details he proposed it—simply

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[4] John Wallis, *Institutio logicae ad communes usus accommodata* (London: 1687), bk. 3, chap. 15, pp. 167–72.

does not work. In 1877, Charles Peirce wrote how "a modern reader is struck by the inadequacy of his [Bacon's] view on scientific procedure."[5] Morris Cohen famously wrote in 1926 of the "utter irrelevance of Bacon's ideas to the actual progress of science." He claimed, "There is . . . not a single authenticated record of any one ever making any important discovery in science by following Bacon's method and its mechanical tables and twenty-seven prerogative instances."[6] This assessment remains essentially unchallenged. Thus, it seems, the remarkable accomplishments of seventeenth-century natural philosophers could not have come from use of Bacon's induction and when Wilkins, Ward, and the others said they were teaching or using induction, they must have meant something else.

Though Bacon liked to call his philosophy one of induction, his treatise on induction per se, *Novum Organum* (*New Organon*, 1620), is a small fraction of his output. Much of the rest of his writings and the more popular parts of them, from the *Advancement of Learning* (1605) to the *New Atlantis* (published posthumously in 1627), are non-technical calls for a new prosperity based on voluminous empirical observations, peaceful collaboration, and a rejection of past authorities. One could be a committed Baconian without being an adept in the details of Bacon's seemingly idiosyncratic method of induction.

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[5] Charles Peirce, "Fixation of Belief," *Popular Science Monthly* 12 (1877): §2.

[6] Morris R. Cohen, "The Myth about Bacon and the Inductive Method," *The Scientific Monthly* 23 (1926): 506, 507.

The concept of induction has a long history. It goes back to Aristotle who said he got it from Socrates. The idea was discussed in late antiquity, got transmitted to Europe by both Latin and Arabic writers, became a topic of contention and confusion in the Renaissance, was venerated in Restoration England, and became positively fashionable in the Enlightenment. But it is not clear which, if any, of these groups were talking about the same thing. And the problem did not stop. It is now conventional wisdom that in the eighteenth century, the Scottish philosopher David Hume unanswerably refuted the validity of induction.[7] Yet Hume would hardly recognize the claim, for he himself never wrote against what he knew by the term *induction*, he claimed to be using Bacon's method, and he even appealed to induction to defend his own arguments. Whatever we think Hume refuted is not what in his day went by the name *induction*. If we are going to see a central role for induction in the history of science, and historians of science rightly do, we need to understand what the idea meant to people in the past. Figuring that out, at least up until the period of the early Royal Society, is the project for this dissertation.

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[7] For informed introductions to the Humean criticism and attempts to skirt it, see John Earman and Wesley C. Salmon, "The Confirmation of Scientific Hypotheses," in *Introduction to the Philosophy of Science*, ed. Merrilee H. Salmon, et al. (Indianapolis and Cambridge: Hackett, 1992), 55–66; Martin Curd and J. A. Cover, eds., *Philosphy of Science: The Central Issues* (New York: W. W. Norton, 1998), 409–547; and Ian Hacking, *An Introduction to Probability and Inductive Logic* (Cambridge: Cambridge University Press, 2001), 247–55.

In a sense this study joins other recent research on ideas fundamental to early modern science, ideas such as *fact* or *experiment*.[8] But in another way, this project is very different. It is necessarily much more technical. Wilkins and Ward and their fellow Royal Society members—and Bacon himself—knew induction as a subject that appeared in logic textbooks beside now unfamiliar topics such as enthymeme and the syllogistic forms of Barbara, Celarent, and Darapti.[9] Bacon, though a government official and not a university professor, began his treatise with a discussion involving such technical topics as major premises, minor premises, and redargutions.[10] In short, the *New Organon* presupposes familiarity with the old *Organon*, that is, the collection of books that together describe Aristotle's system of logic. To reconstruct the context for the debate between Webster and the Oxford natural philosophers, we have to immerse ourselves in technical subject matter and vocabulary that they and their colleagues shared and that draw on discussions about

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[8] E.g., Lorraine Daston, "Baconian Facts, Academic Civility and the Prehistory of Objectivity," *Annals of Scholarship* (1991): 337–63; Barbara Shapiro, *A Culture of Fact: England, 1550–1720* (Ithaca and London: Cornell University Press, 2000); Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago and London: University of Chicago Press, 1995).

[9] An enthymeme is a syllogism in which one of the premises is left unstated. Barbara, Celarent and Darapti are mnemonic names for types of syllogisms. 'All A is B; all B is C; therefore all A is C,' for example, is a syllogism of form Barbara. 'All A is B; some B are C; therefore some A are C' is of the form Celarent.

[10] The roles of major and minor premises in deductions and inductions will be discussed at length. Redargutions are refutations of sophistical arguments.

induction that go back to Aristotle. The necessary background will be introduced as we proceed.

In the late sixteenth and early seventeenth century, Aristotle's *Organon* was still a best-seller. We judge a sixteenth-century textbook to be popular and influential if it went through twenty or thirty printings, fifty if it was extremely popular. But Renaissance editions of Aristotle's logic works number in the hundreds. Virtually every man involved with early modern natural philosophy would have first met induction in an introductory textbook on Aristotelian logic. The better read would then have met it again in the *Organon* and other Aristotelian works. The most astute would have sensed a conflict between what Aristotle said and what the textbooks claimed Aristotle said. This conflict first became evident on the continent during the fifteenth and sixteenth centuries. Whereas Aristotle had said that what induction is is obvious, by the 1540s, the Aristotelian commentator, Agostino Nifo, could say that there is much confusion over what induction is. This confusion is the background to a series of proposals and debates among Aristotelians in the last quarter of the sixteenth century. It was into the aftermath of these discussions that Bacon proposed his new kind of induction in 1620. Any educated natural philosopher of the mid-seventeenth century, even if he did not have advanced training in scholastic logic per se, would have known of the scholastic background to Bacon's proposal. He could not have read the *Novum Organum* without noticing it.

We, on the other hand, might. The scholastic language of the late Renaissance is now unfamiliar to us, the debates of the 1580s forgotten. It is easy for us now—as it was perhaps as early as the eighteenth century—to view Baconian induction as a general preference for observation and experiment over the dictates of past authorities. But it was proposed as something much more specific, something that could challenge the chapter on induction in all those medieval and Renaissance textbooks. It is the goal of this dissertation to understand Baconian induction, its genesis, and its adoption against that background.

To do so requires an unusually long time horizon. Bacon cast his proposal as an alternative to Aristotle's. Bacon named his book a new *Organon*, after Aristotle's work of that name. In Bacon's day, the Roman Cicero was still the preeminent author of humanist study and he, too, had important things to say on induction. Moreover, the ancient ideas were not presented unfiltered, but interpreted by a long line of commentators. The important Alexandrian commentators of late antiquity were reaching Latin readers for the first time in the sixteenth century and important volumes of their works emerged from the presses in the 1590s. Availability of Aristotle and Plato in the original Greek was increasing. In the bookshops of Bacon's formative years, Aristotle, Cicero, Boethius, Philoponus, Avicenna, Buridan, and Zabarella lived side by side.

The historian of an idea has two options. The first is to look for instances of the idea regardless of the name by which it was known, studying, for example, the concept of a scientist throughout history, even though the word *scientist* is a recent invention. This approach runs the anachronistic risk of projecting our modern ways of thinking into the past. The second approach is to follow the history of a word and trace its conceptual evolution. This approach can make the historian blind to conceptual changes developing under a different vocabulary, but can help us better understand the way people of the past actually organized their thoughts. Historians of induction typically adopt the first approach.[11] They presume that induction is about knowing whether the next swan will be white, whether a black raven confirms the theory that all ravens are black, whether and with what degree of confidence we are justified in believing the sun will rise tomorrow or a drug will always cure a disease. They then go looking for instances of similar topics. By this method historians and philosophers conclude, for example, that David Hume was the central figure in the modern history of induction since he wrote about whether

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[11] There have been few such historians. Reference is often made to the final chapter, "Induction," in Ian Hacking, *The Emergence of Probability: A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference* (Cambridge: Cambridge University Press, 1975), 176–185, but this is an example of the first approach. Hacking accepts that his task is to consider the history of what is now called the Humean problem of induction. J. R. Milton, "Induction before Hume," *British Journal for the Philosophy of Science* 38, no. 1 (1987): 49–74, does the same, though with some sensitivity to the shortcomings of the approach. The chapter "Induction in Early Modern Europe" in Dear, *Discipline and Experience* draws on these two earlier studies. In remarks about a scientist for whom induction was a big concern, David L. Hull, *Darwin and His Critics: The Reception of Darwin's Theory of Evolution by the Scientific Community* (Cambridge, MA: Harvard University Press, 1973), 19, defends the first approach. Comments on the history of induction most frequently occur when an editor or commentator remarks that *induction* as used by a writer under consideration should not be taken to mean what *induction* means today. I know of no history of induction like that attempted here.

we can logically expect the next billiard ball to behave like the last.[12] But as mentioned, even though *induction* was a common word in Hume's day, he did not use the word to describe these issues. This dissertation embraces the alternate approach of following a word. This approach that can be particularly rewarding when the word survives as long as *induction* has. Modern languages all use a vernacular version of the Latin *inductio*, which Cicero invented to translate Aristotle's *epagōgē*. The pedigree is direct and unbroken. This essay will not go looking for our modern notion of induction by whatever name it was known, but will concentrate on how that word was actually used and understood.

The dissertation contains five chapters. The first two address the ancient background. Understanding Aristotle's idea of induction and how that idea was modified and transmitted to early modern natural philosophy is important for understanding the early modern context. The first chapter offers what may be the first-ever complete survey of *induction*, or *epagōgē*, in the Aristotelian corpus in an effort to understand what Aristotle meant by the term. Attention is usually concentrated on Aristotle's one chapter dedicated to induction, *Prior Analytics* 2.23. But this passage, as conventionally understood, is inconsistent with virtually everything else Aristotle says about induction. I will conclude the first chapter by arguing that the conventional understanding of that famous passage is incorrect.

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[12] The well-known and oft-cited example of the billiard ball appears in David Hume, *An abstract of a book lately published entituled A treatise of human nature & c* (London: C. Borbet, 1740), ¶9; David Hume, *A Treatise of Human Nature*, ed. David Fate Norton and Mary J. Norton (Oxford: Oxford University Press, 2000), 409.

The conventional understanding dates to late antiquity. The dissertation's second chapter traces the history of the concept of induction (what little of it is knowable) from Aristotle to the Neoplatonic commentators on Aristotle in Alexandria around 500 A.D. It describes their reinterpretation of *Prior Analytics* 2.23, their elevation of that passage to prominence, and the transmission of their interpretation into and through both Latin and Arabic commentary. It concludes with a look at the conflict that began during the Renaissance when Aristotle's contrasting comments on induction came to be noticed.

Once the medieval consensus collapsed, alternative understandings of induction emerged and were debated. Chapter 3 considers four of them, starting with that of Jacopo Zabarella. (1533–1589). Following the work of John Herman Randall in the mid-twentieth century, it has been widely believed that Zabarella made an important contribution to induction theory with his doctrine of 'regressus.' Using a close reading of Zabarella's texts, this widely held view is refuted. The work of three English writers, Everard Digby (c.1551–1605), William Temple (1555-1627), and John Case (1539/40?–1599) is then examined. Digby and Temple were on two sides of a pamphlet war in the 1570s in which they debated proper methods of teaching. For several reasons, including the fact that Bacon was a student at Cambridge in the early 1570s, it has been speculated that the debate may have had an influence on Bacon. The debate is here re-examined in light of Digby's little studied *Theoria Analytica* (1579). John Case is representative of the Aristotelian scholarship that thrived in the last two decades of the sixteenth century. He is important in the history of induction because in his writings, we find the first use of the concept *idol*, used in the distinctive way that Bacon famously used it.

The final two chapters concentrate on the early seventeenth century. Chapter 4 seeks a full reexamination of Baconian induction in light of the Aristotelian context in which it was developed. The proposal is made that Bacon was reviving Aristotelian induction, properly understood—that is, as it was understood before the reinterpretation of late antiquity. Bacon held that the only past view of induction close to his own was that of Socrates, and I will have argued in chapter 1 that Aristotle thought the same of his own. Bacon's induction is thus both new and old, a systematization and codification of the ancient induction of Socrates and Aristotle. Chapter 5 examines three scientific projects of the early and mid-seventeenth century, Bacon's own scientific work, that of the famously Aristotelian William Harvey (1578–1657) and that of Robert Boyle (1627–1691). It will be argued that all three are excellent examples in practice of Baconian induction, rigorously understood.

The period may seem overly long. Is it really necessary to review the whole history of induction just to understand what men of the seventeenth century thought it was? Indeed it is, for though the writers of the past were long dead, their writings were very much alive in Renaissance and Restoration England. The best way to sort out the disagreements between all the works by which Bacon, Wilkins, Ward, Harvey, or Boyle would have learned about induction is to analyze them historically. In the end we will find that at least some of those Oxford natural philosophers understood Bacon's induction in the full sophisticated way Bacon intended it, and that Wilkins and Ward knew what they were talking about when they said that Bacon's induction was being taught at Oxford.

This conclusion may help us reassess the relative influence of Bacon's induction on early modern natural philosophy. Scholars have been limited by not approaching Bacon's induction as Bacon's expected it to be. This dissertation is a contribution toward overcoming that limitation.

1

Induction is Obvious:
Aristotle's Adoption of Socrates' Invention

Modern scholars have struggled to understand what Aristotle meant by *epagōgē*, or as we know it from the Latin-derived cognate, *induction*. He appears to say that induction is the opposite of deduction and elsewhere that it is a kind of deduction, that it is the process for forming universal propositions and elsewhere that it is the process for forming concepts, that it has inferential force and elsewhere that it does not. If there has been anything like a modern consensus it is that Aristotle has two conflicting views. One is that induction is a kind of deductive argument that proceeds by complete enumeration. If, for example, one wants to ascertain that something is true of all the planets, one must confirm that it is true for each planet individually. If the enumeration is not complete, the conclusion cannot be certain. Justification of this interpretation of Aristotelian induction is found in Aristotle's only one chapter dedicated to induction, *Prior Analytics* 2.23. Aristotle's other view has something to do with coming to hold universal concepts based on the experience of particulars. Exactly what is debated. Primary support for this view is found in *Posterior Analytics* 2.19. In the late twentieth century, there has been no stable interpretation that reconciles these two views.[1]

As we will see in the chapters ahead, the modern interpretations of Aristotelian induction are not the same as those of the past. Past interpretations have swung between the two modern views. At times a conflict between them was recognized. At other times one prevailed to the virtual exclusion of the other. In yet other times, as in Francis Bacon's formative years, different groups of Aristotelians adopted different interpretations. I used to believe that for understanding the

[1] In twentieth-century examinations of Aristotelian induction, W. D. Ross, "Commentary," in *Aristotle's Prior and Posterior Analytics* (Oxford: Oxford University Press, 1949), 47–51, 481–487, has been influential. The influence can be seen, for example, in the recent edition, Aristotle, *Prior Analytics*, trans. Robin Smith (Indianapolis and Cambridge: Hackett, 1989), 219–221. Recent research includes Kurt von Fritz, *Die epagōgē bei Aristoteles* (München: Verlag der Bayerischen Akademie der Wissenschaften, 1964); Walter Hess, "Erfahrung und Intuition bei Aristoteles," *Phronesis* 15 (1970): 49–50; Nelly Tsouyopoulus, "Die induktive Methode und das Induktionsproblem in der griechischen Philosophie," *Zeitschrift für allgemeine Wissenschaftstheorie* 5 (1974): 94–122; D. W. Hamlyn, "Aristotelian Epagoge," *Phronesis* 21 (1976): 167–84; T. Engberg-Pedersen, "More on Aristotelian Epagoge," *Phronesis* 24 (1979): 301–19; Jaakko Hintikka, "Aristotelian Induction," *Revue Internationale de Philosophie* 34 (1980): 422–39; Thomas Upton, "A Note on Aristotelian *Epagōgē*," *Phronesis* 226 (1981): 172–76; Richard McKirahan, Jr., "Aristotelian Epagoge in *Prior Analytics* 2.21 and *Posterior Analytics* 1.1," *Journal of the History of Philosophy* 21 (1983): 1–13; Terence Irwin, *Aristotle's First Principles* (Oxford: Clarendon Press, 1988), 32–33; Simo Knuuttila, "Remarks on Induction in Aristotle's Dialectic and Rhetoric," *Revue Internationale de Philosophie* 47 (1993): 78–88; Ilkka Niiniluoto, "Hintikka and Whewell on Aristotelian Induction," *Grazer Philosophische Studien* 49 (1994/95): 49–61; Greg Bayer, "Coming to Know Principles in *Posterior Analytics* II 19," *Apeiron* 30 (1997): 109–42. Of these, the Finnish scholars draw conclusions closest to mine, though by different means. All the attempts to grant priority to the second view remain constrained by the conventional interpretation of *Prior Analytics* 2.23. I below propose an alternative interpretation that removes that constraint.

history of early modern induction it was not crucial to understand what Aristotle wrote on the subject, only what early modern writers thought Aristotle wrote on the subject. I have since changed my mind, for I found it increasingly difficult to understand early moderns thinkers without understanding Aristotle himself and the relevant background, if any can be known, in which he developed his theory. Virtually all early modern commentators, Bacon included, present their understanding of induction with reference to Aristotle, even when they disagree with one another. To understand the positions for which they seek Aristotle's authority, we must understand Aristotle.

The following analysis takes a fresh look at Aristotelian induction with several methodological principles in mind:

(1) Take the easy cases first and leave the difficult ones for later. Throughout the history of commentary on Aristotelian induction, the two chapters mentioned above, *Prior Analytics* 2.23 and *Posterior Analytics* 2.19, have attracted the most, sometimes even exclusive, attention. Both passages are difficult. Both seem to contradict themselves, each other, and other passages in the corpus. Though they have received the most attention, these two chapters include only nine of the ninety-six occurrences of the word *epagōgē* in Aristotle's works. Fortunately, the other eighty-seven are much easier to deal with. I will start with the easiest of the eighty-seven, work up to the more ambiguous or otherwise difficult, and leave the most problematic ones for last.

(2) Assume that Aristotle has one unified, coherent, and consistent concept of induction. Aristotle never suggests that his theory of induction is problematic, complicated, or controversial. He never presents a catalog of competing theories of induction (as he frequently does for other matters), never says there are multiple ways of understanding induction, never says he will consider a kind of induction different from that usually discussed, never even explains fully what induction is. When he uses the word, he assumes his reader (or listener) knows what he is talking about. He says that "What sort of thing induction is, is obvious."[2] I will presume that Aristotle has a single and consistent understanding of induction and it is our job to figure out what that is. I will do everything possible to avoid exiting some difficulty by saying that Aristotle had multiple, inconsistent views of induction.

(3) Assume that Aristotle's concept of induction may be different from ours. There is a tendency among modern commentators to judge Aristotelian induction against the modern concept—against what is considered a proper theory of true, real, and genuine induction. This leads to several practices better avoided. One is to divide Aristotle's usage into technical uses (usually, ones recognizably like ours) and non-technical uses (usually, ones we cannot square with our understanding)—or worse into three, four, five, or six different uses, senses, or meanings.[3] This often

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[2] *Topics*, 8.1 157a8.

[3] Hintikka, "Aristotelian Induction," 425, for example, lists four types, dubbing that of *Prior Analytics* 2.23, the "'official'" account.

results in the impression, and sometimes the explicit claim, that Aristotle was hopelessly or sadly confused by the whole matter.[4] Translators deal with this by trying to find alternatives (sometimes globally, sometimes selectively) for *induction* when translating *epagōgē*. Vlastos said that in the second half of the twentieth century, there is "no excuse" for using the cognate.[5] Annas chose "arguments from particular to general," explaining that Aristotle's use is simply "not . . . the same as modern induction."[6] I agree with her, but the solution here is not to adopt different words for his different uses, but to do what Aristotle did, namely, use just one word and determine what he meant by it. I will follow the practice Cicero began and which was followed into the Renaissance. I will treat *epagōgē*, *inductio*, and *induction* as directly interchangeable.

(4) Give priority to the noun *induction* over the verb *induce*. My analysis is broader than others in that I seriously consider the whole ninety-seven and not just the nine. Compared to others, however, it is narrower, for I consider just the noun *epagōgē*, and not all forms of the root verb *epagein*, 'to induce, to bring in.' Some scholars have made things needlessly difficult by starting with a survey of all

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[4] Ross and Smith think that Aristotle's "enthusiasm" got the better of him on the issue. Ross occasionally claims that some argument Aristotle says is inductive simply is not. Ross, "Commentary," 50, 476, 506; Robin Smith, "Notes," in *Prior Analytics* (Indianapolis and Cambridge: Hackett Publishing Company, 1989), 220.

[5] Gregory Vlastos, *Socrates: Ironist and Moral Philosopher* (Ithaca: Cornell University Press, 1991), 267.

[6] Julia Annas, "Notes," in *Aristotle's Metaphysics Books M and N* (Oxford: Oxford University Press, 1990), 154.

Aristotelian uses of *epagein*, on the hope that an etymological analysis of this ancient word might help illuminate the new locution.[7] But the verb has many uses (Homer used it for dogs rushing in[8]), and it is difficult to know when, if ever, Aristotle is using it in a newer technical sense. I propose that it is better to presume that the noun is always used technically, to figure out what *induction* means from these uses, and leave the verbs for later. To make a modern analogy: It would be of limited use and potentially misleading to begin with *vacate* when trying to understand *vacation*.

(5) Consider the context of the work in which the term appears. Analysts of induction frequently support a contention by juxtaposing short excerpts from throughout the Aristotelian corpus, thus isolating each instance from the context that may offer better clues to Aristotle's meaning than does the juxtaposition. (The practice is particularly detrimental once we begin an historical analysis, for not all of Aristotle's works were equally read or available in all periods.) I will instead proceed through the corpus, volume by volume, considering all discussions of induction within one work before moving to the next. I will begin with the *Topics*.

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[7] Ross, "Commentary," 481-84 adopts this approach and it survives for example in Engberg-Pedersen, "More on Aristotelian Epagoge," 303.

[8] *Odyssey*, 19.445.

Topics and *Rhetoric*

For three reasons, the *Topics* is the best place to begin an investigation of Aristotelian induction.[9] First, the term appears more in this work than in any other. About a quarter of all Aristotle's uses appear in it. Second, the work is a training manual of sorts for the kind of back-and-forth arguing associated with Socrates, and it is Socrates who Aristotle says introduced inductive reasoning.[10] Third and very importantly, Aristotle uses *induction* in passages whose overall meaning is relatively plain. Therefore we can understand the passages without fully understanding what Aristotle means by the term and thus use the passages to elucidate the term. This is in contrast to several passages in the *Analytics*, which are difficult to understand without first understanding what is meant by *induction*. The *Topics* thus provides solid initial ground on which to stand.

Early in the *Topics*, Aristotle offers a chapter that makes four unambiguous claims, frequently repeated throughout the corpus. Here is the chapter in full, with the claims numbered:

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[9] Only the Finnish scholars give the *Topics* much attention in discussions of induction. It features prominently, for example, in Knuuttila, "Remarks on Induction in Aristotle's Dialectic and Rhetoric."

[10] *Metaphysics*, 13.4 1078b24-30. More on this below. It is also possible that the *Topics* was written early in Aristotle's career, perhaps while he was still at Plato's Academy. Aristotle always writes of induction as if his audience already knows what it is. Writing for an audience for whom the inventor of induction was still discussed could help explain the frequency of *induction* in the *Topics* and the familiarity assumed in the audience. For summaries of the chronological theory, see introductory notes in Aristotle, *Aristotle II: Topica*, trans. E. S. Forster (Cambridge, MA and London: Harvard University Press, Loeb Classical Library, 1960), 267.

> With these things defined, then, we need to distinguish [1] how many kinds of dialectical argument there are. One kind is induction, another is deduction. Now what a deduction is has been explained earlier. [2] Induction, however, is proceeding from particulars up to a universal. [3] For instance, if the pilot who has knowledge is the best pilot, and so with a charioteer, then generally the person who has knowledge about anything is the best. [4] Induction is more persuasive, clearer, more intelligible in the way perception is, and commonly used by the public; deduction is more coercive and more effective with those skilled in contradicting.[11]

Aristotle's first claim is that deduction (sullogismos[12]) and induction (epagōgē) are the two kinds of dialectical argument (dialektikos logos). He makes the same claim—never ambiguously, sometimes incidentally, sometimes prominently—not just in the *Topics*, but at least twenty times across at least seven of his major works.[13] Whatever exactly induction is, it is one of the two, and only two, kinds of

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[11] *Topics*, 1.12 105a10-19, Smith's translation. Aristotle, *Topics: Books I and VIII*, trans. Robin Smith (Oxford: Clarendon Press, 1997). For citations of Aristotle, I will provide book and chapter, and where appropriate Bekker line numbers and translator. Full citations for the translations will be included in the bibliography and on first reference in the footnotes. It should be noted that the chapter quoted here is odd. Book 1 is well-structured and Aristotle maintains a running commentary on where in an outline of his material he is. Yet Chapter 12 does not have a place in the narrated outline. Nor does the content fit neatly. The chapter is also short and succinct, even perfunctory. It seems to me Aristotle may have added the chapter later, realizing he needed it for completeness and as preparation for forthcoming material.

[12] I follow Smith's practice of using *deduction* for *sullogismos.* For justification, see Smith, notes to *Prior Analytics*, p. 106.

[13] E.g, *Prior Analytics*, 1.25 42a4; *Posterior Analytics*, 1.1 71a5; *Sophistical Refutations*, 1.4 165b27; *Physics*, 8.1 252a25; *Nicomachean Ethics*, 2.3 1139b28, and *Rhetoric*, 1.2 1356b1.

reasoning, and deduction is the other. In no unambiguous passage anywhere in the corpus does Aristotle waver on this. The second important claim is that induction is a proceeding from particulars to a universal. Again, this is repeated many times, in many different works, in several different contexts.[14] Third, Aristotle gives us in this chapter one of his most cited examples of an induction. Note that there are only two instances, that of a pilot and that of a charioteer. From these Aristotle makes the tremendously broad statement that in any field the most knowledgeable person is the best in that field. Aristotle could not possibly have thought that these were the only two professions in the world or that a complete survey of all professions had been made in establishing this generalization. In every unambiguous example in the corpus, the particulars subsumed by the generalization are, as here, countless. Aristotle never provides an example of induction where the cases are odd and even, or north, east, west and south, or any other finite list that could be surveyed before making the generalization. Aristotle clearly believes that induction is a proceeding to a universal generalization that applies to particulars beyond those considered in forming the universal. Fourthly, Aristotle says that of the two forms of dialectical reasoning, induction is more persuasive, clearer, and more intelligible to laymen. Again, he repeats this throughout the corpus, in several contexts, never ambiguously. Thus, only if faced with the most unambiguous and forceful statements to the contrary should we abandon the belief that, whatever else it is, for

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[14] E.g., *Posterior Analytics*, 1.1 71a6-9; *Topics*, 1.18 108b11; *Topics*, 8.1 155b34-156a5; *Rhetoric*, 1.2 1356b; *Rhetoric*, 2.25 1402b.

Aristotle, induction (1) is different from and a counterpart to deduction, (2) is a proceeding from particulars to a universal, (3) results in a universal generalization that extends beyond the particulars that went into its formation, and (4) is generally easier for people to grasp than deduction.

Remaining uses of *induction* in the *Topics* reinforce these four themes. Reinforcing the last, for example, Aristotle suggests that when arguing with others, one should use deduction with trained debaters, induction with the common crowd, deduction with a mature thinker, induction with a youth, induction to embellish a point.[15] But even with the best trained debating opponent, induction has a crucial role to play. The *Topics* is a handbook for dialectics, for back-and-forth, question-and-answer arguing with a skilled opponent. Much of it is a catalog of techniques and tactics for getting one's opponent to agree on one point and then, based on that agreement, to a second. A common recommendation is to get agreement on the first point by induction and then the second by deduction. For example, establish by induction that courage is desirable and use deduction to then conclude that cowardice is undesirable, or secure the contrapositive of an intended statement by induction, then use modus tollens to establish the intended claim.[16] Aristotle offers about a dozen variations on this pattern, each using induction to establish the premise for a subsequent deduction.[17] In these examples he reaffirms

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15 *Topics*, 8.2 157a19-20; 8.14 164a13; 8.1 157a6.

16 *Topics*, 2.8 113b18–25.

17 *Topics*, 2.5, 2.8, 2.10, 4.2, 4.3, 8.1.

that induction and deduction are complements and shows that induction is the more persuasive and can thus form, in dialectic, an effective starting point for subsequent deductions by providing deduction's necessary and universal premises.[18]

Passages in the rest of the *Topics* affirm and repeat the four claims made in the early chapter, but they also introduce another aspect of induction, similarity. "The study of what is similar [homoiou] is useful for inductive reasoning . . . . because it is by induction of particulars on the basis of similars that we claim to bring in [epagein] the universal."[19] Aristotle does not say that induction gains its force from the *number* of particulars but from their *similarity*. What is similarity and how does one recognize it? Aristotle says that things are similar "in as far as any attribute they possess is the same."[20] Things that are of the same genus, he says,—e.g., man, horse and dog, all of which are animals—are easy to compare. Discerning the similarities among things in widely separated genera—e.g., absence of waves in the water being like the absence of wind in the air—takes more practice. To discern the similarities, Aristotle offers little advice other than to look and see, using verbs such as *skopein*, *skeptomai*, or *sunoridein*, all of whose primary meaning is to look at carefully. (*Nous*, prominent in discussions of induction to be examined later, is absent here.) What makes an induction successful for Aristotle is not the number of particulars but the ease with which the similarities can be discerned. The particulars are the raw

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[18] *Topics*, 8.1.

[19] *Topics*, 1.18, 108b7–12, my translation.

[20] *Topics*, 1.17, 108a18, Forster's translation.

material for an induction, but it is the juxtapositions, the comparisons, the 'parabolai,' that distinguish a good inductive reasoner.[21] The identification of similarities seems, at least in the *Topics*, not to be primarily a contemplative process but a near-perceptual one. As Aristotle said above, induction is easier to grasp 'in the way perception is.'

An 'argument from likeness,' however, is not, Aristotle explains, the same as an 'argument from induction.'[22] An argument from likeness is reasoning from similar particulars *to other similar particulars* without drawing a universal generalization. Induction, on the other hand, is reasoning from the similar particulars *to a universal*. Though the grasp of similarity may be perceptual, Aristotle does not believe that everyone will necessarily discern similarities the same way. For his debating student, he introduces this problem: What is one to do if he "has made an induction on the strength of several cases and yet the answerer refuses to grant the universal proposition?"[23] The problem, Aristotle in effect says, may be that the questioner has not fully advanced from an argument by likeness to an argument by induction, for it is not enough to list particulars and then summarize with "the expression 'So in all cases of this kind.'"[24] It is necessary to have one more thing, a universal term to cover all the cases, and if such a term does

[21] *Topics*, 8.14 164a16.

[22] *Topics*, 8.1, 8.8.

[23] *Topics*, 8.2 157a34, Pickard-Cambridge's translation. Aristotle, *Topica and De sophisticis elenchis*, trans. W.A. Pickard-Cambridge (Oxford: Clarendon Press, 1928).

[24] *Topics*, 8.2 157a24, Forster's translation.

not already exist, "One ought . . . to try oneself to coin a word to cover all things of the sort"[25] and then to identify the particulars to which it applies (apparently with a definition or some other delimiting statement). If this has been done, it is fair to place the burden on the opponent to identify a contravening case. If he can, then the generalization must be modified accordingly, but if he cannot, if "you formulate the proposition [using a newly coined term if necessary] on the strength of many cases and he has no objection to bring, you may claim that he shall admit it,"[26] and proceed in the debate, for a valid argument by induction (an argument that includes statement of the universal, anchored by a possibly new term) and not just an argument by likeness (an argument from similars to similar) has been made.

Aristotle's reference to a connection between induction and the universality of a newly coined term suggests an interpretation of Aristotle's earlier-cited example. He said that, "if the pilot who has knowledge is the best pilot, and so with a charioteer, then generally the person who has knowledge about anything is the best."[27] This could be understood in two ways. One is like a syllogism: An X_1 who has knowledge is the best X_1; an X_2 who has knowledge is the best X_2; therefore, any X that has knowledge is the best X. But this is casting the argument into a syllogistic framework familiar from the *Prior Analytics* but unlike the context of the *Topics*. If we read the passage without influence of the *Prior Analytics* a different

[25] *Topics*, 8.2 157a30, Pickard-Cambridge's translation.

[26] *Topics*, 8.2 157b31-33, Pickard-Cambridge's translation

[27] *Topics*, 1.12 105a10, Smith's translation.

interpretation presents itself,[28] an interpretation more closely related to definitions and the coining of terms than to syllogisms. On this interpretation, Aristotle is simply exploring what makes someone the 'best' in a profession and is concluding that it is not, for example, one's ancestry, physical strength, or popularity, but one's knowledge.[29] This interpretation is consistent with the charter of the *Topics*. As mentioned, the work is a handbook for dialectical debate. The starting point of dialectical debate is not necessarily what is true but what is generally accepted as true, and a major task for the debater is to draw out the implications of such premises. If such debating were to proceed along Socratic lines, then a core task would be to identify the meaning of one's opponent's terms. To begin by identifying the nature or essence of the subject under discussion and then to work out implications would be to proceed first with induction then with deduction as Aristotle advises so many times in the *Topics*. Further supporting this interpretation of induction as a tool for identifying essence is the next occurrence of *epagōgē* after the chapter quoted above. In chapter 1.14, in a discussion about the nature of three kinds of arguments, Aristotle writes,

[28] Again, many believe the *Topics* was largely written before the *Prior Analytics*. On the possibility that the *Topics* was written before Aristotle developed his doctrine of the syllogism, see Forster's introductory notes in Aristotle, *Topics*, 268and Smith's Introduction in Aristotle, *Topics*, xxxiv.

[29] This interpretation is defended and explored in Tsouyopoulus, "Die induktive Methode und das Induktionsproblem in der griechischen Philosophie," 107–14.

> As for what each of the aforesaid kinds is like, it is not easy to state that in definitions about them, and one must try to recognize each of them with the familiarity which comes through induction, studying them in light of the examples given.[30]

A connection between induction and identifying what makes something a kind of thing it is runs throughout not just Aristotle's texts, but the whole subsequent history of induction, as we will see.

After the *Topics*, the *Rhetoric* may be considered next.[31] Like the *Topics*, it discusses methods of persuasion, and in it induction is treated frequently and plainly. Just as the *Topics* is a catalog of methods for dialectic, one-on-one arguing, the *Rhetoric* is a catalog of methods for public speaking in front of a large group, i.e., for arguing a case to an audience.[32] Nearly all references to induction in the *Rhetoric* are to the following fact, stated early in the first book and repeated frequently and never ambiguously: "Just as in dialectic [covered in the *Topics*] there is on the one hand induction and on the other deduction . . . the situation is similar

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[30] *Topics*, 1.14 105b25–29, Smith's translation.

[31] For purposes here, particularly useful material on the *Rhetoric* appears in the introduction and notes to Aristotle, *On Rhetoric: A Theory of Civic Discourse*, trans. George A. Kennedy (New York and Oxford: Oxford University Press, 1991) and in Keith V. Erickson, *Aristotle's Rhetoric: Five Centuries of Philological Research* (Metuchen, NJ: Scarecrow Press, 1975).

[32] *Rhetoric*, 1.1 1354a for Aristotle's introductory remarks on the comparison of rhetoric and dialectic.

in rhetoric. . . . I call a rhetorical deduction an enthymeme, a rhetorical induction a paradigm."[33]

In the *Rhetoric*, Aristotle calls a paradigm what in the *Topics* he called reasoning from likeness, i.e., reasoning from similars to similar with the universal left unstated. Because Aristotle holds that a paradigm is an induction in all but the way it is articulated, nearly everything he says about paradigm holds true also for induction. Unsurprisingly then, all the major points made about induction in the *Topics* are made again in the *Rhetoric* about paradigms.

Occasionally in the *Rhetoric*, Aristotle also discusses induction directly, and at *Rhetoric* 2.23, he gives us the only surviving passage in the whole corpus in which he unambiguously presents several examples in a row of what he considers to be induction. Each includes a universal statement, and two to six particulars. The first is that all women can discern the truth about a child's paternity, as happened in four particular cases Aristotle describes. The second example is that one should not entrust any property to someone who has mishandled horses and ships. The third is that all men honor the wise, no matter what their other shortcomings. The Parians honor the wise Archilochus though he was nasty, the Chians honor the wise but non-citizen Homer, the Mytilenaeans honor the wise Sappho though a woman, the Lacedaemonians the unschooled Chilon, and the Lampsacenes Anaxogoras though

[33] *Rhetoric*, 1.2 1356b1. Kennedy's translation, but with *deduction* instead of his *syllogism*, for the reasons offered by Smith. Aristotle, *On Rhetoric: A Theory of Civic Discourse* . Note that Kennedy and I use *paradigm* for *paradeigma* instead of the more common Latin-derived *example*.

he was a foreigner. Fourthly, all people whose rulers are philosophers thrive, as Athenians did under Solon, Lacedaemonians under Lycurgus, and Thebes under its philosopher-rulers. As with the one example from the *Topics* it is inconceivable that Aristotle thought these inductions were legitimate only because he, or someone he trusted, had or even could survey all the women who spoke in paternity cases, all irresponsible custodians, all wise men honored, or all the cities in the world with philosopher-rulers. He never adds to his list of particulars a phrase such as 'and so on in all cases of the kind.' As he said above, such a statement adds nothing, for determining what particulars are 'of the kind' is the very question at issue. Yet he gives all indications that he believes these and every other inductively established universal is a generalization valid for cases beyond the particulars that went into the universal's development. He cannot here believe that a valid induction applies only to the particulars enumerated.

The *Rhetoric* introduces two further important statements about induction, both in *Rhetoric* 2.20. The first is that "induction is the beginning [archē]."[34] Throughout the corpus Aristotle usually lists induction first: 'induction and deduction' instead of 'deduction and induction.' In the *Topics*, Aristotle had said induction was a good place to begin a line of subsequently deductive arguments, but he did not describe induction as the foundation on which all reasoning rests. Here—depending what he means by archē—he may be saying just that. This theme

[34] *Rhetoric*, 2.20 1393a27, Kennedy's translation.

that induction is or provides a beginning will be elaborated in other works. The second additional statement is a connection Aristotle draws between induction and Socrates. In the *Topics*, Aristotle had said that the mark of a good inductive reasoner was one skilled at drawing comparisons, 'parabolai,' between particulars. In the *Rhetoric*, he says that use of 'parabolai' was Socrates' distinctive method. This association with Socrates deserves immediate attention.[35]

Metaphysics Books 13 (M) and 14 (N): Socratic Induction

The only reference to induction in the related books 13(M) and 14(N) of the *Metaphysics* is this:

> Socrates was occupying himself with the excellences of character, and in connection with them became the first to raise the problem of universal definition. . . . It was with good reason that he should be seeking the essence, for he was seeking to argue deductively and the beginning [archē] of deductive arguments is the essence. . . . For two things may be fairly ascribed to Socrates—inductive reasoning and universal definition, both of which are concerned with the starting point of science [archēn epistēmēs].[36]

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[35] A third interesting observation about Aristotelian induction in the *Rhetoric* is that Aristotle seems to leave open the possibility of an induction based on only one instance when he uses the phrase "induction from what is like, whether one thing or more." (2.25 1042b16, Kennedy's translation). He implies the same at *Sophistical Refutations*, 15. Cicero and Thomas Reid, the nineteenth-century Scottish philosopher, also thought inductions from only one instance were possible.

[36] 13.4 1078b24-30. Ross's translation, slightly modified. Cf. a similar passage in *Nicomachean Ethics*, 6.3 1139b26–33.

Aristotle says that Socrates realized that to successfully argue deductively one needed first principles that identified the essential nature of the subjects under discussion and that these first principles needed to be established by some means other than deduction. For this Socrates introduced the method of induction. Unfortunately, in none of the surviving Platonic dialogues does Socrates use the word *epagōgē*, so we are left to determine, of the many things Socrates did, which were the ones that Aristotle considered epagōgē .

Scholars have differed over which Socratic discussion was an archetype of Socratic induction,[37] but I believe it is easy to find instances of what Aristotle was referring to if we consider the following. First, by my methodological assumption, Aristotle always means the same thing by *induction* unless he tells us otherwise or we are unavoidably forced to conclude otherwise. Second, in the *Rhetoric*, Aristotle gave us the several examples described above of what he unambiguously considered cases of induction. By these two considerations, whatever Aristotle considers instances of Socratic induction must be similar to those examples in the *Rhetoric*. Third, Aristotle specifically says that Socrates used induction when investigating 'excellences of character.' Finally, we will recall that a paradigm is a kind of induction (one with the universal left unstated). Thus, when Aristotle gives us a

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[37] Hamlyn, "Aristotelian Epagoge," 174, focuses on the sequence in the *Meno* where the slave boy comes to know how to double the size of the square, but McKirahan, "Aristotelian Epagoge in *Prior Analytics* 2.21 and *Posterior Analytics* 1.1," 4, rightly observes that it is not clear that the method Socrates there uses is what Aristotle was referring to.

characteristic example of a Socratic paradigm, he is also giving us a characteristic example of Socratic induction, and his example of Socratic paradigm is this:

> if someone were to say that officials should not be chosen by lot (for that would be as if someone chose athletes randomly—not those able to contest, but those on whom the lot fell); or [as if] choosing by lot any one of the sailors to act as pilot rather than the one who knew how.[38]

Although this precise example does not survive in our descriptions of Socratic dialogue, it is similar to so many Socratic passages it is difficult to doubt what Aristotle had in mind. Xenophon reports, for example, "He [Socrates] dwelt on the folly of appointing state officers by ballot, a principle which, he said, no one would care to apply in selecting a pilot or a flute-player or in any similar case."[39] By simply expressing the unstated universal, 'All professionals should be chosen by competence instead of by lot,' this paradigmatic argument becomes an inductive one and we have what Aristotle considered Socratic induction. Note how similar this is to Aristotle's example with which we began, 'if the pilot who has knowledge is the best pilot, and so with a charioteer, then generally the person who has knowledge about anything is the best.' When Aristotle credits Socrates with introducing epagōgē, we do not have to suppose that Aristotle is using the concept differently than he does in his own writings.

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[38] *Rhetoric*, 2.20 1393b, Kennedy's translation and bracketed emendation.

[39] Xenophon, *Memorabilia*, trans. Henry Graham Dakyns (1897), 1.2.9.

Socratic induction has received little scholarly attention.[40] I believe the most insightful understanding remains a short comment by Gregory Vlastos made in 1956 and expanded upon in 1991.[41] Vlastos uses *Ion* 540b-d to make his case. In that passage, Socrates argues as follows (quoting Vlastos's paraphrase):

(1) The pilot is the one who knows best what should be said to the crew of a storm-tossed ship.

(2) The doctor is the one who knows best what should be said to the sick.

(3) The cowherd is the one who knows best what should be done to calm angry cattle.

(4) The expert in wool is the one who knows best what should be said to women working wool.

(5) The military expert is the one who knows best what the general should say to his troops.[42]

The universal conclusion is that the master of any craft "is the one who knows best matters falling within its subject-matter."[43] But on what authority does the universal statement rest? Vlastos observes that this is *not* a case of inferential

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[40] There is a chapter on the topic in Richard Robinson, *Plato's Earlier Dialogue* (Oxford: Oxford University Press, 1953), and some material in Gerasimos Santas, *Socrates, Philosophy in Plato's Early Dialogues* (London and Boston: Routledge and K. Paul, 1979), and Norman Gulley, *The Philosophy of Socrates* (London and New York: Macmillan and St. Martin's Press, 1968). Mark L. McPherran has shared with me his unpublished Mark L. McPherran, "Socratic *Epagoge* and Socratic Induction," (2004), which he has presented at a few regional workshops. See also Hamlyn and McKirahan cited above.

[41] Gregory Vlastos, "Editor's Introduction," in *Protagoras* (Upper Saddle River, NJ: Prentice Hall, 1956), xxix, n. 18. Vlastos, *Socrates: Ironist and Moral Philosopher*, 267–68.

[42] Vlastos, *Socrates: Ironist and Moral Philosopher*, 267–68.

[43] Ibid., 268

induction as commonly understood today. It is not the case that all crafts have been surveyed, nor is it the case that some craft could possibly be found in which experts are not the ones who know best. There is no Humean fear that because they have not all been surveyed the next craft observed could refute the previously established universal conclusion. For the truth of the conclusion is built into the very meaning of what it is to be a 'master.' As Vlastos says, the instances in a Socratic induction do not *prove* the universal conclusion; they *exhibit its meaning*.[44] When Socrates marshals a list of people demonstrating such 'excellences of character' as wisdom, virtue, or confidence,[45] when he draws his Socratic comparisons, his parallel cases, his 'parabolai,' it is to find the essential commonality in all cases of wisdom or courage or confidence; it is not primarily to infer a propositional conclusion. When Aristotle said that 'two things may be fairly ascribed to Socrates—inductive reasoning and universal definition,' he was not referring to unrelated inventions but to two aspects of the same process. This interpretation of Socratic induction by Vlastos is the same as the interpretation I proposed above for Aristotelian induction. By this interpretation, induction is a tool for making conceptual generalizations by identifying the essential nature of things.

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[44] Ibid. Italics in Vlatos's statement.

[45] *Euthydemus*, 279d–280a; *Republic*, *I* 352e–353e; *Protagoras*, 350a–351a.

The Rest of the Corpus, Except for the *Analytics*

If the only thing you knew about Aristotelian induction was what you read in the *Topics* and the *Rhetoric*—perhaps because by the vagaries of history the other works were lost, inaccessible, banned, untranslated, incomplete, unstudied, untaught, or simply uninteresting—and if you read in the *Metaphysics* or in another ancient, non-Aristotelian source that the inductive method was introduced by Socrates, you would reasonably conclude that Aristotelian and Socratic induction were the same thing, a process involved in identifying essences and definitions. You would know that Aristotle thought induction and deduction were two separate kinds of reasoning, induction coming first and producing the universal generalizations on which deduction depends. You would understand that Aristotelian induction goes beyond the observed particulars that went into the formation of the inductive generalization, and which therefore enables universal statements about the unobserved. You would have no reason to think that Aristotle associated induction with so many things scholars later connected to Aristotelian induction. You would have no reason to think that Aristotle considered a valid induction to be a complete enumeration, that he thought an inductively formed generalization applied only to the observed particulars, or that he considered induction a form of deduction or deduction a form of induction; you would not associate induction with nous, with the difference between what is prior by nature and what is prior to us, with the difference between what is better known by nature and what is better known to us, or with the difference between proving the fact and proving the reasoned fact. You would also have read nearly forty percent of the now-known references that Aristotle made to induction, and the least ambiguous ones at that.

If you then gained access to and read *Metaphysics*, *Physics*, *Nicomachean Ethics*, *Parts of Animals*, indeed all the rest of the surviving Aristotelian corpus except the *Prior* and *Posterior Analytics*, you would find many references to induction that would confirm and reinforce what you had already learned about Aristotelian induction. In the *Metaphysics* and *Eudemian Ethics*, Aristotle provides more examples of the Socratic arguments that he considers inductions, one regarding the deceiving, limping man[46] and one regarding the Socratic search for the essence of aretē.[47] In *Parts of Animals*, he repeats his claim that it was Socrates who introduced the method of identifying essences and definitions.[48] In none of these does Aristotle suggest that his understanding of induction is any different from Socrates.' Aristotle also repeats his claim that induction and deduction are the two kinds of reasoning,[49] that induction is the starting point from which subsequent deductions proceed,[50] and that induction is like perception.[51] These are all consistent with Aristotle's treatment of induction in *Topics* and *Rhetoric.*

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[46] *Metaphysics*, 5.29 1025a2–13, referring to Socrates' argument in *Hippias Minor*, 365–75.

[47] *Eudemian Ethics*, 1219a, referring to Socrates' argument in the *Republic*, 353.

[48] *Parts of Animals*, 1.1 642a24–30.

[49] *Sophistical Refutations*, 1.4 165b28; *Physics*, 8.1 251a25.

[50] *Sophistical Refutations* 1.15 174a36; *Nicomachean Ethics*, 6.3 1139b26–30.

[51] *Metaphysics* 6.1 1025b14 and 11.7 1064a8; *Nicomachean Ethics* 1.7 1098b3.

Several occurrences of *induction* in the *Physics*, *Metaphysics*, and *Eudemian Ethics* add striking support to the theory that Aristotelian induction is a tool for identifying essences. The passages follow a pattern. Aristotle first makes a universal statement. He then says, 'This is clear from induction, for . . . ' 'dēlon ek tēs epagōgē, gar . . .' He then makes another universal statement, usually one indicating the essential reason for believing the first. He then proceeds with a list of illustrative examples. Translators and commentators typically translate 'dēlon ek tēs epagōgē' as 'This is clear from a survey of examples,' but that is not what Aristotle says, and what immediately follows is not a survey of examples, but a universal statement. The examples come later. A skeletal instance appears in *Eudemian Ethics*:

> Let it be assumed as to Goodness [aretē] that it is the best disposition or state or faculty of each class of things that have some use or work. This is clear from induction, for we posit this in all cases: for instance, there is goodness that belongs to a coat, for a coat has a particular function and use, and the best state of a coat is its goodness; and similarly with a ship and a house and the rest.[52]

A universal statement is made, followed by 'this is clear from induction,' followed by another universal statement (a simple one in this case), followed then by the introduction of illustrative examples. Note that Aristotle is not claiming to have made a complete enumeration. He is not saying that he has surveyed examples of

[52] *Eudemian Ethics*, 1 1218b36–1219a3. Aristotle, *Eudemian Ethics*, trans. H. Rackham (Cambridge, MA and London: Harvard University Press, Loeb Classical Library, 1938).

aretē and found that every one was such a disposition, state, or faculty, and that therefore it is reasonable to expect that others, unsurveyed, would be the same. Rather Aristotle means that the very essence of aretē is such a disposition, state, or faculty. He is not leaving open the possibility that an unsurveyed instance of aretē would be discovered that is otherwise. The *Physics* offers an instance of the pattern in which the second universal is quite lengthy:

> Nor again is there anything intermediate between that which undergoes and that which causes alteration: this is clear from induction: for in every case we find the respective extremities of that which causes and that which undergoes alteration are adjacent.[53]

A 178-word explanation follows justifying Aristotle's identification of the second universal statement as the essential cause of the first. Only then are the examples given:

> Thus the air is continuous with that which causes the alteration, and the body that undergoes alteration is continuous with the air. Again, the colour is continuous with the light and the light with the sight. And the same is true of hearing and smelling: for the primary movent in respect to the moved is the air. Similarly, in the case of tasting, the flavour is adjacent to the sense of taste.[54]

[53] *Physics*, 7.2, 244b2–5. Rackham's translation. Aristotle, "Physics," in *The Basic Works of Aristotle*, ed. Richard McKeon (New York: Random House, 1941), 218–397. 'This is clear from induction' for Hardie and Gaye's 'this can be proved by induction' for Aristotle's 'dēlon ek tēs epagōgē.'

[54] Physics, 7.2, 245a5–10. Rackham's translation.

In *Metaphysics* 10.3 and 10.4, Aristotle explores the nature of contrariety and concludes that contrariety is a kind of difference, specifically the maximum difference at two ends of a continuum. "This is clear from induction."[55] This conclusion is not an inference drawn from surveying all instances of contraries or even a finite number of categories of contraries and checking whether all or most confirm the hypothesis that all contraries are instances of maximum difference. Rather this is the identification of what it means for something to be a contrary. In *Metaphysics* 6.1 and again at 11.7, Aristotle describes how every field of study uses induction to delimit the genus that forms the subject of that discipline's study. Such induction, he says, is not a demonstration (apodeixis) of the genus's substance (ousia) or essence (ti estin) but a different manner of exhibiting it.[56] In *Metaphysics* 9.6, Aristotle leaves open the possibility that induction may make clear (dēlon) what something is, even if it is difficult or impossible to articulate a definition. For example, what we mean by *potentiality*[57] is clear from an induction of particular

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[55] *Metaphysics* 10.3 1054b33; 10.4 1055a6.

[56] *Metaphysics*, 6.1 1025b15 and 11.7 1064a9. 'Such induction' in the first passage does not refer to the induction across several disciplines, but the induction involved with identifying the essence of the discipline's field of study. Translators and commentators often miss this and thus find Aristotle's use of *epagōgē* here confusing. At 1025b16, Tredennick translated *epagōgē* as 'method of approach,' destroying Aristotle's point. Ross kept 'induction' but then admitted he did not know how to interpret the passage. W. D. Ross, "Commentary," in *Aristotle's Metaphysics* (Oxford: Oxford University Press, 1924), 1:351–2. Note also that Aristotle says induction 'exhibits' the essence. Vlastos said the same about Socratic induction.

[57] When Aristotle here says 'Our meaning is clear,' he is referring to the meaning of the word *potentiality*, not the general meaning of what he has been saying.

instances—sleeping as opposed to being awake, having one's eyes shut as opposed to seeing, the material as opposed to what is made from the material—but it is not easy to define *potentiality*. These and other instances of Aristotle's phrase 'clear from induction' in the *Metaphysics*, *Physics* and *Eudemian Ethics* reinforce the view of Aristotelian induction earlier found in the *Topics* and *Rhetoric*—that it is not a method of inference from complete enumeration. It is primarily a tool for identifying the essence of something.

The works so far surveyed—each with its own fortuna in antiquity and since— account for about seventy percent of all the references to *induction* in the surviving Aristotelian corpus. They all suggest that Aristotle held a view of induction that, though maybe frustratingly incomplete, was consistent on several important issues, such as whether inductively achieved results extend to unobserved instances, whether valid inductions must be fully enumerative, whether induction is a kind of deduction, and in general whether his induction was significantly different from the induction Socrates introduced as part of his project to identify universal essences. Two works remain, the two usually most discussed in modern discussions of Aristotelian induction, the *Prior* and the *Posterior Analytics*. Let us consider the *Posterior* first.

Posterior Analytics

If one approaches the *Posterior Analytics* from the *Topics*, *Rhetoric*, and other works I have surveyed, rather than from the *Prior Analytics*, one could get the impression that the *Posterior Analytics* is all about induction. Aristotle begins by again saying that deduction and induction are the two kinds of reasoning, but adds that the starting point of knowledge remains an open issue. Since all learning proceeds from pre-existing knowledge, how does one begin? In the second and third chapters, Aristotle rejects two theories, the theory that all claims to knowledge are false because of an infinite regress and the theory that all claims to knowledge are true because they are circularly reinforcing. He insists there must be some starting point, some hierarchy. In the next several chapters (4 to 12) he describes that hierarchy: By some process, one comes to know primary and universal principles, archai. These archai are true not just accidentally, but by the essential nature of the subject matter.[58] These archai can form (though not all do) the premises of demonstrative deductions. By suitable arrangement of these demonstrations, one comes to know not just scientific facts but also the reasons why those facts are true (chapters 13 and 14). Several things can go wrong in these demonstrations (chapters 15 to 17), the most severe of which would be the loss of the senses (chapter 18). It is at this point that we get the most concentrated use of the word *induction* (*epagōgē*) in the whole Aristotelian corpus—six occurrences, over six percent of the corpus's total, in a mere twelve lines.[59]

The twelve lines are fairly unambiguous. Aristotle says that it is impossible to obtain universals without induction, that induction proceeds from particulars, that

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[58] We will see later that it is from this passage in the *Posterior Analytics*, chapter 1.4, that Francis Bacon says he develops his thinking on the nature of induction.

[59] *Posterior Analytics*, 1.8 81a38–81b9.

particulars are apprehended by sense-perception, and so if one were to have no sense-perception, one could not grasp universals. This is consistent with all we have seen so far.

What is more curious is why Aristotle invokes induction here at all. Except at the very beginning of the work, where Aristotle contrasts deduction and induction as the two kinds of knowledge, *epagōgē* in the *Posterior Analytics* seems to appear out of nowhere. It is never defined or described. It is always introduced to explicate some other subject, presumably one less clear to the audience than *epagōgē*. The context always suggests that Aristotle's listener has the concept ready at hand. We must remind ourselves that the *Posterior Analytics* may be a collection of Aristotle's lecture notes (or drafts to be filled in later), not a completed essay. It is likely that Aristotle would have been using *epagōgē* throughout the lecture whose notes we are reading. The term made fleeting appearances in chapter 12 and 13 in the explication of other subjects, and now in chapter 18, it is used to explain the dependency of all knowledge ultimately on sense-perception. It is possible that Aristotle would have thought of the *Posterior Analytics* as a lecture fundamentally about induction, that is, about obtaining archai from sense-perception. Book 1 introduces the fact that knowledge cannot be all deductive, for deductions need starting points. The bulk of the book explores aspects of demonstration, including features of deductions that follow from features of properly formed premises, or fail to follow if premises are not properly formed. Book 2 explores how to form these universal premises and their constituent universal concepts. Book 2 is more commonly read as being about definitions and essential natures. But if Aristotle and his students understand definitions and essential natures to be the subject matter of *epagōgē*, Aristotle would have felt free to use the term whenever he needed to refer to the whole project under discussion. This would explain why the term pops up in the way it does throughout the *Posterior Analytics*.

The second book is an extended treatment of the relations between demonstration, definition, essence, and causes. It ends with the frequently cited chapter 19, a chapter that directly recalls issues from the very beginning of the work regarding the ultimate starting points of knowledge. In this final chapter, Aristotle says that universal knowledge is not innate but is developed from sense-perception.

> Thus from perception there comes memory . . . and from memory (when it occurs often in connection with the same thing) experience; for memories which are many in number form a single experience. And from experience, or from all the universal which has come to rest in the soul . . . there comes a principle of skill or of understanding.[60]

As he did in Book 1, chapter 18, he brings in the word *induction* as if it is what he has been discussing all along. "Thus it is plain that we must get to know the primitives by induction; for this is the way in which perception instils universals."[61] Except for one incidental use in chapter 3, this one mention at the very end of the work is

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[60] *Posterior Analytics*, 2.19 100a3–9. Aristotle, *Posterior Analytics*, trans. Jonathan Barnes, Second ed., *Clarendon Aristotle Series* (Oxford: Oxford University Press, 1975).

[61] *Posterior Analytics*, 100b2–3, Barnes' translation, second ed.

the only use of *epagōgē* in the second book. Again, Aristotle uses the term as if his reader, or listener, already knows what it means.

A possible reference to induction in book 2, however, has the potential to confute the claim that induction is a process for identifying essence. In chapter 7, after surveying potential problems in identifying the essence and definition of something, Aristotle asks, "Then how will a definer prove the essence of something or what it is?"[62] Aristotle says it cannot be by deduction and then seems to exclude induction as well. He writes,

> nor, as in an induction, will he show by way of the particulars, which are plain, that everything is thus-and-so inasmuch as nothing is otherwise (for an induction does not prove what a thing is, but rather that it is or is not).[63]

This seems to directly and decisively contradict on two accounts the interpretation I have been proposing. First, Aristotle seems to equate induction with complete enumeration, an equation I have argued he elsewhere repeatedly and unambiguously rejects. Second, Aristotle seems to say that induction is not a process for identifying the essential nature of something. Recall, however, that by my methodological assumption, the noun *epagōgē* is to receive preference over forms of the verb *epagein*, a verb with many non-technical uses. That methodological maxim resolves the apparent contradiction here. Contrary to the impression left by

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[62] *Posterior Analytics*, 2.5 92a34–5, Barnes' translation, second ed.

[63] *Posterior Analytics*, 2.7 92b1, Barnes' translation, second ed.

many translations, Aristotle does not in fact in this passage use *epagōgē* (*induction*), but the present participle *epagōn* (*inducing*). With this in mind, and considering the overall context of the passage, we can see that Aristotle intends to say the following: We cannot prove a particular attribute to be essential by deduction; nor can we prove it by bringing in ('epagōn') all instances and finding the attribute to be true of each, for that merely indicates that the attribute is held in common, not that it is essential. In 2.7, Aristotle does not say that induction (epagōgē) requires complete enumeration.

To reinforce this interpretation of 2.7, and to provide background for the coming discussion of *Prior Analytics*, consider an earlier chapter in the *Posterior Analytics*, chapter 1.5. Here Aristotle gives one of his rare, maybe unique, examples of complete enumeration. He says that knowing something to be true of scalene, isosceles, and equilateral triangles is not sufficient for knowing it to be true of triangles qua triangles. It may be known of each triangle taken singly, but not of triangles "primitively and universally,"[64] not "of triangles as trianlges."[65] By the common understanding of Aristotelian induction as complete enumeration this should be the ideal case. But Aristotle makes no mention here of *epagōgē* and positively rejects the possibility of proving that a characteristic is primarily and universally true of a kind of thing merely by finding it to be true of all kinds of

[64] *Posterior Analytics*, 1.5 74a13, Barnes' translation, second ed.

[65] *Posterior Analytics*, 1.5 74a31, Barnes' translation, second ed.

instances. This passage challenges the conventional interpretation of the chapter we will now examine.

Prior Analytics

In our survey of Aristotle's use of *epagōgē*, the *Prior Analytics* is the only remaining work to consider. *Epagōgē* appears there twelve times. Four add nothing new and are consistent with everything discussed so far. The other eight appear in book 2, chapter 23. This chapter regularly is, and often has been since late antiquity, considered the most central and important treatment of induction in the Aristotelian corpus. In summaries of Aristotelian induction, it is frequently the only passage cited. If there is thought to be one chapter that presents Aristotle's definitive statement on induction, this is it. Unfortunately, when treated in isolation it can create an impression of Aristotelian induction completely at odds with what I have presented so far. Also unfortunately, the *Prior Analytics*, like the *Posterior Analytics*, is cryptic, obscure, and often ambiguous. As I said I would at the beginning, I have left the most difficult passage for last. I have also left for last the passage for which I have an unconventional and revisionist interpretation. If the conventional interpretation is correct then either all I have argued for up to now is refuted or Aristotle held two conflicting views of induction. If my revisionist interpretation is correct, then the eight uses of *epagōgē* in *Prior Analytics* 2.23 are consistent with the other eighty-eight in the known corpus.

The troublesome chapter appears near the end of the *Prior Analytics*, after Aristotle has presented an extended treatment of the syllogism and just finished a discussion on conversion. In five short concluding chapters he relates other types of argument, such as induction and paradigm, to what has preceded. Aristotle begins, "It is evident, then, how terms are related with respect to conversions and with respect to being preferable or more to be avoided."[66] Aristotle continues, "But now, it should be explained that not only dialectical and demonstrative deductions come about through the figures previously mentioned, but also rhetorical ones, and absolutely any form of conviction whatever, arising from whatever discipline."[67] Aristotle then repeats a claim made so many other times, "For we have conviction about anything either through deduction or from induction."[68] This concludes what is regularly treated as the first paragraph of the chapter.

The next few sentences are the problem. Let me present the conventional interpretation first. The paragraph begins, "Induction, then—that is, a deduction from induction—is deducing one extreme to belong to the middle through the other extreme."[69] Aristotle presents this example:

	(1) Man, horse, and mule are long-lived.
	(2) Man, horse, and mule are bileless.
By conversion of (2):	<u>(3) Bileless animals are man, horse, and mule.</u>
By (1) and (3):	(4) Bileless animals are long-lived.

[66] *Prior Analytics*, 2.23 68b10–13, Smith's translation.

[67] *Prior Analytics*, 2.23 68b10–13, Smith's translation.

[68] *Prior Analytics*, 68b13-14, Smith's translation.

[69] *Prior Analytics*, 68b15–16, Smith's translation. This is probably the most quoted passage on induction from Aristotle.

Aristotle is drawing a universal conclusion by deducing one extreme (long-lived) to belong to the middle (bileless) by means of the other extreme (particular types of animals). This is a simple syllogism—all C is A, all B is C, therefore all B is A, with C being the union of the types man, horse, and mule. The syllogism is valid as long as the conversion from (2) to (3) is valid, and that conversion is valid if the only bileless animals in the world are men, horses, and mules. Aristotle asks us to presume this is true for purposes of the illustration. The paragraph ends, "One must understand C as composed of every one of the particulars: for induction is through them all."[70] Aristotle is therefore saying that the only valid induction is a complete enumeration, and induction is ultimately just a kind of deduction. The conventional interpretation of this paragraph in *Prior Analytics* 2.23 then is that an inductive argument, if valid, can be reduced to a deductive one.

The claim, however, that induction is a process of complete enumeration and is therefore a kind of deduction is an extraordinary one. Smith called it "surprising."[71] Ross called it "strange," and chalked it up to Aristotle being overcome with "enthusiasm for his new-found discovery of the syllogism."[72] The claim is completely out of character with everything we have encountered so far in our survey of Aristotelian induction. Every example of induction Aristotle has given has been for a group of particulars that could not possibly be fully

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[70] *Prior Analytics*, 2.23 68b29, Smith's translation.

[71] Smith, "Notes," 220.

[72] Ross, "Commentary," 50,

enumerated. All the way up to this very chapter (and continuing immediately after it), he has consistently, repeatedly, and unambiguously stated that there are two separate ways of acquiring knowledge, induction and deduction. He has repeatedly indicated that of the two, induction is more fundamental. If one depends on the other in some way, it is deduction that depends on induction, not vice versa. Even within the paragraph itself, the conventional interpretation is strained. Aristotle knew that other animals lack bile. In *On the Parts of Animals*, he lists several and gives no indication that the list is even numerable.[73] If Aristotle had wanted to indicate that induction is ultimately just complete enumeration, why did he not choose an example of particulars that could plainly be completely enumerated, such as odd and even numbers or equilateral, scalene, and isosceles triangles? Read in isolation, this and other internal difficulties might be dismissible (maybe for example, he did believe the list of bileless kinds of animals was surveyable), but when the paragraph is considered in the full context of Aristotle's other comments on induction, it seems best to suspect that another interpretation may be possible.

An alternate interpretation can be found by reading the chapter from the outside in rather than from the inside out. Let me explain. The passage has three identifiable sections normally translated as three paragraphs, the first of which (68b8–b14) I quoted in full above and the second of which (68b15–29) is the substantive core whose conventional interpretation I summarized. The third

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[73] *On the Parts of Animals*, 4.2 676a15-677b11, as Hintikka, "Aristotelian Induction," 427 notes. Mention is made of the deer, camel, mouse, and dolphin, among others.

paragraph (68b30–38) is a concluding summary. The first and last paragraphs are typically read in light of the middle core. But instead, imagine that the middle paragraph has been lost and that we have to reconstruct it based on the surrounding sentences. What would we conclude it must have said?

The first paragraph says that all knowledge comes to be such by means of the syllogistic figures that have been presented. The paragraph ends with the familiar statement, "For we have conviction about anything either through deduction or from induction."[74] There is no sign that a new understanding is to follow. Now skip the second paragraph, pretending its existence is known but its contents lost. The third paragraph begins, "This is the sort of deduction that is possible of a primary and unmiddled premise."[75] What did we miss? It sounds as if the second paragraph must have presented an example of something Aristotle is calling the 'deduction of an unmiddled premise.' But what is that? The text continues, "for the deduction of those premises of which there is a middle term is by means of the middle term; but the deduction of those of which there is not a middle term is by means of induction."[76] So there are two kinds of deductions, deductions of middled premises and deductions of unmiddled premises. In the first, it appears, the premise is the conclusion of some syllogistic figure that has in it a middle term. In the second, the premise is also the conclusion of some syllogistic figure, but the role

[74] *Prior Analytics*, 2.23 68b13-4, Smith's translation.

[75] *Prior Analytics*, 2.23 68b30–1, Smith's translation.

[76] *Prior Analytics*, 2.23 68b31–2, Smith's translation.

earlier played by a middle term is now played by an induction. Let us call the first a deduction-from-a-middle and the second a deduction-from-induction. That second paragraph must have given an example of a deduction-from-induction, whatever that is, instead of the more familiar deduction-from-a-middle, which has been the subject of the previous chapters.

Next comes a sentence I will skip and return to in a moment. It is followed by the final sentence of the chapter: "By nature, then, the deduction through the middle term is prior and more familiar, but the deduction through induction is clearer to us."[77] Here again, Aristotle is drawing a distinction between what I have called deduction-from-a-middle and deduction-from-induction. Now that intervening, penultimate, sentence is odd, for it presents a different dichotomy. All the rest of this paragraph concerns the dichotomy between deduction-from-a-middle and deduction-from-induction, but that penultimate sentence presents a dichotomy between deduction and induction: "And in a way, induction is the opposite of deduction, for deduction proves the first extreme to belong to the third term through the middle, while induction proves the first extreme to belong to the middle through the third."[78] Ignore for now Aristotle's description of the difference, with its 'first extreme,' 'third term,' and so on, and simply note that Aristotle contrasts deduction and induction while the surrounding sentences contrast deduction-from-a-middle and deduction-from-induction. How are we to

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[77] *Prior Analytics*, 2.23 68b36–8, Smith's translation.

[78] *Prior Analytics*, 2.23 68b33–6, Smith's translation.

understand the discrepancy? Recall that the *Prior Analytics* is probably a lecturer's notes or other outline material and not a polished treatise. I propose that Aristotle is here using a lecturer's shorthand. By 'deduction' he means deduction-from-a-middle (given what has come before in the *Prior Analytics*, interchanging 'deduction-from-a-middle' and 'deduction-from-deduction' would be unsurprising) and by 'induction' here he means deduction-from-induction. Thus this third paragraph, even with the jarring name change in the center sentence, is about the contrast between deduction-from-a-middle and deduction-from-induction. Let us now return to the chapter's central paragraph and see if we find there what our analysis of the outer paragraphs indicates should be there.

Based on the report in the third, we now expect the second paragraph to have presented an example of a deduction-from-induction, that is, an example that, as the third paragraph describes it, 'proves the first extreme to belong to the middle through the third.' We now drop our pretense about losing the second paragraph and look at it. It begins, ". . . a deduction from induction—is deducing one extreme to belong to the middle through the other extreme."[79] This is almost verbatim what the third paragraph said the second was about. There is, however, one small difference, the words I left out at the sentence's very beginning. The first sentence of the central paragraph actually reads, "Induction then—that is, a deduction from induction— is deducing one extreme to belong to the middle

[79] *Prior Analytics*, 2.23 68b15–16, Smith's translation; "deduction from induction" is "ho ek epagōgēs sullogismos," literally, "a from-induction deduction."

through the other extreme."[80] Commentators have struggled with those first four words. It seems that Aristotle is saying that 'induction' is actually shorthand for the more precise 'deduction from induction.' But does he mean this shorthand to apply to the whole corpus, to everything else he has said about induction? Does he mean that the other eighty-eight instances of *epagōgē* we have surveyed are really to be understood as 'deduction from induction'? I do not think so. I propose that the shorthand applies only to the few sentences that follow, including the one in the third paragraph where we have already seen this very shorthand. If *epagōgē* here is meant literally and not as shorthand, then without warning, Aristotle has proposed a new understanding of induction, inconsistent with the rest of the corpus and inconsistent even with the immediately preceding sentence.

But is not the example that then follows an example of complete enumeration? Doesn't the example that follows confirm the literal reading? Isn't the example an exhibition of how an induction is turned into a deduction? I suggest not,[81] and propose the chapter's second paragraph should be understood in the following way.

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[80] Ibid.

[81] Few agree with me on this. In 1850, William Whewell did. William Whewell, "Criticism of Aristotle's Account of Induction," in *William Whewell's Theory of Scientific Method*, ed. Robert E. Butts (Indianapolis, IN: Hackett Publishing Company, 1989), 311-21. It appears that he was ignored on this, but a few Aristotle scholars have recently begun to entertain the possibility. Tsouyopoulus, "Die induktive Methode und das Induktionsproblem in der griechischen Philosophie," 107–14; Engberg-Pedersen, "More on Aristotelian Epagoge," 311–4; Hintikka, "Aristotelian Induction," 427;

From the opening of the paragraph and from what Aristotle said in the preceding, introductory paragraph we know he wants to exhibit how a deduction-from-induction "comes about through the figures previously mentioned,"[82] that is, through the syllogistic figures. His tool for doing so will be conversion, the subject of discussion in the preceding chapter and the subject Aristotle mentioned right at the beginning of this one. His subject for the chapter's middle paragraph, then, is how conversion is used to effect a deduction-from-induction. Aristotle will first present the relevant syllogistic figure using a simple example, an example in which the conversion is justified by a method other than induction, in this case by surveying one or a few particulars or kinds of particulars. He will then expand the example by replacing a conversion justified by survey with a conversion justified by induction. He will spend the bulk of the paragraph setting up the simple example and discussing the role that conversion plays. He will execute the expansion in the paragraph's final words.

Aristotle's exhibition is an application of a conversion rule he introduced and proved in the preceding chapter: "When A and B belong to the whole of C and C converts with B, then it is necessary for A to belong to every B."[83] He begins his

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Niiniluoto, "Hintikka and Whewell on Aristotelian Induction," 54–60. None have precisely anticipated my interpretation regarding the changing meaning of C.

[82] *Prior Analytics*, 2.23 68b11, Smith's translation

[83] *Prior Analytics*, 2.22 68a21–24, Smith's translation. Here is an illustrative example (not Aristotle's): Having angles that sum to 180° (A) and having three sides (B) are both properties of all triangles (C); C converts with B, that is, not only do all triangles have three sides, but everything

exhibition: "Induction, then—that is, a deduction from induction—is deducing one extreme to belong to the middle through the other extreme, for example, if B is the middle for A and C, proving A to belong to B by means of C."[84] This, we see, is going to be an applciation of that earlier proved conversion. Continuing, Aristotle reminds us, "for this is how we produce [deductions-from-]inductions."[85] His example will be a biological one. "For instance, let A be long-lived, B stand for not having bile, and C stand for a particular long-lived thing, as a man, a horse, or a mule."[86] It is not fully clear whether Aristotle means one particular thing or several, and whether he means particular things or particular kinds of things. Translators have rendered various combinations.[87] But Aristotle *does not mean* that men, horses, and mule are the only long-lived (or long-lived and bileless) animals in the world, nor does he want us to pretend that they are. C is a surveyable and finite list of things or kinds of things. We would call it a sample. Now for reasons that are not important here—maybe direct observation, maybe his biological studies—Aristotle knows that all particulars in his sample are both long-lived and bileless. In the

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with three sides is a triangle; therefore, it is necessary that having angles that sum to 180° (A) is a property of everything having three sides (B). A is proved of B by means of C. If there were three-sided things (B) other than triangles (C), C would not convert with B and the conclusion that A is a property of every B could not be drawn. To validate the conclusion, one must have a way to validate the conversion, that is, show that B does not 'reach beyond' (as Aristotle says it, 68b24) C.

[84] *Prior Analytics*, 2.23 68b15–19, Smith's translation

[85] *Prior Analytics*, 2.22 68a19, Smith's translation.

[86] *Prior Analytics*, 2.23 68b19–21, Smith's translation.

[87] The unclear Greek is 'to kath' hekaston makrobion hoion anthrōpos kai hippos kai hēmionos.'

language of the conversion rule, "A and B belong to the whole of C."[88] Every particular in the list is both long-lived and bileless. Since the list is of finite size, and everything on it is bileless, it is valid to convert C with B.[89] (It is also valid to convert C with A, but Aristotle chose B, being bileless, for reasons we will soon see.) By the conversion then, all B is C, and by the rules of the syllogistic figure, all B is A:

	(1) All C is A.
	(2) All C is B.
By conversion of (2):	<u>(3) All B is C.</u>
By (1) and (3):	(4) All B is A.

	(1) All particular things on the list are long-lived.
	(2) All particular things on the list are bileless.
By conversion of (2):	<u>(3) All bileless things are particular things on the list.</u>
By (1) and (3):	(4) All bileless things are long-lived.

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[88] *Prior Analytics*, 2.22 68a21–24, Smith's translation. Aristotle says it more verbosely in the passage we are analyzing, *Prior Analytics* 2.23 68b21–23, "Now, A belongs to the whole C (for every bileless thing is long-lived); but B (not having bile) belongs to every C." Smith's translation. The first parenthetical is a mystery. It seems it should explain how Aristotle knows that 'A belongs to the whole C.' 'For every C is long-lived,' might be expected, and Ross finds a little support in one manuscript for this. Of course, the reason Aristotle knows that everything in his list C is long-lived is that he picked them that way, so 'by selection' might also be expected. A more interesting question is how does he know that the ones he picked (man, horse, mule) are long-lived. I suspect in the parenthetical he is explaining how he knows that: it is because they have no bile, and it is well known that animals without bile are long-lived (*Posterior Analytics*, 2.17 99b5; *Parts of Animals*, 4.2 677a30–35). This explanation for the parenthetical is generally rejected because it is assumed that Aristotle is building up to a proof that every B is A, and so it appears that the syllogism is circular, defending a premise based on the conclusion. But, I argue, this is to misunderstand Aristotle's project in the paragraph. My analysis does not change if the phrase is altered as Ross suggested or excised as Tredennick suggested, but I see no devastating problem with leaving it as is.

[89] *Prior Analytics*, 2.23 68b23–28.

That is, in the sample of particular things (or kinds of things) that Aristotle defined up front, everything bileless is long-lived.

Aristotle has a deduction from a surveyed list. He does not yet have a deduction-from-induction, but he sees that as a simple extention. He wraps up the paragraph by redefining C: "But one must understand C as composed of every one of the particulars: for [a deduction-from-]induction is through them all."[90] But every one of which particulars? Earlier Aristotle had said that an induction-from-deduction is deducing A to belong to B through C, and that C was "a particular long-lived thing, as a man, a horse, or a mule"[91] He now means C to be *all* particular long-lived things, for a deduction-through-induction is not a deducing through just a surveyed list, but 'through them all.' Aristotle is finished and proceeds to the next paragraph, 'This is the sort of deduction that is possible of a primary and unmiddled premise. . .' He has exhibited how a deduction-from-induction comes about through a syllogistic figure by use of a law of conversion.

We, however, are left hanging. It seems we missed a step. How did Aristotle justify making C refer to all long-lived things, and exactly what conclusion were we supposed to have drawn from that redefinition? What is Aristotle taking for granted that we missed? Here is what he ended up with after his redefinition:

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[90] *Prior Analytics*, 2.23 68b28, Smith's translation, my insertion.

[91] or particular long-lived things or kinds of things, depending how you read 'to kath' hekaston makrobion hoion anthrōpos kai hippos kai hēmionos.'

(1) All particular long-lived things (men, horses, mules, and others) are long-lived.
(2) All particular long-lived things (men, horses, mules, and others) are bileless.
By conversion of (2): (3) All things bileless are particular long-lived things (men, horses, mules, and others).
By (1) and (3): (4) All things bileless are long-lived.

Earlier, Aristotle had justified the conversion by surveying the particulars in his sample. Now he justifies it by induction. That justification lies completely outside this paragraph. Aristotle *is not saying* that because of the survey described earlier he is justified in extending his results to all particulars. He *is saying* that because of some induction performed elsewhere, he is justified in claiming that not only are all particular long-lived things bileless (2), but that every particular thing (or kind of thing) that is bileless is also long-lived (3). What could possibly justify that claim? What would justify it is if Aristotle believed that lack of bile was the essential cause of longevity in all particular animals. If so, the conversion would be valid, and the universal statement (rather than merely the sum of particular statements) would be true. Recall what Aristotle said about triangles. Even if one could know that something were true of all three kinds of triangles one could not conclude that it was true of triangles as triangles. The universal statement is not merely the union of particular statements. It must be justified by finding the essential nature of the universal. But, as we have seen from our survey of the rest of the corpus, to identify the essential cause of something being what it is is in fact what Aristotle believes induction is. It was an ancient view that lack of bile was the essential cause of longevity in animals, and Aristotle agreed.[92] That belief is the step that Aristotle presumed we knew, and that he presumed we knew was a discovery reached by induction.

So a deduction-from-induction 'comes about through' the same figure and is validated by the same conversion rule as a deduction from a surveyed list but the justification for the conversion is completely different. That justification is by a process of induction. The result therefore of the syllogistic figure—of a deduction-from-induction—is a universal statement justified because the component induction is valid for all particulars by their essential nature. The deduction-from-induction is through all the particulars, not just some. Note that the inductive generalization is *not* '(4) All things bileless are long-lived.' That is the deductive conclusion. Induction operates in the premises, not in the conclusion. Exactly *how* one comes to know these by induction does not concern Aristotle here. He simply means to show that once one knows the premises by induction, it is possible to form a syllogism, a deduction-from-induction, in which an induction does the work that a middle term does in a deduction-from-a-middle. That is what the chapter's third paragraph said the second paragraph was about, and read correctly, that is what it is about.

By this interpretation, *Prior Analytics* 2.23 is not about turning an induction into a deduction by presuming that men, horses, and mules are the only bileless and

[92] *Parts of Animals*, 4.2 677a30–35.

long-lived animals in the world. The passage is not a claim that an inductive conclusion is made valid by a complete enumeration. In fact, it is not about coming to an inductive conclusion at all. It is about the reason and method by which inductive conclusions, once reached, can provide the premises for syllogisms. The reason they can be is that conclusions reached inductively are universal. They apply to all particulars of a kind, not just those surveyed in performing the induction. The method by which they can be is the swapping of subject and predicate by conversion.

Such conversion is the goal of identifying essence. If one can determine by Socratic induction that the essence of being the best is having the most knowledge, then one can convert 'All men who are the best in a profession are the ones who have the most knowledge of that profession' with 'All men who have the most knowledge of that profession are the best in that profession.' If, as in the *Metaphysics*, it can be claimed that contrariety is the maximum difference of two ends of a continuum, then 'contrariety' and 'maximum difference of two ends of a continuum' can be interchanged in a syllogistic premise. Induction, for Aristotle, is a process by which such equivalences can be reached, and thus premises for deductions generated.

There are two lacunae here. The first is that Aristotle does not explain anywhere in the surviving corpus how one is actually to use induction to identify essence and to be sure that a correct result is obtained. He simply presumes that the student understands that this procedure is the one Socrates used when seeking the essence of courage, confidence, or aretē. To us this is frustrating, especially because in the surviving dialogues, Socrates always failed. All he ever achieved is convincing his interlocutors that their proposed definition was wrong. Yet Aristotle exhibits no reservation in claiming that the essence of aretē or contrariety is 'clear from induction.' We wish we knew more why he thought so.

The second gap is that Aristotle does not explain the relation between, for example, using induction to identify the essence of contrariety and using induction to conclude that irresponsible custodians should not be trusted or that all wise men are honored. Does he believe that the latter conclusions are contained in or necessitated by the meanings of *irresponsible*, *trust*, *wise*, and *honor*? He believes that Socratic induction addresses the former but that the others can be addressed inductively, too. How precisely is the universal justified by identifying what makes the particular the kind of thing it is? Aristotle does not say.

Summary of Aristotelian Induction

Aristotle expected the concept *epagōgē* to be uncontroversial and for his listeners to know what he meant by it. But we now have two views of induction. By the first, induction is obtaining an open-ended universal based on observation of particulars and validating that universal by determining what makes the particulars the kinds of things they are. By the second, induction is a kind of deduction validated by complete enumeration. The two conflict. By the first, induction is more fundamental than deduction and provides the components of a deduction. By the second, induction is a kind of deduction, usually defective since a complete enumeration is seldom possible. By the first a valid induction applies to particulars beyond those that went into its formation. By the second an induction validly applies only to the particulars that went into its formation. The first method was introduced by Socrates and adopted by Aristotle. Yet the second has often been considered Aristotle's position. How could this happen? How could Aristotle's view come to be considered the opposite of his true view?

Only one passage has ever been used to justify the interpretation, *Prior Analytics* 2.23, and it contains a small fraction of Aristotle's comments on induction. How could this passage come to dominate? Were the others corrupted, lost, ignored, mistranslated, banned? Why was the passage itself misread? I have proposed an interpretation based on a claim that when Aristotle wrote unambiguously that induction applies beyond the particulars that went into the universal conclusion that he meant it and that when he wrote the ambiguous and shorthand 'deduction from induction' he meant something that can be determined only by careful consideration of the surrounding passages and the rest of the Aristotelian corpus. How did a presumed meaning of the ambiguous overwhelm a plain meaning of the unambiguous?

The short answer is that the interpretation I have proposed was accepted through antiquity and was then replaced in late antiquity by a group of Neoplatonic scholars in Alexandria. Their interpretation was passed on through Latin, Syriac, and Arabic study and became canonical when those lines of study united in thirteenth-century Latin scholasticism. The long answer and evidence for these ambitious claims are the subject of the next chapter. Once these claims are justified and the intellectual background established, we may look at alternative interpretations proposed during the late Renaissance.

2

Confusion over Induction:

Transmission into the Renaissance

Many books on method, logic, rhetoric, or dialectics in the late sixteenth century had something to say about induction. Of course, books of the time were not all written in the time.[1] From antiquity, Aristotle's *Organon*, Cicero's *De Inventione* and *Topica*, Boethius's commentaries, translations, and treatise *De Topicis Differentiis*, and Galen's collected works were all popular and contained important material on induction. Less popular, but generating remarkable interest were Greek commentaries on Aristotle written in late antiquity translated and published in the mid-sixteenth century. Treatises by Arabic commentators Avicenna and Averroës,

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[1] For a succinct catalog, see Anthony Grafton, "The Availability of Ancient Works," in *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, et al. (Cambridge: Cambridge University Press, 1988), 767–91. For a full, see Paul Oskar Kristeller, ed., *Catalogus Translationum et Commentariorum: Mediaeval and Renaissance Latin Translations and Commentaries*, 8 vols. (Washington, DC: Catholic University of America Press, 1960). Details on particular authors will be provided below when returning to the period.

scholastic logicians Aquinas, Scotus, and Ockham, and the humanists Buridan, Valla, and Agricola all continued to sell. A rash of new books on logic and rhetoric, many inspired by the continental reformer Peter Ramus, hit the English market in the 1570s and were joined by the latest Aristotelian treatises in the 1580s and 90s, such as the Paduan Zabarella's logical works. All mentioned or discussed induction. But in these books one would find diametrically opposed views. In some, induction was a minor kind of deduction, to be mentioned after the syllogism was fully treated. In others, induction was a tool of oratorical persuasion. In others, induction was the method of identifying what makes something the kind of thing it is. These and all texts on induction written in the previous twelve centuries used Aristotle as their point of reference. All were available to influence a late-sixteenth-century English student of intellectual method such as Francis Bacon or of natural philosophy such as William Harvey.

In all these works, the treatments were important but perfunctory. Therefore a student faced with apparent contradictions would struggle to know whether the problem was his own understanding or a real inconsistency in the authors. It would be difficult to reconcile a mention of induction by Galen with one by Ramus, yet equally difficult to conclude that the two were irreconcilable. What Cicero said and what a typical dialectics textbook said seemed unambiguous and clear, but at odds. Avowed Aristotelians seemed to directly contradict their master. A student of the time would be confused and as we will see textbook writers resorted to eclecticism.

To this day, no order has been brought to these clashing ideas of induction. The only way to successfully do so, I propose, is historically, that is, not to stand in a Renaissance gentleman's library and treat all these texts as timeless, but to walk through history from Aristotle to the sixteenth century, tracing the evolution of the idea of induction. This chapter will make the attempt. The goal will be to determine the main lines of transmissions, interpretations, and conflicts in understandings of induction from antiquity to the late Renaissance, using the previous chapter's analysis of Aristotelian induction as the background. The result will be a mere schematic, but one in which I hope the main lines of transmission, points of departure, and shifts in understanding are sufficiently documented to validate the outline and to explain the source of competing ideas on a sixteenth-century bookshelf.[2]

There is a well-researched path by which Aristotle's ideas reached the modern West.[3] By the standard account, Aristotle's writings and philosophy were

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[2] I know of no similar attempt. The study, Milton, "Induction before Hume," takes the approach of looking back in time for precursors of the modern Humean problem of induction rather than meeting past theoreticians on their own terms. E. P. Bos, "A Contribution to the History of the Theories of Induction in the Middle Ages," in *Argumentationstheorie*, ed. Klaus Jacobi (Leiden: Brill Academic Publishers, 1993), 553–76, identifies important sources, but is cursory and not always accurate. Histories of Aristotelian transmission are valuable but give little attention to induction per se. Beyond these, there are only occasional mentions by scholars working in limited periods and lacking a sufficiently broad perspective necessary for the task at hand. This chapter is exhaustive in part to fill this lacuna in the scholarly literature.

[3] David C. Lindberg, "The Transmission of Greek and Arabic Learning to the West," in *Science in the Middle Ages*, ed. David C. Lindberg (Chicago: University of Chicago Press, 1978), 52–

effectively lost to Latin Europe after the decline of Roman civilization. They survived in the Islamic world, however, in Arabic translations and commentaries. By way of these Arabic works and in a revolutionary development, Aristotle was rediscovered in the twelfth century thanks to translation efforts in Italy and Spain. Western scholars then integrated Aristotelianism and Christian theology into a stultifying medieval scholasticism, against which natural philosophers and humanist scholars rebelled in the late Renaissance and early modern period. As true as this general account may be, it does not describe the path by which the concept of induction was transmitted. Minor events in this account are major ones for induction, and revolutionary events in the general transmission had no bearing at all on understandings of induction.

From Aristotle to Late Antiquity

The first stage in the transmission of the concept of induction is from fourth-century B.C. Athens to sixth-century A.D. Alexandria. From what little we can discern, it appears that one view prevailed, that described in the last chapter. Let us consider Epicurean and Stoic views, then the influential view of Cicero, and then that of Galen.

90; William A. Wallace, "The Philosophical Setting of Medieval Science," ed. David C. Lindberg (Chicago: University of Chicago Press, 1978), 91–119; David C. Lindberg, *The Beginnings of Western Science*, ed. David C. Lindberg (Chicago: University of Chicago Press, 1992); Edward Grant, *The Foundations of Modern Science in the Middle Ages* (Cambridge: Cambridge University Press, 1996).

The term *epagōgē* does not appear much in Hellenistic writing.[4] Recall, however, that Aristotle used the phrase 'argument from similarity [homoiotēs]' for an induction in which the universal was applied to new particulars but was itself left unstated. This phrase did feature prominently in some Hellenistic writing, including a dispute between Stoics and Epicureans over the validity of universal statements. The use of the phrase and the nature of the dispute suggest that the Epicureans maintained a view of argument from similarity, if not also of induction, similar to that of Aristotle and Socrates. Our primary source for the dispute is *De Signis* or *On Methods of Inference* by the Epicurean Philodemus (c. 110–c. 40 B.C.)[5] Though the text was not available in the Renaissance, it will help us understand the texts that were. It is also valuable because of an hypothesized influence of

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[4] A. A. Long and D. N. Sedley, *The Hellenistic Philosophers*, vol. 1, *Translations of the Principal Sources with Philosophical Commentary* (Cambridge: Cambridge University Press, 1987), though indexing the subject, lists no instances of the term. The cited passages concern subjects that we today call *epagōgē*, not what Hellenistic writers did. Epicurus (341–270 B.C.) uses *epagōgē* in only a few surviving fragments, the most complete of which merely indicates he understood induction to be a method by which a statement that applies to some things applies by extension to others. My thanks to James Lennox for translating for me Epicurus, *Deperditorum librorum reliquiae* fragment 31, section 16, line 11.

[5] "Controversy between Stoics and Epicureans" in Philodemus, *On Methods of Inference*, ed. Phillip Howard De Lacy and Estelle Allen De Lacy, trans. Phillip Howard De Lacy and Estelle Allen De Lacy, Rev'd ed. (Naples: Bibliopolis, 1978). The subject is treated at length in Elizabeth Asmis, *Epicurus' Scientific Method* (Ithaca and London: Cornell University Press, 1984), especially the chapter "Philodemus: Inference by Similarity," 197–211; and perceptively in Long and Sedley, *The Hellenistic Philosophers*, 93-7, 261-6.

Epicureanism on Francis Bacon[6] and the fact that the text has been called "the first sketch of an inductive logic . . . inspired and sustained by the breath of the truest Baconian spirit."[7]

According to Philodemus, at issue in the debate are two kinds of argument for universal statements, the argument from elimination (anaskeuē) and the argument from similarity (homoiotēs). In the dispute, both Epicureans and Stoics accept validity of the first, but Stoics reject validity of the second. Both kinds of arguments are ways to justify universal, hypothetical statements, i.e., statements of the form 'if the first, then the second' (using Philodemus' language), or 'if p then q' (using modern symbols). Both sides accept that the statement 'if p then q' can be justified by validating 'if not-q then not-p.' This contrapositive can be justified by two different arguments. The first applies when there is a direct causal dependence. For example: In Epicurean physics, we know that if there is motion (p), there is a void (q), because if there were no void (not-q), there would be no motion (not-p). This is the 'argument from elimination.' But the Epicureans recognize a second type of justification, which the Stoics deny, the argument from similarity. Philodemus offers this example: We know that if Plato is a man (p), Socrates is a man (q), because if Socrates were not a man (not-q), Plato would not be a man (not-p). In this argument, there is no physical, causal connection between Plato and Socrates.

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[6] Peter Urbach, *Francis Bacon's Philosophy of Science* (La Salle, IL: Open Court, 1987), 37–8.

[7] Theodor Gomperz, *Philodem: Über Induktionsschlüsse* (Leipzig: B.G. Teubner, 1865), cited and translated in Asmis, *Epicurus' Scientific Method*, 198.

Plato's existence does not physically depend on Socrates'. Were there no Socrates there could still be a Plato. But, Philodemus argues, Socrates and Plato are so similar that "it is impossible that Socrates is not a man and Plato is a man."[8] For one to be a man and the other not to be is inconceivable, literally inconceptualizable. One could not form the concept *man* without subsuming under it both Socrates and Plato. Philodemus stresses his point by asking how we can justify the claim that man is mortal. If it is merely that men familiar to us are mortal and therefore men everywhere are, then the justification is invalid, he says. But if the justification is that being mortal is an essential part of what it means to be a man, then the justification is valid. Philodemus goes further. He claims that the argument from elimination actually depends on the argument from similarity, for the very concepts and premises presumed in an argument from elimination are justified—and can only be justified—by arguments from similarity. Thus, Philodemus is following Socrates in claiming that a deductive argument (the 'argument from elimination') is valid only to the extent that its component concepts are valid, and Philodemus says that the method of validating those concepts is the 'argument from similarity.' He seems to use the phrase just as Aristotle did, and for Aristotle, the only difference between an induction and an argument from similarity is the form in which the conclusion is stated. If Philodemus is speaking for all Epicureans and if they use the phrase 'argument from similarity' the same

[8] Philodemus, *On Methods of Inference*, cols. 12.28–29, p. 105.

way Aristotle did, then their view of induction was like his and Socrates'. If Philodemus's opponent is representative of Stoicism, then Stoics may have doubted that induction can obtain certainty, but they did not disagree with the Epicureans on what it is.

Contemporary with Philodemus is one of history's most influential writers on induction and partly a Stoic himself, Cicero (106–43 B.C.)—influential not only because he coined the term *inductio*, which has been universally adopted as the translation for *epagōgē*, but because of his prominence in Renaissance humanism. He treats *inductio* in two works, *De Inventione* (ca. 85 B.C.) and the *Topica* (ca. 44 B.C.)[9] While Aristotle's treatments of induction are mostly incidental and often cryptic, Cicero's is direct and straightforward. In the *Topica*, he offers an example of an inductive argument that will now sound familiar: Just as a guardian (tutor), an associate, and others must keep faith, so must an agent (procurator). He continues, "This procedure, which arrives at its aim from several instances, may be named induction, which in Greek is called epagōgē; Socrates made extensive use of it in his discussions."[10] Although Cicero said at the beginning of the *Topica* that he is specifically writing his work as a summary and guide to Aristotle's *Topics*, he

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[9] Ciceronian induction receives a short treatment in the commentary to Marcus Tullius Cicero, *Topica*, trans. Tobias Reinhardt (Oxford: Oxford University Press, 2003), 285-6. Aside from giving the concept its Latin name, Cicero's contribution to both the theory and transmission of induction is unjustly overlooked.

[10] "Haec ex pluribus perveniens quo vult appelletur inductio, quae Graece epagōgē nominatur, qua plurimum est usus in sermonibus." *Topica*, §42, Reinhardt's translation.

associates induction not primarily with Aristotle but with Socrates. He does the same in *De Inventione*.

In *De Inventione*, Cicero offers an orderly and extended treatment of what he says are the two ways in which to conduct an argument, induction and deduction (ratiocinatio). He associates induction "chiefly [with] Socrates and the disciples of Socrates," while saying that deduction "has been exceedingly practiced by Aristotle, and the Peripatetics, and Theophrastus."[11] He treats induction first. He calls it a type of argument from similarity and gives an extended definition: "Induction is a way of speaking that first obtains assent to indisputable things from someone, then by those assents, establishes something else under discussion on account of its similarity to the first things."[12] He offers another example and describes why Socrates preferred this method. Cicero then explains that the force of an induction rests on the soundness of the particular instances and on the essential similarity between them and the new claim for which the induction is made. He asserts that if the resemblance can be reliably shown and no counterexamples found, the burden of proof shifts to him who would deny the proposition. Cicero then elaborates on the structure of an induction, saying it has three parts. The first is the

[11] "maxime Socrates et Socratici," "summe est ab Aristotele atque a Peripateticis et Theophrasto frequentatum." Marcus Tullius Cicero, *De Inventione*, trans. C. D. Yonge (London: George Bell & Sons, 1888), 1:35. Theophrastus succeeded Aristotle as head of the Lyceum.

[12] "Inductio est oratio, quae rebus non dubiis captat assensionem eius, quicum instituta est; quibus assensionibus facit, ut illi dubia quaedam res propter similitudinem earum rerum, quibus assensit, probetur." *De Inventione*, 1.31, my translation.

group of instances.[13] The second is the general principle. The third is the application of that principle to the particular situation at hand, which in Cicero's examples is usually a legal case.[14] Cicero gives one more example, one which highlights the comparison of instances, then the universal principle, then the application to a new situation. In this and all his examples he presumes that it is in the nature of induction that the validity of an inductively advanced claim extends beyond the instances that went into its formation. With this example, Cicero ends a discussion of induction longer, clearer, and more orderly than appears anywhere in the Aristotelian corpus, but one that is fully consistent with the interpretation I have proposed for Aristotelian induction.

Cicero proceeds to describe deduction and along the way makes an important point about the relationship between deduction and induction. Cicero provides an extended discussion about whether a deduction properly includes three parts or five. Cicero acknowledges that the dispute might seem irrelevant, but insists it should not be omitted. He argues that the Aristotelians and "those rhetoricians who are accounted the most elegant and the most skilful"[15] are correct that there are five parts to a deduction. This five-part structure is not explicitly described in the surviving Aristotelian corpus, suggesting that Cicero had access to works by

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[13] As did Aristotle, Cicero accepts the possibility of induction from only one instance.

[14] Cicero does not give a separate name, as Aristotle did with *paradigm* or *argument from similarity* to an argument in which the universal is left unstated. Cicero uses *induction* for both.

[15] "deinde a rhetoribus iis, qui elegantissimi atque artificiosissimi putati sunt." *De Inventione*, 1.35, Yonge's translation.

Aristotle or at least Peripatetics that we do not have. The five parts are the first premise, which he calls the *propositio*, and then its proof, then the second premise, which he calls the *assumptio*, then its proof, and finally the conclusion.[16] Those who claim only three parts group each premise with its proof, but Cicero argues that the separate proofs are important. He acknowledges that sometimes these proofs are simple enough to go unstated, but the proofs are a crucial part of the deduction. Without them the deduction fails. In his several examples of such proofs, the proofs are all inductions. One is this: That house which is well-managed is one managed according to a deliberate plan; that army which is well-managed is one managed according to a deliberate plan; that ship which is well-managed is one managed according to a deliberate plan; the conclusion is that those things which are well-managed are those which are managed according to a deliberate plan. Note the similarity to inductions seen earlier in Socrates and Aristotle. Cicero is not saying that he has checked several instances of well-managed operations, found that they were all managed according to a plan, and then predicts that the pattern will continue based on a presumption that instances yet to be surveyed will be like those that have been. He is instead saying that the very nature of being well-managed is to be managed deliberately rather than haphazardly. He is making a causal

[16] The terms *proposition* and *assumptio* for *major premise* and *minor premise* will be revived in the sixteenth century.

statement about what constitutes being well-managed.[17] Cicero considers it a necessary part of a deduction to establish the essential meaning of the terms and truth of the premises on which the deduction depends. In other words, he treats induction as the foundation for deduction. By insisting that a deduction has five parts instead of three, Cicero insists that validation of a deduction necessarily includes validation of the inductive premises.

In the first century A.D., Quintilian (c. 35–c. 100 A.D.) adopted not only Cicero's neologism *inductio*, but at least one of his examples: "If a guardian (tutor) should be required to be faithful to his trust, so should an agent (procurator)."[18] Like Cicero, he writes about induction directly and orderly. He introduces it as the method "chiefly used by Socrates." "When he [Socrates] had asked a number of questions to which his adversary could only agree, he finally inferred [inferret] the conclusion of the problem under discussion from its resemblance to the points already conceded."[19] Like Aristotle and Cicero, Quintilian finds the crucial

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[17] Cicero's grammatical structure, a structure he uses consistently, supports this. He does not merely say that 'all well-managed things are managed deliberately,' i.e., that 'all As are B,' something that could be true accidentally rather than essentially. Instead Cicero says that 'those things which are well-managed are managed deliberately,' suggesting that what makes something well-managed is that it is managed deliberately, that 'what makes an A an A is that it is B,' that 'it is in the nature of A that it cannot be an A without being a B.' On the difference, compare the analysis of Aristotelian induction, as mentioned earlier, in Tsouyopoulus, "Die induktive Methode und das Induktionsproblem in der griechischen Philosophie," 107–14.

[18] Quintilian, *Quintilian I: The Insitutio Oratoria*, trans. H. E. Butler (Cambridge, MA: Harvard University Press, Loeb Classical Library, 1920), 5.10.73.

[19] *Institutio Oratoria*, 5.11.3, Butler's translation.

component in induction to be the identification of essential attributes. "What is the finest [generosissimum] fruit? The best, I should imagine. What is the finest horse? The swiftest. So too the finest type of man is not he that is noblest of birth, but he that is most excellent in virtue."[20] Quintilian is not setting up a syllogism with one premise about fruit and another about horses, then presuming or pretending that these are all the instances to be surveyed, and then inferring a conclusion. Rather he is trying to identify the essence of what it means for something to be the finest, just as Socrates, Aristotle, and Cicero did.

Like Aristotle, Cicero and Quintilian wrote as if what induction is is obvious. None of the three claimed to recognize any controversy over induction's nature or validity. None claimed to be an innovator on the subject. All wrote as if they were presenting conventional wisdom. If they were in fact doing so, then throughout Greek and Roman antiquity, induction was understood to be the procedure that Socrates used to make generalizations about the essential nature of things, and these generalizations were understood to provide the foundations and premises for deductive reasoning. All three discussed epagōgē or inductio primarily, though not exclusively, in an oratorical context. When the Epicurean Philodemus discussed what seems to be a related, if not identical, subject in a logical context, he used 'argument from similarity.' Yet we should not conclude that *epagōgē* had

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[20] *Institutio Oratoria*, 5.11.8, Butler's translation.

importance only in an oratorical context. Aristotle incorporated it into his works on logic and natural philosophy. So too did Galen (129–c. 199 A.D.)

Galen's treatment of induction is for us very frustrating. He says epagōgē is a subject of major importance and claims to have written extensively on it in his work *Of Demonstration*.[21] Unfortunately, this magnum opus on scientific methodology, known to run to fifteen volumes, does not survive. In his works that do survive, we have about two dozen scattered uses of *epagōgē*. Although some of these are what we may now call conventional, a few suggest important new views on the subject.

In *De sophismatis seu captionibus penes dictionem*, Galen says that induction and deduction are the two ways to establish a claim.[22] In *In Hippocratis librum de officina medici commentarii iii*, he reports that many people associate induction with Plato, that is, with Socrates.[23] But the most substantive surviving treatment of *epagōgē* is in *De simplicium medicamentorum temperamentis ac facultatibus*, and it is here that Galen suggests important new directions. He criticizes those who attempt to gain scientific knowledge by using what they call induction, for they fail to understand

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[21] *Ad Thrasybulum*, 2:404, and *De Simplicium Medicamentorum Facultatibus*, 5:40, in Galen, *Cl. Galeni Pergameni Asiani*, ed. Janus Cornarius (Basil: Froben, 1549). For Galen's works, I have used the digitized Latin facsimilies, Basil 1549 and Venice 1565, available at http://www.bium.univ-paris5.fr/histmed/medica.htm, and the Greek text at *Thesaurus Linguae Graecae (TLG)*, http://www.tlg.uci.edu/. For extended passages, I have generally translated from the Latin, with occasional checking against the Greek as needed.

[22] *TLG*, Kühn, 14.584.9.

[23] *TLG*, 18b.909.4.

induction properly and thus they use it inappropriately. The misuse, he says, stems from failing to understand the difference between an argument from induction and an argument from examples.

> If someone makes a claim only from examples, it applies only to one or two of the same kind, or at any rate to a few others. But using induction, one tries to include all things open to experience, by attending as much as possible not to what is plain and obvious to everyone, but to what is obscure and less well understood.[24]

If these hidden factors are properly identified, induction is binding (biaios) and persuades forcefully (peithei sphodrōs).[25] Galen's suggestion here is important and new. A remedy, for example, may cure a disease a few times or even many. But that is not enough to know that it will always be effective. To gain universal knowledge one must know why the remedy works, and the reason may be obscure. The proper use of induction, Galen seems to say, is to collect the examples but then, crucially, to identify the hidden causal factor. He says this can be done only by those "well-trained in demonstrative methods"[26] and that such methods are described in *On Demonstration*. The claim that induction can be made binding by identification of a causal factor, while pregnant, will not be encountered again until the modern period.

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[24] Galen, *Galeni Isagogici Libri*, ed. A. Gadaldini (Venice: Giunta, 1565), bk. 2, ch. 4; *TLG*, 11.470.16; my translation.

[25] *TLG*, 11.471.3.

[26] *TLG*, 11.471.4.

With Galen we see the first suggestion that the nature and validity of induction is not obvious and may be subject to debate. Galen has added a normative element to the discussion. He says that there is a correct and an incorrect way to perform an induction, that there are methodological standards that should be followed, and that some practitioners are failing to recognize and follow these standards. We do not know what standards he advocated or precisely who he was criticizing. But we do know that an alternate understanding of induction was forming, especially in the schools of Alexandria.

The Neoplatonic Reinterpretation

Alexandria was in Galen's day growing as a leading center for syncretic thought, where scholars sought to reconcile, for example, Stoicism with the emerging Christianity, or Christianity with Platonism, or Platonism with Aristotelianism. Around the 230s, Ammonius Saccas and Plotinus founded Neoplatonism, by which time the schools were already important centers of Christian theology. In this environment, a new understanding of induction arose. By the old understanding, universals were obtained by examining particulars. To gain universal knowledge of what courage is, for example, one looks at courageous men and identifies what they have in common that makes them courageous. The universal is empirically accessible. It can be discovered by observation, for it exists in observed reality. But the Neoplatonists (and the Christians of late antiquity) did not have this confidence that universals could be obtained by observation of particulars, for such universals do not have their primary existence in observed reality. Obtaining universal knowledge by observing particulars was the process known as induction. That concept would either need to be rejected or reinterpreted. The conventional understanding could not stand. To keep Aristotle's text and understand it Platonically, the text would need to be reinterpreted.

The new interpretation of induction was the result of a cumulative series of altered readings of key passages in Aristotle by scholars with Neoplatonic sympathies and a general distrust in the possibility of obtaining universals by means only of observation. While each step claimed sanction in Aristotle, the series cumulatively amounted to a reversal of the previous established view. The change was gradual, beginning in the work of Clement in the late second-century A.D., spreading among Greek scholars, and reaching full systematization in Alexandria around 500 A.D. The new interpretation of induction became canonical all through the Middle Ages, in both Latin and Arabic schools. I will first describe its incremental emergence and then its transmission.[27]

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[27] The transformative role of the Aristotelian commentators of late antiquity has become a significant topic of scholarly study in the last fifteen years, thanks largely to the efforts of Richard Sorabji. See, e.g., Richard Sorabji, ed., *Aristotle Transformed: The Ancient Commentators and Their Influence* (London: Duckworth, 1990); Lawrence Schrenk, ed., *Aristotle in Late Antiquity* (Washington, DC: Catholic University Press of America, 1994); Richard Sorabji, ed., *The Philosophy of the Commentators, 200-600 AD*, vol. 3. Logic and Metaphysics (London: Duckworth, 2004). On-going publication of English translations in the series *Ancient Commentators on Aristotle*, edited by Sorabji and published by Duckworth, is helping make the sources more accessible. The Greek sources appear in Reimer, ed., *Commentaria in Aristotelem Graeca. Edita consilio et auctoritate Academiae Litterarum Regiae Borussicae.*, 14 vols. (1882-1909). Reprints of sixteen-century Latin translations appear in Charles Lohr, ed., *Commentaria in Aristotelem Graeca Versiones latinae termporis*

Clement was born in Athens around 150 A.D. and was exposed to multiple schools of Greek philosophy. He traveled widely, converted to Christianity, and became head of the Christian catechetical school in Alexandria in 180, where he actively sought to reconcile various aspects of Greek philosophy with Christianity. Clement, later St. Clement, greatly influenced the future of Christian theology.

Clement discusses induction in book 8, chapter 6 of *The Stromata*.[28] The chapter demonstrates familiarity with Plato and Aristotle as well as a desire to reconcile the two. But the attempt forces Clement to contradict or misread Aristotle. In the chapter, Clement discusses definitions and their source. He says, "Induction leads to the universal and the definition."[29] In this he is restating what we have seen to be the conventional understanding, articulated by Aristotle, going back to Socrates. But Clement then describes how definitions come to be, and the procedure he describes does not sound like induction at all. Clement says that the definition is the "summation resulting from Division."[30] Though Clement does not

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resuscitatarum litterarum (CAGL), 30 vols. (Stuttgart-Bad Cannstatt: Frommann-Holzboog, 1990–). In this recent scholarship, induction has attracted little attention. The notable exception is Donald Morrison, "Philoponus and Simplicius on Tekmeriodic Proof," in *Method and Order in Renaissance Philosophy of Nature: The Aristotle Commentary Tradition*, ed. Daniel A. Di Liscia, Eckhard Kessler, and Charlotte Methuen (Aldershot: Ashgate, 1997), 1–22, discussed more below. Sources are now available in English translation in chapter 9, "Induction and Certainty," of Sorabji, ed., *The Philosophy of the Commentators, 200-600 AD*, 262–72.

[28] Clement of Alexandria, "Stromata," in *The Ante-Nicene Fathers: Translations of the Writings of the Fathers Down to A.D. 325.*, ed. Alexander Robert and James Donaldson (1885).

[29] Ibid., 8.6.

[30] Ibid.

acknowledge it, his discussion comes right out of *Posterior Analytics* book 2, chapters 5–7, with similar language, structure, and phrases, but in those chapters Aristotle is stressing that definitions are *not* the result of division, not that they are. Indeed, Aristotle is specifically identifying the problems that arise from such a view, a view Plato had advocated. Clement is co-opting the style, structure, and language of Aristotle's argument to defend a Platonic position, without recognizing or acknowledging that he is directly contradicting Aristotle.

To defend his own position, Clement makes a subtle but important shift in the reading of one sentence in particular. He slightly alters one word in Aristotle's sentence, and in so doing, inverts the meaning of the passage. Aristotle had written "inducing [epagōn] proves not what the essential nature of a thing is but that it has or has not some attribute."[31] Given the context, Aristotle clearly meant by *epagōn* a complete enumeration of all groups of individuals, but, as I argued in the previous chapter, he did not mean *epagōgē*. Doing so would contradict the thrust of the whole passage as well as the use of *epagōgē* in Aristotle's other works. Aristotle meant exactly what he wrote, *inducing*, not *induction*. With no mention of Aristotle, Clement repeats Aristotle's sentence verbatim, but he changes *epagōn* to *epagōgē*. Clement thus says that induction is a complete enumeration of groups of particulars, directly contradicting what Aristotle had said about the three kinds of

[31] *Posterior Analytics*, 2.7 92b1, Mure translation, but with *inducing* for Mure's *induction.*

triangles and contradicting the very point Aristotle was making in the passage Clement appropriated.

Clement is the first writer I have found to say that induction obtains its force from some kind of complete enumeration. We do not know if Clement believed he was articulating Aristotle's own view or if he thought he was correcting it. Even though he makes no direct reference to Aristotle, by adopting the language and structure of Aristotle's argument, Clement begins the process of associating this view with Aristotle.

About twenty years after Clement became head of the ecclesiastical school in Alexandria, Alexander of Aphrodisias was teaching Aristotelian philosophy, possibly as head of the Lyceum in Athens.[32] Galen was still alive, and the two disagreed over several philosophical issues. Though we do not know if they discussed it in writing as they did other issues, one such disagreement was over the nature of induction. Alexander is generally considered the last "thoroughly Aristotelian"[33] philosopher of antiquity, but regarding induction he joined Clement and broke with his master.

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[32] We know he had a senior position teaching Aristotle's philosophy somewhere between 198 and 209, but it could have been one of several places. Even if he was not in Alexandria, his thought has affinities with that emerging there. A good analysis of the issue is in the editor's introduction to Alexander of Aphrodisias, *On Aristotle's Prior Analytics 1.1–7*, trans. Jonathan Barnes, et al. (Ithaca: Cornell University Press, 1991), 1-2.

[33] Ibid., 3.

Galen had said that unlike a mere string of examples, a properly formed induction that identified relevant, non-obvious, causal factors could yield a binding conclusion. Alexander, however, unambiguously and repeatedly says that the conclusion of an induction, like the conclusion drawn from a string of examples, may be persuasive but it cannot be necessary, because it cannot be complete.

> For the universal does not follow by necessity from the particulars once these have been conceded, because we cannot get something through induction by going over all the particular cases, since the particular cases are impossible to go through.[34]

He makes this point repeatedly while commenting on the *Topics* and makes it again in his commentary on the first book of the *Prior Analytics*. He there writes,

> Aristotle discusses these types of justification [induction and paradigm] at greater length in the second book [of the *Prior Analytics*], showing how they differ from syllogistic justification, that they too are useful, and how they are subsumed under syllogistic justification. Thus for our present purposes what we have said about them is enough.[35]

Alexander marks another milestone in the history of the interpretation of Aristotelian induction. He agrees with Clement that induction gains force only by surveying all subsumed cases, but he takes a new step by shifting attention away from the *Topics*, the *Rhetoric*, the *Posterior Analytics*, and indeed all the rest of the

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[34] Sorabji, ed., *The Philosophy of the Commentators, 200-600 AD*, 262.

[35] Alexander of Aphrodisias, *On Aristotle's Prior Analytics 1.1–7*, 44,1-3, p. 104.

Aristotelian corpus, and toward *Prior Analytics* 2.23. Alexander considers that chapter to be Aristotle's definitive treatment of induction.

Writers on the subject before Clement held that a result obtained by induction applies to cases beyond those that went into the result's formation. Clement and Alexander disagreed. Clement addressed situations where the particulars are themselves a countable number of groups of individuals, such as kinds of triangles. Alexander addressed situations of countless particulars. Both agreed that if an induction's conclusion is to be universal, all subsumed particulars must be surveyed. The earlier thinkers held that universals are reached by comparing and contrasting a limited number of particulars and thus identifying the essential nature of all members of a kind. They believed Socrates' search for essential natures was the model for induction. Now thinkers believed the archetype was what they took to be Aristotle's attempt in *Prior Analytics* 2.23 to render an induction as a kind of deduction.

In the third century, that following Clement and Alexander, Diogenes Laertius preserved the older view,[36] but others adopted the new. The skeptic Sextus Empiricus, for example, offered this frequently cited treatment in his *Outlines of Pyrrhonism:*

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[36] "Plato" in Diogenes Laertius, *Lives of Eminent Philosophers*, trans. R. D. Hicks (London and New York: William Heinemann and G. P. Putnam's Sons, Loeb Classical Library, 1925), 3.53, p. 323.

> It is also easy, I consider, to set aside the method of induction. For when they propose to establish the universal from the particulars by means of induction, they will effect this by a review either of all or of some of the particular instances. But if they review some, the induction will be insecure, since some of the particulars omitted in the induction may contravene the universal; while if they are to review all, they will be toiling at the impossible, since the particulars are infinite and indefinite. Thus on both grounds, as I think, the consequence is that induction is invalidated.[37]

Sextus was concurring with the emerging view that universal knowledge could not be obtained by observation of a limited number of particulars. In the fourth century, the Greek commentator Themistius took the step that Clement had not, that of attributing to Aristotle the view that *Posterior Analytics* 2.5–7 claimed a valid induction is an enumeration of all subsumed particulars.[38]

If an induction surveys all the particulars or kinds of particulars, then an induction can be reduced to a deduction. If something is true of each of the planets, then it is true of all planets. If the only particular kinds of triangles are isosceles, scalene, and equilateral, and all three kinds have angles that sum to 360 degrees, then it deductively follows that all triangles have angles that sum to 360 degrees. This recasting of Aristotelian induction as a kind of deduction was just one part of

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[37] *Outlines of Pyrrhonism*, book 2, chapter 15, as quoted in Milton, "Induction before Hume," 56.

[38] *Analyticorum Posteriorum paraphrasis* volume 5, 1, pages 44–50 in *TLG;* volume 2, chapter 8 in *CAGL*.

an ongoing reinterpretation of Aristotle that came to maturity in the schools of Alexandria around 500 A.D., under the leadership of Ammonius Hermiae and his students Simplicius and John Philoponus. The scope of this reinterpretation has recently been articulated in an important article by Donald Morrison.[39] He argues that by giving a Platonic reinterpretation to several Aristotelian doctrines, the Alexandrians integrated several distinctions that Aristotle had made but left unconnected, such as deduction vs. induction, 'better known by nature' vs. 'better known to us,' prior vs. posterior, and 'knowing the fact' vs. 'knowing the reasoned fact,' and that the Alexandrians integrated these pairs in ways Aristotle did not intend. We will see that this Neoplatonic synthesis had tremendous influence on all subsequent Aristotelian study, at least regarding induction, up to and including Paduan scholarship of the late sixteenth century.

One of these distinctions was between 'better known with respect to us' and 'better known with respect to nature.'[40] In Aristotle, that which is 'better known with respect to us (pros hēmas or hēmin)' is that which is nearer to sense-perception; that is, it is knowledge of particulars. That which is 'better known with respect to nature (phusei or haplōs)' is furthest from sense-perception; that is, it is

[39] Morrison, "Philoponus and Simplicius on Tekmeriodic Proof." I have deviated from Morrison where I think he erred. I, of course, may have added by own misinterpretations and other errors, and these should not be attributed to Morrison.

[40] *Topics*, 6.4 141b29–34; *Physics*, 1.1 184a16-21; *Metaphysics*, 7.3 1029b3–12; *Nicomachean Ethics*, 1.4 1095b2–4; *Prior Analytics*, 2.23 68b38; *Posterior Analytics*, 1.3 72b29; and chiefly *Posterior Analytics* 1.2 71b35–72a6.

knowledge of universals.[41] Man learns first by moving "from the things which are more known and obvious with respect to us and towards those things which are clearer and more known with respect to nature."[42] By this process man comes to know what he experiences not as particulars but as instances of universals. He comes to know things generally (haplōs) or by their nature (phusei, literally 'from the perspective of their coming to be what they are'). To know hēmin and to know haplos or phusei are two ways for us to know.

Aristotle unambiguously and frequently says that induction is a movement from particulars to universal, and so in terms of the 'better known,' induction would be a movement from what is better known to us to what is better known by nature. It is the process by which we come to know the nature of something so that we may know it other than as the single particular by which it presented itself to our senses. We come to know it as a member of a group and we come to know what makes it such a member.

Another of Aristotle's distinctions is 'prior' vs. 'posterior.' These have many uses. In the *Categories*, Aristotle says there are four ways we use the term *prior*.[43] When finished describing them, he adds a fifth. He says the most proper meaning of *prior* is simply earlier in time. In a speech, the introduction is prior to the

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[41] *Posterior Analytics*, 1.2 72a1–6. In this, Aristotle's most succinct passage on the distinction, he does not mention the possibility that a universal might be closer to perception and a particular further away.

[42] *Physics*, 1.1 184a16–17, my translation.

[43] *Categories*, 12 14a26–14b23. See also *Metaphysics*, 5.8.

narrative. In an argument, some elements are prior, others posterior. The posterior that ends one argument might become the prior that begins another. All in all, the terms *prior* and *posterior* are for Aristotle highly contextual, hardly more technical than *beginning* and *end*. Only in an artificial or provocative construction would Aristotle say that an argument begins with a 'posterior' and ends with a 'prior.' Occasionally, instead of saying 'better known with respect to us' or 'to nature,' Aristotle says 'prior and better known with respect to us' or 'to nature,' treating 'prior' and 'better known' as near synonyms. The Alexandrian Neoplatonist John Philoponus gave this locution both a new interpretation and elevated importance.

Indeed, the whole concept of 'better known with respect to nature' took on for Philoponus and his colleagues a whole new meaning.[44] For Platonists, universals have an existence outside human consciousness. For Philoponus, 'better known with respect to nature' did not mean 'known *by man* with regard to the essential nature of his subject matter,' but actually 'known *by nature*.' In other words, there are two kinds of knowers, two kinds of conscious beings, man and nature. For man, particulars are epistemologically prior. He knows them best and first. From them he seeks to grasp universals. For nature, on the other hand,

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[44] For background see Richard Sorabji, ed., *Philoponus and the Rejection of Aristotelian Science* (Ithaca: Cornell University Press, 1987). The key texts for purposes here are Philoponus's commentaries on the *Prior* and the *Posterior Analytics*, published in *CAG*. I will cite the translations in Morrison, "Philoponus and Simplicius on Tekmeriodic Proof." Though it will not be discussed here, supporting evidence for my proposed interpretation of the Neoplatonic interpretation of induction is found in Simplicius's commentary on the *Physics*. Simplicius, *On Aristotle Physcs 7*, trans. Charles Hagen (London: Duckworth, 1994), 24, 33-5.

universals are epistemologically prior. They are what nature knows first and best. To nature, particulars are posterior and derivative. Indeed, in Neoplatonism, it is the universals known by nature that give the particulars known to man their very existence. As the early Neoplatonist Plotinus had written, “In things in which there is a prior and a posterior the posterior gets its being from the prior.”[45] The objects of nature’s knowledge, the universals, are the very causes of the particulars that humans must take as starting points on their attempted ascent to the knowledge of nature. Considered from the perspective of nature, of true reality, of that which man is trying to understand, human knowledge begins with posteriors. As Philoponus writes, “One produces conviction [pisteis] of the prior things out of posteriors.”[46]

For a Platonist such as Philoponus, truly universal knowledge cannot be obtained by purely observational means. The inductive process of Socrates, Aristotle, and Cicero could not achieve the task given it of identifying universal knowledge that extends beyond the particulars surveyed in the induction. (Recall that Socrates and his interlocutors never succeeded in finding the essence of the virtues they examined.) But Socratic and Aristotelian understanding of induction had already been abandoned by Clement and Alexander. The new standard was

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[45] *Ennead*, 6.1.25.17–8. Translation quoted in Lloyd Gerson, “Plotinus and the Rejection of Aristotelian Metaphysics,” in *Aristotle in Late Antiquity*, ed. Lawrence P. Schrenk (Washington, DC: Catholic University Press of America, 1994), 8.

[46] Philoponus, *In Analytica Posteriora*, *CAG* vol. 13, pt. 3, 31, 9–11; Morrison, 8.

that validity of an induction extended only to the particulars surveyed. Where then did induction fit in Philoponus's new synthesis?

For Philoponus, as in a different sense for Aristotle, the universal is causal. For Philoponus, nature not only knows and makes universals, it knows and makes causes. For man to know the cause of something he must come to know what nature knows. He must come to know what cause (what 'prior') nature uses to effect some humanly perceivable phenomenon (some 'posterior'). But direct knowledge of nature's choice is unavailable to man. It is hidden. Thus the difficulty for induction mounts. For (on this perspective) an effect may have multiple causes. Induction alone becomes unable to determine which cause is operative. Indeed, the Neoplatonists gave a new vigor and importance to the distinction between manifest and hidden. Nature's operation is hidden, obscure, occult. Man has access only to the revealed, exposed, derivative, which can serve only as imperfect indications of nature's underlying operation.

Sometimes, these indications can be reliable, as for example, that where there is ash, there was a fire[47] or if a mother is giving milk she has recently or is about to give birth.[48] Proofs based on these reliable indications Philoponus calls *tekmeriodic* (based on an idea in Aristotle). They are arguments not from cause to effect, but from effect to cause. Following this line of development, Philoponus can claim that induction is a form of proof, like deduction:

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[47] Philoponus, *In Analytica Priora*, *CAG* vol. 13, pt. 2, 481, 11; Morrison, 8.

[48] Philoponus, *In Analytica Priora*, *CAG* vol. 13, pt. 2, 481, 12–13, 25; Morrison, 8.

> The tekmeriodic proof establishes the things which are prior [according to nature] from those which are posterior. Of this sort is proof by induction, which establishes universals on the basis of particulars, that is, priors on the basis of posteriors.[49]

Thus, if induction has force, it does so to the extent it is like deduction. This conforms to the idea introduced by Clement and advanced by Sextus: The only valid induction is a complete enumeration.[50]

Philoponus and the other Alexandrian Neoplatonists crafted a neat synthesis, based on a reinterpretation of 'known with respect to nature.' The new synthesis had a striking unity and comprehensiveness. But it was not a simple adoption of Aristotle. It was a deliberate attempt to reconcile Aristotle and Plato. The result was neither Aristotelianism nor Platonism, but a Platonic interpretation of Aristotle's often obscure texts. On the new interpretation, nature had been abstractly anthropomorphized; it was capable of knowing and of acting on its knowledge. Moreover, such concepts as species, essence, and substance were given a reified Platonic identity.[51] Ambiguous passages such as *Prior Analytics* 2.23 were

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[49] Philoponus, *In Analytica Posteriora*, *CAG* vol. 13, pt. 3, 49, 19–21; Morrison, 9, his insertion.

[50] This is how Philoponus interpreted *Posterior Analytics* 2.7. *In Analytica Posteriora*, *CAG* vol. 13, pt. 3, 358, 21–359, 11.

[51] David M. Balme, "Aristotle's Biology Was Not Essentialist," in *Philosophical Issues in Aristotle's Biology*, ed. Allan Gotthelf and James G. Lennox (Cambridge: Cambridge University Press, 1987), 291–312. "The extraordinary later misrepresentations of Aristotle, the magical entelechies and real specific forms, must be largely due to these imported concepts—Species, Essentia, Substantia—which presided like three witches over his rebirth in the Middle Ages, but

given a simple interpretation that was in fact not Aristotle's. It is yet to be researched how pervasively and influentially the Alexandrian interpretation corrupted Aristotle's view, but in the case of induction, it is clear. Clement had begun the reinterpretation of induction by saying induction is a process of complete enumeration, but his claim was isolated. Now it was part of a complete epistemological system. The new understanding of induction now had staying power, and it was transmitted to scholastic Europe through both Arabic and Latin channels.

Transmission of the Neoplatonic Interpretation

A primary vehicle for this transmission of the Alexandrian interpretation was the *Organon*, the collection of Aristotle's writings on logic. The Alexandrians ordered the writings as follows:[52]

1.	Porphyry	*Isagoge*
2.	Aristotle	*Categories*
3.	Aristotle	*On Interpretation*
4.	Aristotle	*Prior Analytics*
5.	Aristotle	*Posterior Analytics*
6.	Aristotle	*Topics*
7.	Aristotle	*Sophistical Refutations*
8.	Aristotle	*Rhetoric*

should be banished to haunt the neoplatonism from which they came." p. 306. My thanks to Greg Salmieri for drawing my attention to this passage.

[52] Except for removal of Porphyry's introduction and frequent exclusion of the *Rhetoric*, the arrangement remains standard today.

The order is important, both for what it tells us about how Aristotle was understood and for the role it played in the transmission of Aristotle's ideas. In keeping with a Platonic perspective, the order is top-down, from more abstract and formal to more concrete and practical. The first work is an introduction by Porphyry, student of the Neoplatonist founder Plotinus. The second work, Aristotle's first in the collection, is the *Categories*. It treats, among other things, the nature of *substance*, *quantity*, *quality*, *time*, *relation*, the five senses of the word *prior*, and various meanings of the verb *to have*. *On Interpretation* defines *noun*, *verb*, *sentence*, *proposition*, *affirmation* and *denial*. The final three works, on the other end, offer practical advice on how to win arguments with individuals and groups.

Epagōgē is not discussed evenly throughout the *Organon*. Occurences of the word is distributed as follows:

			Instances of *epagōgē*
1.	Porphyry	*Isagoge*	0
2.	Aristotle	*Categories*	1
3.	Aristotle	*On Interpretation*	0
4.	Aristotle	*Prior Analytics*	In bk. 1: 2 In bk. 2: 10
5.	Aristotle	*Posterior Analytics*	13
6.	Aristotle	*Topics*	28
7.	Aristotle	*Sophistical Refutations*	2
8.	Aristotle	*Rhetoric*	13

When I surveyed *epagōgē* in the previous chapter, I began with the most frequent and plain occurrences in the *Topics* and *Rhetoric*, worked through the *Posterior Analytics*, and ended with the difficult instances in book 2 of the *Prior Analytics*.

That is, I worked through the *Organon* backwards. After the Alexandrian ordering of the *Organon*, induction was approached from the opposite direction, if even reached at all, as we will see. This had a large effect on how induction was understood.

The Alexandrian synthesis, and its interpretation of induction, spread in two directions, northwest through Rome into Latin Europe and east through Syria into the centers of Islamic culture. Let us consider the European transmission first. It is well known that with few exceptions, knowledge of Aristotle was lost in medieval Europe until the twelfth century. The exceptions were the translations, commentaries, and treatises on the *Organon* by Boethius (c. 476–524).[53]

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[53] A comprehensive and up-to-date treatment of Boethius now appears in John Marenbon, *Boethius* (Oxford: Oxford University Press, 2003). See especially the chapter "Boethius's Influence in the Middle Ages," 164–82. This joins the valuable collection Margaret Gibson, ed., *Boethius: His Life, Thought and Influence* (Oxford: Basil Blackwell, 1981). Though Boethius's *Consolation of Philosophy* has long commanded attention, his influence on the history of logic and the transmission of Aristotle has only more recently gained due attention. See especially Jonathan Barnes, "Boethius and the Study of Logic," in *Boethius: His Life, Thought and Influence*, ed. Margaret Gibson (Oxford: Blackwell, 1981), 73–89, and the substantial article Osmund Lewry, O.P., "Boethian Logic in the Medieval West," in *Boethius: His Life, Thought and Influence*, ed. Margaret Gibson (Oxford: Basil Blackwell, 1981), 90–134. Much of this development is influenced by new attention given to the *Topics* tradition, as in Lisa Jardine, "Humanistic Logic," in *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, et al. (Cambridge: Cambridge University Press, 1988), 173-98; Niels Jørgen Green-Pedersen, *The Tradition of the Topics in the Middle Ages: The Commentaries on Aristotle's and Boethius' 'Topics'* (Munich: Philosophia Verlag, 1984); and the essays by Stump collected as *Dialectic in Ancient and Medieval Logic* in Boethius, *Boethius's De Topicis Differentiis*, trans. Eleonore Stump (Ithaca and London: Cornell University Press, 1978). On the exclusive reliance on Boethius until the twelfth century for knowledge of Aristotle, see e.g., Lindberg, "The

Boethius was born into elite Roman aristocracy, was a contemporary of Ammonius and Philoponus, and may have personally studied with them in Alexandria.[54] Like the Alexandrians, Boethius' goal was to show fundamental agreement between Plato and Aristotle.[55] Moreover, he wanted to bring this unified knowledge of Greek philosophy to Latin readers. He planned to translate all Aristotle's works (as well as Porphyry's *Isagoge*), write commentaries on them, and then do the same for Plato's.[56] He never completed this grand project, but his Latin translations of the *Organon* may have been the first ever.[57] Except for that of the *Posterior Analytics*, which was lost, his translations became the standard, Vulgate, translations for the next thousand years.[58] We learn little of Boethius's own views from these translations. By his design, they are close, word-for-word renderings.[59]

Transmission of Greek and Arabic Learning to the West," 53–4. See also Ralph McInerny, *Boethius and Aquinas* (Washington, DC: Catholic University of America Press, 1990).

[54] Marenbon, *Boethius*, 7, 11.

[55] Ibid., 18.

[56] Barnes, "Boethius and the Study of Logic," 74.

[57] Ibid., 76.

[58] The twelfth-century translation by James of Venice became the Vulgate for the *Posterior Analytics*. It's unfortunate for this study that Boethius's translation did not survive. We would like to know whether in 2.5 and 2.7 he translated *epagōn* as the Latin for *inducing* or for *induction*.

[59] We do learn from these supposedly literal translations that in the phrase 'better known with respect to nature,' Boethius rendered Aristotle's dative phusei with the Latin ablative natura rather then the dative naturae. Thus begins a long-standing challenge for translators. The choice a translator takes reflects in part whether he thinks the author believed nature was the object of man's thought or was the knower. The translation problem and the interpretive aspect of it drew the attention of Thomas Aquinas in his commentary on the *Physics* and of Agostino Nifo in *Expositio super libros de Physico* (1552), 5r, both of which are discussed in Louis Aryeh Kosman, "The

We also learn little about how Boethius understood induction from his commentaries on the *Organon*. Only those to the *Categories* and *On Interpretation* and a few notes for the *Prior Analytics* survive. We do, however, have extensive material on the subject of the *Topics*. Besides translating Aristotle's *Topics*, Boethius wrote commentaries on Cicero's *Topics* and wrote his own treatise on the subject, *De Topicis Differentiis*, both of which survive and both of which had vigorous fortunes in the Middle Ages.[60]

I have argued that there have been two conceptualizations of induction, one that finds its home in Aristotle's *Topics* and *Posterior Analytics* and one that finds its home in Neoplatonic interpretations of Aristotle's *Prior Analytics* 2.23. Further, I have argued that we can trace the historical dominance of one or the other in antiquity by surveying works of the period, and that one view of induction predominated from Socrates until the Alexandrian Neoplatonists and then the other view incrementally gained prominence. The following objection could be raised. Is it not possible that the historical picture that has emerged is merely an artifact of

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Aristotelian Backgrounds of Bacon's *Novum Organum*," (Ph.D. dissertation, Harvard University, 1964), 122. Thomas Fowler, "Introduction," in *Bacon's Novum Organum* (Oxford: Clarendon Press, 1878), 203, says the dative is a scholastic mistranslation and cites further bibliography. Antonio Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* (Oxford and New York: Oxford University Press, 1989), 229, mentions the instability that prevailed since Averroës. Though modern translators often use 'by nature' for succinctness, I have tried to capture the full ambiguity by using 'with respect to nature.'

[60] There is no up-to-date edition of Boethius's collected works. For an inventory of the logical works that have survived (eighteen in all) and the best editions of each, see Barnes, "Boethius and the Study of Logic," 85. For fortunes of them, see Lewry, "Boethian Logic in the Medieval West."

the documents available? Cicero's writings on induction appear in books like Aristotle's *Topics* and contain no references to works on logic such as Aristotle's *Prior Analytics*. We should then not be surprised that Cicero's view of induction is like that of Aristotle's *Topics*. On the other side, the surveyed writings of the Alexandrians were logical texts. We could expect an understanding of induction like the one presented (on the Neoplatonic interpretation) in the *Prior Analytics*. Thus, might there not be two separate concepts of induction running in parallel, one a rhetorical view presented in works like the *Topics*, the other a logical view presented in commentaries on the *Analytics?*

This is not the case with Boethius. He makes clear that the induction of the *Topics* is the same as the induction of *Prior Analytics* 2.23. When discussing induction in his treatise on the *Topics*, *De Topicis Differentiis*, he writes,

> And so there are two main species of arguing, one called syllogism, the other induction. Under these and, as it were, flowing from them are the enthymeme and the example. . . .

Up to this point, the passage could have come from any discussion of *Topics* in antiquity. But Boethius continues:

> . . . All these are drawn from the syllogism and obtain their force from the syllogism. For whether it is an enthymeme, induction or example, it takes its force as well as the belief [it produces] most of all from the syllogism; and this is shown in Aristotle's *Prior Analytics*, which we

translated. So it suffices to discuss the syllogism which is, as it were, principal and inclusive of the other species of argumentation.[61]

Boethius says unambiguously that enthymeme, induction, and example are all derivatives of deduction, and to the extent they are valid, they are valid because they can be reduced to forms of syllogisms. Here and throughout his writings, Boethius adopts the Neoplatonic interpretation of induction.

Only the first three works of the *Organon* were known in early medieval Europe, but they had virtually nothing to say on induction. The *Prior Analytics* was largely replaced by Boethius's own treatises on logic, especially his *On Categorical Syllogisms*. It said little on induction. Boethius's translation of the *Posterior Analytics* fell into disuse and was lost. The only significant treatment of induction was in Boethius's *De Topicis Differentiis*.

			Instances of *epagōgē*	Latin Transmission
1.	Porphyry	*Isagoge*	0	Survived in Boethius's translations and commentaries
2.	Aristotle	*Categories*	1	
3.	Aristotle	*On Interpretation*	0	
4.	Aristotle	*Prior Analytics*	In bk. 1: 2 In bk. 2: 10	Largely replaced by Boethius's *On Categorical Syllogisms*
5.	Aristotle	*Posterior Analytics*	13	Fell into disuse and lost
6.	Aristotle	*Topics*	28	Replaced by Boethius's *De Topicis Differentiis*

[61] Boethius, *Boethius's De Topicis Differentiis*, 46, 1184D6–15, emendation the translator's.

De Topicis Differentiis was a major text throughout the Middle Ages. Alcuin knew about it in the eighth century,[62] Gerbert of Aurillac lectured on it in the tenth,[63] Abelard paraphrased[64] and commented on it in the early twelfth, all these before Aristotle's logical works reentered Latin discourse. Even thereafter, Boethius' treatise often eclipsed Aristotle's own *Topics*,[65] and was a subject of frequent commentary. In the thirteenth century it was used as an explanatory supplement to Aristotle's treatment. In the early fifteenth century, humanists began to complain of the dominance of Boethius' treatise, but it was frequently reprinted and was still commented on well into the sixteenth century.[66] As we will see, Boethius' claim in *De Topicis Differentiis* that enthymeme, induction, and example gain their force by being reduced to a syllogism (common even today) became a stock component of Latin scholasticism. But before examining treatment of induction in scholasticism, we must return to the other branch by which the Neoplatonic interpretation spread, Syriac and then Arabic study.

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[62] Lewry, "Boethian Logic in the Medieval West," 91.

[63] Ibid., 95.

[64] Ibid., 107.

[65] "About fifteen more or less complete commentaries [on *De Topicis Differentiis*] are known from the twelfth century, and six, of which two are only fragments, from the thirteenth. . . . none shows any knowledge of Aristotle's *Topics*." Ibid., 113.

[66] Ibid., 120–22.

Even in Greek, over time, each succeeding book of the *Organon* was read less.[67] Already in sixth-century Alexandria, the study of the *Prior Analytics* was becoming more important and the study of the *Posterior Analytics* and the *Topics* less. This trend accelerated as the study of Greek philosophy and Aristotelian logic migrated from Alexandria to Baghdad, from pagan to Christian to Islamic thinkers, from Greek to Syriac to Arabic. Syrian Christians considered the latter works inappropriate on theological grounds. St. John of Damascus (c. 675–749) strongly disapproved of the *Posterior Analytics*.[68] Syriac translations of the *Organon* began around 600, but the *Posterior Analytics* was not translated until around 850; for Arabic translations the dates were 820 and 900 respectively.[69] Even after translations became available, both Christian and Islamic students typically stopped their study after the first four works. It was the mark of an expert to have studied even into the second book of the *Prior Analytics*:[70]

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[67] For an overview of the Arabic transmission, see Lindberg, "The Transmission of Greek and Arabic Learning to the West," 55–58, and the many works cited there. For details on transmission of the *Organon*, crucial to the history of induction, I have found Nicholas Rescher, "Al-Farabi on Logical Tradition," *Journal of the History of Ideas* 24, no. 1 (1963): 127–32, and Rescher's extended introduction to Al-Fārābī, *Short Commentary on Aristotle's Prior Analytics*, trans. Nicholas Rescher (Pittsburgh: University of Pittsburgh Press, 1963), to be indispensible. The first of these articles by Rescher includes a translation of al-Fārābī's account on the subject.

[68] Rescher, "Al-Farabi on Logical Tradition," 131–32, citing Richard Walzer, "New Light on the Arabic Translations of Aristotle," *Oriens* 6 (1953): 99.

[69] Rescher, "Al-Farabi on Logical Tradition," 132.

[70] Ibid.:, and both the content and introduction to Al-Fārābī, *Short Commentary on Aristotle's Prior Analytics*.

			Instances of *epagōgē*	Syriac and Arabic study
1.	Porphyry	*Isagoge*	0	
2.	Aristotle	*Categories*	1	
3.	Aristotle	*On Interpretation*	0	
4.	Aristotle	*Prior Analytics*	In bk. 1: 2	
			In bk. 2: 10	
5.	Aristotle	*Posterior Analytics*	13	
6.	Aristotle	*Topics*	28	
7.	Aristotle	*Sophistical Refutations*	2	
8.	Aristotle	*Rhetoric*	13	

Thus nearly the first encounter with induction—and for almost all students nearly the last—is the phrase 'induction, that is, a deduction from induction,' in *Prior Analytics* 2.23. Given the Alexandrian interpretation of this phrase and lack of any contravening word from Aristotle, it would be natural for a reader to believe induction was a kind of deduction.

The first Islamic commentator to comment on and paraphrase the whole *Organon* was al-Fārābī (early 870s–950) in Baghdad.[71] He was the first pivotal figure in the transmission of Aristotelian logic from its Syriac inheritors into Arabic and thus eventually back into Latin scholasticism. His renown gained him the title Second Teacher (Aristotle being the first). Al-Fārābī 's commentary on the *Prior*

[71] A general introduction to al-Farabi is now available in Majid Fakhry, *Al-Farabi, Founder of Islamic Neoplatonism: His Life, Works, and Influence* (Oxford: Oneworld, 2002). Detailed treatment is in Rescher's articles cited above. Citations to al-Farabi will be to Türker numbers and to page numbers in Al-Fārābī, *Short Commentary on Aristotle's Prior Analytics*. All translations, including emendations, are Rescher's.

Analytics includes a considerable treatment on induction (six percent of the whole treatise), and his treatment is detailed, careful, and systematic.

By all the conventional teaching to which al-Fārābī would have been exposed, induction was a kind of deduction effected by complete enumeration. But unlike his immediate predecessors, al-Fārābī read the books in the second half of the *Organon* and there found that Aristotle claims not that induction is a kind of deduction but that it is another waying of knowing that provides the premises for deductions. Regardless how frequently and forcefully Aristotle says this, al-Fārābī was working within an established understanding of induction, and he rejected Aristotle's proposal.[72] Given his starting position, his argument is acute and powerful. He offers the following explanation. "It may be intended to show something by an induction in order to use this thing as [a universal] premiss in a syllogism,"[73] for example, "to show by induction that 'Every motion takes place in time,' in order to use this to show that swimming, for instance, takes place in time." The resulting syllogism would be:

> Every motion takes place in time
> Swimming is a motion
> Therefore, swimming takes place in time.

To know the universal premise, however, one engages in an investigation of particulars, and it is not possible, al-Fārābī insists (and rightly so by the standard

[72] "Induction cannot serve to show the truth of a thing to be used as a [universal] premiss in a syllogism which is intended to prove its predicate to belong to something included within its subject." Al-Fārābī, *Short Commentary on Aristotle's Prior Analytics*, 7.266.8–9, p. 92.

[73] Ibid., 7.265.15–16, p. 90.

interpretation of *Prior Analytics* 2.23), to conclude that every motion takes place in time unless one has investigated every type of motion.[74] Now in the investigation of motion, either swimming was included or it was not. If swimming was not investigated, then the universal premise 'Every motion takes place in time' cannot be known to be true, and the conclusion of the syllogism then does not follow. If, on the other hand, swimming was investigated, then the syllogistic argument is superfluous, and worse, there would be an improper attempt to show something better known by means of something less known. In either case, induction cannot provide the universal premise on which a proper syllogistic argument depends—contra the position Aristotle frequently takes in the second four works of the *Organon*.

What then does provide such premises? To address this, al-Fārābī offers the longest and most original sections in his commentary on the *Prior Analytics*. He introduces what he calls 'inference by transfer.' It is interesting to see what al-Fārābī invented to do the job that Aristotle had assigned to induction.

> It is now necessary that we discuss the 'transfer' from a judgment by sensation in some matter . . . to another matter outside the realm of sensation. . . . what people of our time call 'inference from evidence to the absent.'[75]

[74] Ibid., 7.265.3, p. 89.

[75] Ibid., 8.266.13–15, p. 93, without Rescher's emendations. A similar phrase was used by Philodemus.

The problem, al-Fārābī explains, is to say reliably something about the unobserved given statements about the observed. The solution is to find similarities between the two, not just any similarity, but a "similarity . . . that is relevant to the characterization" of the observed, as having the property under investigation. This similarity must provide "some special form of connection."[76] The matter that forms this special connection "is called by the people of our time 'the cause'; and it is [in actuality] the middle term [of the syllogism]."[77] Thus the crucial element that makes it possible to say whether something unobserved has a particular property is to identify the cause of that property. If the unobserved has that cause, then it will have that property. His example is identifying 'contingency' as the cause of 'being created':

> Plants and animals are created.
> We know this because everything contingent is created and plants and animals are contingent. (That is, we have identified contingency as the cause.)
> <u>Things in the heavens are contingent also.</u>
> Therefore, things in the heavens are created.

But how does one come to know the cause? Al-Fārābī again considers induction and again insists that unless all cases can be investigated, the induction remains defective and "this method is useless in 'inference from evidence to the absent.'"[78] He notes, however, that an inductive consideration can be useful in another way: It

[76] Ibid., 8.267.9, p. 95.

[77] Ibid., 8.267.13–4, p. 97–98.

[78] Ibid., 8.269.1–4, p. 99.

can refute a proposed universal by identifying a counter-instance.[79] Al-Fārābī then suggests a method that goes beyond anything in the *Prior Analytics*, though it recalls the Epicurean Philodemus. Al-Fārābī calls his method 'raising and finding,' and it amounts to an instance of arguing by the contrapositive. His example is this:

Whatever is not corporeal is not an agent.	[What is not-q is not-p.]
Therefore, every agent is corporeal.	[Therefore, every p is q.]

If one can establish the first, the second is a necessary and universal statement that can then be used as a premise in a syllogism. Even better, al-Fārābī says, is to use the contrapositive twice, once in each direction, and thus establish not just a cause-to-effect relationship, but a one-to-one correspondence.[80] But granted that one can get necessarily and universally from 'whatever is not corporeal is not an agent' to 'every agent is corporeal,' how does one get the first part? It too is a universal claim needing justification. In his concluding remarks, Al-Fārābī surrenders and admits that the universal premises on which syllogisms depend simply cannot be known with "altogether perfect exactness." These matters "require a great deal of laxity in order to be useful in providing knowledge."[81]

Recall that in our investigation of Epicurean induction we had to rely on Philodemus and that, though he did not explicitly use the term *induction*, we had reason to believe he was discussing induction in his contrapositive argument that if Socrates were not a man, Plato would not be a man either. Recall Galen also. What

[79] Ibid., 8.269.10–270.12, pp. 99–101. Cf. Karl Popper's falsification.

[80] Ibid., 8.272.14–273.13, pp. 106-8.

[81] Ibid., 8.186.7–20, pp. 131–32.

little we have of his writings on induction indicates that he believed a valid induction requires finding the cause for a correspondence. Both of these have affinity with al-Fārābī, and as we will see, have echoes in the Renaissance, when like al-Fārābī, readers found a discrepancy between the established interpretation of Aristotle and what Aristotle says in the second four books of the *Organon*. Humanists will respond to the discrepancy differently. But that is to look ahead. For now the importance of al-Fārābī is this: He approached induction not from the *Topics*, *Rhetoric*, or *Posterior Analytics*, but by working through the *Prior Analytics* beginning to end. What he found at the end became the reference against which all subsequent discussion of induction had to conform. When it did not, he rejected the later discussion and proposed a new concept that performed the task Aristotle had assigneed to induction.

Al-Fārābī had a general and widely recognized influence on the influential Arabic commentator Avicenna (Ibn Sīnā, 980–1037) in Persia.[82] Avicenna completed the transition by which induction came to be rendered into the language of deduction and by which *Prior Analytics* 2.23 came to be considered the most important Aristotelian text on induction. He also had his own way of dealing with the discrepancy between that crucial chapter and what he found in the second half of the *Organon*. Both elements of his thought were to prove influential.

[82] Avicenna's writings on induction have been little studied and little translated, and I do not read Arabic. For my understanding of Avicenna's induction I am relying exclusively on my understanding of Jon McGinnis, "Scientific Methodologies in Medieval Islam," *Journal of the History of Philosophy* 41, no. 3 (2003): 307–27, and subsequent discussions with the paper's author.

Avicenna put induction fully into the language of the syllogism.

> [Induction is] like judging the middle term through the major term, because of the existence of the major term in the minor term; for instance, all long-lived animals are gall-less, since all long-lived animals are like human, horse and ox; and human, horse and ox are gall-less.[83]

This is close to Aristotle's language of *Prior Analytics* 2.23, but there are differences. The first is that Avicenna unambiguously says that induction is the drawing of (or an attempt to draw) a syllogistic conclusion. As discussed in chapter 1, Aristotle did not say this. Second, Avicenna introduces the phrases 'major term' and 'minor term,' where Aristotle had only said 'the extremes' and did not specify which he considered the major and which the minor. Avicenna resolved this ambiguity and thus completed the casting of induction as a kind of syllogism. Avicenna's choice would go unchallanged until the nineteenth century.[84]

Aristotle held, I have argued based on a reading of the whole *Organon* and not just the first half, that induction is used to identify the essential nature of something, and that it could thereby be used to establish the necessary and universal premises needed for certain deductive knowledge. Avicenna agrees with my interpretation and says that on this point Aristotle is wrong. Avicenna subjects Aristotelian induction to the following penetrating and seemingly devastating analysis. He asks, "How is the necessary and universal relationship between the

[83] Ibid.: 309, without McGinnis' emendation "[and the like]" before "are gall-less" at the end.

[84] The first substantive argument in English over which term plays what role in an induction is Richard Whately, *Elements of Logic*, 4th ed. (New York: William Jackson, 1832), 184ff.

subject and predicate explained or made evident, when there is no middle term that links the two?"[85] That is, how do we arrive at necessary and universal premises that are not themselves the result of other deductions? How do we arrive at the starting points? By induction, Aristotle says. But, Avicenna asks, by what means do we come to know that inductively established propositions are necessary and universal? It must be either by perception or the intellect. But, he continues, it cannot be by the first, for necessity is not perceptual; we do not perceive necessity.[86] That leaves the intellect. Now, the properties known by the intellect are either essential or accidental, and accidental properties are in turn either necessary or not. Avicenna says none of these three can provide necessary and universal propositions. First, any predicate that is not necessary does not meet the requirement of universal and necessary that we are seeking. Second, necessary accidents can simply be reduced to essential properties, thus leaving essential properties as the last candidate. Can the intellect, Avicenna asks, amass several particulars of one kind and, by analyzing them, determine their essential commonality? He argues that this cannot be done because, without knowing what essential characteristic makes things all members of a kind, one cannot know which particulars to subsume in the induction in the first place. Aristotelian (and Socratic) induction is thus caught in a terrible circularity. To find the essence, for example, of aretē, we must be able to reliably identify instances of aretē; but without knowing the essence, we cannot be sure we

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[85] McGinnis, "Scientific Methodologies in Medieval Islam," 310

[86] David Hume will later agree.

are examining true instances. This cuts to the very heart of Socratic induction. When Socrates wanted to find what made, say, courageous men courageous, he assembled a group of courageous men and examined them. Yet how could he be sure, without yet knowing the essence of courage, that these men were in fact courageous. Avicenna concludes that induction is incapable of providing the necessary and universal premises needed for deduction. It should not be surprising that if induction is a kind of deduction then it would be circular to try using it to ground deduction, but Avicenna was the first to work this out so forcefully.[87]

The third of the major figures in the transmission and development of Aristotelian epistemology in Islamic culture was Averroës (1126–1198) in Spain. He fully adopted Avicenna's syllogistic language for describing induction. "[Induction] is an argument which has the force of the syllogism in the first figure, since the minor term is that universal matter, the middle the particulars, and the major the judgment."[88] This statement comes not from Averroës' discussion of *Prior Analytics* or *Posterior Analytics*, but from his commentary on the *Topics*. Discussions about induction in supposedly practical handbooks for debaters and orators, as the *Topics* and *Rhetoric* were intended, are now presented in the technical language of 'major

[87] In the *Topics*, 8.2 157a25, Aristotle had recognized this problem, but since he did not think induction was a kind of deduction, he did not consider the problem devastating in the way Avicenna did. Avicenna, characteristically concentrating on the *Analytics* instead of the *Topics*, did not address Aristotle's attention to the problem.

[88] Commentary on *Topics* in Averroës, *Averroës' Three Short Commentaries on Aristotle's "Topics," "Rhetoric," and "Poetics,"* trans. Charles E. Butterworth (Albany: State University of New York Press, 1977), 48.

term,' 'middle term,' 'minor term,' and 'first-figure syllogism,' rather than in the spirit of Socratic dialogue described in Aristotle's *Topics.* Averroës rejected not only the characteristic debating style of Aristotle's *Topics*, but its understanding of induction, also. Averroës writes,

> Induction—insofar as it is induction—does not by itself and primarily set forth the essential necessary predicate. For it is not possible for that universal to be a predicate of all of those particulars accidentally. . . . Induction used in demonstration is only used for guidance toward certainty, not for providing it primarily and essentially.[89]

For all of Averroës' empiricist sympathies, his view of induction remained that of the Alexandrian Neoplatonists.

Induction was not known in early medieval Christian and early Islamic schools from its frequent mention in Aristotle's *Topics*, *Rhetoric*, and *Posterior Analytics*. These works from the second half of the *Organon* were not read. In the Latin West, induction was known instead through Boethius's *De Topicis Differentiis*. Following the Alexandrian synthesis, it described induction as a kind of deduction formed by a complete enumeration of particulars. Latin readers were unaware of an alternate view. Arabic readers became aware when, beginning with al-Fārābī, they began reading the rest of the *Organon*. They found there a proposal that induction was the method by which essence was identified. They insisted that on this point, Aristotle was wrong. They discovered Aristotle's proposal with an

[89] Commentary on *Topics* in ibid., 50.

established view of induction already in hand. By that view, induction could not make universal statements applicable beyond the particulars surveyed. Though by different paths, Latin and Arabic readers both received the view of induction worked out by the Alexandrian Neoplatonists. Thus when Arabic scholarship entered Europe in the twelfth century, there was no immediate revolution there in the understanding of induction.

Reunion of the Latin and Arabic Traditions in European Scholasticism

By the beginning of the twelfth century, direct exposure to Aristotle was still limited. Boethius's translations of the first three books of the *Organon* did survive and had been studied from the time of the Carolingian Renaissance.[90] Though Boethius's translation of the *Prior Analytics* survived, it was hardly studied if at all.[91] Boethius's own *On Categorical Syllogisms* substituted. His translation of *Posterior Analytics* had fallen into disuse and become corrupt and partly lost. For the next subject in the *Organon*, the *Topics*, the standard text was not Aristotle's or Cicero's but Boethius's *De Topicis Differentiis*. At the turn of the millennium, Greek manuscripts of the first two books of the *Organon* as well as translations of Arabic

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[90] John Marenbon, *Early Medieval Philosophy (480–1150)* (London and New York: Routledge, 1988), 47, 53, 82. Bernard G. Dod, "Aristoteles Latinus," in *The Cambridge History of Later Medieval Philosophy*, ed. Norman Kretzmann, Anthony Kenny, and Jan Pinborg (Cambridge: Cambridge University Press, 1982), 45–79 serves as a good overview to the *Aristoteles Latinus* collection, published under the direction of Katholieke Universiteit Leuven.

[91] Marenbon, *Early Medieval Philosophy (480–1150)*, 130.

medical and other scientific works where entering northern Europe.[92] Works on mathematics and astronomy continued to enter in the eleventh century and in the twelfth century, works of many types were translated from Arabic and Greek into Latin.[93] During this time, virtually all of Aristotle's works were translated, mostly from Greek originals. But the attention remained more on scientific works than on epistemological. While the *Physics*, *On the Heavens*, and *On the Soul* joined the works of Galen in having a large impact on European natural science, the books of the *Organon* attracted less attention. Though three new translations were done of the *Posterior Analytics* in the twelfth century, John of Salisbury (1115 or 1120–1180) said that few masters could deal with it, and his own exposition is the first in the Latin West. Commentary on Aristotle's own *Topics* did not appear until the thirteenth century.[94] Not until long after that did Aristotle's work on the subject supplant Boethius's.

Thus study of logic changed surprisingly little during the inrush of twelfth-century Aristotelian translations. The understanding of induction did not change at all. Indeed it got codified into the most popular and most emulated textbook of the late Middle Ages, Peter of Spain's *Tractatus* (later called *Summule Logicales*), written

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[92] Lindberg, "The Transmission of Greek and Arabic Learning to the West," 59–60.

[93] Grant, *The Foundations of Modern Science in the Middle Ages*, 23.

[94] Green-Pedersen, *The Tradition of the Topics in the Middle Ages: The Commentaries on Aristotle's and Boethius' 'Topics'*, 163, 216, 224

between 1230 and 1245 in southern France or northern Spain.[95] The outline of the book's first half directly follows that of the *Organon*. An introductory chapter is followed by one covering material from Porphyry's *Isagoge*. The third treats the Aristotelian categories and is followed by a fourth chapter on syllogistic logic. Although it covers the subject of the *Prior Analytics*, it more closely follows Boethius's *On Categorical Syllogisms*. Peter skips the subject matter of the *Posterior Analytics* altogether, and the fifth chapter is "On the Topics." It is here that Peter says there are four kinds of argument: syllogism, induction, enthymeme, and example. His whole treatment of induction is, "Induction is a progression from particulars to universal. For instance, Socrates runs, Plato runs, Cicero runs, et cetera; therefore every man runs."[96] Aristotle's frequent mention of induction in his own *Topics* has been replaced by a skeletal treatment derived from the last few chapters of the *Prior Analytics*, and Peter demonstrates no awareness of the ambiguity or complexities in that original. Peter does add one elaboration in chapter 7, the chapter on fallacies. He explains that only the syllogism is a perfect

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[95] For Peter and the *Tractatus*, see Introduction to Peter of Spain, *Tractatus, called afterwards Summule Logicales.*, ed. L. M. de Rijk (Assen: Van Gorcum, 1972), ix–cxx; Joke Spruyt, "Peter of Spain," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (2001),; and "Peter of Spain on the Topics" in Boethius, *Boethius's De Topicis Differentiis*, 215–221.

[96] "Inductio est progressus a particularibus ad universale. Ut 'Sortes currit, Plato currit, Cicero currit,' et sic de singulis 'ergo omnis homo currit.'" Peter of Spain, *Tractatus, called afterwards Summule Logicales.*, 56.12–5, my translation. Peter demonstrates no awareness of Aristotle's statement, "When people have to obtain the universal, they say 'thus in all such cases'. But this is one of the most difficult of things, to determine which of the cases brought forward are 'such' and which iare not." *Topics* 8.2 157a25, Smith's translation.

and complete way of arguing, that there are many ways an otherwise perfect thing can be deficient, and that induction, enthymeme, and example are three kinds of imperfect syllogism.[97] This may have derived from Arabic influence, but it is in keeping with the common Alexandrian heritage. Though written in the century after Aristotle's scientific works swept into Latin Europe, Peter's *Tractatus* is more a continuation of Boethian logic than an adoption of Aristotle's in its treatment of logic in general and of induction in particular. The structure and content of the *Tractatus* and its treatment of induction became the model for countless textbooks on logic all the way into the nineteenth century. In the Renaissance the *Tractatus* itself was reprinted more than a hundred and sixty times.[98] When a Renaissance reformer complains about scholastic Aristotelian logic, it is usually not the original works of Aristotle that he has in mind but textbooks like the *Tractatus* that codified Boethius's interpretation of Aristotle.

A survey of the few most important scholastic thinkers from the mid-thirteenth century to the mid-fourteenth indicates that scholasticism wholly adopted the now conventional view of induction. Let us briefly consider Albert, Aquinas, Duns Scotus, and William of Ockham. Each of them treated differently the conflict between that view and the one they found in Aristotle. Each made

[97] Ibid., 90.1–11.

[98] Brian P. Copenhaver and Charles B. Schmitt, *Renaissance Philosophy* (Oxford and New York: Oxford University Press, 1992), 95

small, though sometimes important, refinements to the conventional view without fundamentally altering it.

Albert the Great (c. 1200–1280) probably first came into contact with the *Organon* just after Peter's *Tractatus* was written, and he had the same understanding of induction as Peter did, i.e. that an induction is a defective deduction made perfect by addition of 'et cetera' ('et sic de aliis' or 'et sic de singulis').[99] He summarizes, "An induction has no necessity unless turned into a syllogism,"[100] and offers this example:

> Everything that is this man, or that man, et cetera, is an animal;
> <u>Every man is this man, or that man, et cetera;</u>
> Therefore, every man is an animal.[101]

Albert casts induction into a syllogistic form that will become standard and important: All of his particulars are of the same kind. In Aristotle's passage on which Albert is commenting, the instances are three different kinds of animals, i.e., man, horse, and mule. Avicenna had followed Aristotle on this. But in Albert's example there is just one kind. By the Socratic understanding of induction, the

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[99] Previous work on induction in Albert includes Auguste Mansion, "L'Induction chez Albert le Grand," *Revue Néo-scolastique* 13 (1906): 115–34, 245–64; and Bos, "A Contribution to the History of the Theories of Induction in the Middle Ages," 562–65. The most important treatment in Albert is his commentary on *Prior Analytics* 2.23. Albertus Magnus, *Opera Omni*, ed. Auguste Borgnet (Paris: Ludovicum Vivès, 1890–5), 2.7.4, p. 793–95.

[100] "inductio nullam necessitatem nisi a syllogismo." Magnus, *Opera Omni*, 2.7.4, p. 794, my translation.

[101] "omne quod est iste vel ille, et sic de singulis, est animal : omnis homo est iste vel ille, et sic de singulis : ergo omnis homo est animal." Commentary on *Prior Analytics* in ibid. 2.7.4, p. 794.

instances should be widely varied. To identify the essence of courage, for example, it is best to survey many kinds of courageous men. To understand longevity of animals it is best to consider several kinds of long-lived animals. But by the alternate understanding, induction is essentially enumeration (complete or otherwise), and the instances, as Albert understands them, should all be of the same kind. Thus the instances are man #1, man #2, man #3, etc. If the instances are all surveyed—or it is pretended so by adding 'et cetera'—then the induction, i.e. the enumeration, is complete, and can be given the form and force of a syllogism. For Albert, variety in the instances in an induction is not required or desired.

Under this interpretation, the concept of a 'probable induction' makes more sense than it does under Socratic induction. Albert uses the phrase *inductio probabilis*[102] to refer to an argument in which many but not all instances of a kind have been surveyed, all have been found to have the property under investigation, and no counter-instances have been found. Of course, Albert's concept of probable does not yet have the mathematical association that it will acquire in the seventeenth century, but it is indicative of the direction theories of induction can go once an induction is interpreted as a defective syllogism that can be made less defective by the inclusion of more instances.

Albert, exposed now to more of the Aristotelian corpus that his Latin predecessors, recognizes the contradiction between his claim that induction can be

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[102] Ibid., 2.7.4, p. 795

reduced to a syllogism and the frequent Aristotelian claim that induction and deduction are separate and distinct. While al-Fārābī and Avicenna had simply said that Aristotle was wrong about this, Albert attempts to preserve Aristotle's claim by proposing a new distinction: "an induction is reduced to a syllogism materially but not formally."[103] That is, an inductive argument is reduced to a syllogism by taking the *material* of the argument—the constituent propositions—and arranging them in the form of a syllogism. But the *form* itself of a syllogism and the *form* itself of an induction remain opposed, since what was an extreme term when the argument had an inductive form (i.e., the particulars) takes on the role of a middle term when the argument is cast in syllogistic form. Induction and a syllogism, Albert says, are not considered opposites generally, but only in a narrow technical sense. Albert thus inverts Aristotle's presentation, for in the Aristotelian corpus, induction and deduction are broadly and commonly set in opposition, and the contents of an induction are placed into the structure of a syllogism only in the narrow, technical sense of *Prior Analytics* 2.23. Finally, Albert does not comment on the contradiction between complete enumeration and the open-end nature of induction presented in *Posterior Analytics* 2.19. There, Albert paraphrases Aristotle and proceeds without comment.

[103] "inductio in syllogismum reducitur materialiter et non formaliter." Commentary on *Prior Analytics* in ibid., 2.7.4, p. 794, my translation.

Thomas Aquinas (1225–1274) agrees with his teacher, Albert, on the nature of induction.[104] Also with his teacher, he is one of the first to give the *Posterior Analytics* serious study. His *Commentary* on it was extended and important. Commenting on book 2, chapter 5 of Aristotle's text, Aquinas writes,

> [In induction it] is required to suppose that he has listed all the things contained under some general heading; otherwise, the person inducing could not conclude a universal from the singulars he assumed. . . . Thus it is obvious that one cannot in virtue of the fact that Socrates and Plato and Cicero run, induce of necessity the conclusion that every man runs, unless his audience concedes that nothing more is contained under man than the ones listed.[105]

I argued earlier that this is a misreading of *Posterior Analytics* 2.5, and is inconsistent with, for example, Aristotle's claim that one would not truly know something of triangles if it were known only by surveying equilateral, isosceles, and scalene triangles, even knowing these were the only three possible kinds. Moreover, Aquinas' reading of the passage will be difficult to reconcile with the open-ended portrayal of induction soon to follow in *Posterior Analytics* 2.19. Aquinas is typically copious in his remarks in his *Commentary*, but when he gets to Aristotle's mention of induction in 2.19, he, like Albert, is terse. He first describes the process that

[104] Milton, "Induction before Hume," 57; Bos, "A Contribution to the History of the Theories of Induction in the Middle Ages," 565–6. Aquinas' substantive comments appear in his commentary on the *Posterior Analytics*. Quoted translations are those of F. R. Larcher. Aquinas, *Commentary on the Posterior Analytics of Aristotle*, trans. F. R. Larcher (Albany: Magi Books, 1970).

[105] Aquinas, *Commentary on Posterior Analytics*, 2.4.178.

Aristotle proposes for how we come to know open-ended universals, concluding with a paraphrase "He concludes that it is obviously necessary to acquire the first universal principles by induction. For that is the way, i.e., by way of induction, that the sense introduces the universal into the mind . . ."[106] Many modern commentators have gotten to this point and realized that Aristotle cannot possibly be speaking here of complete enumeration, for the whole chapter has been about reaching open-ended universal knowledge. Many of these commentators, in order to preserve their belief that Aristotelian induction is primarily complete enumeration, posit a second kind of induction, often called 'intuitive induction' (from the translation of *nous*, Aristotle's subject in this chapter, as *intuition*). Aquinas, however, does not make this move. Instead he extends the passage with this short comment, ". . . inasmuch as all the singulars are considered."[107] He thus repeats his belief that legitimate induction is complete enumeration, but in doing so he also makes it quite unclear what induction has to do with the open-ended process of forming principles through a rising from sense perception to memory to experience to universals by the ability of nous that Aristotle was discussing in the chapter. Aquinas does not linger to address this difficulty.

In addition to the interpretation of induction as a kind of defective deduction, Aquinas adopted and somewhat streamlined the Neoplatonic integration of induction and deduction with, for example, the difference between prior to us and

[106] Ibid., 2.20.239.
[107] Ibid.

prior in nature. "For demonstration proceeds from things that are prior absolutely, but induction from things that are prior in reference to us."[108] Though he rejects the fundmental notion that nature can know, Aquinas consistently uses the Alexandrian synthesis to explain how induction and deduction can be separate while at the same time induction is really a kind of deduction.

John Herman Randall once wrote, "[The] process of learning *archai* Aristotle calls *epagōgē*, 'induction.' The Schoolmen, to distinguish it from another process Aristotle also calls *epagōgē*, and which we call 'complete enumeration', . . . called it 'abstraction.'"[109] As we have seen this dichotomy is not in fact in Aristotle, but Randall is right that for the scholastics epagōgē and induction referred to a process of complete enumeration. Therefore coming to know universal principles from the particulars of sense experience was not known as induction. Duns Scotus (1265–1308) is an example. He offered extended and important commentary on the nature and relationship of particulars and universals, but none of it is cast in the language of induction.[110] When he does use the term, it always means surveying a finite list.

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[108] Ibid., 1.8.28.

[109] John Herman Randall, Jr., *Aristotle* (New York and London: Columbia University Press, 1960), 43

[110] E.g., Duns Scotus, "The Oxford Commentary on the Four Books of the Master of the Sentences," in *Selections from Medieval Philosophers* (New York: Scribner's, 1920), 324–30. A good example of the confusion caused by not appreciating the history of induction is the discussion of Duns Scotus in W. T. Jones, *The Medieval Mind*, vol. 2, *A History of Western Philosophy* (New York: Harcourt Brace Jovanovich, 1969), 308. Jones, a generally very reliable guide, uses *induction*

What Randall says of the scholastics goes back to al-Fārābī. Once complete enumeration was considered the only valid form of induction, discussions of coming to know open-ended universals had to be conducted with a different vocabulary—even though this was the use to which Socrates and Aristotle originally put the term.

William of Ockham (c. 1285–?1349)[111] continued the Scholastic understanding of valid induction as complete enumeration. "For whenever more can be contained in the subject of the universal than are contained in the induction, the consequence does not follow from the induction."[112] He cites as an example of a good induction an argument that demonstrates something to be true of the Father, of the Son, and of the Holy Spirit, and consequently true of God. An incomplete induction, he holds, must be perfected by addition of 'et cetera.' Ockham repeats the now

throughout his description of Scotus's position on universals. But in the original text Jones is glossing, the term *inductio* is nowhere to be found.

[111] For passing mention of Ockham's induction, see Milton, "Induction before Hume," 57. Ockham's extended treatment of induction are chapters 31-5 in part three of the *Summa Totius Logicae*. The material is remarkably "unilluminating," to use Milton's apt summary. Much of it is dedicated to dealing with particulars that are predictions of the future. For example, it appears that the universal 'I know it will happen' may be true while the particulars 'I know it will happen at time A,' 'I know it will happen at time B,' etc. are all false. Ockham addresses this apparent paradox with reference to God's omniscience about future events. I use as source for my own translations, William of Ockham, *Summa Totius Logicae* (Oxford: J. Crosley, 1675).

[112] "Ubicunque enim possunt plura contineri sub subjecto universalis quam continentur in inductione, non valet consequentia virtute talis inductionis." William of Ockham, *Summa Totius Logicae*, 3.33, p. 470, my translation.

common example: Socrates runs, Plato runs, et cetera, and therefore all men run.[113] Thus, Ockham does not directly add anything to the theory of induction, but he does make an important indirect contribution. He challenged what he saw as a Neoplatonic strain in Aquinas, the view that universals are real (even if existing within individuals). Ockham held instead that only individuals are real, and universals are cognitive tools by which we grasp groups of individuals. This Ockhamite 'nominalism' included a new interest in the role and importance of particulars, which would be important for later interest in induction. But like Scotus, Ockham himself explored the role for particulars outside of the language of induction. Induction, for him, remained not a process of rising from sense perception of particulars to a cognitive awareness of universals, but rather a kind of (usually defective) deduction.

Even after Latin theoreticians gained access to virtually the entire Aristotelian corpus, their understanding of induction remained remarkably conservative. They fully adopted the Alexandrian synthesis, held the Neoplatonic interpretation of *Prior Analytics* 2.23 to be Aristotle's definitive treatment, and held that this chapter claimed induction gained its force by being rendered a syllogism. The few mentions of induction in the *Posterior Analytics* caused some difficulty, but the mentions were isolated and incidental enough that they could be addressed creatively or just ignored. A partial explanation for why access to the Aristotelian corpus did not pose

[113] Ibid., 3.32 p. 467–68.

a greater challenge is that scholastics had relatively little interest in Aristotle's *Topics*, the main source of the alternate view of induction. For that field, Boethius's *Topics* remained dominant. There was much greater interest in Aristotle's *Physics*, and this work indirectly supported the conventional understanding of induction because its prominent discussion of 'better known with respect to us' and 'better known with respect to nature' in book 1, chapter 1, was fully assimilated into the Alexandrian synthesis. So by a sort of package deal, induction got swept up into a comprehensive and largely Neoplatonic interpretation of Aristotelian epistemology. Not until the *Topics* of Aristotle and of Cicero gained attention, and not until there was broader familiarity with Socratic induction, was the Alexandrian interpretation of induction challenged. That challenge was initiated by the arrival of Renaissance humanism.

Renaissance Humanism

Before introducing the humanistic logic of the fifteenth and sixteenth century and its traces in theories of induction, we must consider a special case, a younger contemporary of Ockham's, John Buridan (c. 1300–1358/61). Buridan is special because although he wrote the first significant challenge to the 800-year-old consensus view of induction, his writings on the subject were largely lost. He is thus, regarding induction, both revolutionary and unimportant. Let us consider first the revolutionary part and then the issue of his influence.

Buridan[114] agrees with his Scholastic predecessors that an induction can be turned into a deduction by adding 'et cetera' to the list of particulars. Like them he uses the example of Socrates and Plato running. But, he insists, the 'et cetera' can legitimately be added only when it serves as a shorthand for a finite and surveyable list, such as the list of heavenly planets.[115] Unlike his immediate predecessors, however, Buridan does not think that the inability to legitimately add 'et cetera' and to thus convert an induction into a deduction poses any threat to the validity of inductive conclusions generally. For Buridan, an induction with a finite and surveyable list of particulars is hardly induction at all. If it is induction, it is a special case. Induction, properly, is not the process described by the now conventional understanding of *Prior Analytics* 2.23 but, Buridan insists, the process described in *Posterior Analytics* 2.19.[116] For the first time, someone faced with the inconsistency between these two passages gives the second preference.

On Buridan's account, the primary meaning of 'induction' is not complete enumeration, but the process of coming to know universals in a hierarchical process of combining sensations to form memories, memories to form experiences, and

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[114] The important text is John Buridan, *Summulae de Dialectica*, trans. Gyula Klima (New Haven: Yale University Press, 2001), 6.1.4, 6.1.5, and 8.5.4. For background and historical context of the treatise and on Buridan's general influence (not specifically regarding induction), see Klima's valuable introduction. On Buridan's induction, see J. M. M. H. Thijssen, "John Buridan and Nicholas or Autrecourt on Causality and Induction," *Traditio* 43 (1987): 237–55.

[115] Buridan, *Summulae de Dialectica*, 6.1.5, p. 399.

[116] Ibid., 6.1.4, p. 396.

experiences to form universals.[117] This is the hierarchy that Aristotle presents in *Posterior Analytics* 2.19. There, Aristotle says, "The soul is so constituted to be capable of this process."[118] Buridan calls that capability, "the intellect's natural inclination toward truth."[119] It is by this process that

> we know the indemonstrable principle that every fire is hot, and that every magnet attracts iron, and that all rhubarb purges bile, and that everything that comes to be in nature comes to be from some preexisting subject, and so on for many other indemonstrable principles.[120]

Buridan also brings back into the discussion of induction Socrates' claim that just as we should appoint a helmsman, charioteer, and statesman based on prudence rather than chance, so we should choose any ruler.[121] Buridan challenges the notion that there is one 'primo principium,' one first principle, from which all certain scientific knowledge is deduced. Rather, there are many universal, certain, and necessary propositions that are not derived deductively but are built up from sense perception. That every man has a heart is one.[122] Buridan brought back to the discussion of induction the scientific epistemology more characteristic of Aristotle's

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[117] Buridan offers the same hierarchy in *In Physica* book 1, question 4, quoted in Thijssen, "John Buridan and Nicholas or Autrecourt on Causality and Induction," 245.

[118] *Posterior Analytics*, 2.19 100a14. Mure translation.

[119] Buridan, *Summulae de Dialectica*, 6.1.4, p. 396, 6.1.5, p. 399.

[120] Ibid., 6.1.4, p. 396.

[121] Ibid., 6.1.4, p. 397. It is a Socratic example, even though Buridan gets it from Boethius's retelling.

[122] *In Physica*, Book II q.4 (fol. 6ra), quoted in Thijssen, "John Buridan and Nicholas or Autrecourt on Causality and Induction," 244.

Posterior Analytics and the rest of the Aristotelian corpus than the chapter in *Prior Analytics* that had occupied his predecessors since late antiquity.

Buridan's proposal was remarkable. Since the sixth century, it had been held that *Prior Analytics* 2.23 is the definitive statement concerning induction and that this statement defends induction on the grounds that it can be turned into a syllogism by complete enumeration (actual or pretended). The fact that this understanding conflicts with the portrayal of induction in the *Posterior Analytics* was ignored or treated as a minor oddity to be explained away. Buridan, however, claimed that it is the portrayal in the *Posterior Analytics* that is definitive and that *Prior Analytics* 2.23 must be understood in its light. Buridan's comments were not incidental. He offered two thousand words of well-reasoned material on the subject.

This view of induction was just a part of Buridan's comprehensive empiricist philosophy, a philosophy highly influential across Europe during the late fourteenth and all through the fifteenth century.[123] One might expect his writings on induction to have had equal influence, but they did not, because they got overlooked and misrepresented. They were little reproduced and never printed. Here is what happened: Buridan wrote the *Summulae* as a textbook in two interlaced parts. The first part is an edited, paraphrased, and in places much extended version of Peter of Spain's *Tractatus*. The second part is a running commentary thereon. Buridan's

[123] For a forceful presentation of this influence, see Introduction to Buridan, *Summulae de Dialectica*, xxviii–xxx.

changes to the *Tractatus* were significant enough that the result constituted an important treatise in its own right and was reproduced as such without Buridan's commentary. It was published as John Buridan's treatise on logic several times from 1487 into the sixteenth century. As a significant text on logic, it warranted an accompanying commentary, but the commentary that circulated was not Buridan's, but a shorter commentary written by one John Dorp (fl. 1393–1405). On the passages relating to induction, Buridan had followed Peter of Spain without much change and placed his disagreements and new proposals in his commentary. But now his commentary was replaced by Dorp's more conventional one. So what circulated as John Buridan's view on induction was in fact Peter of Spain's conventional view, and Buridan's own radical view was set aside. (It has never been printed in Latin. The English translation was first published in 2001.[124]) Though Buridan's views on induction achieved some exposure in his commentary on the *Metaphysics*[125] and the *Physics*,[126] his most cogent and forceful writings on the subject were effectively lost, and what was presented as his own views were in fact Peter of Spain's.

If Buridan is a special case because what he wrote on induction was revolutionary but ignored, he is also special for being a transition between scholasticism and humanism. His life overlapped that of Ockham, and also that of

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[124] Several of the tracts with the *Summulae* have recently been published, but treatise 6, the important one for induction, has not yet.

[125] Book II q.1 (fol. 8va) cited and quoted in Thijssen, "John Buridan and Nicholas or Autrecourt on Causality and Induction," 248.

[126] Book I q.4 cited and quoted in ibid.: 250.

Petrarch (1304–1374), often called the founder of humanism. That there was a change in the study of logic from the medieval paradigm to a humanist one in the fifteenth century is well known and established.[127] The new logic was as disputatious as the scholastic, but instead of training a student to memorize the categories, moods, figures, forms, and rules by which a syllogistic conclusion is drawn, it trained the disputant in a broader project, which included not just drawing the conclusion but developing the premises, and not just using canonical syllogistic forms but marshalling other types of argument as well. The first was formalized, highly structured, and centered around rigorous syllogistic reasoning. The second was oriented toward persuasiveness rather than formal rigor, more toward rhetorical than dialectical argument. With a comprehensive record of the history of induction behind us, we will be able to readily see the implications of this shift for understandings of induction.

Four aspects of the shift were important for the history of induction. The first was the increase in scope. Interest rose in kinds of arguments beyond the syllogism.

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[127] For overview and introduction to the literature, see E. J. Ashworth, "The Eclipse of Medieval Logic," in *Cambridge History of Later Medieval Philosophy*, ed. Normal Kretzmann, Anthony Kenny, and Jan Pinborg (Cambridge: Cambridge University Press, 1982), 787–96; Lisa Jardine, "Humanism and the Teaching of Logic," in *Cambridge History of Later Medieval Philosophy*, ed. Normal Kretzmann, Anthony Kenny, and Jan Pinborg (Cambridge: Cambridge University Press, 1982), 797–807; E. J. Ashworth, "Traditional Logic," in *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, et al. (Cambridge: Cambridge University Press, 1988), 143-72; Jardine, "Humanistic Logic"; as well as the older Wilbur Samuel Howell, *Logic and Rhetoric in England, 1500–1700* (New York: Russell & Russell, 1961) and the sources cited above when introducing Boethius.

The second was a change in pedagogic material. Medieval logic traced its roots, whether through scholastics, Islamic writers, Peter, Boethius, the Alexandrians, Epicureans, or Stoics, back to the first few books of Aristotle's *Organon*, especially to the *Prior Analytics*. The new logic found its home instead in the *Topics*, the catalog, whether Aristotle's, Cicero's or Boethius's, of tools for composing a persuasive argument. The centrality of the *Topics* has given the new logic the name 'topics-logic.'[128] Third, the preeminence of Cicero in humanist scholarship and the injunction to return to ancient sources broke the monopoly that Boethius's *De Topicis Differentiis* had on the field. Aristotle's own *Topics* and Cicero's *Topics* gained attention. Both presented a different view of induction than Boethius's. It was in Aristotle's *Topics* that we found what I argued was his true view of induction. The fourth important aspect of the shift was access to the Platonic dialogues, which first became accessible with the rise of Greek literacy in the early fifteenth century and accelerated with the Latin translations late in the century. No student of rhetoric or persuasion can help but take notice of the dialogues of Socrates, the man known throughout antiquity as the inventor of induction. The *Topics* of Cicero and Aristotle and the Socratic dialogues of Plato all presented an understanding of induction different than the received view. The result would be disagreement, confusion, and eclecticism. The most important agent of change toward this end

[128] For the term, see Jardine, "Humanistic Logic," 182.

was the Italian Lorenzo Valla (1407–1457).[129] He brought Socrates, the *Topics*, and Cicero fully back into the discussion of induction.

Cicero, who recall coined the term *inductio*, had been absent from the discussion of the subject since antiquity, but Valla begins a full chapter on induction in *Repastinatio Dialectice et Philosophie* (1439)[130] with this: "Cicero defines induction as follows, and offers the following example."[131] Valla quotes Cicero's definition and one of Cicero's examples, and then writes, "Boethius, who followed a different school, disagrees with this definition and example."[132] Valla insists that Boethius has stolen and corrupted the proper view of induction, a view Valla associates partly with Cicero, and even more so with Socrates. Valla says that Boethius acts like someone who has stolen a horse and tries to hide the theft by cutting and dyeing the horse's hair.[133] Valla criticizes those who try to get around the fact that they cannot enumerate all of induction's particulars by adding 'et ita de singulis' to account for the unobserved. This is fatuous (stultum), he says, for if the

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[129] Paul Oskar Kristeller, "Valla," in *Eight Philosophers of the Italian Renaissance* (Stanford, CA: Stanford University Press, 1964), 19–36; Lisa Jardine, "Lorenzo Valla and the Intellectual Origins of Humanist Dialectic," *History of Philosophy* 15, no. 2 (1977): 143–64; Jardine, "Humanistic Logic," 178–181; Peter Mack, *Renaissance Argument: Valla and Agricola in the Traditions of Rhetoric and Dialectic* (Leiden, New York, and Köln: E. J. Brill, 1993).

[130] Lorenzo Valla, *Repastinatio dialectice et philosophie*, ed. Gianni Zippel (Padua: Antenore, 1982), 345-352.

[131] "'Inductionem' Cicero sic diffinit, et hoc pandit exemplo:" Ibid., 3.16.1 p. 345, my translation.

[132] "Ab huius et diffinitione et exemplo discrepant Boetius, diversam sactam secutus." Ibid., 3.16.3 p. 346, my translation.

[133] Ibid., 3.16.5 p. 346.

claim is true, then it is just a statement of the conclusion. He similarly dismisses those who add the premise, 'And these are all the particulars.' Indeed, he insists, all attempts at rendering an induction as some kind of deduction miss the point that induction and deduction are two completely separate things, neither a form of the other.[134] No previous writer on induction treated his predecessors as dismissively as Valla does his. He says that there have been multiple proposals about the nature of induction and some of those proposals are simply wrong. Many of what others have called instances of induction are not actually so. The only style of arguing, Valla says, that can properly be called induction is that of Socrates. This is a striking claim, since as mentioned earlier, Socrates never uses the term *induction* (*epagōgē*). It is a tribute to Valla's wide reading of pre-Boethian writers that, contrary to the whole medieval tradition associating induction with Aristotelian syllogism, Valla associates induction rather with Socrates' characteristic method. In this, Valla is recalling what Aristotle and Cicero said about Socrates and what Aristotle said about induction in his *Topics*. The canonical view of induction is succumbing to interpretations informed by a broader exposure to ancient and late antique philosophy.

Valla's successor in the campaign to promote topics-logic was the Dutch humanist Rudolph Agricola (1443/4–1485),[135] whose *De Inventione Dialectica* would,

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[134] Ibid., 3.16.14 p. 349.

[135] Jardine, "Humanistic Logic," 181–4; Mack, *Renaissance Argument: Valla and Agricola in the Traditions of Rhetoric and Dialectic*.

decades after his death, become a very popular textbook across Europe.[136] He was as innovative as Valla in directing attention away from syllogisms and toward the complete discursive enterprise, and as with other humanists, his point of reference was not Aristotle, but Cicero, Quintilian, and Socrates. Unlike Valla, however, he has nothing new to say about induction and even misunderstands Cicero on the matter. Agricola says there are two perfect forms of arguing, induction and deduction.[137] His example of induction is that we see the moon eclipsed when full several times, never see it eclipsed when not full, and conclude that the moon is eclipsed only when full. The example is conventionally scholastic. The particulars have no variety and are mere repetitions. Indeed enumeration, for Agricola, is the essence of induction. "To me it appears most correct to call induction enumeration, just as Cicero said it is a certain argumentation by enumeration of all parts."[138] It is characteristic of the new view to cite Cicero as the authority on induction, but this is not what Cicero said. For Cicero, induction is an open-ended process that does not require an enumeration of all instances, and in fact Cicero uses enumeratio to refer to a different process, a process of elimination.[139] Unsatisfied with what he thinks is Cicero's view, Agricola offers this supposed improvement: "In fact the name 'induction' fits better to imperfect enumeration, where a listener is induced

[136] Jardine, "Humanistic Logic," 181.

[137] It is a minor innovation that he treats them in the Aristotelian and Ciceronian order rather than the scholastic.

[138] Rudolph Agricola, *De Inventione Dialectica* (Cologne: 1539), 2.18, p. 265, my translation.

[139] *De Inventione*, 1.29 (45); 1.45 (84).

by means of two or three propositions to believe something to be true of all."[140] Thus although Agricola does not seem to realize it, he does in the end endorse what Cicero in fact held. Agricola offers three more examples and then has little more to say on induction, until a small but surprising and important use of the word in the penultimate chapter of the third and final book. In an example intended to demonstrate Agricola's whole method at work, he describes a debate between two disputants.

> [One] asks whether it is admitted that the soul is better than the body. But this also must be built up from a *Socratic induction*. It must be asked whether the driver is superior to his chariot, the helmsman to his ship, the master to his house, and the ruler to his people, or in general whether he thinks that that which commands is superior to that which serves, and whether he thinks the body is ruled by the soul. Which if he concedes it, it will be necessary for him to concede that the soul is superior to the body.[141]

Nothing in Agricola's earlier treatment of induction prepares us for what he here calls 'Socratic induction.' He may have misunderstood Ciceronian induction, but he understood Socratic induction very well. This is an ideal example. The particulars are varied, the results depend on coming to understand the essential nature of 'to command' and 'to be superior,' and the conclusion is valid for instances beyond those surveyed. It would have been natural to find this example in

140 Agricola, *De Inventione Dialectica*, 2.18, p. 265, my translation.

141 Ibid., 3.15, p. 447. As translated by Jardine, "Humanistic Logic," 183, punctuation corrected, italics added.

a Socratic dialogue or in Cicero's *Topics*. Agricola says little on induction, but importantly, in this popular textbook, he holds that the authorities on the matter are Cicero and Socrates.

When Arabic commentators discovered a difference between what Aristotle said on the matter and what they inherited from sixth-century Alexandria, they held to the Alexandrian interpretation and declared Aristotle to be wrong. When the scholastics spotted the difference, they either ignored it, adopted even more of the Alexandrian synthesis than Arabic commentators had, or creatively introduced some new distinction. But when Buridan saw a conflict between the canonical reading of *Prior Analytics* 2.23 and the view of induction he found in the increasingly studied *Posterior Analytics*, he challenged the canonical understanding. When Valla identified a conflict between Boethian induction and Socratic, he rejected the established Boethius. When Agricola sought an ancient authority for induction, he chose Cicero and Socrates and not the conventionally understood Aristotle. As these and other scholars turned increasing attention to the *Topics*, whether Aristotle's or Cicero's, they found a view of logic and of induction at odds with the established syllogism-centered view of both. In the sixty years after Agricola's death in 1485, under the continued pressure of a humanist preference for Cicero and for original sources of later altered ideas, the centuries-old consensus regarding what induction is, what makes an induction valid, and the relationship between induction and deduction collapsed, and from Italy to England, the old stability gave way to disagreement, confusion, and eclecticism.

In the 1480s, thirty years after the invention of printing in the mid-fifteenth century virtually everything one would read on induction told a common story. In the late fifteenth century, the most popular logic textbooks were still Peter of Spain's 250-year-old *Tractatus* (with its 160 Renaissance printings) and Buridan's 150-year-old *Summulae de Dialectica* (which recall was essentially an edited version of Peter's *Tractatus*). These remained the model for many others, including the popular college epitomes *Libellus sophistarum ad usum Cantabrigiensium* and *Libellus sophistarum ad usum Oxoniensium*.[142] The Boethian translations of the *Organon* were still standard, Boethius's treatise on the *Topics* was still widely preferred to Cicero's or Aristotle's, and Boethius's logical treatises were still popular and remained so into the sixteenth century.[143] All these, as well as scholastic treatises and Arabic commentaries still widely read, presented essentially one view of induction.

Starting in the 1480s, texts emerging from the presses offered a different view. In 1484, all of the Socratic dialogues became available in Marsilio Ficino's new Latin translation.[144] It thus became easier to see what Aristotle meant when he said Socrates introduced induction. Soon after (1495–98), nearly the whole Aristotelian

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[142] *Cantabrigiensium*: published four times 1497–1524. *Oxoniensium*: published seven times 1499–1530. Ashworth, "The Eclipse of Medieval Logic," 788.

[143] Anthony Grafton, "Epilogue: Boethius in the Renaissance," in *Boethius: His Life, Thought and Influence*, ed. Margaret Gibson (Oxford: Blackwell, 1981), 410–15; Lewry, "Boethian Logic in the Medieval West," 121; F. Edward Cranz, *A Bibliography of Aristotle Editions: 1501–1600*, ed. Charles B. Schmitt, Second ed. (Baden-Baden: Valentin Koerner, 1984), xii–xiv; Henri Durel, "Francis Bacon lecteur d'Aristote à Cambridge," *Nouvelles de la République des Lettres* (1998): 48.

[144] Plato, *Opera*, ed. Marsilio Ficino (Florence: Laurentius de Alopa, 1484).

corpus was published by Aldus in the original Greek,[145] facilitating new translations and further consideration of everything Aristotle had to say on *epagōgē*. Starting in 1493, commentaries began to deal with the *Organon* as a whole instead of with books in isolation.[146] Ancient Greek commentaries by Alexander, Philoponus, Simplicius, and others began to appear in Latin translations.[147] Though these presented the received view of induction, they added new perspectives that needed to be integrated and reconciled. Editions of Cicero's *Topics*, with its thoroughly Socratic view of induction, were printed in Venice in 1480, 1484, 1485, 1488, 1492 and 1495. Valla's *Repastinatio Dialectice et Philosophie* came into print, and Agricola's *De Inventione* was finally published in 1515. In 1525, the Aldine edition of Galen's works in Greek revealed his comments on induction. In the 1520s, Aristotelian texts and commentaries in the established model dropped sharply.[148] But a new and vigorous humanist Aristotelianism emerged just as sharply starting with the Latin *Opera* published in 1538.[149] The 1540s saw new translations, new commentaries, and new

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[145] Aristotle, *Opera* (Venice: Aldus Manutius, 1495–98).

[146] Ashworth, "Traditional Logic," 144.

[147] Ibid., 145. There are thirty volumes in the series *Commentaria in Aristotelem Graeca: Versiones latinae temporis resuscitatarum litterarum* (*CAGL*), modern reprints of Greek commentaries in Renaissance Latin translations.

[148] Cranz, *A Bibliography of Aristotle Editions: 1501–1600*, xiii. Ashworth, "The Eclipse of Medieval Logic," 790; E. J. Ashworth, "Changes in Logic Textbooks from 1500 to 1650: The New Aristotelianism," in *Aristotelismus und Renaissance*, ed. Eckhard Kessler, Charles H. Lohr, and Walter Sparn (Wiesbaden: Otto Harrassowitz, 1988), 76.

[149] The vigor of Renaissance Aristotelianism has become increasingly appreciated in the last twenty-five years and has been the subject of several monographs, conferences, and edited volumes.

concerns. Underexplored works in the corpus such as the *Posterior Analytics*, *De Generatione et Corruptione*,[150] and the *Rhetoric*[151] attracted new attention. In some quarters the *Posterior Analytics* came to be seen as the book about induction and the

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Particularly relevant for the current study have been the second (1984) edition, revised by Charles Schmitt of Cranz, *A Bibliography of Aristotle Editions: 1501–1600*, XIII, and the monographs and volumes F. Edward Cranz, "Editions of the Latin Arisotle Accompanied by the Commentaries of Averroes," in *Philosophy and Humanism: Renaissance Essays in Honor of Paul Oskar Kristeller*, ed. Edward P. Mahoney (New York: Columbia University Press, 1976), 116-28; Constance Blackwell and Sachiko Kusukawa, eds., *Philosophy in the Sixteenth and Seventeenth Centuries: Conversations with Aristotle* (Aldershot, UK: Ashgate, 1999); Eckhard Kessler, Charles H. Lohr, and Walter Sparn, eds., *Aristotelismus und Renaissance: In Memoriam Charles Schmitt* (Wiesbaden: Otto Harrassowitz, 1988); Daniel A. Di Liscia, Eckhard Kessler, and Charlotte Methuen, eds., *Method and Order in Renaissance Philosophy of Nature: The Aristotle Commentary Tradition* (Aldershot: Ashgate, 1997); Marianne Pade, ed., *Renaissance Readings of the Corpus Aristotelicum* (Copenhagen: Museum Tusculanum Press and the University of Copenhagen, 2001); Charles B. Schmitt, *John Case and Aristotelianism in Renaissance England* (Kingston and Montreal: McGill-Queen's University Press, 1983); Charles B. Schmitt et al., eds., *The Cambridge History of Renaissance Philosophy* (Cambridge: Cambridge University Press, 1988). Particularly relevant essays include Ashworth, "Changes in Logic Textbooks from 1500 to 1650: The New Aristotelianism"; Ashworth, "Traditional Logic"; Jardine, "Humanistic Logic"; Eckhard Kessler, "Metaphysics or Empirical Science? The Two Faces of Aristotelian Natural Philosophy in the Sixteenth Century," in *Renaissance Readings of the Corpus Aristotelicum*, ed. Marianne Pade (Copenhagen: Museum Tusculanum Press, 2001), 79-100; Charles Lohr, "The Sixteenth-Century Transformation of the Aristotelian Natural Philosophy," in *Aristotelismus und Renaissance*, ed. Eckhard Kessler, Charles H. Lohr, and Walter Sparn (Wiesbaden: Otto Harrassowitz, 1988), 89–99; Charles H. Lohr, "Metaphysics and Natural Philosophy as Science: the Catholic and the Protestant Views in the Sixteenth and Seventeenth Centuries," in *Philosophy in the Sixteenth and Seventeenth Centuries: Conversations with Aristotle*, ed. Constance Blackwell and Sachiko Kusukawa (Aldershot, UK: Ashgate, 1999), 280–95.

[150] Kessler, "Metaphysics or Empirical Science? The Two Faces of Aristotelian Natural Philosophy in the Sixteenth Century."

[151] Erickson, *Aristotle's Rhetoric: Five Centuries of Philological Research*, 12.

Prior Analytics the book about deduction.[152] Study of Aristotelian induction could no longer be limited to simply what was found in *Prior Analytics* 2.23.

Students of induction were now faced with multiple traditions and inconsistent interpretations. Those who noticed the inconsistencies, like Buridan or Valla, pointed out that the conventional view was inconsistent with itself, with ancient authorities, or with both. But they offered no comprehensive new theory that would fully reconcile or integrate the valid criticisms that were being raised. They had started to tear down the old, but not yet build up the new. We will see in the next chapter a few theories of induction that emerged in this environment. For now, we may concretize the collapse of the consensus by looking at two events, one quickly and one in more depth, the first in Italy, the second in England.

In the last book of the *Topics*, Aristotle had said that what induction is, is obvious, and in a short chapter in the first book, Aristotle offered a seemingly unambiguous description. Because of its simplicity and clarity, that passage was the first considered in this study. In 1542, in his commentary on that same chapter, the prolific and influential Paduan commentator Agostino Nifo wrote that the nature of

[152] Evidence for this comes from a humorous and unusual source. In 1544 the Protestant apologist Celio Secondo Curione, an Italian professor living in Switzerland, published a defense of Protestant views in the form of a tale. In the tale the character Pasquine recounts a trip he made to heaven. Before he learns how to get to heaven, Pasquine comes upon a friar. "He [the friar] complained that his father Prior commended much more that part of Aristotle called *Posteriora*, than the other called *Priora*, and that being in this preposterous opinion, he never used demonstrations, but only induction." Celio Secondo Curione, *Pasquine in a Traunce* (London: 1566), 10r.

induction was in fact not obvious.[153] "There is uncertainty about the definition of induction."[154] Nifo cites Alexander, Boethius, Philoponus, and Averroës, and what Aristotle himself wrote in the *Prior Analytics*, and concludes that there is in fact no consensus regarding what induction is. There seems to be at least two opposing views. Is, for example, induction a kind of deduction or is it something else? If something else, is that something a kind of reasoning? If induction is a manner of speaking (oratio), how can it be defined as a progression or accession, which are motions from one place to another? If the same road leads both from Athens to Thebes and from Thebes to Athens, and induction is a progression from singulars to a universal, is it not also a progression from a universal to singulars? Must all singulars be included or are merely some sufficient? Is the result of an induction categorical or hypothetical? Is an induction one proposition or many? If induction is an argument, what is the middle term? Where does it come from? By what ability does the mind form inductions? These questions, Nifo noted, had no single answer, and Nifo offered some of his own, the spirit of which we will see in Paduan regressus theory in the next chapter. What Aristotle found obvious, Nifo found

[153] Agostino Nifo, *Aristotelis Stagiritae Topicorum libri octo* (Venice: Girolamo Scotto, 1557), 18v–r, first published 1542. On Nifo, see Schmitt et al., eds., *The Cambridge History of Renaissance Philosophy*, 688–9, 828; *Dictionary of Scientific Biography*, (New York: Scribner, 1970-90), s.v. "Nifo"; E. J. Ashworth, "Agostino's Reinterpretation of Medieval Logic," *Rivista Critica di Storia Della Filosofia* 31 (1976): 355–74.

[154] "dubitatur circa definitionem inductionis." Nifo, *Topicorum libri octo*, 18r.

conflicted. And he made the observations while reviewing not the *Prior Analytics*, but the *Topics*.[155]

Further evidence for breakdown of the consensus is a popular logic textbook in England in the mid-sixteenth century. The book, John Seton's *Dialectica*, was first published in 1545 and was frequently reprinted, eventually with commentary, into the seventeenth century.[156] While previous textbook treatments of induction were short, simple, and nearly identical in content, Seton's was long, eclectic, and unique. In the book's preface Seton explains that he intends to use the new work of Melanchthon and Agricola to prepare the student for further study of Aristotle.[157] For each subject, Seton presents, in larger typeface, a conventional overview and follows it with an expository commentary, in smaller typeface.[158] The three-page chapter on induction begins, "Induction is an argument from several singulars to a universal, or a progression from parts to a whole."[159] This conventional description, little different from Peter of Spain's, appears in the conventional scholastic location,

[155] Nifo's view on induction, and those of the Paduan line of thinkers in general, warrant considerable research.

[156] John Seton, *Dialectica* (London: 1545). Seton receives substantive treatment in Howell, *Logic and Rhetoric in England, 1500–1700*, 49–56. The textbook is set within the context of logic textbooks emerging in the period in Schmitt, *John Case and Aristotelianism in Renaissance England*, 32–33; and Lisa Jardine, "The Place of Dialectic Teaching in Sixteenth-Century Cambridge," *Studies in the Renaissance* 21 (1974): 54–57.

[157] Seton, *Dialectica*, prefatory epistle.

[158] In the many editions after the second (1574), Seton's comments were followed by further commentary provided by Peter Carter.

[159] "Inductio est argumentation a pluribus singularibus ad vniuersale: vel, a partibus ad totum progression." Seton, *Dialectica*, bk. 3, K2r, my translation..

i.e., after an extended treatment of the syllogism and before short chapters on enthymeme and example. Seton offers two examples and short elaborations. Then he begins to deviate from the scholastic treatment. In one of his examples, he adds, almost conventionally, "and in no others is the contrary to be seen,"[160] but otherwise says nothing about whether or how the premises of an induction account for the unobserved, an issue previously considered crucial. He then compares induction to the syllogism, but instead of saying that an induction is a kind of abbreviated syllogism that gains its force by inclusion of 'et cetera,' he says, "It is said that induction is an inverted syllogism, because in a syllogism as such an argument descends from a universal and, on the other hand, in an induction the argument rises from singulars and ascends."[161] In this he is returning to a theme more typical of the Aristotelian corpus outside its Neoplatonic interpretations. He also recalls Aristotelian language in using inductio and epagōgē interchangeably, apparently comfortable that his reader is equally familiar with the Greek term.

Multiple lines of thought become more apparent as we move through Seton's commentary. He says that principles of sciences can be established only by induction, recalling the *Posterior Analytics*. Not fully consistent with that, however, he then says that "Induction is said by Agricola to be enumeration."[162] He returns to themes from *Posterior Analytics* 2.19 by saying that the universal is a notion

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[160] "nec in caeteris est contrarium videre." Ibid., my translation.

[161] "Dicitur inductio inuersus syllogismus, quia sicut in syllogismo ab vniuersali descendit, ita e contrario in inductione a singulari inchoatur, & ascendit argumentation." Ibid., bk. 3, K3v.

[162] "Inductio dicitur ab Agricola enumeratio." Ibid., bk.3, K3v.

(notio), developed by the mind (mens), which some sharpness (acrimonia) of the spirit (anima) can ascertain from similarities held in memory. His source for this, he says, is the ancient Greek commentator Themistius, whose paraphrase of the *Posterior Analytics* was printed many times from 1499 through 1560.[163] Seton then attempts to place induction in the context of the new topics-logic, first using the language of the new humanist writings on invention and judgment, then paraphrasing passages from Aristotle's *Topics*. He then says that "induction is called Socratic, because Socrates used it so frequently,"[164] and gives a good example of Socratic induction involving whether the best of something is also the best stock. Seton paraphrases material Aristotle presented in the *Topics* and the *Rhetoric* about how to use induction most effectively and ends by referring to Plato and Cicero as the source for the best inductions. In Seton's chapter on induction therefore, nearly all the traditions on induction make an appearance, but little attempt is made to reconcile them. It is not clear whether Seton recognized the incongruities. The multiple lines of thought were incorporated, but not integrated. Seton's treatment is representative of the eclecticism and confusion that now prevailed regarding induction.

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[163] Themistius, *Expositiones in Posteriora Aristotelis* (Venice: Bartholomeum de Zanis de Tortesio, 1499).

[164] "Inductio appellatur Socratica, propterea quod ea Socrates, creberrime usus est." Seton, *Dialectica*, bk. 3, K3r.

3

Debating Induction:

Aristotelianisms of 1575–1600

By the 1540s, the medieval consensus regarding the nature of induction had collapsed. This was not perceived to be a major problem warranting focused attention—not until the *Novum Organum* in 1620 would there be a treatise dedicated to induction—but it did leave theoreticians free to incorporate differing views of induction into their larger epistemological systems. This chapter considers aspects of four such systems of the late sixteenth century, four that are important (or proposed to be important) for the subsequent history of induction, viz., those of Jacopo Zabarella in Padua, Everard Digby and William Temple at Cambridge, and John Case at Oxford. Zabarella, whose logical works were published from 1578 to 1590, was probably Europe's leading Aristotelian. He was a major advocate for a methodology called 'regressus,' a system in which—it has been proposed—induction played an important and influential role. Digby, though an avowed Aristotelian, in fact represents the beginnings of a new Neoplatonism at Cambridge. His ideas are likely the object of some of Bacon's attacks. In 1580–82

Digby engaged in a pamphlet war with Temple, England's leading advocate for the educational approaches of the continental reformer Peter Ramus. In the midst of that debate, Temple reveals stong views about induction that are not commonly associated with Ramus. Bacon later acknowledges that a core Ramist teaching lay at the foundation of his own thinking on induction. John Case represents humanist Aristotelianism in England in the 1580s and 90s. At least one of Bacon's key and now famous ideas is first found in Case's writings. These four thinkers represent leading factions in an epistemological debate underway while Bacon was developing his ideas for the *Novum Organum*. We can better understand Bacon's contribution if we better understand the conversation he entered.[1]

Jacopo Zabarella (1533–1589)

In the late sixteenth and early seventeenth centuries, Zabarella's writings were well known throughout Europe and in England. He has also been well known in the twentieth century, largely because of an hypothesized influence on early modern natural philosophy. A component of that hypothesis is that natural philosophers at the University of Padua, especially Galileo, enthusiastically adopted Zabarella's regressus, that induction is one half of a regressus (deduction being the other), and that therefore Zabarella in effect introduced induction into early modern

[1] A more comprehensive account would consider Protestant reformers in Germany such as Phillip Melanchton, the Portuguese Jesuit Collegium Conimbricenses such as Pedro Fonseca, and others in Padua besides Zabarella. Preliminary research suggests there was little development in induction theory in the first two schools that is not reflected in the Englishmen in our sample, but the third surely warrants further study.

natural philosophy. No survey of the history of induction would be complete without considering Zabarella. After reviewing his biography, the genesis of the twentieth-century interpretation will be examined. A close reading of Zabarella's writings other than those typically considered and an examination of his views in light of the now understood medieval background will challenge the widely held view of induction's role in regressus. This analysis will give a more accurate account of Zabarella's contribution to the period's conversation on induction.

Jacopo Zabarella was born in 1533 in Padua to a wealthy family. He graduated from the University of Padua with his doctoral degree in 1553. He was appointed to the chair of logic at the university in 1564 and chair of natural philosophy in 1569. In his personal life, he inherited a sizable fortune; in his professional life, he inherited and brought to its most mature development a vigorous tradition of Paduan Aristotelianism.

Padua had long been a great center of both scholastic learning and natural philosophy, especially medicine. Albert the Great studied there in the thirteenth century. Already then professors such as Peter of Abano were advocating the integrated study of logic and natural philosophy,[2] and the study of Aristotle flourished. Over time Thomist, Scotist, Averroist, and Alexandrian interpretations of Aristotle were all represented. In the fifteenth century, with the rise of

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[2] Grant, *The Foundations of Modern Science in the Middle Ages*, 157; Pearl Kirbe and Nancy G. Siraisi, "The Institutional Setting: The Universities," in *Science in the Middle Ages*, ed. David C. Lindberg (Chicago: University of Chicago Press, 1978), 133–41.

humanism and a growing awareness of Plato, Aristotelian commentary was brought to bear on subjects such as the immortality of the soul. Leading Aristotelian commentators were Nicoletto Vernia (1420–1499), Pietro Pomponazzi (1462–1525), and Agostino Nifo (1473?–?1538). As the sixteenth century advanced, increasing attention was turned toward natural philosophy and Aristotle's contribution thereto. Copernicus studied medicine in Padua in 1501–3, as later in the century did William Harvey. Vesalius taught there in the 1540s, Fabricius from 1562 to 1613. Galileo taught mathematics from 1592 to 1610. In Zabarella's days, Padua had a prominence in natural philosophy and scholastic study of Aristotle unmatched in Europe. Shakespeare called it "fair Padua, nursery of the arts."[3]

In the late sixteenth century, Zabarella was Padua's most distinguished Aristotelian. His writings were extensive and widely read well into the seventeenth century. His most important works were on methods of logic and natural philosophy. They included *Opera Logica* (1578), *Tabulae Logicae* (1580), *De Naturalis Scientiae Constitutione* (1586), *De Rebus Naturalibus* (1590) and many commentaries on Aristotle. His works were well known in England. Zabarella died, in Padua, in 1589.[4]

[3] *The Taming of the Shrew*, 1.2.2. Copenhaver and Schmitt, *Renaissance Philosophy*, 105.

[4] Brief biographical sketches appear in *Dictionary of Scientific Biography*,; and Schmitt et al., eds., *The Cambridge History of Renaissance Philosophy*, 841. The fullest available biographical material appears in William F. Edwards, "The Logic of Iacopo Zabarella," (Columbia University dissertation, 1960), 1–82.

Through nearly the whole twentieth century, there has been a debate among historians and philosophers of science regarding the extent to which Zabarella's ideas influenced early modern natural philosophers.[5] Central to that debate has been induction and the way Zabarella incorporated it into his methodological system.

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[5] Important documents in the debate have been, in chronological order (pro) Ernst Cassirer, *Das Erkenntnisproblem in der Philosophie und Wissenschaft der Neueren Zeit*, 2nd, revised ed., vol. 1 (1922; reprint, Darmstadt: Wissenschaftliche Buchgesellschaft, 1974), 136–44, first published in 1906; (pro) John Herman Randall, Jr., "The Development of Scientific Method in the School of Padua," *Journal of the History of Ideas* 1, no. 2 (1940): 177-206; (con) Neal W. Gilbert, *Renaissance Concepts of Method* (New York and London: Columbia University Press, 1960); (con) Neal W. Gilbert, "Galileo and the School of Padua," *Journal for the History of Philosophy* 1 (1963): 223-31; (pro) William F. Edwards, "Randall on the Development of Scientific Method in the School of Padua—a Continuing Reappraisal," in *Naturalism and Historical Understanding: Essays on the Philosophy of John Herman Randall, Jr.*, ed. John P. Anton (Albany: State University of New York Press, 1967), 53–68; (con) Harold Skulsky, "Paduan Epistemology and the Doctrine of the One Mind," *Journal for the History of Philosophy* 6, no. 4 (1968): 341–62; (con) Charles B. Schmitt, "Experience and Experiment: a Comparison of Zabarella's View with Galileo's in *De motu*," *Studies in the Renaissance* 16 (1969): 80–138; Nicholas Jardine, "Galileo's Road to Truth and the Demonstrative Regress," *Studies in History and Philosophy of Science* 7 (1976): 277-318; (con) Paolo Rossi, "The Aristotelians and the 'Moderns': Hypothesis and Nature," *Annali Dell'Istituto e Museo di Storia Della Scienza di Ferenze* 7 (1982): 3–27; Luigi Olivieri, ed., *Aristotelismo Veneto e Scienza Moderna* (Padua: Editrice Antenore, 1983); (pro) William A. Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton: Princeton University Press, 1984); (con) Heikki Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences* (Helsinki: Suomen Historiallinen Seura, 1992); (pro) William A. Wallace, "Circularity and the Paduan *Regressus:* From Pietro d'Abano to Galileo Galilei," *Vivarium* 33, no. 1 (1995): 76–97. Surveys of the debate appear in Bruce S. Eastwood, "On the Continuity of Western Science from the Middle Ages: A. C. Crombie's *Augustine to Galileo*," *Isis* 83, no. 1 (1992): 84–99; H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago and London: University of Chicago Press, 1994), 279–84; and Sean Martin O'Connor, "*Regressus* and the Scientific Revolution: A Defense of Zabarella's Contribution to Scientific Method" (Master's Thesis, Arizona State University Department of Philosophy, 1995).

Given the prominence of induction in early modern natural philosophy, given that we can trace the idea back to Aristotle, given that the most advanced place for Aristotelian scholarship at the beginning of the scientific revolution was Padua, given that so many of the founders of that revolution, including Galileo and Harvey, taught or studied there, and given that at the time Zabarella was at the pinnacle of Aristotelian scholarship, it is natural to suspect we will find a new concept, theory, or prominence for induction in Zabarella's writings. Indeed, induction does play a role in Zabarella's scientific methodology, but it is not the role generally believed. To properly assess Zabarella's influence on inductive science, we need to first understand Zabarella's concept of induction.

The core of Zabarella's scientific epistemology[6] is the theory of regressus, a two-part procedure for coming to know things in natural philosophy.[7] One part,

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[6] Considering how much interest Randall's article has received in the English-speaking world, there is in that world surprisingly little literature dedicated to Zabarella. No English translations have been published. The only two monograph-length treatments in English are the unpublished dissertation, Edwards, "The Logic of Iacopo Zabarella," and the Finnish work Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences* . The Italian reprint of *De Methodis* and *De Regressu*, Jacopo Zabarella, *De Methodis Libri Quatuor; Liber De Regressu* (Venice: Paulus Meietus, 1578; reprint, edited by Cesare Vasoli, Bologna: CLUEB, 1985), contains an introduction in English. There is a German translation of *De Methodis* and *De Regressu*, Jacopo Zabarella, *Über die Methoden (De Methodis); Über den Rückgang*, trans. Rudolpf Schicker (München: Wilhelm Fink, 1995), which contains an introduction and also a bibliography. Though that bibliography is comprehensive and includes works in English, German and Italian, it lists only forty secondary works, many only tangentially related to Zabarella. Zabarella's works other than *De Methodis* and *De Regressu* have received very little attention.

resolution, infers causes from observed effects. The other, composition, infers effects from causes. Resolution comes first, because—consistent with the Aristotelian tradition—it is by way of the senses that we come to know anything and what we perceive are the sensible effects of (sometimes hidden) causes. By resolution we infer those causes from what we perceive. Once we understand causes we, in the composition half of the regressus, infer effects from the causes and in so doing come to explain and understand those effects, for—again consistent with the Aristotelian tradition—to fully know something is to know its cause. Resolution infers causes from effects; composition infers effects from causes. Zabarella describes the combined use of these two in *De Methodis* and the shorter *De Regressu*, both published as part of *Opera Logica* in 1578.

In 1906, Ernst Cassirer drew attention to the popularity in the late sixteenth and early seventeenth century of Zabarella's writings and especially those on regressus. He suggested a possible connection between that popularity and the rise of early modern scientific method, especially the method of Galileo. He also began an association between regressus and induction that is, in fact, not in Zabarella. Here is how the association got made. Cassirer dedicates several pages in *Das*

[7] A concise and informed treatment of *regressus* theory (not just Zabarellian) appears in Nicholas Jardine, "Epistemology of the Sciences," in *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, et al. (Cambridge: Cambridge University Press, 1988), 686–93. Extended and important treatments appear in Wilhelm Risse, *Die Logik der Neuzeit*, vol. 1: 1500-1640 (Stuttgart: Friedrich Frommann, 1964), ch. 4-5; and Kosman, "The Aristotelian Backgrounds of Bacon's *Novum Organum*." The structure of regressus will be treated further below.

Erkenntnisproblem to Zabarella.[8] He describes regressus and its complementary methods of resolution and composition. He then writes,

> The meaning of these remarks [Zabarella's remarks] becomes clear as soon as we translate them into modern language. The distinction between the compositive and the resolutive methods is a matter of the contrast between deduction and induction.[9]

A confusion ensues, for 'deduction and induction' are not just terms in 'modern language.' They are also terms Zabarella uses. Cassirer selectively quotes a few such uses[10] and leaves the impression that Zabarella considers induction to be the same as resolution. He then credits Zabarella with "a reorganization and reinterpretation of the Aristotelian concept of experience into the modern concept of analytic induction."[11]

This near identification of the modern concept of induction with Zabarella's concept of resolution pervades the twentieth-century debate on Zabarella's influence on early modern science. Randall says, without citation, that induction was first formally identified with resolution (or actually, with 'demonstratio quia,' which Zabarella does regularly identify with resolution) by Zabarella's teacher

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[8] Cassirer, *Das Erkenntnisproblem in der Philosophie und Wissenschaft der Neueren Zeit*, 136–144.

[9] "Die Bedeutung dieser Ausführungen Zabarellas ergibt sich uns sofort, sobald wir sie in moderne Sprache übersetzen. In der Unterscheidung von kompositiver und resolutiver Methode handelt es sich um den Gegensatz von Deduktion und Induktion." Ibid., 137, my translation.

[10] Ibid., 138–40.

[11] "Eine Umbildung und Umdeutung des Aristotelischen Erfahrungsbegriffs in den modernen Begriff der analytischen Induktion." Ibid., 140, my translation.

Bernardinus Tomitanus.[12] Randall then says that Zabarella followed "his teacher Tomitanus in making 'induction' *a form of* the method of resolution."[13] There is a subtle and not inconsequential inconsistency here. John Herman Randall said that Tomitanus considered induction and resolution the same thing, then that Zabarella followed Tomitanus regarding this, but then that Zabarella identified induction as just one kind of resolution. I have not been able to find a relevant passage in Tomitanus to confirm which he held, but Zabarella certainly believed the second, that induction is just one kind of resolution, exactly what kind to be discussed below. But this subtlety was frequently overlooked by subsequent commentators,[14] and even the more careful commentators who maintain the distinction often leave

[12] Randall, "The Development of Scientific Method in the School of Padua," 196. The claim is repeated, again without detailed citation, by Giovanni Papuli, "La Teoria del *Regressus* Come Metodo Scientifico Negli Autori della Scuola di Padova," in *Aristotelismo Veneto e Scienza Moderna*, ed. Luigi Olivieri (Padua: Editrice Antenore, 1983), 255; by Wallace, "Circularity and the Paduan *Regressus:* From Pietro d'Abano to Galileo Galilei," who cites Randall and Papuli; and without reference by Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* .

[13] Randall, "The Development of Scientific Method in the School of Padua," 198, emphasis added.

[14] This confusion pervades A. C. Crombie, *Augustine to Galileo: The History of Science, A.D. 400–1650* (London: Falcon Press, 1952); A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science 1100–1700* (Oxford: Clarendon Press, 1953); and appears in Skulsky, "Paduan Epistemology and the Doctrine of the One Mind," 341; Edwards, "Randall on the Development of Scientific Method in the School of Padua—a Continuing Reappraisal," 54, "the *principia* discovered by resolutive (inductive) method"; and Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*, 232–36.

the impression that induction is the normal or most important kind of resolution.[15] But for Zabarella, induction is only a kind of resolution, and in fact, peripheral, positively powerless for the discovery of the most important scientific principles, and usually not even worth mentioning. As a component in a normal regressus, induction is no more a part of resolution than of composition.

Commentators on the debate about the influence of regressus typically concentrate their attention on chapter 4 of the short *De Regressus* and on *De Methodis*, book 3, chapter 19. None of these commentators has drawn attention to the focused and extended treatments of induction in the *Tabulae Logica*, in Zabarella's commentary on the *Posterior Analytics*, in *De Methodis* book 3, chapter 3, or in *De Methodis* book 4, chapter 13. To fully understand Zabarella's view on induction let us consider these in turn.[16]

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[15] Examples include Jardine, "Galileo's Road to Truth and the Demonstrative Regress," 277, and Wallace, "Circularity and the Paduan *Regressus:* From Pietro d'Abano to Galileo Galilei," 92. Wilhelm Risse, "Zabarellas Methodenlehre," in *Aristotelismo Veneto e Scienza Moderna*, ed. Luigi Olivieri (Padua: Editrice Antenore, 1983), 155–72, further develops Cassirer's idea that the first step in a regressus is what is now called analytic induction.

[16] Comments about what Zabarella thought of induction appear throughout the literature on regressus. Besides those mentioned in the text, concentrated treatments include Randall, "The Development of Scientific Method in the School of Padua," 203, in which Randall mistakenly treats induction as the paradigmatic case of resolution; Risse, *Die Logik der Neuzeit*, 286, in which Risse adopts Cassirer's misassociation of resolution with analytic induction; Skulsky, "Paduan Epistemology and the Doctrine of the One Mind"; Jardine, "Galileo's Road to Truth and the Demonstrative Regress," 299-300, in which Jardine describes Zabarella's account as inconsistent, which I do not think is correct (it appears inconsistent only if we accept Caissirer's attempt to equate induction and resolution); Risse, "Zabarellas Methodenlehre," esp. 164, in which Risse pursues a

In a section of *Tabulae Logicae* entitled *De Inductione*, Zabarella writes (presented as he presents it),

> There is no one who denies induction to be a logical instrument by which, from better known particulars, an unknown universal is shown, and it is of two types:
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> | | |
> |---|---|
> | Perfect, which concludes necessarily, because it takes in all particulars; for example, if we suppose that there are no other individual men than these three, Peter, Socrates, and Plato, this will be a perfect induction. | Imperfect, which does not conclude necessarily, because it does not take in all particulars; for example, if we suppose that there are other men than Peter, Socrates, and Plato, this will be an imperfect induction. |
>
> Peter, Socrates and Plato are biped; therefore every man is biped.
>
> Following the wise Aristotle, considering the nature and force of induction, we say that induction shows the first term to belong to the

promising approach in attempting to untangle Zabarella's topology with distinctions between different kinds of induction; and Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences*, an admirable attempt to bring a fresh perspective and a close reading of Zabarella's text to the debate. Also demonstrating much more attention to the texts and less reliance on the Randall thesis is the very recent James South, "Zabarella, Prime Matter, and the Theory of *Regressus*," *Graduate Faculty Philosophy Journal* 26, no. 2 (2005): 79–98.

> middle through the third, and that a perfect induction is reduced to the correct form of the syllogism and to the useful mode of the first figure.[17]

This is all a purely conventional scholastic understanding of induction, using language and structure of presentation that derive directly from the Alexandrian Neoplatonic interpretation of *Prior Analytics* 2.23. Zabarella continues at length along the same vein, drawing on the scholastic language of syllogistic figures and convertibility, stressing repeatedly that perfect induction concludes necessarily and imperfect induction does not, because a perfect induction can be rendered as a syllogism and an imperfect one cannot. He proceeds by saying there are two kinds of perfect induction. In the first, "all individuals are singularly and expressly named."[18] In the second, "not all are expressly named, but only a certain number are stated, and we briefly denote the rest implicitly by virtue of some distributive

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[17] "Nemo est, qui ignoret inductionem esse logicum instrumentum, quo ex particularibus notioribus ostenditur vniuersale ignotius, eam que duplicem esse.

Perfectam, quae necessario concludit, quia sumit omnia particularia, vt si supponamus non dari alium indiuiduum hominem praeter hos tres, Petrum, Socratem, & Platonem, haec erit inductio perfecta	Imperfectam, quae non necessario concludit, quia non sumit omnia particularia, vt si supponamus dari alios singulares homines praeter Petrum, Socratem, & Platonem, haec erit inductio imperfecta

Petrus, Socrates, & Plato sunt bipedes ergo omnis homo est bipes

Sed cum Arist. profundis inductionis naturam, & vim consyderando dicimus inductionem ostendere primum inesse medio per tertium, & et inductionem quidem perfectam ad rectam syllogismi formam, et vtilem primae figurae modum redigi." Jacopo Zabarella, *Tabulae Logicae* (Venice: Paulus Meietus, 1604), 66. All translations of Zabarella are mine unless otherwise noted.

[18] "nominantur singillatim, & expresse omnia indiuidua." Ibid., 67.

statement, as saying, Peter is biped and Socrates is biped and any other individual man is biped; therefore every man is biped."[19] Zabarella's view is not only conservative, but retrograde. He shows no sensitivity to the issues introduced by Buridan or Valla (e.g., how it is possible, if at all, to keep the argument from being question-begging), and whereas his fellow Paduan, Nifo, had earlier acknowledged debate over what induction is, Zabarella disregards any such disagreement.

Note that, on Zabarella's account, there is a difference between the following two arguments: 'Peter is biped and Socrates is biped; therefore every man is biped.' and 'Peter is biped, Socrates is biped, and any other man is biped; therefore every man is biped.' The first is an imperfect induction and thus invalid. The second is a perfect and legitimate induction. Though the particulars have not all been enumerated, the induction has been perfected by inclusion of the phrase 'and any other man is biped.' In summary, (assuming a population of A, B, C and D) there are, according to Zabarella, three kinds of induction:

[19] "non nominantur omnia expresse, sed aliqua tantum exprimuntur, reliqua vero implicite denotamus breuitatis gratia per dictionem aliquam distributiuam, vt dicendo, Petrus est bipes, & Socrates est bipes, & quilibet alius, seu singulus alius homo est bipes, ergo omnis homo est bipes." Ibid.

A, B, C, D are biped. Therefore, all are biped.	Perfect	Valid
A, B are biped; Therefore, all are biped.	Imperfect	Invalid
A, B, etc. are biped; Therefore, all are biped.	Perfect	Valid

For an example of the second type of perfect induction, Zabarella refers his reader to Aristotle's argument in the first few sentences of the *Posterior Analytics*. As Zabarella wrote a commentary on the *Posterior Analytics*, we can follow his understanding of the passage.

Aristotle's work begins, "All teaching and all learning of an intellectual kind proceed from pre-existent knowledge. This will be clear if we study all the cases: the mathematical sciences are acquired in this way, and so is each of the other arts."[20] In his comments, Zabarella says that Aristotle's argument here is an inductive one in which Aristotle intends to include such fields as arithmetic and geometry under the heading 'mathematical sciences' and then to complete the induction by adding 'and so is each of the other arts,' "just as when we might say, 'This man, and that, and any other one is risible,' and it is to be assumed that none is left out, and it only remains for the universal to be inferred; 'therefore, every man is risible.'"[21] But, Zabarella asks himself, "how is Aristotle able to prove the

[20] *Posterior Analytics*, 1.1 71a1–5, Barnes' revised translation.

[21] "vt quum dicimus, hic homo, & ille, & quilibet alius est risibilis, nil enim aliud assumendum relinquitur, sed solum superest vt inferatur vniuersale, ergo omnis homo est risibilis." Jacopo Zabarella, "In Duos Aristotelis Libros Posteriores Analyticos Commentarii," in *Logica Opera* (Venice: Paulus Meietus, 1604), 326.

universal proposition?"[22] That is, what justifies sweeping all the unobserved under 'etc.' or the like? Zabarella says the answer lies in the fact that the propositions here being discussed are a certain kind of principle, principles "which are called known 'per se.'"[23] For more on principles known 'per se,' he refers the reader to the final chapter of the *Posterior Analytics*.[24]

An understanding of the difference between the Scholastic concepts *per se* and *de omni* is crucial to understanding not only Zabarella's concept of induction, but—as we will see later—for understanding the genesis of Francis Bacon's, too. The distinction derives from *Posterior Analytics* 1.4.[25] An attribute applies de omni if it applies to a subject in each and every case; such perfect correlation may be coincidental or it may be necessary. On the other hand, an attribute applies per se if it applies by the essential natures of the subject and the attribute; the fact cannot be a coincidence. To use Aristotle's examples,[26] a line is an attribute of all triangles per se, because having lines is an essential characteristic of being a triangle; straight (or curved) is a per se attribute of line, for the very definition of straight includes the

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[22] "quomodo potest Aristoteles illam propositionem vniuersalem probare." Ibid.

[23] "quae per se nota dicuntur." Ibid.

[24] Ibid. The final chapter in *Posterior Analytics* is book 2, chapter 19 in our numbering, book 2, chapter 15 in Zabarella's.

[25] The distinction is a standard topic of Aristotelian and scholastic commentary. Barnes' modern commentary on the chapter, Jonathan Barnes, "Commentary," in *Posterior Analytics* (Oxford: Clarendon Press, 1975), 110–22, runs about twelve pages as does Zabarella's own. My introduction covers only the minimum required for following Zabarella and then later Bacon. I leave aside whether the understanding by Zabarella and the scholastics is a correct reading of Aristotle.

[26] *Posterior Analytics*, 1.3 73a14, 1.4 73a37, 73b22.

concept of line. On the other hand, all men may be walking, but if so that is just a coincidence; such walking would be an attribute of man de omni but not per se. To follow Zabarella's forthcoming logic, note that if something is true per se, it is also true de omni.

Consider now that final chapter of *Posterior Analytics*. This is the chapter in which Aristotle describes how essential and universal knowledge is gathered from sense-perception and memories thereof. It is the core chapter in Aristotle that commentators find difficult to reconcile with the conventional scholastic interpretation of *Prior Analytics* 2.23. The chapter in *Posterior Analytics* seems to indicate that induction is an open-ended process that provides valid conceptual knowledge of things not observed, yet the conventional interpretation of *Prior Analytics* 2.23 is that induction is valid only if all particulars are observed. In a commentary on *Posterior Analytics*, Zabarella must reconcile these, for he considers *Prior Analytics* 2.23 the definitive statement of what induction is.[27] Zabarella performs his reconciliation by introducing what he calls 'demonstrative induction.'[28]

Two steps are involved in demonstrative induction. In the first,

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[27] Every one of Zabarella's significant discussions of induction in the *Opera Logica* explicitly cites that passage as its point of reference. *De Methodis* 3.3, 3.19; *Posteriores Analyticos Commentarii*, 1.1, 2.4, 2.15.

[28] He attributes the term to Averroës. *De Methodis* 3.14; *De Regressu* 4; *Posteriores Analyticos Commentarii* 2.15.

> we do not enumerate all the singulars, because with only a few the intellect begins to observe the essential connection of the two terms [subject and predicate]. Thus while not enumerating the other individuals, the intellect immediately forms the universal based on the few.[29]

The universal is grasped 'immediately,' that is, without the mediation of a middle term. The connection is simply grasped "by its own light," "proprio lumine."[30] The result is that the mind comes to recognize that the attribute is true per se. Zabarella holds, for example, that being biped and being risible are per se features of man. After observing a few men, the intellect simply grasps that these features are a necessary aspect of man's essence. The second step of a demonstrative induction uses the fact that what is true per se is true de omni to give the induction the same force as a demonstrative syllogism. It is thus legitimate to say, 'Peter is biped and Socrates is biped and any other individual man is biped; therefore every man is biped,' or 'This man, and that, and any other one is risible; therefore, every man is risible.' In the language of *Prior Analytics* 2.23, 'Peter and Socrates and any other individual man' is seen by an intellectual grasp to be convertible with 'man,' thus rendering the induction as a demonstrative, first-figure syllogism:

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[29] "non enumeramus omnia singularia, quia in paucis intellectus incipit conspicari essentialem connexum duorum terminorum, ideo neglecta reliquorum indiuiduorum enumeratione statim ex illis paucis colligit vniuersale." Zabarella, "In Duos Aristotelis Libros Posteriores Analyticos Commentarii," 2.15, 650.

[30] *De Methodis*, 3.19 p.180; *Posteriores Analyticos Commentarii*, 1.2, p. 649.

Peter, Socrates, and any other man are biped.
Every man is Peter, Socrates, and any other man.
Therefore, every man is biped.

By the two steps,[31] justified by the insight that being biped is essential to being man, an inconclusive induction has been rendered as a demonstrative induction. The requirement from *Prior Analytics* 2.23 for full enumeration has been reconciled with the open-end nature of induction of *Posterior Analytics* 2.19 by claiming that in the latter passage, Aristotle is discussing not induction in general, but demonstrative induction in particular.

The kind of induction that is not demonstrative induction, Zabarella elsewhere calls "dialectical induction."[32] Dialectical induction requires all particulars to be observed to be valid. Demonstrative induction does not. Thus, the summary of kinds of induction is now:

[31] cf. *Tabulae Logicae*, 67. Stated more technically, the steps are the following. (Step 1) 'Peter, Socrates, and any other man are biped; Peter and Socrates and any other man are men; therefore, every man is biped.' This is a third-figure syllogism and as such is not valid. But a third-figure syllogism can be converted to a first-figure syllogism by conversion of the minor premise. Conversion of the minor (Step 2) is here justified by the recognition that biped is a per se attribute, and therefore a de omni attribute. The resulting syllogism, 'Peter, Socrates, and any other man are biped; all men are Peter, Socrates, and any other man; therefore, every man is biped,' is a valid first-figure syllogism in Barbara.

[32] *De Regressu*, 1.

A, B, C, D are biped. Therefore, all are biped.	Perfect	Valid	Dialectical
A, B are biped; Therefore, all are biped.	Imperfect	Invalid	Dialectical
A, B, etc. are biped; Therefore, all are biped.	Perfect	Valid	Demonstrative

Zabarella's defense of demonstrative induction is both circular and unoriginal. As I said above, Zabarella's understanding of induction is not only not innovative, it is retrograde. Over 140 years earlier, Valla had mocked the very line of reasoning Zabarella is using. But these problems need not detain us, for our current task is not to evaluate whether Zabarella's demonstrative induction is valid, but to identify its relation to Zabarellian regressus.

Regressus is a combination of two procedures. "The one, which the Greeks call 'curios apodeixin' or 'apodeixin tou dioti,' and we commonly call 'demonstratio potissima' or 'demonstratio propter quid,' is called in the highest sense the demonstrative method."[33] Zabarella says it proceeds from cause to effect and may also be called compositio. The second proceeds from effect to cause and is called resolutio. "The Greeks call this method 'sullogismon tou oti' or 'dia semeion'; it is commonly called by us 'demonstratio quia,' or the 'syllogism a signo,' or demonstration of the second grade."[34] The synonyms are important. They will

[33] "altera per excellentiam demonstratiua methodus dicitur, quam Graeci χυριως ἀπόδειξιν, vel ἀπόδειξιν τοῦ διότι vocant, nostri potissimam demonstrationem, vel demonstrationem propter quid appellare consueuerunt." *De Methodis*, 3.4, 134 [154].

[34] "methodum hanc Graeci, συλλογισμὸν τοῦ ὅτι, vel διὰ σημείων, nostri demonstrationem quia, vel syllogismum a signo, vel secundi gradus demonstrationem." *De Methodis*, 3.4, 134 [154].

later help us understand the relationship between induction and regressus. (Note that *inductio* does not appear in either list.) The synonyms also help us understand the Aristotelian background.

The distinction Zabarella is making goes back to *Posterior Analytics* 1.13,[35] where Aristotle distinguishes knowledge of the fact (hoti) from knowledge of the reasoned fact (dioti). He contrasts two syllogisms.

Knowledge of the fact:	Knowledge of the reasoned fact:
What does not twinkle is near.	What is near does not twinkle.
Planets do not twinkle.	Planets are near.
Therefore, planets are near.	Therefore, planets do not twinkle.

In the first, we prove that planets are near by knowing that they do not twinkle. Not-twinkling may be the cause of our knowing that the planets are near, but it is not the cause of the planets being near. We have knowledge of the fact that planets are near, but our knowledge is incomplete. It is not by knowing *why* the planets are near that we have come to know *that* they are. That is, not-twinkling does not make something near. In fact, it is the other way around. Being near makes something not twinkle. This knowledge is articulated in the second syllogism. Here we do not know merely the fact. We know also why it is true; that is, we know the reasoned fact. In the first, we prove a cause (being near) by means of knowing an effect (not twinkling). In the second, we prove an effect (not twinkling) by means of the cause (being near). In Latin, these two syllogisms became known as

[35] *Posterior Analytics*, 1.13 78a23–78b12.

‘demonstratio quia’ and ‘demonstratio propter quid,’ or among regressus theoreticians such as Zabarella, as ‘resolutio’ and ‘compositio.’

Several things are important to note. The first is that in both cases, the knowledge is by means of a syllogism. In one the cause serves as the middle term; in the other the effect serves as the middle term. Both cases are deductions; neither is an induction. Second, the syllogisms may prove the cause or the effect, but neither proves that the cause is in fact the cause or that the effect is an fact an effect. Whether being near is really the cause of not twinkling is completely outside the scope of these two deductive syllogisms. How one discovers which is the cause and which is the effect is unaddressed. Lastly, nothing discussed so far addresses how one justifies the major premise, whether ‘What doesn’t twinkle is near’ or ‘What is near doesn’t twinkle.’

Though in what we have reviewed so far, Zabarella draws no connection between regressus and induction, in other writings he relates them in two ways, one treated primarily in book 3 of *De Methodis*, the other primarily in *De Regressu*. The treatment in *De Methodis* 3 begins in chapter 3. Here, Zabarella describes induction as a secondary kind of resolution. Zabarella writes, “There are said to be four instruments of logic, about which Aristotle speaks in the *Prior Analytics*: syllogism, enthymeme, induction, and example.”[36] Zabarella says that the two kinds of knowing are by syllogism and by induction and that an enthymeme is a kind of

[36] “quatour dicuntur esse logica instrumenta, de quibus loquitur Aristoteles in prioribus Analyticis, syllogismus, enthymema, inductio, & exemplum.” *De Methodis*, 3.3, 152.

syllogism, an example a kind of induction, and an induction ultimately (if it has any validity) a kind of syllogism. "There is no conclusive force, except by means of usable syllogisms of the three figures, to which all methods making any valid assertion are reduced."[37] Zabarella's treatment is perfectly canonical, familiar since Peter of Spain, and consistent with what Zabarella says in the *Tabulae Logicae* and his commentary on the *Posterior Analytics*.

Following the substantive treatment of the syllogism and its kinds in chapter 3, Zabarella introduces resolution and composition in chapter 4, in the passage quoted earlier.[38] After giving the synonyms for resolution and composition, he mentions, in an aside, "Induction is contained under the resolutive method, as we will explain later."[39] The elaboration does not appear until near the end of the book, in chapter 19.[40]

Chapter 19 is not large, merely two pages of the 105-page *De Methodis*, or prominent, appearing as the penultimate chapter of book 3, late in Zabarella's treatment of resolution. It sits within a string of short chapters dedicated to cleaning up loose ends, integrating the main work with ancillary topics, or responding to possible objections. The chapter begins, "Regarding the indicated

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[37] "nullam esse vim illatiuam nisi in syllogismis vtilibus trium figurarum, ad quos methodi omnes fidem aliquam facientes reducuntur." *De Methodis*, 3.3, 153.

[38] Page 10 above.

[39] "sub resolutiuam methodum reducitur inductio, vt postea declarabimus." *De Methodis*, 3.4, 134 [154].

[40] There are brief mentions of induction in 3.9 and 3.14.

nature of each method, it remains to be considered whether they are divided into kinds."[41] Zabarella says that there is no important division of the compositive method, but there is of the resolutive.

> The resolutive method divides into two kinds, differing greatly between themselves in efficacy. One is 'demonstratio ab effectu' [or 'demonstratio a signo'[42]] which in the performance of its function is most efficacious and is used for the discovery of things that are very obscure and hidden. The other is 'inductio,' which is a much weaker kind of resolution and is used only for the discovery of things which are not entirely unknown and require a mere declaration.[43]

The second kind, inductio, is of such low efficacy and marginal use that Zabarella earlier in the book treated the first kind, demonstratio a signo, and the broader class, resolutio, as synonyms. Induction was added only afterward for completeness. The difference between demonstratio a signo and inductio is the subject of the rest of Zabarella's chapter.

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[41] "Natura vtriusque methodi declarata consyderandum manet an hae in species diuidantur." De Methodis, 3.19, 180.

[42] Throughout this chapter, Zabarella uses 'demonstratio ab effectu' (as in this passage) and 'demonstratio a signo' interchangeably and in equal number.

[43] "Methodus autem resolutiua in duas species diuiditur efficacitate inter se plurimum discrepantes, altera est demonstratio ab effectu, quae in sui muneris functione est efficacissima, & ea vtimur ad eorum, quae valde obscura, & abscondita sunt, inuentionem; altera est inductio, quae est multo debilior resolutio, & ad eorum tantummodo inuentionem vsitata, quae non penitus ignora sunt, & leui egent declaratione." *De Methodis*, 3.19, 180.

Back in chapter 3, Zabarella had stressed that any method that makes a valid assertion can be reduced to a syllogism.[44] He now says the same here, claiming that both kinds of resolution are syllogistic. "Regarding the demonstratio a signo, no one can doubt, for it is a syllogism proceeding from the effect to the discovery of a cause."[45] But what of induction? As always, Zabarella turns to *Prior Analytics* 2.23 and the conventional scholastic interpretation thereof. "Aristotle, in the second book of the *Prior Analytics* in the chapter on induction, says induction is in fact a syllogism."[46] So resolution and its two kinds are all syllogistic. But Zabarella then recognizes an inconsistency. "But Aristotle also says in many places . . . that induction is a tool for knowing principles."[47] How is it that induction is both a tool for coming to know principles and a syllogism based on those principles? Zabarella resolves the inconsistency by claiming Aristotle did not mean all principles are known by induction, only some—those which Zabarella calls 'known according to

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[44] Zabarella, *De Methodis Libri Quatuor; Liber De Regressu*, 153–54.

[45] "de demonstratione a signo nemo dubitare potest, est enim syllogismus procedens ab effectu ad inuentionem causae." *De Methodis*, 3.19, 180.

[46] "Inductionem vero esse syllogismum docet Aristoteles in secundo libro Priorum Analyticorum in capite de inductione." *De Methodis*, 3.19, 180.

[47] The omitted text is: "(such as the end of the second book of the *Prior Analytics* in the chapter on induction, in section 134 [*Posterior Analytics*, 1.18] in the first book of the *Posterior Analytics*, and in the third chapter of the sixth book of the *Ethics*.)" "quod autem inductio sit instrumentum cognoscendi principia Aristoteles multis in locis testatur, in calce secundi libri Priorum Analyticorum in capite de inductione, in contextu 134. primi Posteriorum, & in vltimo capite secundi, & capite tertio sexti libri de moribus." *De Methodis*, 3.19, 180.

nature' ('secundam naturam' or 'naturaliter'). Others, those 'unknown according to nature,' are known not by induction, but by 'demonstratio a signo.'

Those 'known according to nature' are the easy cases. They require no cognitive work beyond direct perception. "'Man is biped,' is said to be known according to nature, because whatever individual man is put forward, the sense immediately knows him to be biped."[48] Thus, "by induction no things are discovered except those principles, which are known according to nature, and require mere confirmation."[49] That is, once a few particulars have been observed, the conclusion needs merely to be stated. By merely making the statement, its truth becomes obvious. These principles are, of course, the same as the ones Zabarella elsewhere called 'known per se.' "'Known according to nature' and 'known per se' mean the same thing."[50] Because these principles are known per se, they are also known de omni, and thus the induction converts to a valid syllogism.

The principles 'unknown according to nature' are the difficult cases, the ones normally under consideration when resolution is being discussed. Zabarella's example involves triangles:

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[48] "homo est bipes, dicitur nota secundum naturam, quia quocunque indiuiduo homine oblato statim cognoscit sensus eum esse bipedem." *De Methodis*, 3.19, 180.

[49] "inductione non inueniuntur nisi illa principia, quae sunt nota secundum naturam, et leui egent comprobatione." *De Methodis*, 3.19, 180. "require mere confirmation" = "leui egent comprobatione"; cf. "require mere declaration" = "leui egent declaratione" above. This theme appears also in the commentary on the *Posterior Analytics* 2.5, 556.

[50] "notum secundum naturam idem significat ac per se notum." *De Methodis* 3.19, 181.

> This proposition, 'A triangle has three angles equal to two right angles,' is called unknown according to nature, because the predication of it can not be discerned by sense, but becomes known through another; indeed never do we learn that 'Triangle has three angles equal to two right angles,' by long inspection of the triangle; instead reason demonstrates it to us.[51]

These principles require cognitive work and thus the other kind of resolution. "Demonstratio a signo is much more efficacious; for by it those principles are discovered which are unknown according to nature, for the discovery of which induction is utterly useless."[52] By the powerful, more useful type of resolution, a syllogism, such as the one proving that the moon is near by knowing that it is twinkling, is established, and reason demonstrates a cause from an effect.

Zabarella's distinction between known and unknown according to nature is not the same as the distinction between better known to nature and better known to us. Zabarella thoroughly rejects that long-standing dichotomy, for nature itself,

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[51] "ita haec propositio, triangulum habet tres angulos duobus rectis aequales, dicitur ignota secundum naturam, quia eius praedicatum sensu discerni non potest, sed innotescit per aliud, ex longa enim trianguli inspectione nunquam cognosceremus tres illos angulos esse duobus rectis aequales, sed ratio id nobis demonstrat." *De Methodis* 3.19, 180–1.

[52] "demonstratio a signo est multo efficacior, per eam enim illa principia inueniuntur, quae secundum naturam sunt ignota, ad quorum inuentionem inductio est prorsus inutilis." Ibid., 181. "The other principles are naturally unknown, because unknownable by sense. Therefore for the discovery of them, induction has absolutely no effectiveness; they require demonstratio a signo." "Alia vero principia sunt naturaliter ignota, quia insensilia, ideo ad eorum inuentionem inductio nihil penitus efficacitatis habet, sed egent demonstratione a signo." *De Methodis* 3.19, 180.

he insists, knows nothing.[53] It is important to recognize the difference between Zabarella's distinction and the conventional one because failing to do so can reinforce confusion between resolution and induction. In both the conventional dichotomy and Zabarella's, it is said that induction is used to discover what is known according to nature, given what is known according to us. But the alternatives are different. In the conventional approach, the alternative to induction is the other kind of knowing, i.e., deduction, by which we learn what is better known according to us, given what is better known by nature. In that approach, the two elements of the dichotomy are complementary, induction and deduction working together to provide complete knowledge. In Zabarella's system, the alternative to induction is demonstratio a signo, i.e., the other kind of resolution, by which we come to learn what is unknown according to nature. In this system, the two elements are not complementary. Either one is used or the other, but not both. In the conventional approach, the opposite of 'known according to us' is 'known according to nature'; in Zabarella's, the opposite of 'known according to us' is 'unknown according to us.' Overlooking this difference can encourage one to think that regressus is a combination of induction and deduction rather than of resolution and composition, and that induction is the same as resolution. In fact, induction is not the same as resolution but is a minor, special case of it, little treated by

[53] *De Regressu* 2; *De Regressu* 10; Commentary on the *Posterior Analytics* 1.2. Kosman, "The Aristotelian Backgrounds of Bacon's *Novum Organum*," 131-35.

Zabarella, and often not even mentioned. For obtaining the difficult principles of natural philosophy, it is positively useless.

We might ask why Zabarella considers induction a kind of resolution at all. He answers this when he says that "induction is a progression from posteriors to priors, because the universal is by nature prior to the particulars, and *accounts for the cause*" (emphasis added).[54] Recall that the defining characteristic of resolution is that it argues from effects to cause. But how does an induction do that? Consider Zabarella's stock example:

Plato is biped.	an effect
Socrates is biped.	an effect
<u>Each other man is biped.</u>	<u>an effect</u>
Therefore, all men are biped.	the cause

What does it mean to say the conclusion is the cause that Plato is biped? It means that the following syllogism can be constructed:

> All men are biped.
> <u>Plato is a man.</u>
> Therefore, Plato is biped.

'Man' is the causal middle. That is, Plato is a biped *because* he is a man. The universal is the cause of the particular. "The universal is by nature prior to the particular."[55] This is a standard component of the Alexandrian Neoplatonic synthesis.

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[54] "Est autem inductio processus a posterioribus ad priora, quia vniuersale est natura prius particularibus, & habet rationem causae." *De Methodis* 3.19, 180, emphasis added.

[55] "quia vniuersale est natura prius particularibus." *De Methodis* 3.19, 180.

It is not, however, of any significance in regressus theory. Because induction includes the causal term in its result, induction can be classified as resolution. But such a resolution is not paired with a composition to form a full regressus. When resolution is paired with a composition, the resolution is not of the inductio type; it is of the demonstratio a signo type. As a matter of completeness, Zabarella notes that induction is a kind of resolution, but if he had not noticed or mentioned this, it would have made no difference to his regressus theory.

There is a second way in which induction relates to regressus. It is explained in the fullest example of a regressus that Zabarella offers. The example appears in chapters 4 and 5 of the book dedicated to the subject, *De Regressu*,[56] and refers to Aristotle's demonstration in the first book of the *Physics* of the existence of prime matter.[57]

Resolution, the first part of this or any regressus, is the inference of a cause from observation of the effect, i.e., a demonstratio ab effectu or demonstratio a

[56] The passage is treated in Jardine, "Epistemology of the Sciences," 691–2; Edwards, "The Logic of Iacopo Zabarella," 265–83; Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences*, 99

[57] Though Zabarella refers to "the demonstration of Aristotle in book 1 of the *Physics*, by which from the generation of substances he shows that prime matter occurs" (Jardine's translation), Aristotle makes only a small mention of this (190b1–4) and presents little by way of demonstration. The argument that Zabarella presents is a sizable expansion beyond what Aristotle actually says in *Physics* 1. Indeed, Zabarella, like other Scholastics, is probably attributing to Aristotle a position he did not hold. See "Appendix: Did Aristotle Believe in Prime Matter" and "Note on Recent Work" in W. Charleton, *Aristotle's Physics, Books One and Two* (Oxford: Oxford University Press, 1984), 129–47. (My thanks to James Lennox for this reference.) See also Aristotle, *On Generation and Corruption*, book 1, and Edwards, "The Logic of Iacopo Zabarella," 262, 277.

signo. The 'effectum' or 'signum' here is the observed fact of generation and is the middle term of a syllogism. The cause being demonstrated, the major term, the predicate of the conclusion is 'prime matter.' The syllogism for the demonstratio is:

> Where there is generation, there is prime matter.
> In a natural body, there is generation.
> Therefore, in a natural body, there is prime matter.[58]

The minor premise, 'In a natural body, there is generation,' is known by observation. The major premise, Zabarella says, is known by demonstrative induction, i.e., an induction in which not all particulars are surveyed, but the intellect's recognition that the subject and predicate are essentially connected justifies sweeping all the unobserved under 'etc.' (or the like) and thus converting an induction into a valid syllogism. Zabarella makes no mention here or anywhere in *De Regressu* of induction being a kind of resolution. Rather, induction is the means by which the major premise of the resolutive (and, later, compositive) syllogism is known. The syllogism would be equally valid, and the nature of the resolution would be no different, if the major premise were supplied some other way, such as by being the conclusion of an earlier demonstration.

In this resolution, we observe generation or change, and infer there must be prime, underlying matter. But the generation or change is not what enables or causes the prime matter; it is the other way around—but we do not yet know this. Our knowledge is confused. In the second half of the regressus, i.e., composition,

[58] *De Regressu*, 4, 325.

cause and effect will be reversed in the syllogism and our knowledge will be distinct. But there is an intermediate step, by which the mind comes to see that the reversal is valid, that is, that prime matter is what causes or enables generation. This realization is arrived at not by any new observations or by any particular induction or deduction but by a 'consideratio' or a 'mentale examen,'[59] a turning of the matter in one's mind. The obscurity of this intermediate step need not detain us.[60] For us the important thing is the result, a new demonstrative syllogism:

> Where there is prime matter, there is generation.
> <u>In a natural body, there is prime matter.</u>
> Therefore, in a natural body, there is generation.[61]

The middle and major terms, and respectively the cause and effect, have been reversed. From the cause, prime matter, the effect, generation, is concluded.

Whereas the first stage of the regressus, the resolution, was (synonymously) a demonstratio ab effectu, or demonstratio a signo, or demonstratio quia, the second stage, the composition, is a demonstratio propter quid. Both stages are demonstrations, i.e., deductive syllogisms. Neither is an induction. In this example,

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[59] For the name, see Mikkeli, *An Aristotelian Response to Renaissance Humanism: Jacopo Zabarella on the Nature of Arts and Sciences*, 99.

[60] This step has been subject to vigorous, even mocking, criticism. Jardine, "Galileo's Road to Truth and the Demonstrative Regress," 301–3, says it is marked by "startling illogicality." "This example speaks for itself. . . . It is hard to see how anyone could possibly regard his *regressus* theory as anticipating an experimentally oriented, hypothetico-deductive approach to scientific inquiry." See also Skulsky, "Paduan Epistemology and the Doctrine of the One Mind," 358–6; and Schmitt, "Experience and Experiment: a Comparison of Zabarella's View with Galileo's in *De motu*," 125–126.

[61] *De Regressu*, chap. 5, pp. 327–28.

Zabarella's fullest, presented in his one book dedicated to regressus, induction has only one role to play, the role of supplying a major premise, and it plays that role both in the resolution and the composition stages of the regressus. It has no unique relationship with resolution.

The relation then between induction and regressus is not that proposed by Cassirer and presumed by nearly everyone working on the question of Zabarella's influence on early modern science. Induction is not half of a regressus, deduction being the other half. Instead, both halves of a regressus are deductions. Induction is one procedure by which one can obtain the major premises of these two deductions, but it contributes nothing to the advance from the half of the regressus that deduces the cause to the half that deduces the effect. That transition is made possible by a contemplative insight, a middle step in the regressus. It is true that, according to Zabarella, an induction can be classified as a kind of resolution, but this is possible because, by adding 'etc.' to a surveyed list, an induction can be reduced to a deduction—just as Zabarella explained in his introductory textbook on logic. For Zabarella, induction is not a complement to deduction. It is a kind of deduction, and plays only an ancillary and inessential role in a regressus. There is one way, however, in which a regressus and induction are similar. Each is justified 'by its own light.' That is, one simply comes to see, after sufficient contemplation, that adding 'etc.' to the surveyed list is justified, just as one comes to see that reversing the terms of the regressus is justified. Both induction and regressus obtain their validation by a contemplative insight.

By the conventional understanding, on the other hand, regressus is a combination of deduction and induction. Once this interpretation of Zabarella was proposed, and once it was accepted that this combination may have contributed to the scientific revolution, it was natural to begin looking for precursors. This was part of A. C. Crombie's project, and it helped shape mid-twentieth-century discussions about whether the scientific revolution involved a methodological revolution or a continued application of past methodology. Crombie found the regressus combination as far back as the thirteenth century,[62] and considered Robert Grosseteste (c.1175–1253) to be a prototypical practitioner.[63] It was an interest in anticipations of regressus that led Don Morrison to find in the Greek commentators of Alexandria the Neoplatonic synthesis described in the previous chapter.[64] Morrison concluded, "The theory of tekmeriodic proof which we find in Simplicius and Philoponus [the Alexandrian synthesis] is the earliest theory which deserves to be called an 'early version' of the *regressus*. . . . [T]ekmeriodic proof . . . performs the function of the *methodus resolutiva* portion of the *regressus*."[65] Neither seventeenth-century regressus nor its Alexandrian equivalent is a combination of deduction and induction, but a combination of two deductions, a (tekmeriodic)

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[62] A. C. Crombie, *The History of Science from Augustine to Galileo* (New York: Dover, 1995), 1:82.

[63] Crombie, *Robert Grosseteste and the Origins of Experimental Science 1100–1700*, 25, 35, 52–53, 61–90.

[64] Morrison, "Philoponus and Simplicius on Tekmeriodic Proof," 17.

[65] Ibid.

syllogism in which the cause is the minor premise and a syllogism in which the effect is the minor premise. A contemplative insight obtained from outside the regressus validates obtaining one of the syllogisms from the other. At least regarding induction, Zabarella is not a revolutionary, but the leading representative of a tradition that goes back through medieval scholasticism to the Neoplatonic reinterpretation of Aristotle in sixth-century Alexandria.

Though not a revolutionary regarding induction, Zabarella is important in the history of induction nonetheless. As probably the last of the great Aristotelians working in a recognizably scholastic framework, he serves as a foil for the next generation. Though Bacon does not name him, Bacon's criticism of the established induction applies as much toward Zabarella as toward any medieval logician. Bacon's insistence that induction be used not just for major but for minor premises is directed toward the kind of interlocking syllogistic reasoning exemplified by regressus. Zabarella's system is, however, not Bacon's only foil. Zabarella's brand of Aristotelianism—precise, learned, steeped in traditions of detailed scholarship—was just one of several in the late sixteenth century.[66] A seemingly very different type was promoted by a professor in England named Everard Digby.

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[66] On the theme of competing Aristotelianisms, see Copenhaver and Schmitt, *Renaissance Philosophy*, 60–62.

Everard Digby (c. 1551–1605)

The study of Aristotle had waned in the 1520s across Europe. It revived in the 1540s with new translations, new commentaries, and a new humanist character. The revival in England, however, was delayed, for in the 1540s higher education in England began a decades-long decline.[67] In principle, the ultimate charter of English universities was to train the clergy. They, therefore, fell under the dissolution efforts that Henry VIII began after his break with Rome. The first Chantries Act, passed in 1545, nationalized not just assets of chantries, but that of colleges and other institutions as well. A second act affirming and extending the first was passed in 1547, and special commissions were established to determine what to do with the assets of Oxford and Cambridge. By clever financial and legal legerdemain, both universities stayed open and independent,[68] but several functions and faculties were eliminated, new religious directives were imposed, and the universities suffered in faculties, enrollment, finances, and scholarship. The presses at both universities were shuttered, the university libraries stopped acquiring printed books, and scholarly links with the continent declined. What few links existed were flows to, not from, the island. England had little to offer continental scholarship. Credit for being the first academic to make a serious attempt to

[67] Schmitt, *John Case and Aristotelianism in Renaissance England*, 17-29; Norman Jones, *The English Reformation: Religion and Cultural Adaptation* (Oxford: Blackwell Publishers, 2002), 176.

[68] They argued that their expenses matched or exceeded their income and that therefore there were no net assets to seize. Jones, *The English Reformation: Religion and Cultural Adaptation*, 75.

contribute significant scholarly work to European discourse may go to the young Cambridge professor, Everard Digby.[69]

Digby's treatise was entitled *Theoria Analytica* and was published in 1579, the year after Zabarella's *Opera Logica*.[70] In it, Digby describes the method by which he believes human knowledge is acquired. The treatise is not primarily a normative work, explaining how knowledge should be acquired, or pedagogic work, teaching the student practical methods for acquiring knowledge, but rather a psychological work, explaining how knowledge is acquired. Digby believes his theory is

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[69] This Everard Digby was not the same as, nor was he lineally related to, the Everard Digby that was involved in the Gunpowder Plot of 1605. After a long period of neglect, attention was first drawn to Digby by J. Freudenthal, "Beiträge zur Geschichte der englischen Philosophie," *Archiv für Geschichte der Philosophie* (1890-1): 4:450–77, 578–603; 5:1–41. Freudenthal suggested that more should be done to examine Francis Bacon's forerunners. Freudenthal proposed to begin that examination by considering the debate between Everard Digby and William Temple, a debate that would surely have been known to Bacon. Freudenthal's lengthy article remained the fullest examination of Digby for almost ninety years. After Freudenthal, Digby received a few pages of consideration by each of Gaston Sortais, *La Philosophie moderne depuis Bacon jusqu'à Leibniz*, 2 vols. (Paris: Paul Lethielleux, 1920), 1:53–55; Gilbert, *Renaissance Concepts of Method*, 200–8; Lisa Jardine, *Francis Bacon: Discovery and the Art of Discourse* (Cambridge: Cambridge University Press, 1974), 59–65; and Schmitt, *John Case and Aristotelianism in Renaissance England*, 47–52. The definitive treatment is now Shaan Akester, "The Life and Works of Everard Digby" (DPhil. dissertation, Oxford University, 1979). It contains the only full and accurate biographical study. Its chapter-by-chapter analysis of Digby's obscure text is indispensable for any study of Digby, including this one. The honor of being the first scholar to attempt a contribution to European scholarship is bestowed by Schmitt, *John Case and Aristotelianism in Renaissance England*, 47, 50.

[70] Everard Digby, *Theoria analytica viam ad monarchiam scientiarum demonstrans, totius philosophiae & reliquarum scientiarum, necnon primorum postremorumq[ue] philosophorum mysteria arcanaq[ue] dogmata enucleans* (London: Henrici Binneman, 1579). Translations from *Theoria Analytica* are Akester's unless otherwise noted.

thoroughly grounded in Aristotelian thought and he cites Aristotle more than any single author. The lengthy treatise is of little philosophical or scientific merit and has been described as on "the lunatic fringe of Renaissance thought."[71] It does, however, have historical importance. First, the book did find an audience on the continent and reveals therefore what could pass for Aristotelian scholarship among some European scholars at the time.[72] Second is the relationship between Digby and Francis Bacon. There is a possibility that Francis Bacon was a student of Digby's when Bacon was at Cambridge in 1572–74. Whether he was or not, criticisms Bacon later made against induction as it was taught in the universities sound targeted directly at Digby. In fact, some of Bacon's attacks have little context unless we understand the thought of Digby or those who shared his views. Third, Digby got into a pamphlet war with another young Cambridge scholar, an advocate of Ramism named William Temple. Temple had very important things to say about induction, but they cannot properly be understood without reference to Digby's *Theoria Analytica*. Finally, although Digby believes himself an Aristotelian,

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[71] Gilbert, *Renaissance Concepts of Method*, 200-9. Howell, *Logic and Rhetoric in England, 1500–1700*, 194-6, and Jardine, *Francis Bacon: Discovery and the Art of Discourse*, 59-65, give the work little consideration. Schmitt, *John Case and Aristotelianism in Renaissance England*, 47, remarks on the lack of attention it has received. Digby was about twenty-eight when he wrote it.

[72] William Temple reports on its reception among theologians at the Sorbonne and over faculty members at European universities. William Temple, *Francisci Mildapetti Nauerreni ad Euerardum Digbeium Anglum admonitio de unica P. Rami methodo reiectis Caeteris retinenda* (London: Henricus Middletonus, 1580), 22. See also Akester, "Life and Works of Everard Digby," 232.

he is in fact the first in a line of Neoplatonists at Cambridge. In our sample of late century views on induction, he provides a mystically Platonic perspective.

The tension in the *Theoria Analytica* is plain in the preface's very first sentence: "Often reading through the excellent work of Aristotle on demonstration, after long consideration, I seemed to understand the great and almost mystical beginnings of knowledge."[73] Digby explains that in Aristotle something is hidden, something Digby himself has discovered. It is the divine, mystical component of knowledge.[74] Although Digby cites Aristotle frequently, his real inspiration comes from the also-cited Pythagoras, Plato, Plotinus, and a host of medieval and Renaissance, Neoplatonic and mystical writers.[75] Although Zabarella accepted the Alexandrian understanding of induction, he rejected the foundation by which the Alexandrians reached it. He rejected that nature can know something and thus rejected the scholastic distinction between 'better known to us' and 'better known to nature.' Digby, on the other hand, adopts this distinction wholly and with gusto and makes it the foundation of his whole system. On this foundation he erects a

[73] "Saepe multumque eximium opus Aristotelis de demonstratione perlegens, post diutinam contemplationem magna multaque eademque paene mystica . . . comprehendere videbar." Digby, *Theoria analytica*, A1v; Akester, "Life and Works of Everard Digby," 84.

[74] Digby, *Theoria analytica*, A1v; Akester, "Life and Works of Everard Digby," 85.

[75] The images that front each of the three chapters are right out of mystic traditions. The first (B2r), for example, depicts a man's head surrounded by rings of fire or some sort of emanation, surrounded in turn by a supra-stellar ring labeled *Universale*. A sweeping, ethereal conduit, labeled *Apprehensio*, joins the man's forehead and the outer reaches of the *Universale*. For an analysis of Digby in the context of medieval mysticism, see Akester, "Life and Works of Everard Digby", especially chapter 4, "The Theoria Analytica: Divine Light," 136–97.

bipartite epistemology, the first part of which he calls an ascent and the second a descent. In the first, man rises in thought from what is better known to him, that is, the observations of sense, to what is better known to nature, that is, universal abstract knowledge. In the second part, man descends in thought from that universal knowledge to the particulars of sense perception. Although Digby describes his system as essentially bipartite, it actually has three major parts, three phases one traverses on the way to true knowledge and in the *Theoria Analytica* Digby dedicates one book to each.

The progression toward knowledge begins with a logically complete demonstration regarding some subject under investigation.[76] The starting point in Digby's system is not sense-experience, but an already crafted syllogism. Digby does not say precisely where this syllogism comes from. A person first presented with this demonstrative syllogism understands it only confusedly, for he does not fully understand its components, that is, the premises and their concepts, and the causes that make the demonstration true. In an effort to understand this demonstration, the person begins the process of cognitively ascending through a hierarchical field of abstract notions, what Digby calls the 'intelligible realm' (universam intelligentiam).[77] As a person tries to navigate this realm, he realizes that there are causal connections between various concepts in the hierarchy, the causes needing to be understand before the effects, but that there must be one 'first

[76] Digby, *Theoria analytica*, bk. 1, pp. 1–87.

[77] Ibid., B2v; Akester, "Life and Works of Everard Digby," 93.

principle,' which is the cause of all, and which must be understood fully if anything else lower in the hierarchy is to be understood. This 'first principle' is God, the source of all truth, including the truth of the demonstrative syllogism with which the process began. The first stage of Digby's process is thus an ascending from consideration of that first demonstration to a consideration of higher- and higher-level abstractions, what he calls 'notions,' to a consideration ultimately of God. The words *ascent* and *ascending* are frequent and central in Digby. He describes this ascent as a flight on swift wings to thresholds of the gods and palaces of the mind.[78]

A person who has flown so swiftly to contemplation of the divine still has only a confused understanding of the notions traversed. He is not ready for the descent. Between the ascent and the descent lies the second of Digby's three stages, the most important, the one where true knowledge is obtained.[79] Here, one traverses the full hierarchy of the 'intelligible realm,' participating in the divine, the way illuminated by God's light. By divine illumination, one comes to understand the cause of all causes, and thus the certainty of all conclusions. Here are Digby's words:

> The human mind, refined through the goal of apprehension, and placed near the summit of the shining pyramid, now sees distinctly, by the miracle of its light, the reflected light in all intelligibles and sensibles, which formerly it had comprehended only confusedly. It discerns, distinguishes and demonstrates ideas, angels, pure acts, and at the same

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[78] "Celeri ala deorum limina aduolat mentis pallatia pandens." Digby, *Theoria analytica*, A2v [p. 3]; Akester, "Life and Works of Everard Digby," 86.

[79] Digby, *Theoria analytica*, bk. 2, pp. 49[89]–287.

time natural actions below it, as he who has gained the mountain peak with difficulty, through many stages and levels, when once he has mastered its height contemplates in a single vision every way on all sides leading to the summit, by the clear light.[80]

Thus one understands by a clear light (clara luce) and distinctly (distincte) what was earlier understood only confusedly (confuse). This is the mystical component that Digby thought Aristotle had overlooked.

Now endowed with this clear and distinct understanding of the first cause, i.e., God, one enters the third and final phase.[81] "The human mind . . . descends from the lofty summit of the abundantly shining pyramid to its earthly dwelling place."[82] The original demonstration is now seen as one part of the whole fabric of truth that emanates from God. It is now fully understood, and its certainty assured. All aspects of the material world, all specific scientific conclusions are now comprehended as inescapable effects of God's divine causal being. The three stages of Digby's *Theoria Analytica* are thus complete: ascent, contemplation, and descent.

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[80] Under the heading "Argumentum Libri secundi": "Per metam apprehensionis sublimata mens humana, & prope summitatem lucibilis pyramidis locata, eius beneficio lucis, distincte iam videt lumen in omnibus intelligibilibus sensibilibusque, quod antea confuse tantum apprehenderat, Ideas, Angelos, actus puros, simul ac naturales infra se cernens, decernens, demonstrans, haud aliter atque is qui per multos gradus gressusque difficulter cacumen montis aduolaverit: cuius semel superata altitudine, uno conspectu omnem ad cacumen montis methodum undique dirigentem clara luce intuetur . . ." Ibid., 88; Akester, "Life and Works of Everard Digby," 94.

[81] Digby, *Theoria analytica*, bk. 3, pp. 289–404.

[82] "A summo superlucentis pyramidis cacumine . . . descendit mens humana ad habitaculum suum terrestre."Ibid., 288; Akester, "Life and Works of Everard Digby," 95.

All this is similar to a whole tradition of Platonic, Neoplatonic and Cabbalistic, Hermetic and alchemical mysticism, and also to Descartes, whose use of 'clear and distinct' Digby anticipates. But there are also remarkable similarities to Zabarella's regressus. Both begin with a demonstrative syllogism, the source of which lies mostly outside the described system. This demonstration is known confusedly because the causes are not fully understood. A second phase is needed to come to clear understanding of the causes. For both Digby and Zabarella, this phase is purely contemplative. It makes no appeal to further empirical or experimental evidence. What in Zabarella is a contemplative insight is in Digby a mystical revelation. What Zabarella grasped 'by its own light,' Digby grasps 'by a clear light.' Zabarella does not employ the metaphors of divine illumination that Digby uses, but in both systems the method and the results are the same. One simply thinks deeply and at some point comes to have a clear idea of the demonstrative cause. Confident of the truth of this cause, one can revisit (in the case of Digby) or reformulate (in the case of Zabarella) the original demonstrative syllogism, and come to fully understand that the observed effect is the result of a newly understood cause. What began as confused understanding of a syllogism, has by way of deep contemplation, resulted in clear and distinct understanding of a syllogism. In neither Digby's analytic theory nor Zabarella's regressus is the first phase induction and the final phase deduction. In both systems, both phases are demonstrations.

In *Theoria Analytica*, rooted in an Aristotelian framework but with a progression from 'confused' knowledge to 'clear and distinct' knowledge by way of contemplative enlightenment, we may be able to detect a transition from the scholastic epistemology of Zabarella's regressus with its underlying vestiges of Alexandrian Neoplatonism to the more conspicuously Platonic epistemology of the seventeenth-century Cambridge Platonists and European Cartesians. Though Digby does not draw much attention to induction until his later writings (when he suggests that the first phase is induction), his epistemology, with its flight to abstract notions, will be one target of Francis Bacon's attack. In Digby's own day it was the target of attack by another young Cambridge scholar, William Temple.

William Temple (1555–1627)

Digby had entered St. John's College in 1567. William Temple entered Kings College in 1574.[83] Though Temple was only a few years younger than Digby, the two were ideologically of different generations. For all his Platonic mysticism, Digby fashioned himself an Aristotelian working in the great tradition of Catholic scholasticism, and believed he was bringing to its greatest development the work of the ancient master. Temple, though he had been a student of Digby's, was a Ramist, a follower of the sixteenth-century humanist, acclaimed anti-Aristotelian, and recently martyred Protestant, Peter Ramus.

[83] For biographical information on Temple, see Freudenthal, "Beiträge zur Geschichte der englischen Philosophie," 2:1 ff.; Elizabethanne Boran, "Temple, Sir William (1554/5–1627)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

In 1543, Ramus published a comprehensive attack on, he claimed, all things Aristotelian, *Aristotelicae animadversiones*.[84] He proposed a wholesale rearrangement of the teaching of rhetoric, dialectic, and logic, which he believed were infected with Aristotelian exegesis. The most prominent aspect of his new pedagogy was the presentation of nearly all subjects in a distinctive hierarchical, define-and-divide arrangement. A Ramist logic textbook, for example, would began: 'Logic is the art of disputing well. It is divided into two parts, invention and judgment.' Invention would then be defined and divided into two kinds, artificial and without art. Each of these would be defined and then divided into two kinds, say, simple and complex. Ramus claimed that this kind of hierarchical presentation, starting with the general and subdividing down to the specific, was the single proper method for teaching any topic. The method gained a tremendous vogue, especially in England in the late 1570s and the 1580s,[85] when English educational institutions were again beginning to prosper, and were doing so in a way that welcomed pedagogic innovation.

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[84] Peter Ramus, *Aristotelicae animadversiones* (Paris: Jacques Bogard, 1543). Ramus and his school have been treated in several works. Particularly useful for purposes here are W. J. Ong, *Ramus, Method, and the Decay of Dialogue* (Cambridge, MA: Harvard University Press, 1958); W. J. Ong, *Ramus and Talon Inventory* (Cambridge, MA: Harvard University Press, 1958); Gilbert, *Renaissance Concepts of Method*, 129–44; and for its coverage of Ramism in England, Howell, *Logic and Rhetoric in England, 1500–1700*, 146-281. A more recent overview of high-quality appears in Jardine, "Humanistic Logic," 184-86.

[85] Howell, *Logic and Rhetoric in England, 1500–1700*, 146–281; Schmitt, *John Case and Aristotelianism in Renaissance England*, 34-37.

William Temple was Ramus's most vigorous champion in England. In published essays he defended Ramus against criticisms by Digby and by one John Piscator.[86] In 1584 Temple published an edition of Ramus' *Dialecticae Libri Duo*[87] with extensive commentary, and his Ramist scholarship gained him recognition even at the court of Elizabeth.[88] His debate with Digby began after Digby published an attack on Ramism in early 1580. Over two years, Temple and Digby, both still in their mid to late twenties, attacked and counter-attacked in a total of four, often vitriolic pamphlets, two of them running to a hundred and twenty-five pages each.[89] The debate was of interest as far away as Germany.[90]

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[86] On Piscator, Howell, *Logic and Rhetoric in England, 1500–1700*, 195–96.

[87] Peter Ramus, *P. Rami Dialecticae libri duo, scholiis G. Tempelli Cantabrigiensis illustrati*, ed. William Temple (Cambridge: 1584).

[88] This by Philip Sidney and then the Earl of Essex, who then employed him as a secretary. Howell, *Logic and Rhetoric in England, 1500–1700*, 204-5; Schmitt et al., eds., *The Cambridge History of Renaissance Philosophy*, 837.

[89] The debate was treated in Freudenthal, "Beiträge zur Geschichte der englischen Philosophie," but Freudenthal, on whom many relied, misunderstood the chronology. This confused his interpretation. A confused understanding persisted in Gilbert, *Renaissance Concepts of Method*, 200–9. The basic outline of the debate was finally sorted out by Jardine, *Francis Bacon: Discovery and the Art of Discourse*, 59–65, but Jardine gave little consideration to the important background provided by *Theoria Analytica.* The first and still only detailed, comprehensive, and fully informed treatment is Akester, "Life and Works of Everard Digby," 198–247. Unfortunately, Akester failed to recognize the larger issue at stake and accepted without sufficient caution the prevailing interpretation that the debate was a semantic quibble over the meaning of *method.*

[90] The documents were reprinted in Frankfurt a few years later. Schmitt, *John Case and Aristotelianism in Renaissance England*, 50.

The debate concerned method. Ramus was well known for his advocacy of the single, define-and-divide method described above. In the face of Ramism's rising popularity in England, Digby attacked this core idea in the first pamphlet of the debate, *De duplici methodo libri duo, vnicam P. Rami methodum refutantes*,[91] that is, *Two books concerning the double method, refuting the single method of P. Ramus*. Digby there argued that method is always and everywhere two-fold. This is evidenced, he claimed, by many dichotomies, such as 'better known by us' and 'better known by nature,' 'prior to us' and 'prior by nature,' Plato's 'genesis' and 'diaeresis,' Galen's 'synthesis' and 'analysis,' Aristotle's 'induction' and 'deduction,' and Digby's own 'ascent' and 'descent.'[92] Writing under a pseudonym, Temple countered his ex-teacher and defended his master with *Francisci Mildapetti Nauerreni ad Euerardum Digbeium Anglum admonitio de unica P. Rami methodo reiectis Caeteris retinenda*,[93] that is, *An admonition . . . to retain the unitary method of P. Ramus*. . . . Digby's reply was a *Response . . . to an admonition to retain the unitary method of P. Ramus*[94] and Temple's

[91] Everard Digby, *De duplici methodo libri duo, vnicam P. Rami methodum refutantes* (London: Henrici Binneman, 1580).

[92] "Plato harum primam, appellat genesin, alteram diaresin. Galenus priorem synthesin, posteriorem analysin. Aristoteles, priorem inductionem: posteriorem resolutionem, seu demonstrationem." Ibid., C1r-C2v [pp. 18–9].

[93] Temple, *Admonitio*.

[94] Everard Digby, *Everardi Dygbei Cantabrigiensis admonitioni F. Mildapetti navareni de vnica P. Rami methodo retinenda, responsio* (London: Henrici Binneman, 1580).

final a *Commentary in defending the unitary method against the double-lover*.[95] The titles do not let us mistake the poles of the debate: Temple says method is unitary, and Digby says it is two-fold.[96]

The debate has been characterized as an academic quibble over the meaning of the term *method*.[97] By this interpretation, Digby and Temple agree that there are two separate processes, one for discovering new knowledge and the other for imparting existing knowledge to a student. Digby thinks both are subsumed under the term *method*, Temple that only the second should be. This interpretation, however, describes a disagreement that seems too trite to so provoke these man and hardly explains the interest that the debate garnered internationally. Once we see Digby's larger system for what it is, Temple's criticism appears more substantive and the debate more important, especially for an understanding of how knowledge was conceived and constructed at the end of the sixteenth century, and especially for how induction was conceived by the supposedly anti-Aristotelian Ramist school.

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[95] William Temple, *Pro Mildapetti de unica methodo defensione contra diplodophilum, commentatio Gulielmi Tempelli* (London: Henricus Middletonus, 1581).

[96] The debate ended when Digby got a court injunction barring Temple from further attacks. Akester, "Life and Works of Everard Digby," 199.

[97] E.g., "It may readily be seen that, as with most Ramist-Aristotelian controversies, this one turns on the meaning to be assigned to *methodus*." Howell, *Logic and Rhetoric in England, 1500–1700*, 208. "Temple's main argument with Digby is over what should and should not be called method." Akester, "Life and Works of Everard Digby," 239, cf. 200, 234. "To us, this seems a mere verbal quibble." Akester, "Life and Works of Everard Digby," 201. See also Jardine, *Francis Bacon: Discovery and the Art of Discourse*, 59-65.

To see why this was not a semantic quibble, it is important to note that Temple was responding not only to Digby's 1580 pamphlet attacking Ramus, but also to Digby's 1574 *Theoria Analytica*.[98] Temple said that he had been willing to criticize the earlier work in private, but on reading the pamphlet, the public attack on Ramus, he decided a published response was necessary.[99]

Recall that Digby adopts and then extends the long-standing understanding of the dichotomy 'better known by man' and 'better known by nature.' Digby believes that what is 'better known to man,' i.e., that which is known through the senses, is fleeting and uncertain, and that certain knowledge comes from mystical contemplation of the intelligible realm, the realm of that which is 'better known to nature,' i.e., that which is known by supra-human consciousness unconstrained by sense perception. Digby thinks that to man, particulars are clear and universals obscure, and to nature universals are clear and particulars obscure. Temple thinks this is nonsense.[100] Temple rejects Digby's claim that universal knowledge is obscure and instead believes that man's clearest form of knowledge is the universal.[101] For by the universal man understands causes and explanations. For Temple, that which is clear to man about something is that which is clear most

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[98] Among commentators, only Akester makes this attempt.

[99] Akester, "Life and Works of Everard Digby," 232.

[100] Temple writes in the first person and addresses Digby in the second. His style is mocking. Though I cannot do it justice, I will try to suggest some of the attack's spirit. All translations of Temple are mine unless otherwise noted.

[101] Temple, *Admonitio*, 47–56; Akester, "Life and Works of Everard Digby," 233.

generally and by nature. Indeed, it is the core of the Ramist method to first identify the general as the easiest to grasp, and then to subdivide down to the particular. Temple thus rejects this very fundamental of Digby's dichotomies.

Indeed he points out that Digby himself is trapped in inconsistency when he tries to apply the distinction. For example, Digby says that the universal is obscure yet also that it is the most lucid and illuminates and renders certain all knowledge.[102] This is a pervasive instability in the *Theoria Analytica* and only one of many inconsistencies Temple highlights. The most important for the study of induction and central to Temple's attack is this: Although Digby parades his two methods of ascent and descent, they are in fact the same thing. Digby says that one is a progression from particulars to general and the other from general to particulars. Yet whenever he says he claims to provide an example of a progression from particulars to the more universal, Temple says, Digby does the opposite. He starts with the most general and proceeds to the less abstract.[103] For example, Temple writes, "In grammar, you want the letter placed before the syllable, syllable before the word. . . . In geometry, you want to have the line precede the surface, the surface precede the object,"[104] but the letter and the line are the more abstract, the word and the object closer to perception. Digby does the same with dialectic and arithmetic, confusing the concrete for the abstract and vice versa. Digby also

[102] E.g., Temple, *Admonitio*, 83.

[103] Ibid., 114.

[104] "In grammatica vis literam syllabae, syllabam voci . . . praeponi. . . . in Geometria vis ut linea superficiem, superficies corpus antecedat." Ibid.

says that his ascent is an induction, his descent a deduction, but he gets this confused also. By his own logic, Temple notes, both must be demonstrative syllogisms, since both are aspects of method and Digby has equated method with demonstrative syllogism.[105] Temple is right that both Digby's ascent and the descent are syllogisms, but Digby might not acknowledge an inconsistency, for he believes that induction is a kind of confused deduction. That is, the supposedly inductive ascent is actually a confused syllogism, the supposedly deductive descent a clearly understood syllogism. But, Temple is arguing, there is nothing double about this. Confusion and understanding are not two kinds of knowledge.

In his next pamphlet, Digby replies to Temple's attack with fifty-two citations from Aristotle, all supposedly defending the two-fold nature of method.[106] In Temple's response, he rebuts each citation in turn, describing the actual meaning of the passage and dismissing any claim that it describes a double method.[107] The spirit of Temple's response is that Digby is a terrible Aristotelian who misunderstands his master at every turn, reads into the text things not there, ("Where here is a double method?"[108]), fails to distinguish medieval commentary from Aristotle's own work ("Oh, would that the interpreters of Aristotle's teaching

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[105] Ibid., 92; Akester, "Life and Works of Everard Digby," 236.

[106] Digby, *Responsio*, f. A5v [p. 5]–A8r [p. 12].

[107] Temple, *Commentatio*.

[108] "Vbi hic duplex methodus?" Ibid., 45[65]. Also "But in what way from this testimony can one conclude there is a double number of methods?" "Sed enim quomodo ex isto testimonio binarius methodorum munerus [*sic*; numerus?]concluditur?" 66.

had attended to this reasoning more carefully"[109]), and simply does not understand Greek ("I cannot even say what confusion your understanding of the Greek language produces"[110]). Temple is correct that this self-proclaimed champion of Aristotle is not a good Aristotelian. Once Digby decided that Aristotle had overlooked a mystical element of knowledge and that he, Digby, would correct the mistake by a wholesale grafting of medieval mysticism, there was little to keep him tethered to Peripatetic doctrine. The Ramist Temple emerges from the debate as the better defender of Aristotle. This becomes notably apparent when Temple explains induction to Digby.

There are two important things on which Digby and Temple agree: Method is the progression from general to particular, and it is the appropriate procedure for imparting to an ignorant student knowledge that the teacher possesses. Their disagreement is over discovery of *new* knowledge. When Temple says that discovery is not part of method, it is not a quibble over the meaning of *method*. On that he and Digby basically agree. Rather it is a substantive and important claim that discovery cannot be effected by using demonstration, deduction, or syllogistic reasoning, not, in other words, by starting with the abstract. Discovery of new knowledge—and therefore ultimately all knowledge—must begin with the particulars of sense perception. That is, Temple says, discovery of new knowledge

[109] "Vtinam Aristotelicae disciplinae interpretes istum soritem diligentius attendissent." Ibid., 62.

[110] "Tua . . . graecae orationis interpretatio nescio quam obscuritatem peperit." Ibid., 56.

must be by induction. "Cognition of principles is not native but is received from somewhere else, from that progression of singulars through the senses by means of induction."[111] "For from observation and induction of observed things, precepts arise."[112] These precepts or principles are the result, not the starting point, of discovery. "Science . . . does not exist outside universals, nor is the universal reached without induction, nor is induction formed unless the sense is engaged. How long will you mock us for this induction? How long in the investigation of science will you deliberate with a precept?"[113] This understanding of induction that Temple defends against Digby's mockery is not the conventional scholastic view by which induction is a (usually defective) form of deduction, but that of the *Posterior Analytics*. It is there, Temple says, that Aristotle argues "elegantly,"[114] "copiously, and magnificently"[115] about the nature of proper induction, for there Aristotle explains how man develops universal notions by gathering sense-perceptions into memories and memories into experiences. So the essence of the disagreement between the scholastic Digby and the Ramist Temple is that Digby believes new

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[111] "Cognitionem scilicet principiorum non esse natiuam sed ascitam aliunde, ab illa nempe singularium per sensus inductione profectam." Ibid., 64.

[112] "Nam e quarum rerum observatione & inductione praecepta oriuntur." Temple's commentary in Ramus, *P. Rami Dialecticae libri duo, scholiis G. Tempelli Cantabrigiensis illustrati*, 2.

[113] "Scientia . . . non existit absque vniuersali nec vniuersale efficitur sine inductione, nec inductio efformatur nisi accesserit sensus. Quamdiu nos inductione ista eludes? Quamdiu in scientiae inuestigandae praecepto delirabis?" Temple, *Commentatio*, 63.

[114] "eleganter." Ibid., 62.

[115] "copiose magnificeque." Temple, *Admonitio*, 76.

knowledge can be discovered by some form of deductive reasoning and Temple insists that new knowledge can be discovered only by the inductive process that Aristotle describes in the *Posterior Analytics*.

Inductio appears little in Ramist writing and it has been easy to believe the Ramists had little concern for the concept. The whole Ramist project was, after all, to promote a top-down approach to teaching that began with the most abstract and proceeded to the particular. Yet Temple seemed to claim for all Ramists a central role for induction when he wrote, 'How long will you mock *us* for this induction?' Moreover, Temple is adamant that induction is not a kind of deduction, as Digby believes, but a separate process that provides the abstractions from which deductions—and Ramist teaching of discovered knowledge—begin. Thus Ramism, at least as Temple represented it in England, not only does not ignore induction, but insists on its importance and its nature. For Temple, induction is the only means to discover new knowledge, is not reducible to a deduction, and is the process of forming abstractions from particular sense experience that Aristotle described in *Posterior Analytics* 2.19. If Zabarella is a scholastic Aristotelian and Digby a mystical Aristotelian, Temple should be seen—at least regarding induction—not as an anti-Aristotelian but as a classical Aristotelian.

John Case (1539/40?–1599)

Last in the sample of late sixteenth-century thinkers whose writings manifest discussions of induction which Bacon enters is John Case. Though, like Digby, Case is not of much philosophical interest, he is of an historical one. He is too eclectic to warrant a detailed examination, but it is nonetheless useful to look quickly at his writings, for there we see not only affirmation of themes found in Zabarella and Digby, but suggestions for new themes that come to the fore in Bacon.[116]

We may fairly characterize Case as an eclectic Aristotelian. He became a student at St. John's College, Oxford, in 1564 and a fellow there in 1568. St. John's was a new college, started in 1554 and offering a mix of traditional and humanistic learning. He resigned his fellowship in 1574 (in order to marry a local widow) but continued to teach logic in his home until at least 1590. He acquired a reputation as an outstanding teacher. Throughout the 1580s and 1590s he maintained good relations with St. John's and a prominent position in Oxford intellectual circles, though he was occasionally suspected of Catholic sympathies also. He wrote several pedagogical works and commentaries on Aristotle that were published between 1584 and 1599, the year he died. One of them was, in 1585, the first major publication by the newly opened Oxford University Press. During his life, he acquired some wealth and bequeathed much of it to St. John's. About forty editions of his works were published through 1630, both in England and Germany, making them the

[116] After the mid-seventeenth century, Case received little attention until Schmitt, *John Case and Aristotelianism in Renaissance England*, now the fullest treatment. Schmitt's study is as much a portrayal of vigorous but eclectic Aristotelianism in late Renaissance England as a detailed study of Case. For biographical information on Case, see its chapter, "The Life and Works of John Case," pp. 77–105; and also Edward A. Malone, "Case, John (1539/1540?–1599)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

most frequently reprinted British works of philosophy of the sixteenth century.[117] In 1632, he was described as "the greatest philosopher that our English universities have brought forth in this time."[118]

Three of Case's works are important for a study of induction. His first publication, *Summa veterum interpretum in universam dialecticam Aristotelis*, published in 1584 and reprinted several times over the subsequent twenty years, is a logic textbook that, like others of the late sixteenth century, such as Seton's *Dialectica*, attempted to combine traditional and humanistic themes. The other two were published near the end of his life (one maybe posthumously) and were commentaries on Aristotle's *Physics*. One, *Ancilla Philosophiae*,[119] was a short textbook, the other, *Lapis Philosophicus*,[120] a full treatise. The second, in particular, shows Neoplatonic accretions (though not as mystical as Digby's) on an Aristotelian frame. In all these works of Case's we find, in inchoate form, three themes that will be central for Bacon.

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[117] Copenhaver and Schmitt, *Renaissance Philosophy*, 123.

[118] Though Case's success in Oxford and his publication record support the sprit of the remark, it may fairly be accused of some exaggeration. It was not made by someone prominent, but by the translator (a Catholic priest) of Edmund Campion, *Campian Englished or a Translation of the Ten Reasons in which Edmund Campian (of the Societie of Jesus) Priest, Insisted in His Challenge to the Universities of Oxford and Cambridge*, trans. Laurence Anderton (Cambridge: 1632). It is cited by Schmitt, *John Case and Aristotelianism in Renaissance England*, 3.

[119] John Case, *Summa veterum interpretum in universam dialecticam Aristotelis* (London: Thomas Vautrollier, 1584).

[120] John Case, *Lapis philosophicus seu commentarius in 8 libros physicorum Aristotelis in quo arcana physiologiae examinantur* (Oxford: Joseph Barnes, 1599).

The first such theme is the relationship between art and nature.[121] The subject goes back to Aristotle's comments in Book II of the *Physics*,[122] and it is in his commentary on that book that Case develops his own views.[123] Aristotle said that art imitates nature. This came to be interpreted (possibly as Aristotle intended it) as meaning that though the raw materials of practical human effort are natural, the process and the result are not. The wood from which a bed is constructed may be natural, but the construction process and the bed are artificial. Accordingly, something man-made can imitate, but can not be the same as, something natural. Bronze can imitate copper and tin, its constituent parts, but whereas they are natural, it is artificial, and there is an unbreachable, qualitative difference between the two. One cannot make gold, not for a scientific reason but for a philosophical one. The best one could hope for is artificial gold, a mere imitation of natural gold. The alchemical tradition challenges this, but it accepts the premise that a man-made process can only produce something unnatural. It seeks a process that is beyond the constraints of the man-made, imploring the supernatural if necessary, in order to produce something natural and real and not imitative. John Case shares with the alchemists the belief that the produce of human effort can be natural, but does so by challenging the Aristotelian premise that human processes are unnatural.

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[121] Schmitt has well explored this theme in Case, and I will follow what I understand to be his interpretation. Schmitt, *John Case and Aristotelianism in Renaissance England*, 191–216. The term a*rt*, of course, has the sense here of *technē*, craft, any human operative process, not the sense of fine art.

[122] *Physics*, 2.1–2 192b8–194b15.

[123] Case, *Lapis Philosophicus*, 2.1.3, pp.175–81.

He claims that in any productive activity it is nature not man which does the work. The process itself is fully natural. It is not the medicine itself, but the curative power of nature that heals. Neither the doctor, the architect, the alchemist, nor the sorcerer should take credit for the cure, the house, the gold, or the storm, for in all cases it is nature itself that deserves credit. With this idea, Case is only a short distance from Bacon's 'Nature to be commanded must be obeyed.'

Another seminal idea in Case that will be more fully developed by Bacon regards induction directly. Even a belief that practical results can be obtained by directing nature along its course leaves open a crucial philosophical question: How does one know that what effected a result in the past will effect the same result in the future? This is a problem of induction. Case treated induction fifteen years earlier in his 1584 logic textbook *Summa veterum interpretum*.[124] The relevant part of that textbook follows the conventional outline for presentation of scholastic logic, though it includes a more generous use of the scholastic device of objection-and-response than was typical for introductory textbooks and makes extensive use of the Ramist method of hierarchical division. Induction, as it normally does, receives short treatment immediately following the long exposition on the syllogism and is sandwiched between similarly short treatments of the enthymeme and example.[125] Indeed, the treatment is even shorter than is common, and there is no mention of some issues or examples often covered. There are, however, two new things. The

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[124] Case, *Summa veterum interpretum*.

[125] Ibid., bk. 1, ch.19, pp. 36–37.

first is that Case prefaces the conventional definition of induction by saying that induction is better used by orators than by philosophers, better used than deduction to affect popular sentiment. This is an appeal to the way induction was treated in the *Topics*, the new humanist source, rather than in the *Prior Analytics*, the standard medieval source. Case then defines induction in a conventional way and gives a common example. He then offers this new contribution to the study of induction:

<table><tr><td>In induction, these are considered:</td><td>The material, which is the singular things collected.
The form, which is a sufficient enumeration of the particular things and their connection in something universal.
The order of enumerating the propositions.
The goal, which is a powerful persuasion of the masses.[126]</td></tr></table>

The list clearly suggests the four Aristotelian causes—material, formal, efficient, and final. And if Case had explicitly said that validating an induction requires identifying an underlying cause, as Galen had, his treatment would have been revolutionary. But he does not. He says nothing more about the list, nothing about how these four are to be considered, only that they should be. It will be for Bacon to explicitly propose a relationship between induction and causality.

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[126] Ibid., 37.

<table><tr><td>“In inductione considerantur</td><td>Materia, quae est res singularis numerose collecta.
Forma, quae est sufficiens rerum singularium enumeratio connexioque in re universa.
Ordo propositiones enumerandi.
Finis, qui est firma persuasio multitudinis.”</td></tr></table>

The third theme inchoate in Case is not really a new theme but a new vocabulary applied to an old theme, an aspect of the earlier discussed epistemology of Zabarella and Digby. Zabarealla and Digby published their major works in 1578 and 1579, as Case was establishing his teaching practice and before he had published anything. The *Lapis Philosophicus* was published twenty years later. In it we find the now familiar theme that abstract ideas are known at first only confusedly (confuse) and then after sufficient cogitation come to be known distinctly (distincte).[127] This pattern is the same in both composition and resolution.[128] What is important about Case's presentation is not the content, but the terminology. *Notio* (and its cognate *notitia*) are used much more frequently than we have seen. The term will be central for Bacon. Furthermore, Case calls the ill-formed abstractions known only confusedly 'abstract phantasms' or 'idols,'[129] another concept central for Bacon. The word *idol* has two ancient senses, one as a distorted image in a mirror and the other as an object of veneration. Case alludes to both. In the *Lapis Philosophicus*, he describes how ill-formed concepts distort further thinking, and in the *Ancilla*, the shorter version of the same material, he writes, "He who, in scrutinizing the natural world, is content to be an idolater, is no

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[127] See especially Case, *Lapis Philosophicus*, bk. 1, ch. 1, pp. 31–43, under the heading "Whether universals are better known to us than to nature." "Utrium universalia nobis sint notiora quam naturae." Also John Case, *Ancilla philosophiae seu epitome in octo libros physicorum Aristotelis* (Oxford: Joseph Barnes, 1599), 11.

[128] Case, *Lapis Philosophicus*, 37.

[129] E.g., ibid., 34, 202. Cf., 200–202.

Philosopher."[130] Case does not further develop *idol* as a technical philosophical term, but he does use it in the same sense Bacon will, for an idea reached without empirical foundations, like Digby's mental flight to the summit.

These three inchoate themes in Case, how man effects works by guiding natural processes, how the four Aristotelian causes have a role to play in performing valid inductions, and how ill-formed ideas must not be allowed to thwart one's correct thinking, will all be developed into particular and crucial topics in Bacon's *Novum Organum*.

Summary

Around 1580, Jacopo Zabarella, leading Aristotelian of his day, working at the center of Europe's most advanced Aristotelian scholarship, argued for a two-fold procedure for coming to know, a procedure he calls 'regressus.' The first part, resolution, is a syllogism, but a syllogism that is inadequate, because it fails to explain something by its cause. The issue under discussion is thus understood only confusedly. The second part of the regressus, composition, is a new syllogism, one that identifies a cause and thus leaves one with distinct scientific knowledge. Between these two phases lies another, consideratio or a mentale examen. By this contemplation, what had been 'confused' knowledge becomes 'distinct.'

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130 "Si in rebus naturalibus scrutandis acquiescat Idololatra est nec Philosophus." Case, *Ancilla Philosophiae*, 8.

Around the same time, Everard Digby, a young man living on the outskirts of European scholarship, but fashioning himself ready to make a big contribution to Aristotelian thought, argued for a two-fold procedure for coming to know, a procedure he identifies as 'methodus.' The first part, the ascent, is a syllogism, but a syllogism understood only confusedly, because the cause of its truth is not grasped. The second part is the same syllogism, but now fully understood. Between these two parts is a cognitive wandering through the 'intelligible realm' and a mystical consideration of God. By this contemplation, what had been 'confused' becomes 'clear' and 'distinct.'

For these self-proclaimed Aristotelians, each attempting to advance scholastic thought as far as he could, the proper way to know is by demonstration, by the deduction of particulars from clearly and distinctly known universals. For each of these thinkers, each part of the double process is a demonstration. There is first a demonstration poorly understood and then a demonstration fully understood, with an enlightening realization intervening. In other words, for both Zabarella and Digby the so-called double processes are really a single process, the process of coming to understand a demonstrative syllogism. Neither thinker was a champion of induction nor a theorist offering a new understanding of induction.

Opposing these and other Aristotelians were the followers of Peter Ramus, such as Digby's adversary, William Temple. Like other Ramists, Temple defends not a double method, but a single one. He points out that what goes by the name *method* is a single procedure for going from a universal to particulars. Temple claims this is the only proper way to teach. But though it is appropriate for imparting existing knowledge, it is not appropriate, Temple claims, for discovering new knowledge. For that, one must revive the system of true induction that Aristotle described in the *Posterior Analytics* and discard the errors on the subject of induction offered by past and current Aristotelian commentators.

If in the late 1570s and early 1580s, Zabarella and Digby were representative of the forefront of Aristotelian thought, then the self-identified Aristotelians were neither championing induction nor offering anything new on the subject. In England, the champion of induction was William Temple, prominently known as an anti-Aristotelian but calling for the return in effect to a pre-medieval interpretation of Aristotelian induction.

What the doctrines of Zabarella and Digby had in common was that the first stage toward epistemic knowledge is an immediate leap to a deductive syllogism whose components are only confusedly understood. John Case called components that make up these demonstrations 'notions' and ill-formed ones 'idols.' Temple said that the leap to abstract knowledge cannot be done successfully the way Digby proposed. Universal knowledge should be sought not by leaping to a deduction, but by incrementally using the process of abstraction that Aristotle described in *Posterior Analytics* 2.19, the process Aristotle called *induction*. Case suggested that such an induction could only be made valid by considering causes. These elements, lying scattered in the late seventeenth-century theories of a scholastic Aristotelian, a mystic, a reforming Ramist, and a humanist Aristotelian, form the bare outline for

Francis Bacon's proposal for a new kind of induction, including what problems it is meant to address, from where in antiquity it came, how it is to be performed, and how it is to be made certain. Although none of the four views surveyed here included theories of induction, each one included elements that Bacon would either address or adopt. Bacon did not write a treatise on induction to rebut someone else's treatise, but nor did his proposal enter a vacuum. It entered epistemological discussions underway in the last years of the sixteenth century. Induction was not central in those discussions. Bacon proposed that it should be.

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Induction New and Old:

Bacon's Rediscovery of Ancient Induction

Francis Bacon's *Novum Organum* is written in the language of Renaissance Aristotelianism. Its prefatory discussion of syllogisms, axioms, middle terms, and major and minor premises, its central topic of induction, its concern with redargutions, its core concepts of notions and forms, even its famous idols, and of course its title, come right out of contemporary Aristotelian discourse. Bacon expected his readers to understand that language and thus to have their reading informed by Aristotelian associations. This has generally been overlooked by scholars.[1] From both an

[1] Exceptions are the unpublished Kosman, "The Aristotelian Backgrounds of Bacon's *Novum Organum*"; the little noticed Robert E. Larsen, "The Aristotelianism of Bacon's Novum Organum," *Journal of the History of Ideas* 23, no. 4 (1962): 435–50; and Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*, chs. 15–17. Although containing much good material, the first is unfortunately shaped by an acceptance of the Randall thesis regarding Paduan Aristotelianism that was rejected in chapter 3 above. The second discusses similarities between Bacon and Aristotle, but has little historical context. Neither benefited from the subsequent discovery by F. Edward Cranz, E. J. Ashworth, Charles H. Lohr, Charles B. Schmitt, and others of just how vigorous Aristotelian scholarship was on the Continent after 1540 and in England starting about the time Bacon arrived at Cambridge. Neither study benefited from the fuller understanding of the Temple-Digby debate

historical and a philosophical perspective, that is unfortunate. For if we do not recognize this Aristotelian context, we will fail to fully understand Bacon's contribution to the development of early modern natural philosophy and we will fail to fully understand his proposed method. This chapter seeks to situate and interpret the *Novum Organum* in its intended Aristotelian context.[2] It is hoped that this will provide new insight into Bacon's proposal for a new kind of induction.

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presented in Jardine, *Francis Bacon: Discovery and the Art of Discourse*; in Akester, "Life and Works of Everard Digby"; and in the previous chapter above. Perez-Ramos's short chapter on Aristotle is a very valuable contribution but the chapter on medieval and Renaissance induction shaped, like Kosman's treatment, by adoption of the Cassirer/Randall interpretation of Renaissance induction.

[2] No attempt will be made to review and evaluate the vast—and partisan—secondary literature on Bacon. Particular works will be cited as needed. In general the important works for this study include the main philosophical examinations made in the twentieth century: Cohen, "The Myth about Bacon and the Inductive Method"; B. Farrington, *The Philosophy of Francis Bacon: an Essay on its Development from 1603 to 1609* (Liverpool: Liverpool University Press, 1964); Mary Hesse, "Francis Bacon," in *A Critical History of Western Philosophy*, ed. D. J. O'Connor (New York: Free Press, 1964), 141–52; Paolo Rossi, *Francis Bacon: From Magic to Science*, trans. Sacha Rabinovitch (London: Routledge & Kegan Paul, 1968); Mary Horton, "In Defence of Francis Bacon: A Criticism of the Critics of the Inductive Method," *Studies in History and Philosophy of Science* 4 (1973): 241–78; Jardine, *Francis Bacon: Discovery and the Art of Discourse*; L. Jonathan Cohen, "Some Historical Remarks on the Baconian Conception of Probability," *Journal of the History of Ideas* 41 (1980): 219–31; Urbach, *Francis Bacon's Philosophy of Science*; Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*; the several valuable articles in Brian Vickers, ed., *Essential Articles for the Study of Francis Bacon* (Hamden, CT: 1968) and Markku Peltonen, ed., *The Cambridge Companion to Bacon* (Cambridge: Cambridge University Press, 1996); as well as editors' commentaries in Francis Bacon, *The Collected Works of Francis Bacon*, ed. James Spedding, Robert Leslie Ellis, and Douglas Denon Heath, New ed., 14 vols. (London: Longmans & Co., 1857–70); in Francis Bacon, *Selected Philosophical Works*, ed. Rose-Mary Sargent (Indianapolis and Cambridge: 1999); and in Francis Bacon, *Bacon's Novum Organum*, ed. Thomas Fowler (Oxford: Clarendon Press, 1889).

I do not suggest that Aristotelianism is the only context in which Bacon should be read. Indeed, fruitful results have been obtained in the last few decades by situating Bacon's work in the contexts of law,[3] politics and society,[4] natural

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Citations to Bacon's work other than the *Novum Organum* and the *Advancement of Learning* will be to volume and page number in the standard (London, not American) Spedding edition. Citations to *Novum Organum* will be by book and aphorism, to *Advancement of Learning* by book, chapter and paragraph. Under the editorship of Graham Rees and Lisa Jardine, a new critical edition of Bacon's complete works is being published by Clarendon Press. It is expected that this *Oxford Francis Bacon* will supplant the Spedding edition as the standard reference. Thankfully, it includes a high-quality Latin transcription with a modern English translation on facing pages. Unfortunately, the new translation of *Novum Organum*, prepared by Rees, is not sufficiently literal for detailed textual analysis. Rees's standard is "'How would you say this in modern English?'" (p. cxxvii). To take a few examples, Rees translates Bacon's "In Logica enim vulgari opera fere vniuersa circa Syllogismum consumitur" *(Distributio Operis)* as "For in the common logic the syllogism takes up practically the whole field," Bacon's "praesertim cum hoc vocabulum inualuerit, & familiariter occurrat" (2.2) as "especially as this term is current coin and crops up all the time," and Bacon's famous "praerogativae instantiae" as "instances with special powers." His translations of "confusius" as "haphazardly" and "Artes populares & opinabiles" as "popular arts and matters of opinion" in the passage analyzed below mask the references to contemporary Aristotelian scholarship. I will instead use the recent translation by Michael Silverthorne in Francis Bacon, *The New Organon*, ed. Lisa Jardine and Michael Silverthorne (Cambridge and New York: Cambridge University Press, 2000), modified as noted where necessary. Silverthorne's translation of the above are "For in ordinary logic almost all effort is concentrated on the syllogism," "especially as this word has become established and is in common use," "prerogative instances," "in confusion," and "popular arts which are based on opinion." I will include Bacon's Latin in footnotes. For translations of other Baconian works, unless otherwise indicated, I will use Spedding, or Farrington for the three works for which translations are not in Spedding.

[3] E.g., Daniel R. Coquillette, *Francis Bacon*, ed. William Twining and Neil MacCormick, *Jurists: Profiles in Legal Theory* (Stanford, CA: Stanford University Press, 1992); and Shapiro, *A Culture of Fact: England, 1550–1720*.

[4] E.g., Daston, "Baconian Facts, Academic Civility and the Prehistory of Objectivity"; Mary Poovey, *A History of the Modern Fact* (Chicago and London: University of Chicago Press, 1998); and

history,[5] rhetoric and humanism,[6] and natural magic and crafts.[7] These last are particularly important, for Bacon was much impressed by advances in the mining, agricultural, navigational, and mechanical arts of his time and admired some of the work of nature philosophers such as Telesio, whom he called the "first of the moderns."[8] It was central to Bacon's project to learn and show how natural philosophy could be applied to improving the material conditions of life. But Bacon considered something else more fundamental. For his magnum opus he did not write a New *De Rerum Natura* or a New *Magia Naturalis*. He wrote a New *Organon*. He saw the need to fashion a new epistemology, which would be built not around deduction as the old *Organon* was, but around induction. His insight here

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Julie Robin Solomon, *Objectivity in the Making* (Baltimore and London: Johns Hopkins University Press, 1998).

[5] E.g., Virgil K. Whitaker, "Francis Bacon's Intellectual Milieu," in *Essential Articles for the Study of Francis Bacon*, ed. Brian Vickers (Hamden, CT: Archon Books, 1968),; and Paula Findlen, "Francis Bacon and the Reform of Natural History in the Seventeenth Century," in *History and the Disciplines*, ed. Donald R. Kelley (Rochester, NY: University of Rochester Press, 1997), 239–60.

[6] E.g., Craig Walton, "Ramus and Bacon on Method," *Journal of the History of Philosophy* 9 (1971): 289–302; Jardine, *Francis Bacon: Discovery and the Art of Discourse*; and John C. Briggs, *Francis Bacon and the Rhetoric of Nature* (Cambridge, MA and London: Harvard University Press, 1989).

[7] E.g., Rossi, *Francis Bacon: From Magic to Science*; and Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*.

[8] On possible influences of Telesio on Bacon, see Brian P. Copenhaver, "Astrology and Magic," in *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, et al. (Cambridge: Cambridge University Press, 1988), 296–300; Stephen Gaukroger, *Francis Bacon and the Transformation of Early-Modern Philosophy* (Cambridge: Cambridge University Press, 2001), 179–180; Graham Rees, "Bacon's Speculative Philosophy," in *The Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 121–45.

was correct and important. For knowledge to be power, one most know what will be effective, what will work. One must know, of the things that worked in the past which will work in the future, of the things that worked in some cases which will work in all cases. Knowledge of the past is not knowledge of the future unless one can legitimately form universal statements based on past particulars. Thus, one must discover the conditions for a valid and certain induction, just as Aristotle discovered and explicated in the *Organon* the foundations and conditions of a valid and certain deduction. Bacon can and should be read within different contexts, but the one most fundamental for understanding the *Novum Organum* as Bacon meant it to be understood is the Aristotelian.

Bacon's Early Aristotelian Exposure

Francis Bacon's father, Nicholas Bacon,[9] was one of the nouveau riche of Renaissance England. Born a commoner, he received a good education, became a talented and hard-working lawyer, acquired property in the reorganizations of land that followed Henry VIII's dissolution of religious institutions in the 1530s and 40s, and rose through administrative ranks to be knighted and made Lord Keeper by Elizabeth upon her accession in 1558. His rise was attested and advanced by his second marriage in 1553 to Anne Cooke, a young woman well known at court and well connected with several important families. Anne was very well educated,

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[9] Robert Tittler, "Bacon, Sir Nicholas (1510–1579)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

independent-minded, and a devout Calvinist.[10] Her husband Nicholas was a lifelong enthusiast for education and educational reform and a committed if politically moderate Protestant. Francis was born to the couple in 1561 and educated by tutors at home starting at age five.[11] He was a gifted young student, and in 1573, when he was twelve, and when his father was at the height of his national prominence, Francis was sent with his older brother to Trinity College, Cambridge. There he was under the direct care and supervision of John Whitgift, Master of the college, humanist scholar, leading intellectual defender of Elizabeth's Church, and future archbishop of Canterbury.[12] Bacon arrived on campus just as prospects for Cambridge and Oxford, and the study of Aristotle there, were beginning to improve. At Oxford, John Case was becoming a popular teacher of logic, and at Cambridge, the young Everard Digby was beginning to teach, not yet having written his *Theoria Analytica*. Bacon's own master was particularly active in helping rebuild Cambridge.

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[10] She knew Latin, Greek, and Italian and had a published English translation of the Italian sermons of Bernadino Ochino to her credit. The first of several editions was printed when she was twenty.

[11] On Bacon's early education, see Lisa Jardine and Alan Stewart, *Hostage to Fortune: The Troubled Life of Francis Bacon* (New York: Hill and Wang, 1998), 32; andBrian Vickers, "Bacon and Rhetoric," in *The Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 205.

[12] William Joseph Sheils, "Whitgift, John (1530/31?–1604)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

Books were one casualty of the mid-century decline. In early 1573, Whitgift was seeking donors who could help the university library acquire books again. One man who responded to the appeal was Sir Nicholas Bacon. In the first year of his sons' enrollment he donated ninety-nine books,[13] including complete works of Aristotle in both Greek and Latin. If these were the same editions that Whitgift bought for the Bacon brothers in late 1573 (and there are reasons to believe they were[14]) then Francis's first close encounter with Aristotle's collected works was with handsome Greek and Latin editions published in Basel. The impression they made on Francis, however, was not good. The edition claimed to be a complete repository of all natural knowledge.[15] That claim alone would have disquieted a smart young man raised in a maternal culture of independent thinking and a paternal culture of respect for material progress. Francis's exposure to the traditional way the book's contents were still taught would have confirmed the impression. There is no reason to doubt the biographer William Rawley's statement that "Whilst he was commorant in the university, . . . he first fell into the dislike of the philosophy of Aristotle."[16] Many a second-year Cambridge

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[13] Oxford DNB says "some seventy." I take ninety-nine from the detailed study in Durel, "Francis Bacon lecteur d'Aristote à Cambridge," 39.

[14] Ibid.: 31–45.

[15] Ibid.: 44.

[16] Rawley's full comment is "Whilst he was commorant in the university, about sixteen years of age, (as his lordship hath been pleased to impart unto myself), he first fell into the dislike of the philosophy of Aristotle; not for the worthlessness of the author, to whom he would ever ascribe all high attributes, but for the unfruitfulness of the way; being a philosophy (as his lordship used to say)

student, especially those tutored in progressive households, must have felt the same way. But Francis's dislike did not keep him away.

Bacon's study of Aristotle continued beyond his Cambridge days,[17] and his mature understanding of Aristotle was neither shallow nor merely second-hand. More examples will be seen, but one will suffice for now. In the unpublished *Redargutio Philosophiarum* (1608), Bacon writes, referring to Aristotle's two works, "I appeal to your memories, sons, and ask whether, in his Physics and Metaphysics, you do not hear the voice of dialectics more often than the voice of nature."[18] This is an insightful observation that could only be made by someone who has read (or tried to read) the *Physics* and the *Metaphysics*. Bacon was also familiar with Aristotelian commentaries, and he sometimes failed to distinguish Aristotle's own

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only strong for disputations and contentions, but barren of the production of works for the benefit of the life of man; in which mind he continued to his dying day." (Spedding 1:4.) The account is sometimes ridiculed, for surely a twelve-year-old could not have had such a mature reaction. That Rawley got Bacon's age wrong further taints the account. But, first, Rawley's estimate on Bacon's age is not far off. Bacon was "commorant in the university" until just before his fifteen birthday. Second, Rawley does not say that the young man articulated at the time the initial impression that he later came to better understand. For other defenses of Rawley's account, see Farrington, *The Philosophy of Francis Bacon: an Essay on its Development from 1603 to 1609*, 30; and Gaukroger, *Francis Bacon and the Transformation of Early-Modern Philosophy*, 39–40, which includes a reference to a Oxford statue which fined students who deviated from Aristotle's *Organon.*

[17] For which of Aristotle's works Bacon surely, probably, and possibly read while still at Cambridge, see Durel, "Francis Bacon lecteur d'Aristote à Cambridge," 32. Durel concludes that Bacon certainly read the *Topics*, probably the *Analytics*, possibly the *Physics*, and not the *Metaphysics*.

[18] "memoriam vestram, filii, testamur, si in physicis ejus et metaphysicis non saepius dialecticae quam naturae voces audiatis." *Redaurgutio Philosophiarum*, Spedding, 3:566; Farrington, 112.

words from that of his Scholastic commentators. The above quoted passage is followed by this question intended to be about Aristotle: "Who describes the nature of the soul in terms of second intention?"[19] The correct answer is not Aristotle, but Aristotle's scholastic commentators, for the concept *second intention* is their creation not his. Bacon's occasional confusion aside, he clearly had first-hand exposure and moderately advanced knowledge of Aristotle and Aristotelian scholarship of both medieval and contemporary commentators when he was developing his own ideas for a new *Organon*.

After almost three years at Cambridge (interrupted twice by plague in the town), Bacon spent two and a half years in France as a member of the English ambassador's house. Upon his father's death in 1579, he returned to London and began study of law at Gray's Inn. Through his twenties and even beyond, he appears to us as a stereotypical youngest son of a nouveau riche government official—spoiled, financially irresponsible, dabbling in international intrigues, asking for favors from his extended and powerful family, and trying to get government positions for which he was too young. He would not have a full-time job until he was in his forties, but by the time he was thirty, he had found both a patron and a passion. The patron was the successful military commander Robert Devereux, second earl of Essex. The passion was the reform of learning, especially in natural philosophy. In 1592, he wrote to his uncle, "I confess that I have as vast

[19] "qui animae genus non multo melius quam ex vocibus secundae intentionis tribuerit?" *Redaurgutio Philosophiarum*, Spedding, 3:566, Farrington, 112.

contemplative ends, as I have moderate civil ends; for I have taken all knowledge to be my province."[20] He was frustrated in his political ambitions and thought of abandoning them. Instead he fell into a pattern of providing council and help to Essex, taking on projects for the Queen and her administration, and pursuing his studies during out-of-town retreats to Twickenham Park, an eighty-five-acre family estate.[21] Later comments suggest these studies included experimentats in natural philosophy, but we know neither the seriousness nor subject matter.[22] In 1594, Bacon made the acquaintance of the Ramist William Temple, who had left behind his feud with Everard Digby and joined Essex's circle as secretary. Both he and Bacon were in their thirties, both worked directly for Essex, and both had a passion for the reform of human learning. It is hard to imagine Bacon not arguing philosophy with the country's most prominent Ramist while Bacon developed the core of his own philosophical system. From the nominally anti-Aristotelian Temple, Bacon could have heard an insightful understanding of Aristotelian induction.

At the end of 1594, Bacon wrote the script for some Christmas festivities at Gray's Inn. They included a speech to the queen explaining that she should take responsibility for advancing natural philosophy in the kingdom and giving her

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[20] Jardine and Stewart, *Hostage to Fortune: The Troubled Life of Francis Bacon*, 134. In 1620 he wrote the king that he had been "about some such work near thirty years." October 12, 1620, Spedding, 14:120.

[21] Ibid., 121–208.

[22] Ibid., 138.

specific advice on how to do so.[23] In the speech, Bacon included themes that would recur in the later "Parasceve" of the *Novum Organum* and in the *New Atlantis*. Court activities took Bacon away from his studies in the few years around 1600. The queen had given him an informal position as Learned Counsel after he helped her prosecute his own patron Essex for traitorous actions. When James acceded to the thrown after Elizabeth's death in 1603, James let Bacon keep the position, but it had no formal responsibilities. So Bacon again had time to think and write.

Bacon's Start in the *Posterior Analytics*

In the eight years from 1603 to 1611, Bacon wrote published or unpublished works that included nearly all the main themes and tropes of the *Novum Organum*. One of the first of these works was *Valerius Terminus of the Interpretation of Nature: with the Annotations of Hermes Stella*, written around 1603.[24] This text is particularly important for revealing both the progression of Bacon's thought and his sources. He begins this draft of an essay by recognizing that the pursuit of knowledge is subject to moral evaluation, and he claims that such pursuit is proper only if it is

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[23] Spedding, 8:355; Gaukroger, *Francis Bacon and the Transformation of Early-Modern Philosophy*, 72.

[24] This manuscript, in English, is carefully transcribed by one of Bacon's servants and has edits and rearrangements marked by Bacon in his own hand. Many of the sections are left incomplete. The title suggests that Bacon was experimenting with a genre that he would use in the *New Atlantis*, an account by a fictional character commented on by another fictional character. The text is reprinted in Spedding, 3:215–252, rearranged as Bacon's edits indicate he intended.

directed toward one end, "the endowment of man's life with new commodities."[25] Such knowledge properly seeks to return man to his prelapsarian state of full control over nature. In the pursuit of knowledge for other purposes, such as to satisfy curiosity or to gain fame, the resulting knowledge may not be untrue, but the pursuit is "inferior and degenerate."[26] Even the pursuit of knowledge of God is improper. God should be the object of awe or wonder, not of rational inquiry. Knowledge should be pursued for the "discovery of particulars not revealed before for the better endowment and help of man's life."[27]

One way to discover new particulars is by chance. Bacon writes in another draft of the same year, "Everybody stumbles on some truth sooner or later."[28] In several of his writings, Bacon cites the compass and gunpowder as examples of such serendipity. But these are "contradictory and solitary. . . . If gunpowder had been discovered, not by good luck but by good guidance, it would not have stood alone but been accompanied by a host of noble inventions of a kindred sort."[29] Bacon's

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[25] Spedding, 2:223. Said in different words: "the benefit and relief of the state and society of man," 2:222; "new experiences and inventions," 2:232; "to increase and multiply the revenues and possessions of man," 2:233; "the revealing and discovering of new inventions and operations," 2:235.

[26] Spedding, 2:222.

[27] Spedding, 2:233.

[28] "Nemo enim non quandoque in aliquod verum impingitur." *Temporis Partus Masculus,* Spedding, 3:537; Farrington, 70.

[29] "haec discors et solitaria. . . . Pulvis tormentorum si ductu, non casu (ut loquuntur) et impactu inventum fuisset, non solitarium, sed cum multa inventorum nobilium (quae sub eundem meridianum cadunt) frequentia prodisset." *Temporis Partus Masculus,* Spedding, 3:358; Farrington, 71.

project is to provide such good guidance. He says this guidance will have two crucial characteristics. "The fulness of direction to work and produce any effect consisteth in two conditions, certainty and liberty."[30] The first, certainty, is "when the direction is not only true for the most part, but infallible."[31] Thus, if one seeks to bring about some material condition, it is best if the actions taken are known to lead always to the result intended. The second condition ensures that one is free to take action under the most diverse conditions and still be assured of the desired result. Bacon offers the example of whiteness. Maybe one knows how to froth water with air to produce whiteness. "This direction is certain, but very particular and restrained, being tied both to air and water."[32] A second direction (we might say 'degree of freedom') would be to do the same with egg whites instead of water. Further liberty would ensue if one could move beyond clear liquids to dark ones, then to finely-ground solids, then to hard solids, then to all bodies of any type. What is sought is a method for producing whiteness that works always and in all cases without exception, no matter how different the new situation is from any that have gone before. Unless the two requirements of certainty and liberty are met, the discovery of new particulars relies on luck.

To develop the philosophical underpinnings for a method that meets these requirements, Bacon turns to Aristotle.

[30] Spedding, 2:235.

[31] Spedding, 2:235.

[32] Spedding, 2:236.

> This notion Aristotle had in light, though not in use. For the two commended rules set down by him, whereby the *axioms* of science are precepted to be made convertible, and which the latter men have not without elegancy surnamed the one the rule of truth because it preventeth deceit, the other the rule of prudence because it freeth election, are the same thing in speculation and affirmation which we now observe.[33]

The 'rule of truth' and the 'rule of prudence' are the Ramist's name for the two Aristotelian principles from *Posterior Analytics* 1.4 that were known in Latin as 'de omni' and 'per se.' Recall that by the rule of 'de omni,' a relationship holds in every case, though possibly only by coincidence. By the rule of 'per se,' a relationship holds necessarily, because it holds by the very nature of the things involved. Bacon continues to endorse the "received philosophies,"[34] in arguing that the way to ensure these two rules are met is to identify "the form or formal cause"[35] of the attribute, such as whiteness, that one wants to impart to new particulars. It is not just a cause that one must find, but the formal cause, and for any attribute there is only one formal cause. Again, Bacon draws this doctrine from Aristotle.

> Aristotle's school confesseth that there is no true knowledge but by causes, no true cause but the form, no true form known except one, which they are pleased to allow; and therefore thus far their evidence standeth with us, that both hitherto there hath been nothing but a

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[33] Spedding, 2:236. Italics in Spedding.

[34] Spedding, 2:239.

[35] Spedding, 2:239.

> shadow of knowledge, and that we propound now that which is agreed to be worthiest to be sought, and hardest to be found.[36]

Aristotle's error, as Bacon see it, is not that Aristotle had the principles incorrect, but that he or at least his followers failed to articulate exactly how to identify formal causes or forms. Some, Bacon says, despaired of the attempt, considering forms to be outside the "compass of human comprehension."[37] Other relied on "anticipations,"[38] the products of reason formed with little regard for observation. Some few geniuses seem able to succeed with antipications, and they "cannot receive too high a title."[39] But mostly anticipations lead to fictions in the mind, fictions which Bacon calls 'idols.' These ill-formed ideas infect all future thinking. Anticipations therefore lead mostly to error, contention, and the "infinite detriment of man's estate,"[40] instead of to identification of the true, formal causes that Aristotle said was the important goal. Bacon says a new method of finding formal causes is needed. He calls it "the interpretation of nature."[41] *Valerius Terminus* ends with an outline of subjects that will need to be covered in a full treatment of this new method.

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[36] Spedding, 2:239.

[37] Spedding, 2:239.

[38] Spedding, 2:239–41, 244.

[39] Spedding, 2:239.

[40] Spedding, 2:244.

[41] Spedding, 2:244 ff.

In *Valerius Terminus*, Bacon hardly mentions *induction.* He also hardly mentions it in the *Advancement of Learning* (1605), but in this published work the few mentions are in contexts more like those that will follow in *Novum Organum*. Bacon lists induction and deduction together as two kinds of demonstration, for example.[42] He says that the form of induction used by the logicians is "utterly vicious and incompetent."[43] Induction may have little prominence, but other themes first seen in *Valerius Terminus* and to be central in *Novum Organum* receive full force. For example, the Ramists are to be commended for reintroducing Aristotle's rules of de omni and per se (though for little else),[44] the highest and most urgent form of knowledge is the finding of formal causes,[45] and current methods of doing so are corrupt. One important new development in this 1605 work is a sentence that Bacon will simplify and later use repeatedly: "For arguments consist of propositions, and propositions of words, and words are but the current tokens or marks of popular notions of things."[46] The relations between this and induction, to be central in *Novum Organum*, are left unexplored. For the first time also, Bacon

[42] *Advancement of Learning*, 2.14.12. His inclusion here of "demonstration in orb or circle" requires further research. I think he is referring to regressus.

[43] *Advancement of Learning*, 2.8.3.

[44] *Advancement of Learning*, 2.17.12. Here Bacon uses Aristotle's Greek terms rather than Ramist's modern ones.

[45] *Advancement of Learning*, 2.7.5–6.

[46] *Advancement of Learning*, 2.8.4.

associates induction with Socrates, "a true and unfeigned inquisitor of truth,"[47] but finds Socrates' use of induction unstructured.

From 1603 to 1607, Bacon developed in his writings the ideas that the material conditions of life can be advanced by attending to Aristotle's rules of 'de omni' and 'per se,' that these rules can be followed by identifying formal causes, that 'certainty' and 'liberty' in action will result, and that the previous method of identifying formal causes, 'anticipation,' should be replaced by a new methodology, the 'interpretation of nature.' Induction was on the sidelines and its relationship to all this, if any, was left unclear. But that changed in 1607, in the manuscripts *Partis Instaurationis Secundae Delineatio et Argumentum* and *Cogitata et Visa de Interpretatione Naturae*. Induction took a prominent role and Bacon started referring to his whole doctrine as "my inductive philosophy."[48] The themes and positions presented in these two works are similar enough to those in *Novum Organum*, on which Bacon began work in 1608, that we may examine them in the mature work, published in 1620.

The *Novum Organum*

When Bacon's magnum opus was published he was the king's Lord Chancellor, and this fact is prominently announced on the book's title-page. Indeed on that elaborately engraved page, printed by the king's printer, Bacon's title is

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[47] *Advancement of Learning*, 2.1.6

[48] *Cogitata et Visa*, Farrington, 100.

elegantly set larger than the book's own. The image of a ship between two pillars recalls England's mighty maritime successes. Appearing just after this title-page, but before the dedication to the king is a short encomium, reading like a modern dust-jacket blurb. In it, the Lord Chancellor calls for a "wholesale *Instauratio [Renewal]* of the sciences, arts and all human learning."[49] The book has the grand title, *Instauratio Magna [the Great Renewal].* It is written in Latin. It appears splendid, weighty, and authoritative,[50] reminiscent perhaps of that edition of Aristotle's *Organon* that so offended Bacon when he first arrived at Cambridge.

The work must have appeared a disappointment, however. The first thirty-six pages of the encomium, dedicatory letter, preface, and *Distributio Operis (Outline of the Work)* refer to a forthcoming six-part *Instauratio*. But these are followed by a one-page announcement that the first of the six parts is missing and that the second part will be presented only in summary form. A look at the back of the book shows that the third, fourth, fifth, and sixth parts are also missing. The second part, and thus virtually the whole of the *Instauratio Magna*, is entitled *Novum Organum*.[51] It

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[49] "Scientiarum, & Artium, atque omnis Humanae Doctrinae, in vniuersum Instauratio."

[50] For details on the first printing and bindings, see "Introduction," xcviii–cxxiii, in Francis Bacon, *The Instauratio magna Part II: Novum Organum and Associated Texts*, ed. Graham Rees, vol. 11, *The Oxford Francis Bacon* (Oxford: Clarendon Press, 2004). See especially xcix for the solemnity of the first large-paper copies.

[51] It was not long before the work was commonly called by the name of its largest part. The 1650 edition is entitled *Novum Organum Scientiarum.* Bacon's editor Rawley referred to the work as *Instauratio Magna* in 1657, in Francis Bacon, *Resuscitatio, or, Bringing into publick light severall pieces.*, ed. William Rawley (London: Sarah Griffin for William Lee, 1657), b2v–c4r. Just a year later,

appears that the Lord Chancellor believed that the great renewal of all human learning comes down to the need to replace Aristotle's *Organon*.

The new *Organon*, however, is not a complete rejection of the old. In fact, Bacon begins by situating his whole project in an Aristotelian context, as can be seen by examining the language of the outline that Bacon offers in the *Distributio Operis* and reading it in the context of our earlier discussions of Zabarealla, Digby, Temple, and Case, that is, in the context of contemporary Aristotelian discourse. Note that this outline is the reader's first introduction to the main section of the book. The book is written by a senior government official. It concerns a subject, the advancement of knowledge and learning in the kingdom, that should make the book widely read. Considering all this, it is remarkable how much technical Aristotelian vocabulary and how many technical Aristotelian issues Bacon broaches without introduction, explanation, or reminder. He clearly expects the reader to have a general knowledge of the old *Organon*.

Without delay, Bacon announces in this outline that he will propose a doctrine for "a better and more perfect use of reason, in the investigation of things."[52] His proposal is thus for a new kind of logic, similar in some ways to the old, but in other ways, he says, separated by a great and even vast difference. The

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however, a Latin edition appeared in Francis Bacon, *Opuscula varia posthuma, philosophica, civilia, et theologica*, ed. William Rawley (London: R. Danielis, 1658), 3v–**7r, and in this edition, Rawley referred to the work as *Novum Organum.*

[52] "de meliore & perfectiore vsu rationis in Rerum inquisitione." Silverthorne, 15.

old type "claims to devise and prepare assistants and supports for the intellect"[53] and in this way is like Bacon's new logic, but the new differs from the old in three primary ways. The first is in its end. The end or goal of the old logic is disputatious argumentation. The goal of the new is practical application. While the old is capable of only "probable reasonings,"[54] the new seeks reliable and certain guides to action.

Out of context, it might be unclear at this point which old logic Bacon is attacking, whether Aristotelian logic, scholastic logic, humanist topics-logic, or Ramist define-and-divide logic. The reference to 'probable reasonings' might suggest he is attacking the humanist methods that emerged in the previous century and that focused more on non-demonstrative tools of oratorical influence, tools that could be criticized for their lack of rigor. But the title and what soon follows make it clear. The new *Organon* is a direct alternative to the old, and the disputatious argumentation of the old *Organon* is not humanist, Ciceronian oratory. It is the academic exercise that was still the mainstay of academic training in Aristotelian logic. Such disputations were a stock object of humanist criticism, and Bacon is joining the humanists in the attack. Also situating himself with the humanists, he says his new logic will be used in "what we are accustomed to call the *Interpretation*

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[53] "auxilia & praesidia Intellectui moliri ac parare profitetur." Silverthorne, 15.

[54] "Rationes probabiles." Silverthorne, 16. Note the inversion of modern understanding. For Bacon, deduction can generate only probable conclusions. Induction can generate certain ones.

of Nature."[55] The italicized phrase becomes prominent in the *Novum Organum*, and Bacon is famous for it.[56] But Bacon does not say it is original with him. In fact, Pico della Mirandola had said in 1486 that many people were calling man the "interpreter of nature,"[57] and this was a common theme in several Renaissance sources.[58] Bacon thus appears at this point as just another humanist educational reformer, and in a way he is. But unlike some such reformers, he conspicuously situates his new logic within the established Aristotelian framework.

The second difference between the old logic and his new one, Bacon says, is in the order of demonstration. He explains this in paragraphs so packed with Aristotelian reference, so crucial for situating Bacon's project in its Aristotelian

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[55] "quam *Interpretatione Naturae* appellare consueuimus." My translation.

[56] The *Oxford English Dictionary* gives Bacon's use pride of place, noting it immediately after the first definition of interpretation and suggesting Bacon as the originator: "*Interpretation of Nature:* a phrase used by Bacon to denote the discovery of natural laws by means of induction." q.v. "interpretation."

[57] "On thinking over the reason for these sayings, I was not satisfied by the many assertions made by many men concerning the outstandingness of human nature: that man is the messenger between creatures, familiar with the upper and king of the lower; by the sharpsightedness of the senses, by the hunting-power of reason, and by the light of intelligence, the interpreter of nature; the part in between the standstill of eternity and the flow of time; and, as the Persians say, the bond tying the world together, nay, the nuptial bond; and, according to David, 'a little lower than the angels.'" Giovanni Pico della Mirandola, *Oration on the Dignity of Man*, trans. Charles Glenn Wallis (Indianapolis: Bobbs-Merrill, 1965), 3. My thanks to Sophie Weeks of Leeds University for pointing this out to me.

[58] Rossi, *Francis Bacon: From Magic to Science*, 16. Paolo Rossi, "Bacon's Idea of Science," in *The Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 31

framework, and so easily overlooked, that it is worth quoting the passage in full and glossing it in detail. I italicize phrases or terms that refer to specific and technical topics in Aristotelian scholarship, pedagogy, or contemporary debate. Note how many there are. For now I excise sentences in which Bacon elaborates on why he rejects the syllogism. We will return to those later.

> The nature and order of our *demonstrations* agree with such an end [practical use instead of disputation]. For in ordinary logic almost all effort is concentrated on the *syllogism*. The logicians seem scarcely to have thought about *induction*. They *pass it by with barely a mention*, and hurry on to their formulae for *disputation*. But we reject *demonstration by syllogism*, because it operates *in confusion* . . . . We reject the *syllogism*; and not only so far as *principles* are concerned *(they do not use it for that either)* but also for *intermediate propositions*, which the *syllogism* admittedly *deduces* and generates in a fashion, but is incapable of producing works, quite divorced from practice and completely irrelevant to the active part of the sciences. For even if we leave to the *syllogism* and similar *celebrated but notorious kinds of demonstration* jurisdiction over the *popular arts which are based on opinion* (for we have no ambitions in this area), still for the nature of things we use *induction* throughout, and as much for the *minor propositions* as for the *major* ones. For we regard *induction* as the form of *demonstration* which respects the senses, stays close to nature, fosters results and is almost involved in them itself.
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> And so the order of *demonstration* also is completely reversed. For the way the thing has normally been done until now is to *leap immediately* from sense and particulars to the *most general propositions*, as to fixed poles around which *disputations* may revolve; then to *derive* everything else from them by means of *intermediate propositions*; which is certainly a

short route, but precipitate, inaccessible to nature and inherently prone to *disputations*. By contrast, by our method, *axioms* are gradually elicited step by step, so that we reach the *most general axioms* only at the very end; and the *most general axioms* come out not as *notional*, but as well defined, and such as nature acknowledges as truly *known to her*,[59] and which adhere in the core of things.

By far the biggest question we raise is as to the actual form of *induction*, and of the *judgement* made on the basis of *induction*. For the form of *induction* which the logicians speak of, which proceeds by *simple enumeration*, is a childish thing, which *concludes precariously*, is exposed to the danger of *instant contradiction*, observes only familiar things, and reaches no result.

What the sciences need is a new form of *induction*.[60]

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[59] I will not discuss this reference. It is explored by Kosman, "The Aristotelian Backgrounds of Bacon's *Novum Organum*," 172–179.

[60] "Atque cum hujusmodi fine conveniunt demonstrationum ipsarum natura et ordo. In logica enim vulgari opera fere universa circa Syllogismum consumitur. De Inductione vero Dialectici vix serio cogitasse videntur; levi mentione eam transmittentes, et ad disputandi formulas properantes. . . . Rejicimus igitur syllogismum; neque id solum quoad principia (ad quae nec illi eam adhibent) sed etiam quoad propositiones medias, quas educit sane atque parturit utcunque syllogismus, sed operum steriles et a practica remotas et plane quoad partem activam scientiarum incompetentes. Quamvis igitur relinquamus syllogismo et hujusmodi demonstrationibus famosis ac jactatis jurisdictionem in artes populares et opinabiles (nil enim in hac parte movemus), tamen ad naturam rerum Inductione per omnia, et tam ad minores propositiones quam ad majores, utimur. Inductionem enim censemus eam esse demonstrandi formam, quae sensum tuetur et naturam premit et operibus imminet ac fere immiscetur.

"Itaque ordo quoque demonstrandi plane invertitur. Adhuc enim res ita geri consuevit; ut a sensu et particularibus primo loco ad maxime generalia advoletur, tanquam ad polos fixos circa quos disputationes vertantur; ab illis caetera per media deriventur: via certe compendiaria, sed praecipiti, et ad naturam impervia, ad disputationes vero proclivi et accommodata. At secundum nos, axiomata

In this passage, so very early in the book, Bacon uses a wealth of Aristotelian vocabulary without preface or introduction. He presumes his reader is familiar with these terms. Three of these terms are *demonstration*, *syllogism* and *induction*.[61] Bacon claims that syllogism and induction are two kinds of demonstration. The relation between induction, syllogism, and demonstration had always been a

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continenter et gradatim excitantur, ut nonnisi postremo loco ad generalissima veniatur: ea vero generalissima evadunt non notionalia, sed bene terminata, et talia quae natura ut revera sibi notiora agnoscat, quaeque rebus haereant in medullis.

"At in forma ipsa quoque inductionis, et judicio quod per eam fit, opus longe maximum movemus. Ea enim de qua dialectici loquuntur, quae procedit per enumerationem simplicem, puerile quiddam est, et precario concludit, et periculo ab instantia contradictoria exponitur, et consueta tantum intuetur, nec exitum reperit.

"Atqui opus est ad scientias inductionis forma tali."

Silverthorne, pp. 15–16. "is incapable of producing works" for Silverthorne's "without effects" for Bacon's "operum steriles." "adhere in the core of things" for Silverthorne's "live in the very heart of things" for Bacon's "rebus haereant in medullis." "reject demonstration by syllogism" for Silverthorne's "reject proof by syllogism" for Bacon's "demonstrationem per Syllogismum reijcimus." "precipitate" for Silverthorne's "dangerously steep" for Bacon's "praecipiti." On this last, I adopt Spedding's translation. Bacon's choice is powerful but difficult to render in current English. English now has two words, *precipitous* meaning 'steep' and *precipitate* meaning 'headlong,' the first a property of the decline, the second a property of someone falling down it. Into the nineteenth century, each could carry the other's meaning. It might seem *precipitous* is the more natural, but a subtlety in Bacon's statement is then missed. In the Latin, "praecipiti" is genitive, not nominitive, as the noun it modifies is. That noun, "via," is by the end of the sentence slightly anthropomorphized, being prone to argument. Though slightly Victorian and admittedly anachronistic, I have adopted Spedding's choice in an effort to capture what I think is Bacon's intent.

[61] When Bacon sent King James a copy of the Novum Organum, he provided this overview, "The work . . . is no more but a new logic, teaching to invent and judge by induction, (as finding syllogism incompetent for sciences of nature)," (Spedding 14:120) as if the King of England needed no introduction to the concepts or importance of syllogism and induction. Based on the reply, it seems the King had no difficulty understanding (Spedding 14:122).

contentious issue, but never was induction considered to have the demonstrative certainty that Bacon is now claiming for it. Bacon's claim that he will leave the syllogism and other celebrated kinds of demonstration (cataloguing the various forms and derivatives of the syllogism was a staple of scholastic training) to 'popular arts which are based on opinion' is a reference to university training in dialectics. A theme of dialectics, going back to Aristotle's *Topics*, is that in one-on-one debate one should get an opponent to first accept some commonly held belief, an 'opinion,' and then to argue deductively from it. Broadly, this is the method of the common university disputation (with the emphasis on the deductive part) and, approached from a different direction (with an emphasis on the appeal to persuasion and opinion), the theme of Ciceronian oratory so popular in Renaissance humanism. Bacon is proposing a remarkable inversion here (and particularly remarkable for a lawyer). He says that the syllogism can be left to the less rigorous field of popular persuasion or to the common and frivolous university disputations, but for the reliability and certainty desired in natural philosophy, induction is the proper type of demonstration.

Bacon does not claim to introduce induction for the first time. He recognizes that it is already a standard part of logic. But the logicians 'pass it by with barely a mention.' He has textbooks on Aristotelian logic in mind. Since at least Peter of Spain's textbook in the thirteenth century, induction had a canonical place in scholastic pedagogy. Thomas Wilson's *Rule of Reason* (1551),[62] the first logic book in English and a popular one in Bacon's school days,[63] is representative of the objects of Bacon's attack. In Wilson's text, after extensive treatment of the syllogism and its forms, figures, moods, rules, conversions, etc. across many pages, there are just two-and-a-half short pages on induction. An induction is described as a kind of argument that reaches a universal conclusion by gathering a sufficient number of particulars. Wilson's example is this: "Rhenyshe wine heateth; Maluesey [wine] heateth; Frenche wine heateth, neither is there any wyne that doth the contrary; Ergo all wine heateth."[64] The only guidance Wilson offers regarding whether such an argument is valid is that "if any [of the particulars] be found contrary, the Argument is of no force."[65] As an example of an invalid induction, he presents the example of unmarried bishops. He lists several who were unmarried and draws the conclusion that all were. But the argument is instantly refuted when it is discovered that several bishops in the early church were unmarried. It is this 'simple enumeration' that Bacon said is a 'childish thing which concludes precariously.' It 'reaches no result' because the conclusion cannot be applied to unobserved

[62] Thomas Wilson, *The rule of reason, conteinyng the arte of logique, set forth in Englishe* (London: Richard Grafton, 1551).

[63] Bacon himself probably used Seton, *Dialectica*, since this was what Whitgift usually used with his students. Jardine and Stewart, *Hostage to Fortune: The Troubled Life of Francis Bacon*, 35. Seton is in Latin and follows the same basic canonical pattern though, as discussed earlier, with some eclecticism and humanist accretions.

[64] Wilson, *The rule of reason*, H5r.

[65] Ibid., H6v.

instances without 'the danger of instant contradiction.' Bacon will propose a new kind of induction that safely goes beyond the instances observed.

A repeated theme of this early passage in the *Distributio Operis* is that Bacon will use induction not just for major premises ('principia,' 'mairoes,' or 'maxime generalia'), but for minor propositions ('propositiones medias,' 'minores,' or 'media') as well. Bacon is here referring to a specific technical issue in contemporary Aristotelian scholarship and is contrasting himself with men such as Zabarella and Digby. To see what Bacon means, recall Zabarellian regressus. A regressus is composed of two syllogisms, such as these:

Knowledge of the fact:	Knowledge of the reasoned fact:
MAJOR: What does not twinkle is near.	MAJOR: What is near does not twinkle.
MINOR: Planets do not twinkle.	MINOR: Planets are near.
Therefore, planets are near.	Therefore, planets do not twinkle.

Each syllogism has a major proposition, a minor proposition, and a conclusion. In both syllogisms, as we saw in Zabarella, the major is obtained by induction. (As Bacon says, 'They do not use [deduction] for that either.') But deduction is used to obtain the minors. For the conclusion of one syllogism 'deduces and generates in a fashion' the minor premise of the other. The conclusion of one becomes the minor of the other. In the common logic, therefore, induction is used to obtain the major, deduction to obtain the minor. Bacon says he instead will use induction for both.[66]

[66] Bacon is responding to Renaissance Aristotelians, not Aristotle himself. I do not claim they were interpreting Aristotle correctly on this point. For an 'inductive middle' in Aristotle, cf. *Posterior Analytics*, 1.12, 77b35, and *Prior Analytics*, 2.23, as discussed in chapter 1.

The problem with the common system, Bacon says, is that it is incapable of guiding practical works. One reason is that it is incapable of ascertaining what is an effect and what is a cause. Consider an example widely discussed in the twentieth century, a flagpole casting a shadow.[67] Knowing the shadow is long, one can conclude that the flagpole is tall; and similarly, knowing the flagpole is tall, one can conclude that the shadow is long. But for practical works, it is important to know that the height of the flagpole causes the long shadow and not the other way around.[68] The method of natural philosophy advocated by Renaissance Aristotelians such as Zabarella and Digby cannot determine which is the cause. Their whole process, says Bacon, 'operates in confusion,' ('confusius agat'). Indeed Digby and Zabarella admit as much. They say their systems begin with a syllogism understood confusedly ('confuse'). They both claim to escape the confusion by the experience of a contemplative insight that leads to clear and distinct knowledge. By that insight, they say, one sees which is cause and which effect. Bacon finds this proposal empty and useless. As far as he is concerned the syllogistic process, as advocated by Aristotelians of the time, is infected with confusion from beginning to end, and thus wholly incapable of satisfying the proper goal of knowledge: practical works.

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[67] An example attributed to Sylvain Bromberger.

[68] Bacon gives an example of a shiny and smooth stone. It is crucial, he says, to recognize that being smooth is the cause, being shiny is the effect. *Valerius Terminus*, Spedding 2:240.

Moreover, Bacon contends that not only development of the minor propositions, but even development of the major—the part of the process supposedly inductive—is flawed. It begins in sense and particulars and leaps ('advolat') to the most general principles or axioms. This is precisely how Digby described his system, using this very vocabulary. But while Digby considered this leap to be one of the highlights of his theory, Bacon attacks it as rash, wholly separated from nature, and subject to instant contradiction by a single observation (as with discovering a married bishop). Instead, Bacon insists, a new kind of induction is required by which propositions can be obtained incrementally and cautiously, reaching 'the most general axioms only at the very end.'

This brings us to the sentences, excised from the passage above, in which Bacon elaborates on why the syllogism has the problems it does. Instead of italicizing all the Aristotelian vocabulary again, I will emphasize one important statement.

> But we reject demonstration by syllogism, because it operates in confusion and lets nature slip out of our hands. For although no one could doubt that things which agree in a middle term, agree also with each other (which has a kind of mathematical certainty), nevertheless there is a kind of underlying fraud here, in that *a syllogism consists of propositions*, *and propositions consist of words*, *and words are the tokens and signs of notions*. And therefore if the very notions of the mind (which are like the soul of words, and the basis of every such structure and fabric) are badly or carelessly abstracted from things, and are vague and not

defined with sufficiently clear outlines, and thus deficient in many ways, everything falls to pieces. And therefore we reject the syllogism.[69]

The statement I have italicized is central to Bacon's thought. He made the claim earlier in the *Advancement of Learning*,[70] repeats it in the body of the *Novum Organum*,[71] and again later with fuller treatment in *De Augmentis*.[72] The statement introduces the term *notion* or *notio*, a term too often overlooked by Bacon's commentators. An understanding of what Bacon means by *notion* is crucial for understanding his induction as well as his 'forms' and 'idols,' to understanding what he is railing against in contemporary Aristotelianism, and to understanding how he proposes to give induction demonstrative certainty. As with other vocabulary in this section of the *Distributio Operis*, Bacon is using, in *notio*, a term out of Aristotelian scholarship of the 1580s and 1590s.

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[69] "At nos demonstrationem per Syllogismum reijcimus, quod confusius agat, & Naturam emittat e manibus. Tametsi enim nemini dubium esse possit, quin, quae in medio termino conueniunt, ea & inter se conueniant, (quod est Mathematicae cuiusdam certitudinis), nihilominus hoc subset fraudis, quod Syllogismus ex propositionibus constet, propositiones ex verbis, verba autem notionum tesserae & signa sint. Itaque si Notiones ipsae mentis (quae verborum quasi anima sunt, & totius huiusmodi structurae ac fabricae basis) male ac temere a rebus abstractae, & vagae, nec satis definitae & circumscriptae, denique multis modis vitiosae fuerint, omnia ruunt." Silverthorne, p. 16., italics added. "tokens" for Silverthorne's "counters" for Bacon's "tesserae." Bacon himself uses "tokens" when he makes the same statement in English in *Advancement of Learning*, 2.13.4.

[70] *Advancement of Learning*, 2.13.4.

[71] *Novum Organum*, 1.14.

[72] *De Augmentis*, 5.2, 4:411, 1:621.

The term *notio* comes from discussions about the problem of universals. The problem is to identify to what universal terms refer, and discussion of the problem goes back to Socrates. Plato held that the universal is a real but incorporeal exemplar, an exemplar which Augustine later located in the mind of God. Aristotle proposed that the universal is inherent in all individual members of the group. Both proposals have problems that attracted the attention of several medieval thinkers. One difficulty early medieval philosophers had in exploring the issue was a paucity of vocabulary. They found no well-defined equivalent in Aristotle for what we today call a concept, the unit of thought that corresponds to a word.[73] The investigations were greatly aided in the early twelfth century by availability of Avicenna's commentary, for Avicenna did have a word for *concept*. Latin translators translated it as *intention*, and that term was commonly used through the remaining scholastic period. In the late sixteenth and early seventeenth century, however, a few other words came to replace it. By then Plato had become better known and among his sympathizers, *ideas* was used. Cicero, favorite of the humanists, had used *notio*,[74] and this gained currency among Aristotelians, Ramists, and theologians. In 1584, the continental writer Julius Pacius, in commentary on the *Organon*, equated

[73] It seems that *noēma* might qualify. But the only time it appears in the *Organon*, at *De Interpretatione* 1.2, 16a10 and 16a14 (a part of the *Organon* to which early medieval thinkers had access), it clearly includes propositions, a unit of thought larger than that of a word. Outside the *Organon* (i.e., in parts of the corpus only later rediscovered), Aristotle discusses *noēma* at *De Anima* 3.6, *De memoria et reminiscentia* 450b29 and 451a1, *Metaphysics* 981a6, 990b25, 1009b25, and 1079a21, and *Politics* 1259a7. My thanks to Greg Salmieri for discussion on this issue.

[74] See Lewis and Short, *A Latin Dictionary*, s.v. "notio" for several examples.

notio and *intentio*,[75] and John Case used *notio* in his 1599 *Lapis Philosophicus*.[76] Bacon picked up this term and it became central to his project.[77] (He occasionally used *conceit*, *conception*, and *conceptus*, also.[78])

Though Bacon adopted the term *notion*, he took discussion of it in a new direction. He notices that concept-formation is a normative process. It can be done properly or improperly. For Bacon, there is such a thing as a poorly formed concept. As he said above, 'If the very notions of the mind . . . are badly or carelessly abstracted from things, and are vague and not defined with sufficiently clear outlines, . . . everything falls to pieces.' Specifically what falls to pieces are propositions and anything—including syllogisms—that are based on them. Thus Bacon rejects the syllogism as the foundation of reasoning in natural philosophy. The correct foundation is the proper formation of notions.

It should be made clear that Bacon does not reject syllogistic reasoning altogether. In this very passage he points out that it can have mathematical certainty, and he gives an example where its use is appropriate. In *de Augmentis*, he

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[75] *Oxford English Dictionary Online*, Second Edition 1989, s.v. "intention," cites this as possibly the earliest such equation in print.

[76] Case, *Lapis Philosophicus*, 35.

[77] Until the late sixteenth century, *notio* simply meant 'understanding' or 'knowledge,' as evidenced, for example, by many dictionaries. Then, Francis Gouldman, *A Copious Dictionary in Three Parts* (London: John Field, 1664) s.v. "notio," says that in philosophical contexts, *notio* is a technical term equivalent to the Greek *noēma*. (See footnote above.) *Oxford English Dictionary Online*, Draft Revision Dec. 2003, s.v. "notion," says that the new usage was very common in the seventeenth and eighteenth centuries, especially in the phrase "under the notion of."

[78] E.g., *Advancement of Learning*, 2.16.3, 2.7.2; *Cogitata et Visa*, Spedding, 3:607, respectively.

provides a short inventory of kinds of reasoning, including the syllogism, and the situations in which each is best used.[79] In the Preface to the *Novum Organum*, he says he does not intend to discourage use of syllogistic reasoning where it is appropriate.[80] After the *Novum Organum* was published Bacon replied to an Italian reader, saying he "does not propose to give up syllogism altogether. . . . In the Mathematics [for example] there is no reason why it should not be employed."[81] The context for his attack must be remembered. Bacon is offering a replacement to the old *Organon*, and the old *Organon* was understood to be the document that laid out the syllogism as the foundation for scientific reasoning. Bacon is not challenging the validity but merely the role of the syllogism.

The third way in which Bacon says his logic is different from the old is the starting points of inquiry. It is here that Bacon explains the typical causes and the pernicious effects of poorly formed notions. He calls poorly formed notions *idols*, another word he uses without introduction or explanation and the word John Case used in 1599 with the same distinctive meaning.[82] Bacon then explains how notions can be properly formed, that is, how idols can be avoided, by adopting the proper starting points of inquiry. Since this proposal is the core of the *Novum Organum*, it will be examined in detail below. Bacon closes the outline of the *Novum Organum*

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[79] *De Augmentis*, 5.4, Spedding 4:434, 1:646.

[80] "Preface," Silverthorne, 29.

[81] "Non est meum abdicare in totum syllogismum. . . . Ad Mathematica quidni adhibeatur?" Letter to Father Redemptus Baranzan, July, 1622, Spedding 14:375. Spedding's translation.

[82] Case, *Lapis Philosophicus*, 34.

by saying that his system consists of three *redargutiones*. Though typically translated as *refutations*, the choice masks the reference. Though Bacon uses it many times, *redargutio* was an uncommon Latin word. Its most prominent medieval use was as translation for the Greek *elenches* in the title of the last book of Aristotle's *Organon*, the book called *Peri Sophistikōn Elenchēōs*, or *On Sophistical Refutations*. Bacon thus ends the outline of his new *Organon* where Aristotle's ended, with redargutions.

From beginning to end, this short outline of the *New Organon* that Bacon provides in his prefatory material is steeped in the Aristotelian language and discourse of the 1580s and 1590s. It is Bacon's intention to challenge the foundation of that Aristotelian scholarship and he expects his work to be read by those familiar with it.

Notions and Idols

The fundamental concept of the *Novum Organum* is not *induction*, *form*, *idol*, *interpretation of nature*, or *prerogative instance*. All these are important, but they can be properly understood and interrelated only by reference to the more fundamental *notion*. A notion, for Bacon, is a unit of thought signified by a word.[83] That is, its scope is smaller than that of a treatise, a paragraph, or a proposition, and broader than that of a sense-perception. Its foundation, however, is sense-perception. Bacon

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[83] This is not strictly true. There are a few cases where Bacon cites a notion marked by a two-word phrase. For example, in *Novum Organum*, 2.19, he gives this list of "vague and poorly defined" notions: "the notion of an elementary nature, the notion of a heavenly nature, the notion of rarity." Also, see below about ideograms and gestures.

recognizes no other source of knowledge about nature. In the very first aphorism of the *Novum Organum*, Bacon says that man can understand no more than what he has observed or what he has derived from what he has observed.[84] At the same time, Bacon acknowledges that the senses are limited. The eyes cannot see things far away or things very small. The skin is limited in its ability to detect differences in temperature. But from this fact he does not draw the conclusion of "Sceptics and Academics" that no knowledge is possible beyond "appearances and probabilities."[85] "Their great error was, that they laid the blame upon the perceptions of the sense, and therefore pulled up the sciences by the very roots. . . . They ought rather to have charged the defect upon the mind."[86] For the senses are fully capable of certifying and reporting truth, if they are properly aided.[87] Instruments such as telescopes, microscopes, and thermometers are one kind of aid, but not the most important. The most important is a proper method by which the mind processes the evidence of the senses, that is, the method by which the mind forms notions.

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[84] "Homo Naturae minister, & Interpres, tantum facit, & intellegit, quantum de Naturae Ordine, re vel mente, obseruauerit, nec amplius scit, aut potest." "Man is Nature's agent and interpreter; he does and understands only as much as he has observed of the order of nature in fact or by inference; he does not know and cannot do more." *Novum Organum*, 1.1.

[85] "Academici . . . et Sceptici." "verisimilitudinem aut probabilitatem." *De Augmentis*, 5.2, 4:411–2, 1:621 Cf. *Advancement of Learning*, 2.13.4.

[86] "Verum in hoc maxime ab illis peccatum est, quod sensuum perceptions calumniabantur; unde Scientias radicitus evellebant. . . . Debuerant autem potius defectum hac in parte imputasse mentis." *De Augmentis*, 5.2, 4:412, 1:622.

[87] Preface, Silverthorne, 28.

A few pages into the *Novum Organum*, Bacon repeats what he said in the *Advancement of Learning* and the *Distributio Operis*, "The syllogism consists of propositions, propositions consist of words, and words are the tokens of notions. Hence if the notions themselves . . . are confused and abstracted from things without care, there is nothing in what is built on them."[88] Note Bacon's use again of 'confused,' and also his use of the modern 'abstracted.' *Abstraction* is not the common scholastic verb for the process of developing concepts from sense-perceptions, but Bacon uses it frequently for this, and the term became standard after him. Bacon believes that this process can be done well or poorly. That is, abstraction is a normative process. Without well-defined concepts, Bacon believes, not only can one not communicate clearly, one cannot think clearly. This is the fundamental idea of the *Novum Organum*, the one that makes it possible to fully understand Bacon's 'induction,' 'idols,' 'forms,' 'tables,' 'instances,' and so on.

Bacon justifies this position by appealing to a combination of a basic fact about nature and a basic fact about the mind. The first is that "nothing exists in nature except individual bodies."[89] (Bacon rejects the possibility of Platonic ideals or attributes without bodies.) The second is that the human mind has a difficult time dealing with a large number of individual bodies. So, Bacon says, the mind

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[88] "Syllogismus ex Propositionibus constat, propositiones ex verbis, verba Notionum tesserae sunt. Itaque si notiones ipsae . . . confusae sint, & temere a rebus abstractae, nihil in ijs, quae superstruuntur, est firmitudinis." *Novum Organum*, 1.14. Again, "tokens" for Silverthorne's "counters."

[89] "Licet enim in Natura nihil vere existat praeter Corpora individua."*Novum Organum*, 2.2.

tries to find order among the many and then to group individual bodies or their properties into "bundles,"[90] the mental units that Bacon calls *notions*. But notions too are difficult to retain. So the mind associates with each notion an 'emblem.' "An emblem reduces the intellectual to the sensible."[91] These sensible images could be the hieroglyphics of Egypt, the ideograms of China, the gestures of speechless people,[92] anything that "can be divided into differences sufficiently numerous to explain the variety of notions (provided those differences be perceptible to the sense)."[93] A word is one kind of emblem.

The definition of a word or of a notion identifies contents of the bundle, but if the definition is confused, attempts to use the word or notion—not just in practice or communication, but even in personal thought—fail. Consider, for example, the concept *wet*. Bacon says it is poorly defined. "The word 'wet' is simply an undiscriminating token for different actions which have no constancy or common denominator."[94] Bacon gives several definitions, all of which sound plausible, but he then points out that by one definition flame is wet, by another glass is, by another a speck of dust is. This confusion hinders clear thinking.

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[90] "manipulos."*De Augmentis*, 5.5, 4:436–7, 1:648–9. *Novum Organum*, 2.25.

[91] "Emblema vero deducit intellectuale ad sensible." *De Augmentis*, 5.5, 4:437, 1:649. My translation.

[92] *Advancement of Learning*, 2.16.3. *De Augmentis*, 6.1, 4:439–40, 1:651–2.

[93] *Advancement of Learning*, 2.16.2.

[94] *Novum Organum*, 1.60. "*Humidum*, nihil aliud quam nota confusa diuersarum actionum, quae nullam constantiam aut reductionem patiuntur."

Though Bacon adopted Case's term *idol* for an ill-formed notion, he gave the term a new precision and centrality. Before examining what idols are, it is worth discussing what they are not, for the meaning of the term has been confused in the history of Baconian scholarship and is getting more so as we become further removed from the Aristotelian context in which Bacon wrote. Latin *idolum* is a transliteration of the Greek *eidolōn*, and was understood to be so in the seventeenth century.[95] The standard dictionary definition was 'image.'[96] Plato uses *eidolōn* for a shadow on the wall in his parable of the cave. John Case uses *idolum* as a synonym for *phantasma*. Bacon equates *idola* with *imagines*.[97] In medieval Christianity, *idolatry* is the worship of images, and by extension, an *idol* could be a 'false god.'[98] But in the late sixteenth century and continuing into the time of Bacon's writings, 'false god' was a derivative and secondary meaning. It is certainly not the meaning that would first come to mind if the word were used without prefatory remarks in a philosophical treatise written in Latin and claiming to be the new *Organon*. The association might not go unnoticed, however, especially after Bacon describes the

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[95] E.g., Francis Holy-Oke, *Dictionarium Etymologicum Latinum.* (London: Adam Islip and Felix Kyngston, 1633); Gouldman, *A Copious Dictionary in Three Parts*; Elisha Coles, *A dictionary, English-Latin, and Latin-English* (London: 1679); s.v. "idolum."

[96] E.g., John Veron, *A dictionarie in Latine and English.* (London: Rafe Newberie and Henrie Denham, 1584); Holy-Oke, *Dictionarium Etymologicum Latinum.*; Gouldman, *A Copious Dictionary in Three Parts*; Coles, *A dictionary, English-Latin, and Latin-English*; s.v. "idolum."

[97] *De Augmentis*, 5.4, 1:643;.

[98] *Oxford English Dictionary*, second edition, s.v. "idol," claims that this was the more common Middle English use and that the meaning discussed here entered English in the mid-sixteenth century with increased interest in ancient Latin and Greek philosophy.

problems that these false notions can cause. Bacon's choice demonstrates his talent as a writer, but it did lead to future confusion. By the time of Johnson's *Dictionary of the English Language* (1755), the literal Greek and Latin meaning for the English *idol* had become secondary. Henry Hallam in 1872 and Thomas Fowler in 1889, both scholars of early modern Latin literature, took their colleagues and recent predecessors to task for reading Bacon's 'idola' as nineteenth-century 'idols.'[99] By the twentieth century, the literal meaning was largely forgotten, but commentators knew that Bacon did not take *idola* to literally mean a false god. To understand what he did mean, they read about the damage caused by Baconian idols, and inferred what Bacon could have meant by the term. In doing so, they read back into Bacon a much broader meaning that he intended. They concluded that *idols* is Bacon's name for a whole host of problems that hinder clear thinking, including "paradoxes,"[100] "prejudices and preconceptions,"[101] and incorrect "philosophical systems,"[102] to take just a few from the recent *Cambridge Companion to Bacon*, or to take the grab-bag that Graham Rees uses, "pernicious illusions, prejudices, mental

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[99] Henry Hallam, *Introduction to Literature of Europe in the Fifteenth, Sixteenth, and Seventeenth Centuries*, New ed., 4 vols. (London: John Urray, 1872), 3:44–6; Bacon, *Bacon's Novum Organum*, 204.

[100] Sachiko Kusukawa, "Bacon's Classification of Knowledge," in *The Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 63.

[101] John Channing Briggs, "Bacon's Science and Religion," Ibid., 196.

[102] Ian Box, "Bacon's Moral Philosophy," Ibid., 260.

habits and false perceptions."[103] Idols may cause all these, but the idols themselves are not these. Idols are something quite specific. They are poorly-defined concepts or notions. If we fail to recognize this, we will not understand exactly why Bacon thinks his new induction will solve the problems of idols.

Across all his writings, Bacon identifies five kinds of idols, three of one type, two of another.[104] Sometimes, as in *Novum Organum*, he treats each of the first three individually and leaves the other two grouped as one.[105] He thus describes four kinds of idols in the *Novum Organum*, and he gives each a name. Idols of the first kind are called 'idols of the tribe.'[106] These "are founded in human nature itself and in the very tribe or race of mankind."[107] Bacon identifies seven attributes of human nature that lead to this kind of idol. The first two[108] are a tendency to suppose a

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[103] Graham Rees, "Introduction [vol. XI]," in *The Instauratio magna Part II: Novum Organum and Associated Texts*, ed. Graham Rees, vol. 11, *The Oxford Francis Bacon* (Oxford: Clarendon Press, 2004), li.

[104] Idols are discussed in *Temporis partus masculus* (c.1602) Spedding 3:536; *Valerius Terminus* (c.1603) Spedding 3:241–5; *Advancement of Learning* (1605) 2.14.11; *Partis instaurationis secundae delineation* (c.1606–7) Spedding 3:547–557; *Novum Organum* (1620), 1.38–59; *De Augmentis* (1623), 5.4, 1:641–6, 4:431–4.

[105] For the taxonomy, see Walter H. O'Briant, "The Genesis, Definition, and Classification of Bacon's Idols," *The Southern Journal of Philosophy* 13, no. 1 (1975): 347–57; and Rees, "Introduction [vol. XI]," li–lvii.

[106] *Novum Organum*, 1.41, 1.45–52.

[107] *Novum Organum*, 1.41. "sunt fundata in ipsa Natura humana, atque in ipsa Tribu seu gente hominum."

[108] *Novum Organum*, 1.45, 1.46. In 1.45, Silverthorne falls into the trap of misunderstanding the precise meaning of *notio.* He generally and rightly reserves *notion* as the translation for Bacon's *notio.* But in this passage, in which Bacon refers to the 'commenta' that all heavenly bodies move in

greater uniformity in things than actually exists and a tendency to fit new experiences into judgments already made. The third cause[109] of idols of the tribe is that the mind's ability to categorize can be impaired by perceptions that leave overwhelming impressions, encouraging the mind to ignore less prominent subsequent experiences, but ones that that might be just as important. The fourth cause[110] is restlessness to order things into familiar categories. Bacon says this is particularly visible in the eagerness to find final causes in things for which no final cause exists. Fifth,[111] human understanding is subject to the influence of emotions. The sixth cause[112] is a failure to recognize the limitations of the senses and to sufficiently structure experiences and experiments to overcome these limitations. The seventh cause[113] is a tendency to fly off to high-level abstractions instead of looking to the material world for the essence of things. All seven of these tendencies are, Bacon believes, part of universal human nature, part of the very nature by which the mind performs its organizing function, but the prejudices, the

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circles, Silverthorne translates *commenta* as *notions*, overlooking the fact that for Bacon, a notion has the scope of a word, not a proposition (for which Bacon typically uses *axioma*) or complete theory (for which, in this passage, Bacon uses *dogma*). *Fictions* or *false dogmas* would have been a better translation for *commenta*.

[109] *Novum Organum*, 1.47.

[110] *Novum Organum*, 1.48.

[111] *Novum Organum*, 1.49.

[112] *Novum Organum*, 1.50.

[113] *Novum Organum*, 1.51.

susceptibilities, the restlessness, and so on are not idols. They are the causes of poorly formed notions, but not the poorly formed notions themselves.[114]

Idols of the second kind have their origin not in universal human nature, but in the particulars of each individual's life and character.[115] Some people, by training or disposition, are better at noticing differences, others at noticing similarities. Some admire antiquity, others novelty. Some are prone to concentrate on the simplicity of things, others on the complexity. All of these tendencies, if taken to extremes, can impair one's judgment. All can cause the formation of poorly defined notions. Such notions, when caused by these tendencies, are called 'idols of the cave,' so-called because they emerge from the idiosyncrasies of the little world in which each person lives.

Idols of the third kind have their source not in the individual life but in the communal. They arise not from life inside one's one cave, but from life out among others. These are called 'idols of the marketplace,'[116] and Bacon calls them the "biggest nuisance of all."[117] They arise as follows. One goes out into the world and finds people using words. One assumes that these words refer to things that actually exist and that the words are the signs of well-abstracted notions. Both assumptions are too often false. Of the former sort, Bacon says, are fortune, the first mover, heavenly spheres, fire as an element, and similar fictions. The notion *wet*, discussed

[114] *Novum Organum*, 1.52.

[115] *Novum Organum*, 1.42, 1.53–58.

[116] *Novum Organum*, 1.43, 1.59–60.

[117] "omnium molestissima." *Novum Organum*, 1.59.

earlier, is an example of the latter. One encounters the word and assumes its meaning is clear. But "words are mostly bestowed to suit the capacity of the common man, and they divide things along the lines most obvious to the common understanding."[118] The definition may be fine for the common understanding applied to common situations. But "when a sharper understanding, or more careful observation, attempts to draw those lines more in accordance with nature, words resist."[119] It is difficult to give words new meanings, so these words and their notions linger, "confused and badly defined, being abstracted from things rashly and unevenly."[120] These pernicious notions are idols of the marketplace.

Idols of the fourth kind, 'idols of the theater,' are different in several ways.[121] Unlike idols of the first three types, for example, idols of the theater have active proponents. In the marketplace, a person hears a word and just assumes it means something. No subterfuge was intended. But in the theater, actors make it their business to get people to believe things that are not true. With the name of this fourth kind of idol, Bacon is again being linguistically clever. Etymologically, a theoria or theory, as in Everard Digby's *Theoria Analytica*, is something presented in a theatrum or theater. Bacon is saying that for centuries, scholastic philosophers

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[118] "Verba autem plerunque ex captu vulgi induntur, atque per lineas vulgari intellectui maxime conspicuas, res secant." *Novum Organum*, 1.59. "divide" for Silverthorne's "dissect."

[119] "Quum autem Intellectus acutior, aut obseruatio diligentior, eas lineas transferre velit, vt illae sint magis secundum naturam, verba obstrepunt." Novum Organum, 1.59.

[120] "confusa, & male terminata, & temere & inaequaliter a rebus abstracta." *Novum Organum*, 1.60.

[121] *Novum Organum*, 1.44, 1.62–67.

like Didgy have played the role of actors, foisting on their students such false notions as *actuality*, *potentiality*, the Aristotelian categories, *specific motion*, *corruption* and the medieval *elements*. To Bacon, these are all idols of the theater, that is, idols placed in men's mind by the dogmas of beguiling philosophers like Everard Digby.

Another difference is that idols of the theater are the easier to identify and get rid of. They do not enter one's mind "by stealth."[122] Their source is plain and in the open. But plain or not, all the idols "must be rejected and renounced and the mind totally liberated and cleansed of them,"[123] so that a person may enter into the sciences as if a baby. For all idols, all ill-defined notions, whatever their cause, not only impair one's ability to communicate. They also corrupt ones thinking. The most fundamental tool, Bacon is saying, for the successful understanding of nature is a set of well-defined concepts. The method of reaching well-defined concepts is, he says, a new kind of induction. Though the causes of idols may never be removed, true induction can eliminate and prevent the idols themselves.

Bodies, Natures, and Forms

Bacon proposed a natural science influenced by both Renaissance natural magic (as Rossi and others have argued[124]) and scholastic natural philosophy (as I have been arguing). From the first he draws language about man being the

[122] "insinuate occulto." *Novum Organum*, 1.61.

[123] "omnia constanti & solenni decreto sunt abneganda, & renuncianda, & Intellectus ab ijs omnino liberandus est." *Novum Organum*, 1.68.

[124] Rossi, *Francis Bacon: From Magic to Science*; and e.g., Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*.

interpreter of nature and the themes of effecting change by understanding the ways of nature. From the second he draws the philosophical underpinnings for proposing how such change may be reliably brought about. In the first nine aphorisms of book 2 of the *Novum Organum*, he explains how this philosophical foundation will support putting knowledge to practical use. The aphorisms recall material that Bacon presented in the *Advancement of Learning*, book 2 and would later expand in *De Augmentis*, book 3, chapter 4. As elsewhere, Bacon builds on contemporary Scholastic language and develops it in new directions. Again, an understanding of this background is crucial for understanding Bacon's new induction.

A view of nature commonly held by scholastic natural philosophers was that there are two fundamental categories of being: substance and accidents. Accidents are qualities or attributes that we perceive. A substance is what underlies those attributes. The attributes may change—something cold may become hot, something brown may become red—but the substance remains the same. This taxonomy, adapted from the *Categories*, the first book of Aristotle's *Organon*, caused no end of difficulties for Christian scholastics. A general problem is that these thinkers accepted the existence of a host of immaterial beings, such as human souls, angels, and God. If these beings are to have attributes it must be possible for attributes to exist without underlying material substance. Only in a strained way can Aristotle's view of accidents then apply. The Eucharist presented a particularly difficult problem. Here, the substance was material and the accidents perceptible. The priest began with the substance of bread and the substance of wine, each having the common accidents of each. But by consecration, the accidents remained while the substance changed from bread and wine to the body and blood of Christ. The way to explain this and the general difficulties was to attribute to substance and accidents virtually independent reality. Scholastic natural philosophers came to view accidents as having a reality effectively independent of substance and substance as without perceivable properties in and of itself. That is, substance acquired its perceptible identity only by the acquisition of perceptible accidents. A taxonomy in which what had the taste, texture, color, and all perceivable attributes of wine could actually be blood was fraught with difficulties. Bacon was one of several early modern natural philosophers who tried to move away from this taxonomy.

But Bacon did not move away from the Scholastic paradigm without situating his new taxonomy in it. Instead of *substance* and *accident*, Bacon uses *body* and *nature*. But his two do not have independent and equal reality. "Nothing really exists except individual bodies."[125] Natures, that is, do not exist independent of bodies. To think about them independently, we must mentally separate them from the bodies of which they are attributes. Bodies, Bacon says, are "concrete," but natures are "abstract."[126] A ball, a concrete body, rolls because of its roundness, an abstract nature, but it is the ball, not the roundness, that rolls. Bacon relates his taxonomy to the scholastic one as follows: study of bodies concerns "substances,

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[125] "nihil vere existat praeter Corpora indiuidua." *Novum Organum*, 2.2. My translation

[126] *De Augmentis*, 3.4. 4:347; *Novum Organum*, 2.5.

with every variety of their accidents"; study of natures concerns "accidents through every variety of substances. For example, if the inquiry be about a lion, or an oak, these support many different accidents; if contrariwise, it be about heat or gravity, these are found in many different substances."[127]

Bacon's use of the term *nature* can be confusing. As we do, he uses it in several ways. He sometimes uses it to mean 'all of physical reality as we find it,' saying, for example, "some things in nature are so common"[128] or "the force of poisons in nature."[129] This meaning is familiar to us. But when he pairs *body* and *nature*, his meaning is slightly and importantly different from ours. We think of something as having one nature, one inherent and essential property or set of properties. Bacon thinks of things as having many natures. If we were to heat a ball and set it rolling, we would not say we have changed the ball's nature. But Bacon would say we have added two natures—heat and rotation—to those the ball already had. We do well to think of *nature*, when paired with *body* in Bacon, as simply *attribute* or *property*.

[127] "de accidentibus, per omnem varietatem substantiarum. Veluti, si inquiratur de leone aut quercu, illa complura diversa accidentia suffulciunt: contra, si inquiratur de calore aut gravitate, illa plurimis distinctis substantiis insunt." *De Augmentis*, 3.4, Spedding 1:551, Spedding translation 4:437.

[128] *Advancement of Learning*, 2.5.2.

[129] *Advancement of Learning*, 2.6.2.

"The task and purpose of human Power is to generate and superinduce on a given body a new nature or new natures."[130] Thus begins book 2 of the *Novum Organum* and thus Bacon puts his theory squarely in the tradition of craft or magic. It is the practical art of magic,[131] he says, to know how to reliably change a body from silver to tawny, light to heavy, and one grade of ductility to another. Indeed to change a body into gold would mean changing its color, weight, ductility, melting point, solubility, and all its other natures into that of gold.[132] But what does it mean to change color or weight or ductility? How does one know what these attributes are? How would one know how to effect such a change? How does one know that what has effected such change in the past will do so in the future or that what worked in some instances will work in all? Bacon presents his answer to these questions in the rest of book 2 and begins that presentation in the second sentence of the book: "The task and purpose of human Science is to find for a given nature its Form, or true difference, or causative nature or the source of it coming-to-be (these are the words we have that come closest to describing the thing)."[133] Bacon is going to claim that finding the 'form' of a given nature is what is necessary in order to know how to reliably effect that nature in a given body. He will claim that if and

[130] "Super datum corpus novam naturam sive novas naturas generare et superinducere, opus et intentio est humanae potentiae." *Novum Organum*, 2.1.

[131] *Novum Organum*, 2.9.

[132] *Novum Organum*, 2.5.

[133] "Datae autem naturae Formam, sive differentiam veram, sive naturam naturantem, sive fontem emanationis (ista enim vocabula habemus, quae ad indicationem rei proxime accedunt) invenire, opus et intentio est humanae scientiae." *Novum Organum*, 2.1.

only if the 'task and purpose of human Science' is achieved can the 'task and purpose of human Power' be achieved, and he will conclude that 'the task and purpose of human Science' can be achieved only by means of his new kind of induction.

In the book's first sentence, Bacon situates his theory in natural magic tradition. In the second, he situates it in the Aristotelian tradition. But, remarkably he places it far from the normal place for induction in that tradition. He does not place it in the context of the syllogism or other types of demonstration. Instead he says the task of science is to identify the 'Forma' of something. *Form* is a stock element of ancient philosophy, Aristotelian, Platonic, or otherwise. Paired with *matter*, little in Scholastic thought was more prominent. But Bacon admits his meaning may not be clear and offers three synonyms, unsure that any one is ideal. The first, 'true differentia' or 'Differentiam veram,' appeals directly to a tradition going back to Socrates in which a term is defined by identifying its genus and differentia.[134] His second synonym 'naturam naturantem' (or in the nominative 'natura naturans') is a very specific Scholastic term that came into use with Michael Scot's translation of Averroës in the mid-thirteenth century.[135] It is a very artificial construction, equivalent to 'nature naturing,' 'nature coming to be what it is.' Scholastics identified this with God and opposed it to 'natura naturata,' 'nature

[134] For parallels in Aristotle, cf. *Metaphysics* 7.12 and *Posterior Analytics* 2.3, 2.7, 2.10, 2.13.

[135] Lucy K. Pick, "Michael Scot in Toledo: *Natura naturans* and the Hierarchy of Being," *Traditio* 53 (1998): 93–116.

having come to be what it is.' Bacon breaks the identification with God, but retains the core meaning, thus making an important metaphysical statement, that the form of something is that by which it comes to be what it is.[136] Bacon's fourth synonym, 'fontem emanationis' 'source of coming to be,' captures this sense in (what I think is) an original formulation.[137] After appealing to this set of scholastic themes, Bacon shifts to a less obscure one, Aristotle's four causes.

Bacon now introduces what is his most lasting contribution to induction theory, the association of causality with induction.[138] John Case had hinted in this direction, but Bacon makes the connection explicit. He says it is correct that to truly know something is to know its cause (a common Aristotelian adage). Bacon then asks which of the four Aristotelian causes, material, efficient, formal, and final, is the important one for natural philosophy. He rejects final as applicable only to human actions.[139] He rejects material and efficient because "he who knows only the

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[136] Graham Rees says that Bacon "simply swept aside traditional usage and identified *natura naturans* with 'form.'" I would rather say that Bacon swept aside the association with God but retained the most important core meaning of the phrase.

[137] For parallels in Aristotle on the nature of something being the source of its coming to be what it is, cf. *Physics*, 1.1–2.

[138] As we will see in the Epilogue, the association of induction with causality outlasted the association with concept-formation.

[139] "But of these, the Final is a long way from being useful; in fact it actually distorts the sciences except in the case of human actions." "At ex his causa finalis tantum abest ut prosit, ut etiam scientias corrumpat, nisi in hominis actionibus." *Novum Organum*, 2.2. Recall that in *Valerius Terminus* (and then again in *Advancement of Learning*), Bacon claimed it was inappropriate to subject God and his actions to rational inquiry. In his discussion of idols of the tribe, Bacon criticized the universal eagerness to seek final causes in all natural phenomena (*Novum Organum*, 1.48). For Bacon,

Efficient and Material causes . . . may achieve new discoveries in material which is fairly similar . . . , but does not touch the deeply rooted ends of things."[140] For example,[141] heat melts butter. The material cause is butter, the efficient is heat. But heat hardens clay. Maybe one can be confident that heat will melt cheese, since cheese is like butter, but what of wax or wood? Knowledge of material and efficient causes does not provide true, universal knowledge and is of limited practical use. "True Thought and free Operation result from the discovery of Forms,"[142] or formal causes. Bacon no longer uses the terminology he used in *Valerius Terminus*, but he will now elaborate on both how to find the formal cause and how it provides certainty and liberty.

To have universal knowledge and universal power one must know, in the case of butter, what melting is. In general, one must have a sound notion for any nature (any attribute) one wants to effect. If the notion is false, if it is a mere idol, there will be neither true knowledge nor reliable power. Some notions, Bacon says, do not cause much trouble. "The notions . . . of the immediate perceptions of sense,

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God's actions as final cause (if indeed Bacon even acknowledged them) were outside the scope of natural philosophy.

[140] "At qui Efficientem & Materialem Causam tantummodo nouit . . . is ad noua Inuenta, in Materia aliquantenus simili . . ., peruenire potest, sed rerumTerminos altius fixos non mouet." *Novum Organum*, 2.3.

[141] Adaptation of an example given in *Advancement of Learning*, 2.7.4.

[142] "Quare ex Formarum Inuentione, sequitur Contemplatio vera, & Operatio libera." *Novum Organum*, 2.3.

hot, *cold*, *white*, *black*, do not much mislead."[143] But "all the others (that men have so far made use of) are aberrations, not being drawn and abstracted from things in the proper ways."[144] These include "the notions of logic and physics: neither *substance*, nor *quality*, nor *action* and *passion*, nor *being* itself are good notions; much less *heavy*, *light*, *dense*, *rare*, *wet*, *dry*, *generation*, *corruption*, *attraction*, *repulsion*, *element*, *matter*, *form*, and so on; all fanciful and ill defined."[145] These are, of course, the stock components of Aristotelian natural philosophy in the late Renaissance. That whole science collapses if these notions are mere idols.

As he had in *Valerius Terminus*, Bacon identifies two ways in which notions (and principles based on them) can be formed: the wrong way, 'anticipation,'[146] and

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[143] "Notiones infimarum Specierum, *Hominis*, *Canis*, *Columbae*, & prehensionum immediatarum sensus, *Calidi*, *Frigidi*, *Albi*, *Nigri*, non fallunt magnopere." *Novum Organum*, 1.16.

[144] "reliquae omnes (quibus homines hactenus vsi sunt) aberrations sunt, nec debitis modis a rebus abstractae, & excitatae." *Novum Organum*, 1.16.

[145] "In Notionibus nil sani est, nec in Logicis, nec in Physicis; non *Substantia*, non *Qualitas*, *Agere*, *Pati*, ipsum *Esse*, bonae notiones sunt; multo minus *Graue*, *Leue*, *Densum*, *Tenue*, *Humidum*, *Siccum*, *Generatio*, *Corruptio*, *Attrahere*, *Fugare*, *Elementum*, *Materia*, *Forma*, & id genus; sed omnes phantasticae & male terminatae." *Novum Organum*, 1.15.

[146] This word, too, comes out of contemporary readings of ancient philosophy. Recall that Aristotle did not have a word for *concept.* This stymied medieval commentators, who adopted *intentio* in translating Avicenna. One word in ancient Greek that came close was *prolepsis.* (My thanks again to Greg Salmieri for this.) This is the word Epicurus used. In his philosophy, a prolepsis is a universal image acquired by repeated exposure to multiple instances of something. This image then serves as a container into which future observations are sometimes inappropriately forced. It thus acts as a Baconian idol. Lucretius used *notities* or *notitia* (considered an alternate spelling of *notio* in the seventeenth century) for the Epicurian *prolepsis*, but the more common translation in Bacon's day was *anticipatio*. For Bacon, then, an Epicurian *anticipatio* is an *idol.* He adopts the term, but

the right way, interpretation. Both start with "senses and particulars and comes to rest in the most general,"[147] but the first flies there (again using Digby's term, *advolat*[148]) and "merely brushes experience and particulars in passing."[149] The other rises slowly and methodically. The method Bacon proposes is a new kind of induction, one that he calls "true," "legitimate," and "perfect."[150] He describes this new induction in the rest of book 2.

Induction

Bacon proposes that if one can know the formal cause, or form, of a nature, one can obtain a universal principle. His example is heat. If one can know the form, the essence, of heat, if one's notion of heat is well-abstracted and well-defined, if the notion of heat is not a mere idol, then one can know how to 'generate and superinduce' heat on any body, at any time, anywhere. Bacon proposes a three-step process: a comprehensive natural history, an orderly arrangement of the relevant

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shifts its meaning slightly (staying truer to the Latin). He uses it to refer to the process by which the idol is formed rather than to the idol itself. For the relationship between *anticipatio* in Bacon and *prolepsis* in Epicurus, see Urbach, *Francis Bacon's Philosophy of Science*, 37–8.

[147] *Novum Organum*, 1.22, "via orditur a sensu & particularibus, & acquiescit in maxime generalibus."

[148] *Novum Organum*, 1.19.

[149] *Novum Organum*, 1.22. "cum altera perstringat tantum experientiam & particularis cursim."

[150] *Novum Organum*, "vera": 1.14, 1.40, 2.7, 2.10, 2.16, 2.19, 2.21; "legitima": *Distributio Operis*, 2.10; "perfecta": 2.21. Note that, for Bacon, "perfect" does not mean that the induction fully enumerates all particulars, as it does in modern theories of induction. For Bacon, if an induction could not be applied to new, unobserved instances, it would not be perfect.

parts of that history, and finally, a "true and proper induction."[151] To the *Novum Organum*, Bacon appends guidelines on how to collect that natural history and what should be in it. In the *Novum Organum* itself, he concentrates on the second and third steps.

To order the observations of natural history (what we would call the facts), Bacon proposes using three tables: a table of instances where the nature under investigation is present ("*Tabulam Essentiae & Praesentiae*"[152]), a table of instances that are like the first but in which the nature is not present ("*Tabulam declinationis*, siue *Absentiae in Proximo*"[153]), and a table of instances where the nature varies ("*Tabulam Graduum*, siue *Tabulam Comparatiuae*").[154] The first should include "all known instances which share in the same nature, however disparate the materials may be."[155] Bacon's sample table for heat includes the sun's rays, lightning, flames, boiling liquids, hot smoke, air trapped in caverns, bodies brought near a fire, a body forcefully rubbed, animals, animal excrement, wet plants compacted, quicklime sprinkled with water, hot spices, and many other things. There are twenty-eight in total. The most remarkable feature of the list, for one accustomed to theoretical discussions of induction in the twentieth century, is the variety. The canonical

[151] "inductio legitima et vera." *Novum Organum*, 2.10.

[152] *Novum Organum*, 2.11.

[153] *Novum Organum*, 2.12.

[154] *Novum Organum*, 2.13.

[155] "omnium Instantiarum Notarum, quae in eadem Natura conueniunt, per Materias licet dissimillimas." *Novum Organum*, 2.11. Rees's "share" for Silverthorne's "meet.

example of what Keynes called 'pure induction' is a series of identical white swans.[156] Bacon mocks such an example as puerile and insists that a valid induction must include 'contradictory instances.'[157] What Bacon means by 'contradictory instances' can be seen in his second table. It includes moonlight and starlight, which are like sunlight but different; sheet lightning, which is like regular lightning; liquids in a natural state, corresponding to boiling liquids; insects, corresponding to animals; and so on, each absence of heat corresponding to an instance of heat. All told, Bacon lists thirty-two instances in the second table.[158] The third table includes seasons, some of which are hot and some cold; flames of different temperatures; fish, which appear to have varying temperatures; and so on for a total of forty-one instances. Many items in all the lists are tentative, and Bacon says more research would need to be done were this not a mere illustration. Only some of the instances result from experimentation. In fact, most are common observations, merely organized carefully. Though historians and philosophers of science sometimes ridicule Bacon's tables, many a practicing scientist would find

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[156] "The Value of Multiplication of Instances, or Pure Induction" in John Maynard Keynes, *A Treatise on Probability* (London: Macmillan and Co., 1921), 233–41.

[157] "to conclude upon an enumeration of particulars, without instance contradictory, is no conclusion, but a conjecture." *Advancement of Learning*, 2.13.3.

[158] To again invoke modern discussions: Bacon would accept that a non-black, non-swan can confirm the hypothesis that all swans are white, if but only if it helps us identify what makes something a swan and what makes something white. Thus various colored pigeons may help us understand whether color is essential to species, and a red truck may help us understand the nature of specific colors and therefore of white and black. Observation of a gray pigeon or a red firetruck can therefore contribute to confirming whether all swans are white.

the underlying strategy familiar, even if now buried within a regimen of statistical experimentation. To eradicate malaria, increase adhesive strength, predict interest rates, or even repair a squeak, one begins by identifying instances, similar absences, and related variations.

With his observations collected and organized, Bacon moves on to the third phase, a 'true and proper induction.' His goal is to define heat, that is, to discover the essence or form of heat. His induction has four stages. In the first Bacon calls on the mind to identify possible candidates and then to exclude candidates refuted by some instance or instances. For example, many of the instances of heat involve light. Might heat be a form of light? No, for dark things can be hot, too. Might heat be something celestial? No, for terrestrial things can be hot, too. Might heat be a kind of expansion? Boiling water, smoke, and many other instances involve expansion. But some do not. Might heat be a kind of rarity? Some instances refute that. Might heat be a kind of motion? Bacon concludes that it is. Every instance of heat involves some kind of motion. The second stage, identification of a genus, has thus been reached. But this is not complete, for although all instances of heat involve motion, not all instances of motion involve heat. There is not a one-to-one correspondence. The two are not "convertible."[159] The true differentia must still be identified. The third stage is like the first. By a process of comparing and

[159] *Novum Organum*, 2.4. This is another technical Aristotelian term. On convertibility in general, see *Prior Analytics* 2.22. On convertibility in relation to identifying a cause, see *Posterior Analytics*, 2.15–17. On convertibility in relation to induction, see *Prior Analytics*, 2.23.

contrasting, it proposes and excludes possible differentia. The fourth stage is reached once the differentia are found. Bacon concludes that heat is a motion of small particles with certain qualifications involving direction, enclosure, speed, and force. The genus and differentia have been specified. The true form of heat has been identified. The true and proper induction has been completed.

The result, of course, looks nothing like a scholastic or modern example of induction. It looks instead like what Bacon intended it to be: a definition, that is, a genus and differentia. From this, Bacon can now make the statement of certainty and liberty that he sought in *Valerius Terminus*. He first emphasizes that he is not claiming that the identified kind of motion generates heat or that heat generates this kind of motion, but that this kind of motion *is* heat and heat *is* this kind of motion. The two are logically convertible. Then, based on this convertibility, he can conclude the following:

> *If in any natural body you can arouse a motion [of this certain type], you will certainly generate heat.* It is irrelevant whether the body is elementary (so-called) or imbued with heavenly substances; whether luminous or opaque; whether rare or dense; whether spatially expanded or contained within the bounds of its first size; whether tending toward dissolution or in a steady state; whether animal, vegetable or mineral, or water, oil or air, or any other substance whatsoever which is capable of the motion described.[160]

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[160] "*Si in aliquo corpore naturali poteris excitare Motum . . . proculdubio generabis Calidum:* non habita ratione, siue corpus illud sit Elementare (vt loquuntur) siue imbutum a Coelestibus; siue

Bacon has drawn a universal conclusion, but how he or anyone else could have thought of this whole process as induction may be unclear. An example might help.

Consider the following observations.

> Ignited French gunpowder is hot.
> Ignited German gunpowder is hot.
> Ignited English gunpowder is hot.

The conventional inductive question is: Is all gunpowder hot when ignited? Bacon would say that if one knows the material cause, gunpowder, and the efficient cause, ignition, then one might be able to conclude that Italian gunpowder is hot when ignited, for Italian gunpowder is 'fairly similar' to the others. But the conclusion would be tenuous and subject to instance contradiction. Bacon wants a conclusion with certainty and liberty. To accomplish this, he shifts attention from the particular subjects to the universal predicate. Bacon does not first ask, 'What can be said about all gunpowder?' but 'What can be said about all heat?' Bacon looks at the argument this way:

> Ignited French gunpowder is hot.
> Ignited German gunpowder is hot.
> Ignited English gunpowder is hot.

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luminosum, siue opacum; siue tenue, siue densum; siue localiter expansum, siue intra claustra dimensionis primae contentum; siue vergens ad dissolutionem, siue manens in statu; siue Animal, siue Vegetabile, siue Minerale, siue Aqua, siue Oleum, siue Aer, aut aliqua alia substantia quaecunque susceptiua Motus praedicti. Calidum autem ad Sensum, res eadem est, sed cum analogia, qualis competit Sensui." *Novum Organum*, 2.20. The first sentence is one of the very few in the *Novum Organum* that Bacon italicized.

If asked, 'Is all ignited gunpowder hot?' Bacon would not reply, 'That depends on how many kinds have been observed.' Instead he would reply, 'That depends on what heat is.' 'To identify what heat is' means to identify the formal cause or form of heat. To do so, one should use an exhaustive process of comparing and contrasting instances of the widest possible variety, first identifying the genus, and then identifying the true differentia. The result will not be an idol but a well-formed notion. With this well-formed notion in hand, the inductive conclusion follows directly. If igniting gunpowder arouses motion of a certain type, then igniting gunpowder will generate heat. For "heat itself . . . is [such] motion and nothing else."[161] The conclusion is inescapable, and the inductive inference is certain.

Bacon's goal was to find a way with certainty and liberty to effect designated natures (properties) in bodies (substances) of wide variety. This led him to shift attention from the subject of the inductive observations to the predicate, and to seek the formal cause thereof, to ask, for example, what makes heat heat. An obvious extension presents itself: What makes gunpowder gunpowder? Must one not also identify the formal cause of gunpowder? How does one know that the observed particulars are gunpowder? Is the ability to become hot a defining characteristic? As we will see in the next chapter, Bacon does not make this

[161] "quod ipsissimus Calor . . . sit Motus, & nihil aliud." *Novum Organum*, 2.20.

extension in the *Novum Organum*, but does, at least implicitly, in his own research projects in natural philosophy.

At this point in the *Novum Organum*, Bacon is only sixty percent of the way through the presentation of his new system of induction. He has much more to say. The first thing to say is that the example of heat is merely illustrative and preliminary. Since this whole approach is new, many of the needed observations are still unavailable. Moreover, only the "first harvest"[162] has been finished. Bacon says he has yet to describe further aids and supports for the process and how the results are to be refined, adapted, limited, used, and extended to higher-level principles.[163] Unfortunately, in the rest of the *Novum Organum* as published, Bacon only gets to the very first of these.

The whole process of the first harvest was rather haphazard, even arbitrary. Any and all observations were put into the tables with little priority or focus. All instances were treated equally. To improve the process, Bacon says, one should give some instances more attention than others. Bacon calls these 'praerogativae instantia' 'privileged instances.' Privileged instances help one find the form and thus reach a universal conclusion quicker and more reliably. Bacon lists twenty-seven kinds of privileged instances, some having many subdivisions. A few examples will suffice. The first kind are 'solitary instances.' These are instances that have nothing in common with other instances except the one nature under

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[162] "Prima Vindemiatio." *Novum Organum*, 2.20.

[163] *Novum Organum*, 2.21.

investigation. To investigate the nature of orange, for example, it is useful to consider orange flowers and burning orange logs. But the flowers and the logs have several things in common other than color. It is better to include the orange color produced by a prism. The only thing the orange of a prism-produced rainbow has in common with the flower is the color itself. A prism, therefore, can be very useful in investigating the form of color. Another kind of privileged instance is the 'unique instance,' such as quicksilver among metals or the magnet among stones. 'Borderline instances' such as the bat or the flying fish can be very helpful. 'Bundled instances' are instances that are different but seem always to go together. When investigating the nature of taste, for example, one should consider the sense of smell. 'Crucial instances' or 'instances of the signpost,' the most famous of Bacon's privileged instances, can help one decide between two competing candidates. For example, an investigation into the nature of gravity may suggest it is either a natural inclination downwards or an attraction between bodies. A crucial instance would be the behavior of a weight-driven clock when placed deep in a mine and when placed high on a mountain.[164] Bacon lists over twenty types or sub-types of 'mathematical instances,' instances of measurement or numeric comparison that can greatly help in identifying the essence of some property. (The extent of this discussion is overlooked when Bacon is criticized for failing to appreciate the importance of mathematics.) Bacon's final privileged instances are 'magical

[164] *Novum Organum*, 2.36. Bacon offers these two theories and the test to choose between them sixty-seven years before Newton's *Principia* and many years before Galileo's *Dialogo* or *Discorsi*.

instances,' instances in which a small event causes a large one, such as an explosion. If understood, these can suggest possibilities for great human benefits. These and all the privileged instances help develop and then refine one's notions of particular natures.

The pattern of a Baconian inductive inference is thus the following:

(1) Collect observations.

(2) Arrange them in a way that facilitates comparing and contrasting:

Positive premises	Contrary instances	Varying instances
. . . is hot.	. . . is not hot.	. . . is seldom hot.
. . . is hot.	. . . is not hot.	. . . is sometimes hot.
. . . is hot.	. . . is not hot.	. . . is somewhat hot.

(3) Identify the formal cause of the nature under investigation.
(a) By comparing, contrasting, suggesting, and excluding,
(b) identify the genus.
Heat is motion . . .
(c) By comparing, contrasting, suggesting, and excluding,
(d) identify the differentia.
. . . of a certain type.

(4) Draw the universal conclusion.
Heat is a certain type of motion.
by conversion (justified because the essence has been identifed):
Anything with this certain type of motion is hot.
<u>All bodies of a certain kind have this certain type of motion.</u>
Therefore, all bodies of this kind are hot.

The crucial part of the inference is getting the definition of the conclusion's predicate right. If heat is correctly defined, that is, if heat really is a motion of this certain type, then all exploding gunpowder is hot, for all exploding gunpowder has this motion. Bacon is saying that an inference is only as good as the concepts that compose it, but *is* as good as the concepts that compose it. A modern scientific example might clarify. Tetracycline cures cholera in Peter, Paul, and Mary. But does it always cure cholera? By the Baconian method the proper procedure is not to simply amass cases where tetracycline cures cholera, but to ask: What is cholera? The goal is to find the cause of cholera—not just the material cause (say, dirty water) or the efficient cause (drinking that water), but the formal cause, the essential cause, that which makes cholera cholera. The inductive conclusion will be justified if cholera can be correctly defined. If cholera is merely defined as an intestinal disease accompanied by diarrhea and vomiting, then the induction will not be valid, but if cholera is defined as an intestinal disease caused by a certain bacteria and if tetracycline kills that bacteria, then the inductive inference will always be certain. Tetracycline will always cure cholera. If definitions are arbitrary, then this whole system of induction falls apart, but Bacon is saying that definitions are not arbitrary. He is saying that, at least with concepts in natural philosophy for which inductive universality is desired, definitions must be carefully discovered, not rashly chosen based on a few instances. The proper procedure requires careful and extensive comparing, contrasting, suggesting, and excluding. At bottom, this procedure—and not an enumeration of similar instances—is what induction is.

Bacon's proposal, of course, raises a tremendous number of questions. Maybe all heat is that kind of motion, but how does one know that all gunpowder creates that kind of motion? Killing the cholera bacteria will certainly cure cholera, but how does one know that tetracycline always kills the cholera bacteria? The answers depend on the meanings of *gunpowder*, *tetracycline*, *bacteria*, and *kills*. And how does one know if enough instances have been surveyed and enough comparisons and exclusions made? How can one be sure the definition was reached correctly? What if a mistake is made? Bacon excluded expansion as the essence of heat because he thought hot iron did not expand. We now know it does. He considered spicy foods to be instances of heat. We now say that the meanings of *hot* in 'hot chili pepper' and 'hot molten iron' are different. How can an inductive inference be certain if definitions change? If Bacon is right, then would discovering new scientific principles be simply be a matter of defining new scientific concepts? All these questions raise even more.

Regardless whether the answers to all these questions support or refute Bacon's method, his proposal that induction is at bottom a procedure for identifying the essence of a concept (or, the 'form' of a 'notion') was a major departure from the Aristotelian scholasticism out of which it developed. It was a return to induction as it was understood in the ancient world.

Induction Old and New

Bacon did not set out to reinvent induction. He set out to invent the means by which to effect change with certainty and liberty. The change he had in mind was giving to a body a property, or 'nature,' it did not have. This goal led him to Aristotle's four causes. Bacon concluded that it was crucial to determine what would cause a body to have the desired property but that determining the material and efficient causes was not sufficient. Knowing these, one might be able to effect the desired property in bodies similar to those in which it had already been observed, but one could not be confident in effecting the change in all sorts of bodies. One might have certainty within a limited range not not liberty to go outside that range. Drawing on the scholastic vocabulary Bacon said that he wanted to discover how to ensure that the property would apply 'per se,' that is, by the very essence of the property, and not merely 'de omni,' by a universal coincidence. To reach this goal, he concluded, one has to find not merely the material or efficient cause, but the formal cause. For the formal cause is the very essence of the property, that which makes the property what it is. If the formal cause exists, then the property necessarily exists. If the property exists, the formal cause necessarily exists.

> This then will have to be our declaration on the true and perfect precept of operation: *it should be certain, free and favourable to, or tending towards, action.* And this is the same as the discovery of true Form. For the form of a nature is such that if it is there, the given nature inevitably follows. Hence it is always present when the nature is present; it universally affirms it, and is in the whole of it. The same form is such that when it is taken away, the given nature inevitably disappears. And therefore it is always absent when that nature is absent, and its absence always implies the absence of that nature, at it exists only in that nature.[165]

[165] "Itaque de praecepto vero et perfecto operandi, pronuntiatum erit tale; *ut sit certum, liberum, et disponens sive in ordine ad actionem*. Atque hoc ipsum idem est cum inventione formae verae. Etenim forma naturae alicujus talis est ut, ea posita, natura data infallibiliter sequatur. Itaque adest perpetuo, quando natura illa adest, atque eam universaliter affirmat, atque inest omni. Eadem forma talis est ut, ea amota, natura data infallibiliter fugiat. Itaque abest perpetuo, quando natura illa abest, eamque perpetuo abnegat, atque inest soli." *Novum Organum,* 2.4. Emphasis in Bacon's original.

Thus if the form of the desired property can be found and brought into existence, the property itself can be brought into existence with certainty and liberty.

> He who knows forms comprehends the unity of nature in very different materials. And so he can uncover and bring forth things which have never been achieved, such as neither the vicissitudes of nature nor experimental efforts nor even chance have ever brought into being and which were unlikely ever to enter men's minds. Hence true Thought and free Operation result from the discovery of Forms.[166]

The above passage from the *Novum Organum* articulates the principle with which Bacon began in *Valerius Terminus* in 1603: It is knowledge of formal causes, or forms, that will give man power.

"The task and purpose of human Science is to find for a given nature its Form."[167] A method for doing so was the task Bacon set for himself in the years after 1603. The result would be, by 1620 at the latest, a remarkable synthesis. Bacon had found in Aristotle and in Ramus the first crucial principle, per se predication, and in Aristotelian scholasticism the second principle, formal cause. Bacon also adopted the Aristotelian adage that a definition, that is, the statement of an essence, should be in terms of a genus and differentia. "And so our declaration and precept

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[166] "At qui formas novit, is naturae unitatem in materiis dissimillimis complectitur; itaque quae adhuc facta non sunt, qualia nec naturae vicissitudines, neque experimentales industriae, neque casus ipse, in actum unquam perduxissent, neque cogitationem humanam subitura fuissent, detegere et producere potest. Quare ex formarum inventione sequitur contemplatio vera, et operatio libera." *Novum Organum*, 2.3.

[167] "Datae autem naturae Formam . . . invenire, opus et intentio est humanae scientiae." *Novum Organum*, 2.1.

about the true and perfect axiom of knowledge is this: *find another nature that is convertible with a given nature, and yet is a limitation of a better-known nature, as of a true genus*.[168] Bacon did not find in Aristotle the next crucial step, the procedure for identifying the genus and differentia. He did find them, however, in Plato, or rather in Socrates. In the Platonic dialogues, Socrates sought the essence of courage, virtue, temperance, or wisdom by an iterative process of proposing, comparing, and excluding. By 1607, Bacon had adopted this procedure and identified it as a kind of induction. The correct procedure, he said, "has not yet been done, nor even certainly tried except only by Plato, who certainly makes use of this form of induction to some extent in settling on definitions and ideas."[169] Bacon's induction is a codification of Socrates'.

It is difficult to know where Bacon got the idea that finding the essence by a Socratic process is a procedure that should be called *induction*—possibly from humanist writers such as Valla or Agricola, possibly from Cicero, possibly from Peter Ramus via William Temple, or possibly from his own recognition of the similarity between what he was attempting and induction as conventionally presented. Conventional presentations attributed a property to several observed

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[168] "Itaque de axiomate vero et perfecto sciendi pronuntiatum et praeceptum tale est; *ut inveniatur natura alia, quae sit cum natura data convertibilis, et tamen sit limitatio naturae notioris, instar generis veri.*" *Novum Organum*, 1.4. Emphasis in Bacon's original.

[169] "Quod adhuc factum non est, nec tentatum certe, nisi tantummodo a Platone, qui ad excutiendas definitiones et ideas hac certe forma inductionis aliquatenus utitur." *Novum Organum*, 1.105.

subjects. Socrates, Plato, and Aristotle run. French, German, and Cretan wine heateth. Bacon wanted to know how a property could be effected not just in already observed bodies but in unobserved as well. Though he approached it from the direction of practical use rather than logic, the problem he was trying to solve was the same as that presented in logic textbooks right after the syllogism and enthymeme. But the concept of induction he found there, he found puerile. The change Bacon proposed was revolutionary.

No one had ever connected induction to causality as Bacon did. We saw a shallow anticipation in John Case's treatment of induction, and Galen suggests that he made this connection in his lost treatise on demonstration. We do not know what Galen had to say, but Case certainly offered nothing near the force and precision with which Bacon argued that an induction can be justified by identifying the cause of a predicate. It has become a stock part of training in scientific method (or at least was until recently) that to draw a universal conclusion, one must identify a cause. To know that the medicine will always cure the disease, we need to know what causes it to work. To know that the transistor will always have the transfer coefficient that others have had, we need to know what factors determine transfer coefficient. To know two chemicals will combine and always form a third, we need to understand the causes of chemical combination. 'Correlation is not causation,' as the engineer is taught. 'Per se is not de omni,' as Bacon would have put it.[170] No matter how many bodies have taken on a given property, one cannot with certainty and liberty know that a dissimilar body will take on that property until one understands the cause of the property. A mere repetition of instances, Keynes's 'pure induction,' is, Bacon says, 'puerile' and 'subject to instant contradiction.'

The need to find causes to validate an induction is now a familiar part of Bacon's proposal. Less familiar is his focus on formal cause and his belief that by correctly identifying formal cause one can make an inductive inference that is as binding as a syllogism. Inductive arguments are now called ampliative, deductive arguments non-ampliative. In a deductive argument, such as 'All men are mortal; Socrates is a man; therefore Socrates is mortal,' the conclusion does not say anything that was not already contained in the premise 'All men are mortal.' Nothing new is added. Some component of the premise is merely being made manifest. The situation is different in inductive arguments, such as 'Socrates is mortal; Plato is mortal; Aristotle is mortal; therefore all men are mortal.' Here, the universal conclusion makes a claim that extends beyond the claims made in the particular premises. The inference is ampliative. What justifies this ampliation? After the Alexadrian synthesis of late antiquity, it was held that induction is justified only by a complete enumeration of particulars. A shorthand may be used

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[170] A colleague recently told me that when he was a boy in Vermont, he figured out that when the cows were lying down, it was going to rain. So he knew that if he saw the cows lying down, he should hurry up and get some stones to throw at them.

by adding 'etc.' as a premise, but if this justifies the conclusion it is only because it stands in for a number (possibly countless number) of propositions. By this understanding of induction, an ampliative induction, i.e., one that does not include a complete enumeration cannot be certain. Bacon argues against this whole approach. (Buridan and Valla had partly anticipated him here). He argues, in effect (now going well beyond Buridan or Valla), that in a valid induction, ampliation occurs not at the propositional level but at the conceptual level. An open-ended induction is made valid not by adding more propositions, but by properly identifying the formal causes of the constituent concepts. If mortality is 'being subject to the cessation of life,' then all men are mortal. This is assured not by surveying many men, but by correctly identifying the essence of mortality.

Consider the case of the white swans. A series of white swans are observed, and it is concluded that all swans are white. A black one appears. Is the hypothesis refuted? That depends on what is meant by *black*, *white*, and *swan*. A defender of the hypothesis could reply, 'That black thing is not a swan,' or 'That swan is not black; it is white.' If all sea-level samples of water boil at 212°F, and then one is found not to, do we conclude that not all water boils at 212°F, or do we conclude that the sample is not water? Bacon is claiming that an hypothesis is only as good as its constituent concepts. There can be no method for determining whether an inductive conclusion is true or false that does not also address whether the concepts are correctly defined. Moreover, Bacon says not only that an inductive inference is *only as good* as its constituent concepts but also that an inductive inference can be *fully as good* as its constitutent concepts. An inductive inference can be as certain as the meaning of the terms it uses. If the terms are properly defined, the induction can be certain.

For Bacon, induction is not primarily about propositions. It is about concepts. For him, induction is not the inference of a proposition from other propositions. It is the identification of the essence of concepts. If the concepts are ill-formed, that is, if they are mere idols, they corrupt all thinking. But if they are well-formed and their essences properly identifed, propositional inferences can be drawn with certainty and liberty. At one level, then, Bacon is returning to a conception of induction that predominated in antiquity, invented by Socrates, adopted by Aristotle, articulated by Cicero. In it, a conclusion can be drawn that applies beyond the particulars that went into its formation because a concept can be formed that refers to particulars other than those that went into its formation. But in another sense, Bacon went well beyond any of his predecessors. His proposed integration of concept-formation, propositional inference, causation, practical efficacy, and a methodical approach to identifying the essence of properties was a remarkable synthesis. Baconian induction was something old, but on both a practical and theoretical level something very new.

5

Regula Socratis:

Baconian Induction in Practice

About thirty years ago, to help settle debate about the extent to which Francis Bacon did or did not influence early modern science, Theodore Brown pointed out that to be a follower of Bacon meant different things to different people at different times.[1] His reminder has been heeded ever since, and it is now standard to trace the influence of various Baconianisms rather than one Baconianism. Brown himself identified three, the Baconismism of Protestant educational reformers in the late 1630s through 1650s including especially Samuel Hartlib, the Baconianism of physicans and natural philosophers at the London College of Physicians and the University of Oxford during in the latter part of the same period, and the Baconianism of the Royal Society soon after its founding in 1662.[2] Subsequent

[1] Theodore M. Brown, "The Rise of Baconianism in Seventeenth-Century England," in *Science and History: Studies in Honor of Edward Rosen* (Wroclaw: Polish Academy of Sciences Press, 1978).

[2] Ibid., 505.

studies have added the Baconianism in England in the late 1620s and early 30s,[3] the Baconianism of Descartes, Marsenne, and Gassendi in France during the two decades after Bacon's death, the Baconianism of Voltaire, D'Almbert, and others of the French Enlightenment, and the Baconianism of William Whewell, John Stuart Mill, and Bacon's editors in Victorian England.[4] While the current study has examined alternate meanings of *induction*, it must now recognize multiple meanings of *Baconianism*, in order to understand the influence of Baconian induction on early modern natural philosophers.

Bacon thought of his published works as falling into three groups.[5] He considered his chief work to be the *Novum Organum*,[6] but he recognized that this work was challenging. He feared it "flies too high over men's heads."[7] The second group comprised works that support, build upon, and/or help people understand

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[3] M. L. Donnelly, "Francis Bacon's Early Reputation in England and the Question of John Milton's Alleged 'Baconianism'," *Prose Studies* 14, no. 1 (1991): 1–20.

[4] Chapter 2, "The Meanings of Baconianism," 7–31, in Pérez-Ramos, *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition*; and Antonio Pérez-Ramos, "Bacon's Legacy," in *Cambridge Companion to Bacon*, ed. Markku Peltonen (Cambridge: Cambridge University Press, 1996), 311–34. Brown's basic outline survives in William T. Lynch, *Solomon's Child: Method in the Early Royal Society* (Stanford, CA: Stanford University Press, 2001), 4–33.

[5] I adopt the taxonomy but slightly modify the assignments proposed by Donnelly, "Francis Bacon's Early Reputation in England and the Question of John Milton's Alleged 'Baconianism'," 4–5. A fourth group of professional legal writings should probably be added.

[6] Rawley reported that "in his own account," Bacon considered *Instauratio Magna* "the chiefest of his works." William Rawley, "The Life of the Honourable Author," in Spedding 1:11. Bacon said of the *Novum Organum*, that it is "the work, that in my own judgment I do most esteem." Dedicatory Epistle to "Advertisement Touching an Holy Warre," Spedding 7:13.

[7] Ibid.

the *Novum Organum*. The *Advancement of Learning* and *De Augmentis Scientiarum*, for example, "may be some preparative, or key, for the better opening of the Instauration."[8] They exhibit "a mixture of new conceits and old."[9] The natural histories, such as the *Historia Ventorum* and *Historia Vitae et Mortis*, help draw the elevated argument of the *Novum Organum* "down to the sense."[10] Though it was published posthumously, the *Sylva Sylvarum* would fall into this second category, also. All these supporting works make the *Novum Organum* more accessible. Of the third group Bacon wrote, "As for my Essays, and some other particulars of that nature, I count them but as . . . recreations."[11] *De Sapientum Veterum* would also fall into this last category, as would the *New Atlantis*. This last was never finished, and Bacon was not actively seeking its publication. Of this group of recreational writings, Bacon added, "I am not ignorant that those kind of writings would with less pains and embracement (perhaps) yield more lustre and reputation to my name."[12] This comment was prescient, for although Bacon was universally known as the author of the *Instauratio Magna*, many followers had little knowledge of its content and crafted their own Baconianism from what they found in Bacon's recreational and secondary works.

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[8] Ibid.

[9] Ibid.

[10] Ibid.

[11] Spedding, 7:14.

[12] Spedding, 7:15.

From the time of its publication in 1620 until Bacon's death in 1626, the *Novum Organum* attracted more attention on the continent than in England. Bacon received more approving comments "from many parts beyond the seas" than he expected for "so abstruse an argument."[13] Though in England the *Essays* were widely admired, the *Instauratio* was little read or recommended. In the books Cambridge graduate John Harvard gave in 1638 to the college that now bears his name, the *Advancement of Learning* and *Sylva Sylvarum* were included, but the *Novum Organum* was not. In Richard Holworth's manuscript of around the same time offering "Directions to Students," the *Essays* and *Sylva Sylvarum* are recommended, but not the *Novum Organum*. The list of books purchased by Joseph Mead's Cambridge students through 1637 includes *Advancement of Learning*, the natural histories, and *De Sapientia Veterum*, but not the *Instauratio*.[14] A tally of editions in Gibson's bibliography[15] helps confirm generally what was true for these Cambridge students in particular: Into the 1630s, several of Bacon's writings were well published and widely read, but the *Novum Organon* was not one of them.

One of the most prominent champions of Bacon in the 1640s was the German-Polish immigrant and energetic educational reformer, Samuel Hartlib. Hartlib's influence on young and soon-to-be-prominent natural philosopers such as Robert

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[13] Spedding, 7:13.

[14] These three examples are presented in Donnelly, "Francis Bacon's Early Reputation in England and the Question of John Milton's Alleged 'Baconianism'," 4–8.

[15] R. W. Gibson, *Francis Bacon: a bibliography of his works and Baconiana to the year 1750* (Oxford: Scrivener Press, 1950).

Boyle has been the subject of scholarly study and debate.[16] Even if that debate continues, it is now clear that Hartlib's enthusiasm for reform under a Baconian banner did not extend to Bacon's theory of induction. Theodore Brown suggested this, and more recently Stephen Clucas[17] has shown that Bacon's proposal for inductive logic simply had no significant role in Hartlib's circle. Indeed, the continental logicians and methodologists on whom Hartlib relied dismissed Baconian induction. For Hartlib, Baconianism was an anti-authoritarian educational reform that included the empirical study of nature. His image of Bacon was what one would gather from the *Advancement of Learning*, *De Augmentis Scientiarum*, and to a lesser extent the natural histories, not from the *Novum Organum.*

The French thinkers Descrates, Mersenne and Gassendi were similarly enthusiastic about parts of Bacon's doctrine and similarly dismissive of his induction.[18] Descartes and Mersenne admired the natural and experimental histories and the revolutionary, anti-authoritarian spirit of Bacon's project, but Descartes ignored Baconian induction and Mersenne rejected it. Gassendi did the

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[16] The central study is Charles Webster, *The Great Instauration: Science, Medicine and Reform 1626–1660* (New York: Holmes & Meier, 1975).

[17] Stephen Clucas, "In Search of 'The True Logicke': Methodological Eclecticism among the 'Baconian Reformers'," in *Samuel Hartlib and Universal Reformation: Studies in Intellectual Communication*, ed. Mark Greengrass, Michael Leslie, and Timothy Raylor (Cambridge: Cambridge University Press, 1994), 51–74.

[18] Pérez-Ramos, "Bacon's Legacy," 312–14.

same and said that "induction is unable to prove anything except by virtue of the syllogism."[19]

Accepting yet another Baconianism is the group introduced at the outset of this study, the leading scientific thinkers in England in the 1650s. Here the situation is more complicated and ambiguous. Neither Hartlib's circle nor Mersenne's claimed that they made important advances in natural philosophy based on Bacon's epistemology. But leading members of the communities of natural philosophers in the 1650s and 60s centered at Oxford, the London College of Physicians, Gresham College, and the Royal Society of London did. Many claimed familiarity with all of Bacon's works and a wholesale commitment to Bacon's program. John Wilkins and Seth Ward insisted that Baconian induction was in fact taught in Oxford. By the time Thomas Sprat published his *History of the Royal-Society* in 1667,[20] Bacon was treated as the chief intellectual progenitor of the Society and of England's most progressive scientific pursuits. Bacon's appeal for educational reform, his commitment to the practical application of knowledge, his vision of a peaceful community of cooperative researchers, his insistence on observation, and his particular method of induction were all endorsed. The difficulty comes in sorting out what parts of this endorsement were informed and sincere.[21]

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[19] *Syntagma philosophicum* 1.6, quoted in ibid., 313.

[20] Thomas Sprat, *The history of the Royal-Society of London for the improving of natural knowledge* (London: Royal Society, 1667).

[21] Brown stated the question this way: "Did Ent and Glisson of the College of Physicians, or Wilkins and Willis of Oxford, really understand the intentions of Bacon's *Novum Organum* . . . ?

Brown proposed that, though this new generation included "truer representatives of Lord Verulam's program," the program was adopted primarily for political cover.[22] In the early days of the royal Restoration, it was more prudent to identify one's roots in the loyal Lord Chancellor of a previous royal administration than in the activities of innovative academics of revolutionary interregnum years.[23] Charles Webster concluded that "Bacon's philosophy was the most effective façade for the Royal Society, ... adopted as a defensive mechanism against critics," and in fact masked "diverse philosophical outlooks."[24] By this interpretation, the Baconianism that this generation shared was not rooted in the *Novum Organum*, but in the *New Atlantis* and its vision of progressive, apolitical, and non-authoritarian cooperation among natural philosophers.

This interpretation has continued to attract sympathy but it has failed to fully satisfy. There is something unsettling about a hint that some of history's most successful scientists touted a particular methodological doctrine as a conspiracy and a sham. Other proposals have tempered or augmented Brown's. One recent line of research has considered Bacon's background in law, a profession in which one is trained to establish a 'matter of fact' by convincing a small group of those deemed

This is an important question, although the evidence for its answer is fragmentary at best." Brown, "The Rise of Baconianism in Seventeenth-Century England," 517.

[22] Ibid., 517, 519.

[23] Pérez-Ramos, "Bacon's Legacy," 315.

[24] Charles Webster, "The Origins of the Royal Society," *History of Science* 6 (1967): 115–16.

qualified to judge.[25] Thomas Sprat's account of how the Royal Society actually worked and reports on how Robert Boyle's ideas were promulgated have been taken as evidence that it is in this sense that mid-century natural philosophers should be considered Baconians. Another, perhaps more widely shared, line of thinking has been that mid-century Baconianism can be equated with an experimental methodology. Here, the term *experiment* creates a problem, for in the mid-seventeenth century, the term had not unambiguously taken on its current meaning. Bacon himself still used *experimentum* and *experientia* interchangably.[26] If *experiment* means an operation carried out under artificial conditions, then it is misleading to call Baconian induction an experimental philosophy, for experiments in this sense are not an essential part of Bacon's induction. In his example of the three tables for discovering the form of heat, the instances are of the most mundane type—sunlight and moonlight, animals and insects, burning wood, and fetid caves. Some of the prerogative instances are experiments, but only some. The Parasceve appended to the *Novum Organum* calls for an active collection of observational data, but only some of the observations are to be collected under artificial and controlled conditions. If, on the other hand, a call for experiments is merely a call for observation over the dictates of past authorities, Bacon is an experimentalist but not

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[25] Studies in this 'matters of fact' research include Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life* (Princeton: Princeton University Press, 1985); Daston, "Baconian Facts, Academic Civility and the Prehistory of Objectivity"; Shapiro, *A Culture of Fact: England, 1550–1720*; and others.

[26] Bacon, *The New Organon*, 57.

notably innovative. The beginnings of early modern observational natural philosophy date back at least to the 1540s. If Baconian induction is a general respect for exhaustive collection of observational data and cautious development of theories based on that data, then natural philosophers at Oxford and Gresham College, members of the Royal Society, progressive physicians of the College of Physicians, and educated virtuosi in London may indeed have been adopters of Baconian induction. But in this case, the term is more a banner under which they marched than a new logic. Baconian induction would be little more than a name for humanist natural philosophy and Bacon little more than the master promoter.

What has not been entertained is the possibility that successful natural philosophers of the mid-seventeenth century understood the details of Bacon's induction and used that induction to obtain the results they did. A good reason this has been overlooked is that, according to philosophers of science, it is just not technically possible for successful scientific discoveries made by Boyle, Hooke, and others to result from the use of Baconian induction. Recall that Charles Pierce described Baconian induction as inadequate for making scientific progress and Morris Cohen called it utterly irrelevant. This assessment has not changed. In the 1960s it was advanced by Paolo Rossi in his influential, sophisticated, and generally sympathetic treatment *Francis Bacon: From Magic to Science*,[27] and by Mary Hesse

[27] Rossi, *Francis Bacon: From Magic to Science*.

in her widely followed assessment of Bacon's induction.[28] In the 1970s, Imre Lakatos wrote, "among philosophers of science Baconian method is now only taken seriously by the most provincial and illiterate."[29] The majority of recent works on Bacon gives his theory of induction no attention. In one of the few that do, Stephen Gaukroger equated Baconian induction with "eliminative induction"[30] and concluded his analysis this way: "In sum, it is difficult to find a case where eliminative induction does real work."[31] Robert Ellis's 1857 assessment stands virtually unchallenged:

> It is neither to the technical part of his method nor to the details of his view of the nature and progress of science that his great fame is justly owing. His merits are of another kind. They belong to the spirit rather than the precepts of his philosophy.[32]

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[28] "To summarize, many things may be said in criticism of Bacon's method: he made little first-hand contribution to science by means of it, and his successors did not use it." Hesse, "Francis Bacon," 152.

[29] I. Lakatos, "Popper on Demarcation and Induction," in *The Philosophy of Karl Popper*, ed. P. A. Schilpp (La Salle, IL: Open Court, 1974), 259, cited by Barry Gower, *Scientific Method: A Historical and Philosophical Introduction* (London: Routledge, 1996), 12.

[30] i.e., a disjunctive syllogism: The cause is A, B, or C; it is not A or B; therefore the cause is C. The problem is knowing whether A, B, and C exhaust all possibilities.

[31] Gaukroger, *Francis Bacon and the Transformation of Early-Modern Philosophy*, 152.

[32] Spedding 1:64. One exception to the consensus has been Urbach, *Francis Bacon's Philosophy of Science*, which tries to recast Bacon as a proto-Popperian, against Popper's own claim that his doctrine directly opposed Bacon's. A succinct summary of the modern assessment of Bacon's induction and insightful explanation of the cause are provided in Lynch, *Solomon's Child: Method in the Early Royal Society*, 2. Lynch begins his study of Bacon's influence in the early Royal Society with an understanding of Baconian induction directly opposed to mine: "Unlike Aristotle's forms,

With the new understanding of Baconian induction developed in the previous chapter, this chapter considers the overlooked possibility that some natural philosophers in the mid-seventeenth century were using Bacon's induction as he intended it to be used—that they understood it as I have proposed and that they effectively put it into practice. Three cases will be considered. The first choice may seem odd; it is Bacon's own work on the nature of the tides. Though we are not accustomed to viewing Bacon as a practicing scientist, his work on tides presents a valuable case, for here we get to see Bacon trying to apply his own theory. It helps us understand what Baconian induction in practice would look like. The second case is William Harvey. He is widely considered to have dismissed Bacon's methodology, but I will show that the circumstantial evidence for this dismissal is weak and is contradicted by direct statements Harvey makes. I will argue that in fact Harvey's work is a fine example of Baconian induction in practice. The third case is Robert Boyle. In hitherto overlooked ways, Boyle draws directly on details of Bacon's theory of induction and claims to model his most important own work on Bacon's induction of the form of heat. The chapter cannot hope to be comprehensive, but merely to broach the possibility that some successful and important mid-century science was conducted not only according to the spirit but also according to the detailed precepts of Bacon's proposal for a new kind of induction.

Bacon does not seek the essential characteristics invariably associated with particular natural kinds" (9). I have argued that this is precisely what Bacon's forms are.

Bacon's and Galileo's Theories of the Tides

Bacon intended the *Instauratio Magna* to be a comprehensive renewal of natural learning and philosophy built around the new epistemology presented in part II, the *Novum Organum*. That part was published in 1620, Bacon was forced out of his position as Lord Chancellor the following year at age sixty, and he died in 1626. In his final six years, he wrote and published a remarkable amount, both material related to the *Instauratio* and material that he considered recreational. In 1623, he published a much-expanded Latin translation of the *Advancement of Learning*, titled *De Augmentis Scientiarum*, as in effect part I of the *Instauratio*. It was a comprehensive and orderly survey of the state of learning in all branches of knowledge and an identification of those branches most in need of a new inductive methodology. Part III was to be a collection of natural histories. In October or November, 1622, Bacon published the first, *Historia Ventorum* (*History of the Winds*). To it he appended abstracts for five more, which he intended to publish at the rate of one per month. The second, *Historia Vitae et Mortis* (*History of Life and Death*), was published in January or early February, 1623. Drafts for the third, *Historia Densi et Rari* (*History of Dense and Rare*), were never completed and were published only posthumously in 1658. Bacon abandoned this goal of short and methodical treatments in Latin and substituted a less structured collection in English of one thousand observations, published for Bacon by his chaplain and amanuensis William Rawley in 1627 just after Bacon died. The collection was titled *Sylva Sylvarum, or A Natural History in Ten Centuries*, and was frequently thereafter known as Bacon's *Natural History*. These natural histories, both this one and the earlier ones on winds and on life and death, were examples of the surveys of observational data that Bacon believed provided the starting points for the inductive search for forms.

Part IV of the *Instauratio* was to provide examples of the new epistemology in practice, but nothing was completed or published. Only fragments survive. This is frustrating because the only example Bacon provided in the *Novum Organon* was that of finding the form of heat, and even he admitted it was only skeletal and illustrative. The longest of the part IV drafts, *Topica Inquisitionis De Luce et Lumine* (*Topics of Inquiry Concerning Light and Luminosity*), includes incomplete tables of presence, related absences, and degrees, nine short chapters on prerogative instances, and nothing more. I suggest that better examples of Bacon applying his own method may be found in notes on particular topics in natural philosophy that he made earlier while writing the *Novum Organum*.[33]

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[33] Of the later works, the *Historia Densi et Rari* deserves more attention. It was written around 1622–24 but according to Bacon recounts experiments done much earlier. It begins with a list of measurements that Bacon made of the weight of seventy-seven materials relative to gold of the same volume. He describes in reproducible details the methods by which he took the measurements, and he tabulates his results orderly. He explores many facets of the density and rarity of solids, liquids, and 'pneumatic bodies' such as flame, air, and breath. The analysis runs to sixty-six pages in the *Oxford Francis Bacon* edition (vol. XIII). Bacon ends with provisional conclusions, the first of which is that "The sum of matter in the universe stays the same; and there is no transaction which either comes from nothing or gets reduced to it." ("Summa Materiae in Vniverso easem manet; neque fit transactio, aut a Nihilo, aut ad Nihilum.") If the experiments themselves were made when Bacon was at Twickenham Park, then they preceded by at least five years the folios in

Particularly interesting from that period is *De Fluxu et Refluxu Maris* (*On the Ebb and Flow of the Sea*), written around the end of 1611. It is interesting for three reasons. First, it shows us Bacon at work on a contemporary problem in natural philosophy. Second, the draft was published in 1653,[34] the beginning of the period in which the Baconianism of the Oxford circle and of the future Royal Society was taking shape. Third, it allows a direct comparison to Galileo's contemporary theory on the same subject and to Galileo's method. Galileo's theory is a good example of Zabarellian regressus in practice, Bacon's theory a good application of his own method. The comparison further highlights the difference between Zabarella's (purportedly inductive) method and Bacon's. A look at Bacon's theory of the tides will show us what natural philosophy done according to Bacon's method would look like. This will help us when we consider the work of mid-century natural philosophers in order to determine the extent to which they used Baconian induction.

Daily periods of the tides, monthly correlations with the moon, and annual variations were known in Hellenistic, Roman, and Islamic times and were known in the Renaissance through the works of Pliny, Strabo, and other ancient or

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Galileo's famous manuscript 72 on which Galileo recorded experiments on free fall and from which scholars have tortuously and only tentatively reconstructed Galileo's experiments and results. It appears Bacon kept much better lab notes than Galileo did.

[34] Francis Bacon, *Scripta in natvrali et vniversali philosophia* (Amsterdam: Elzevir, 1653).

medieval writers.[35] Sixteenth-century global exploration increased interest in the tides and by 1600, rules-of-thumb and almanacs gave fairly reliable forecasts for the tides based on geographic location and phase of the moon. There was no crying need for better predictions, but there was increasing interest in understanding the causes of the ebb and flow. Three types of possibilities were discussed:[36] Animistic or vitalistic theories, such as that water flowed in and out of underground chasms as if the earth were breathing; naturalistic, non-astronomical theories, such as that the tides were the effect of winds or river flows; and astronomical explanations, such as that the moon had some kind of affinity with the seas by which the moon pulled the seas as it circled the earth. Exactly how such an affinity caused the observed phenomena was more difficult to identify. Theories and methods varied. The first to achieve some success was Federico Chrisogono in a work published in Venice in 1528.[37] Chrisogono used observations and well-established correlations to identify a few key assumptions from which he deduced the daily and monthly cycles. Several Venetians adopted his ideas. Another theoretician, Simon Stevin, used a more

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[35] David Edgar Cartwright, *Tides: A Scientific History* (Cambridge: Cambridge University Press, 1999); Federico Bonelli and Lucio Russo, "The Origin of Modern Astronomical Theories of Tides: Chrisogono, de Dominis and Their Sources," *The British Journal for the History of Science* 29 (1996): 385–401; W. R. J. Shea, "Galileo's Claim to Fame: The Proof that the Earth Moves from the Evidence of the Tides," *The British Journal for the History of Science* 5 (1970): 112–3.

[36] Bonelli and Russo, "The Origin of Modern Astronomical Theories of Tides: Chrisogono, de Dominis and Their Sources," 386–87.

[37] Federico Chrisogono, *Tractatus de occulta causa fluxus et refluxus maris* (Venice: Joan. Anto. de Sabbio, 1528).

Euclidean method in a work published in 1608.[38] A third method, one of hypothesis-testing, was used by Marco Antonio de Dominis (1560–1624). His theory was published in 1624.[39]

De Dominis and Bacon had much in common. De Dominis was born to a prominent Dalmation family the same year Francis Bacon was born to England's Lord Keeper. De Dominis had a strong interest in natural philosophy early in life, publishing on optics and teaching mathematics at the University of Padua, but spent most of his career in legal and church affairs. Trained by the Jesuits, he abandoned the Catholic Church and moved to England where he became prominent at court while Bacon was serving James. De Dominis eventually returned to the continent and to Catholicism, but died out of favor with both the English and Italian churches in 1624, two years before Bacon's death. When De Dominis came to England in 1616, he was already an admirer of Bacon; he had published an Italian translation of *De Sapienta Veterum* in 1609. Maybe inspired by discussions with Bacon on the topic or reading Bacon's writings on it, de Dominis returned to his old interest in natural philosophy with his short book on the tides, entitled *Euripus seu de fluxu et refluxu maris sententia*. From observations, de Dominis developed multiple hypotheses, then eliminated (sometimes erroneously) those whose implications failed to match other observations. Several features of his resulting theory were not improved upon until Newton. Most notable is his

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[38] Simon Stevin, *Van de Spiegheling der Ebbenvloet* (Leiden: 1608).

[39] Marco Antonio De Dominis, *Euripus seu de fluxu et refluxu maris sententia* (Rome: 1624).

recognition that action of the sun and moon raises seawater not only on the side toward the luminary bodies but on the opposite side as well. De Dominis's theory attracting Galileo's criticism in 1632.[40]

In the 1610s, first Bacon then Galileo wrote unpublished accounts of their respective theories. Bacon wrote *De Fluxu et Refluxu Maris* around the end of 1611. He probably intended it for use in the *Instauratio Magna*, but as it comes down to us, the essay is a tentative and preliminary draft. Some ideas from it were revised and included in the *Novum Organum* in 1620, but the whole was not printed until 1653 when it was included as part of a posthumous transcription of several unpublished papers.[41] In 1616, Galileo wrote a letter to Cardinal Orsini (1593–1626) in which he put into writing the theory of the tides that he had recently recounted to the cardinal in person. The letter was never published but circulated throughout

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[40] In the *Dialogo*, Galileo refers to de Dominis as "a certain prelate." Galileo Galilei, *Dialogue Concerning the Two Chief World Systems*, trans. Stillman Drake (New York: Modern Library, 2001), 487.

[41] Bacon's theory has drawn little comment. The lengthiest treatment remains Robert Leslie Ellis's Preface to *De Fluxu et Refluxu Maris*, Bacon, *Works*, 3:39, which places Bacon's theory in its historical context. Graham Rees's introduction to the essay, Francis Bacon, *Philosophical Studies c.1611–c.1619*, ed. Graham Rees, vol. 6, *The Oxford Francis Bacon* (Oxford: Clarendon Press, 1996), xxiv–xxv, offers less on the tidal theory itself but places it within Bacon's overall natural philosophy. Cartwright, *Tides: A Scientific History*, 26–28, considers Bacon's proposal as a scientific theory, offers a respectful treatment, and gives it nearly as much coverage as Galileo's. Shea, "Galileo's Claim to Fame: The Proof that the Earth Moves from the Evidence of the Tides," contrasts strengths in Bacon's proposal with corresponding weaknesses in Galileo's.

Europe.[42] A copy made its way to Bacon in 1619, by which time Galileo had read and commented on Bacon's proposal.[43] Slightly revised and expanded, the material from Galileo's letter to Orsini became the topic of conversation in the climactic fourth day of the 1632 *Dialogo*.[44] We are reminded disciplinary lines were fluid in

[42] Galileo Galilei, "Discourse on the Tides," in *The Galileo Affair: A Documentary History*, ed. Maurice A. Finocchiaro (Berkeley, Los Angeles, London: University of California Press, 1989), 119–33.

[43] It is frustrating that little is known of this interchange. Our only substantive evidence is one short letter of April 4, 1619, from Tobie Matthew to Bacon. The two maintained a friendship since their joint residence in Gray's Inn in 1595. Matthew came from a clerical family but converted to Catholicism and spent much of his adult life in the courts of Europe, including Florence and Rome, publishing religious essays and translations of other writers' works (including a translation of Bacon's *Essays* into Italian). Matthew appears to have been on familiar terms with Galileo. They may have first met in Florence in the summer of 1608. In the letter of April 4, 1619, Matthew reports that Galileo had read and reviewed Bacon's "discourse concerning the flux and reflux of the sea." Galileo's response was given to one Richard White for transmission to Bacon, but the response was so plainly in error regarding the period of tides that White was not forwarding it. Matthew reported that he himself would go talk with Galileo. Matthew also reported that White was now on his way to London, carrying several of Galileo's published and unpublished works, which he was sure Bacon would want to read. Matthew urged Bacon to see White when he calls. For the letter and a small amount of background, see Bacon, *Works*, 14:36–7. The interchange is mentioned in Jardine and Stewart, *Hostage to Fortune: The Troubled Life of Francis Bacon*, 306–7, and explored in some depth in Paolo Rossi, *Aspetti della rivoluzione scientifica* (Naples: Morano, 1971), 163–9. Rossi includes speculation on what may be Galileo's only mention of Bacon.

[44] Galileo's theory drew comment from the time of his unpublished manuscript, then less after Newton's *Principia* explicated the essentially correct theory, but then more again after Ernst Mach, *The Science of Mechanics*, 6th ed. (La Salle, IL: 1960), 262–4 (first published in 1883), criticized Galileo's theory in modern frame-of-reference language. In the second half of the twentieth century, Galileo's theory was a subject for historians of science beginning especially with E. J. Aiton, "Galileo's Theory of the Tides," *Annals of Science* 10, no. 1 (1954): 44–57. Harold L. Burstyn, "Galileo's Attempt to Prove That the Earth Moves," *Isis* 53, no. 2 (1962): 161–85, made an attempt to

the Renaissance. De Dominis and Bacon, both involved in matters of church and state at the highest levels, were also involved in a discourse on the nature of tides, and the contributions of these statemen were of sufficient quality to warrant comment by Italy's prominent mathematician. A comparison of Bacon's theory and Galileo's and especially of the methods implicit in them, is instructive. I will note some similarities, summarize each theory along with its strengths and shortcomings, then examine the method behind each.

The most notable thing about both theories is that they are wrong.[45] Galileo denies that the moon has any role to play in the tides, and Bacon denies that the earth moves. Both theories, however, are advances on previous theories in one important way: both focus on the dynamic behavior of moving water rather than on static forces. Both hold that there is one main daily tidal motion and that the rises and falls of less than daily period are the result of water shifting around within its containing bodies and bouncing off coastlines. Neither theory, even if the

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claim that Galileo was in fact correct in many essential ways. The attempt largely failed, though Stillman Drake expressed some sympathy in Stillman Drake, "Galileo's Theory of the Tides," in *Galileo Studies: Personality, Tradition, and Revolution* (Ann Arbor: University of Michigan Press, 1970), 200–13, and Stillman Drake, "Galileo Gleanings X: Origin and Fate of Galileo's Theory of the Tides," in *Essays on Galileo and the History and Philosophy of Science*, ed. N. M Swerdlow and T. H. Levere, vol. 2 (Toronto: University of Toronto Press, 1999), 97–106, as recently has Paolo Palmieri, "Re-examining Galileo's Theory of Tides," *Archive for History of Exact Sciences* 53 (1998): 223–375. The most important article for purposes here, since it looks at Galileo's method instead of his conclusion, is Shea, "Galileo's Claim to Fame: The Proof that the Earth Moves from the Evidence of the Tides."

[45] This partly explains the little interest in Bacon's theory. Galileo's theory too would have raised little interest were it not for his other achievements in natural science.

fundamental flaws were corrected, had any hope of accuracy without major advances in the science of fluid dynamics.[46] But both rightly gave such dynamics a central role.

Galileo accepted Copernicus's theory that the earth rotates on its axis and revolves around the sun. By this theory, a point on the earth's surface—considered from the perspective of a viewer far north of the earth's orbital plane looking on a counter-clockwise orbit and a counter-clockwise rotation—moves at different speeds at different times of the day. When the point on the surface is directly on the orbital path, its tangential movement is at the same speed as the earth's rotation. But at other times, the speed is greater or less. At midnight, when the point on the surface is away from the sun, the point is moving faster, because the speed of revolution around the sun combines with the speed of rotation around the axis. Twelve hours later, the speed of that same point is lower, because the speed of revolution counters the speed of rotation. A sea basin on the globe's surface thus speeds up and slows down at different times of the day, and Galileo compares the resulting phenomenon to water in a barge.[47] When the barge slows down, the water rushes to the front, rising there and falling at the back. When the barge speeds up, water rushes to the back, rising there and falling at the front. Analogously, as the sea basin speeds up and slows down, the sea waters slosh back and forth creating

[46] For an attempt to cast Galileo's theory in terms of modern fluid dynamics, see Palmieri, "Re-examining Galileo's Theory of Tides."

[47] Galilei, "Discourse on the Tides," 121; Galilei, *Dialogue Concerning the Two Chief World Systems*, 493.

tides on eastern and western shores. Unfortunately, this whole theory contradicts Galileo's own theory of inertia, and it was not long before his readers were pointing out that the speed of a point on the earth's surface relative to a point far off in space is unimportant.[48] In all relevant ways, the speed of the sea basin is constant. There is no speeding-up and slowing-down to cause the tides.

It may seem inappropriate to criticize Galileo too harshly for his mistake. The whole science of inertial mechanics—which Galileo himself was inventing—was in its infancy, and how inertial frames of reference do and do not combine is a subtle and sophisticated issue. What is not subtle, however, is abundant contradiction between Galileo's theory and well-known observational evidence. One particularly glaring discrepancy is that according to Galileo's theory there should be only one tide per day.[49] Moreover, high tide should be at noon, low tide at midnight. There are, though, two tides per day and their times lag fifty minutes each day, making a full cycle though the day in a lunar month. Between 1616 and 1632 Galileo modified his theory to try accounting for this well-known lunar correlation and another well-known solar cycle, but by his updated theory tides should be greater at new moon than full moon and greater at solstices than equinoxes. Neither is true. All told, Galileo's theory contradicted more than ten simple, well-established, and well-

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[48] The first to observe this in writing may have been Jean-Jacques Bouchard, in a letter to Galileo in 1633 on behalf of a group of French physicists. We do not know Galileo's response. The letter is quoted in Shea, "Galileo's Claim to Fame: The Proof that the Earth Moves from the Evidence of the Tides," 116.

[49] This is the error that Richard White found embarrassingly egregious.

known facts.[50] After a summary of Bacon's theory, we will consider what methodology would allow such a talented natural philosopher as Galileo to overlook such contradictions.

Bacon's theory of the tides did not depend on Copernican cosmology, about which Bacon was unconvinced.[51] Instead Bacon held that there was a universal, daily, cosmological, east-to-west motion around the earth. The motion is strongest in the celestial bodies, shared to some extent by the clouds and trade winds, and is most attenuated in the waters of the earth. It may be that the water is pulled along by an attraction with the celestial bodies, or it may be that the earth itself is rotating as the Copernicans say. Either way, Bacon claims, because of this universal motion, if the earth were covered by water, the water would simply flow evenly east to west around the globe. If instead there were one large landmass running north and south on the globe, the water's flow would be thwarted and there would be one large daily wave hitting that shore. But the earth in fact has two large north-south landmasses standing in the way of the water's flow, the Eurasian-African landmass

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[50] Shea, "Galileo's Claim to Fame: The Proof that the Earth Moves from the Evidence of the Tides," 125.

[51] Bacon was suspicious of mathematical constructs that could not claim physical correlate. He was thus unwilling to accept a theory merely because it saved the phenomena better. *Novum Organum*, 2:36, includes as an example of a 'crucial instance' a particular celestial observation that would help decide in favor of the physical reality, and not just the mathematical excellence, of the helio- or the geocentric theory. See also *Novum Organum*, 2:5 and 2:48. For Bacon's preferred cosmology, see Graham Rees, "Introduction [vol. VI]," in *Philosophical Studies c.1611–c.1619*, ed. Graham Rees, vol. 6, *The Oxford Francis Bacon* (Oxford: Clarendon Press, 2004), xxxvii–lii.

and the American landmass. These create two daily waves, and thus two tides per day. The fact that the landmasses have irregular shapes creates all sorts of variations on the basic twice-daily tidal pattern.

Bacon's theory has several problems. Its failure to accept Copernican helio-centricism is the most glaring, but not the most egregious. Bacon thought his theory was compatible with either the Copernican or the Ptolemaic model, and in fact a roughly correct theory of the tides can be developed within a Ptolemaic framework.[52] The most egregious error in Bacon's system is that it fails to show how a constant east-to-west motion would result in an inconstant water level. Constant water pressure against an obstruction does not itself produce a periodic wave. Bacon recognized the possibility of an attraction between a heavenly body and the seas, but he failed to focus attention on how the moon could provide the inconstant motion he was implicitly presuming. Moreover, Bacon (like Galileo) failed to distinguish tangential movement of a wave from tangential movement of the water itself, another concept difficult to grasp without a better understanding of fluid dynamics. The strength of Bacon's theory, on the other hand, is that it generally coincides with observations.

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[52] In a three-body universe of earth, moon, and sun (the bodies important for tides), the two models are not very different. It is with the consideration of the planets (of no importance for tides) that the Ptolemaic system shows it weakness. Kepler's proposal for the tides, which is based on a Copernican cosmology, attributed the tides to attraction from the moon and is more like Bacon's theory than like Galileo's. On the other side, some thinkers of the late sixteenth century, though they still accepted the Ptolemaic system, were nonetheless on the right track toward the correct solution.

Bacon and Galileo got to their theories in different ways. Bacon used his own induction, and, I propose, Galileo used Zabarellian regressus. Bacon's project was to construct a sound notion of the tides by discovering the concept's essence, using an extended process of comparing and contrasting observational evidence. Galileo's project was to construct mutually linked proofs, the cause (Copernican cosmology) explaining the effect (the tides) and the effect confirming the cause. Let us examine each thinker's method by following his argument.

Bacon begins *De Fluxu et Refluxu Maris* by summarizing well-known observational evidence and stressing the importance of identifying which phenomena are and which are not under investigation.[53] The focus of attention, he says, is motion that is "natural and universal."[54] It is not the currents that are specific to local conditions, such as flows down inclines, disturbances along protruding rocks and uneven sea bottoms, and interferences from winds.[55] Bacon recognizes that often these local conditions hide or destroy the natural ebb and flow, but it is the constant and universal motions that are tides. Bacon explains, again recognizing well-known observations, that these universal motions are of four types, each on its own cycle. By the first motion, the seas approach and recede from the shores about twice a day. The frequency is not exactly twice a day, for each rise occurs twelve hours and twenty-five minutes after the previous. After one lunar

[53] Spedding, 5:443.

[54] Spedding, 5:444; "de motibus oceani naturalibus et catholicis," 3:48.

[55] Bacon excludes interferences from winds even when the winds are seasonally periodic. Periodicity is not the essential and sufficient characteristic.

month, the times of rising and falling are again the same. This monthly cycle is the second motion. The third is a half-monthly cycle by which tides are increased at new and full moons. The fourth is a half-yearly cycle whereby tides are increased in equinoxes. These four motions are observed, to some extent and unless hidden by local currents, everywhere in the world. The first motion is the strongest and the other three are modifications of it. These universally observed motions are what Bacon seeks to explain. They are what he calls tides. His task is to find their cause, their essence, their 'form,' that is to find what makes a tide a tide.

Bacon starts his search by drawing a conclusion from the fact that the tides are global.[56] Either there must be a global increase and decrease in the volume of water, or the same amount of water must be moving from place to place.[57] Working as de Dominis did, eliminating candidates refuted by observations, Bacon eliminates the first possibiliy primarily because tides occur at different times in different parts of the world. He provides many examples. He notes, secondarily,

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[56] "It is unusual to find someone of that epoch without professional experience of the sea taking such a global view of the ocean tides." Cartwright, *Tides: A Scientific History*, 27. It is unclear to me precisely where Bacon got his data. Most of it would have been readily available in almanacs and natural histories. How the tides moved along the coasts of the British Isles and northwestern Europe, on which Bacon placed great importance, was well known. Bede recorded this in the eighth century for the coast along which he lived. Cartwright, *Tides: A Scientific History*, 13–14. Bacon also used recent data from overseas travelers, probably gathered sporadically. Sir Francis Drake returned to England from one of his voyages the year Bacon went to Cambridge. We know that Bacon was familiar with at least some reports of Portugese explorations. Benjamin Farrington, *Francis Bacon: Philosopher of Industrial Science* (New York: Collier Books, 1961), 41.

[57] Spedding, 5:445. Bacon also considers and rejects the possibility that the water lifts up off the seafloor.

that it is very difficult to imagine a cause for a global increase and decrease. One possibility is an expansion by heating. Another is a source that constantly adds and removes water from the seas. A third is an attraction between the water and one of the heavenly bodies. None of these possibilities is incredible, Bacon says, but the sheer volume of water and speed with which it would have to increase and decrease weighs against them. But regardless whether a reasonable cause for a global increase and decrease can be envisioned, observation that tides occur at different times in different places precludes this candidate. Tides, Bacon concludes, must be a movement of water from place to place.[58]

It is next necessary to find the cause of that movement. This is the second stage of Baconian induction as articulated in the *Novum Organum*. In the first stage, Bacon has identified the genus of the nature under investigation. By next identifying the specific cause, he will have identified the differentia. This second step requires a careful and extended process of comparing and contrasting abundant and varied observational evidence. It requires, in effect, a creation and working of the three Baconian tables. But before proceeding, Bacon warns that correspondence is not the same as causality.[59] This is particularly to be heeded in the case of celestial correspondence. The fact that tidal motion corresponds to the motion of the moon, or the half-yearly motion to that of the sun, is insufficient for claiming that one causes the other. Other correspondences must be researched (i.e., the table

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[58] Spedding, 5:447.

[59] Spedding, 5:448.

of instances must be expanded), similar but non-corresponding instances must be sought (the table of contradictory instances must be populated), and the instances of variation must be explored in detail. Bacon then proposes specific questions and experiments that will form the basis for a methodical investigation.[60] The first is whether the daily motion of the heavens, which appears to have a correspondence with the tides extends to other non-celestial bodies. Second, Bacon proposes to research the extent to which the waters of the earth move from east to west. This will require collecting evidence from around the globe, and Bacon cites the need in particular for data from Gibraltar, Cape St. Vincent, Ile de Ré, Cape Finisterre, Normandy, the Indian Sea, the German Sea, the Black Sea, the Persian Gulf, Norway, the Baltics, and sites in America, Africa, and China, all because of their distinctive conditions or relations. The result would be the kind of data that in the *Novum Organum* Bacon calls evidence from prerogative instances. Third, Bacon insists on detailed analysis of the fact that the daily cycle has a period of twenty-four hours and fifty minutes and not exactly twenty-four hours. Based on the partial data he has, Bacon proposes that the tides are a reverberation of the sea's daily east-west motion off the globe's two north-south landmasses. But this is a tentative proposal, what in the *Novum Organum* is called the 'first harvest.'[61] Bacon insists much more data is required to confirm, refine, or replace this proposal. At the end of his essay, Bacon includes first a reminder that this research project must not be satisfied with

[60] Spedding, 5:449.

[61] *Novum Organum*, 2.20.

finding correspondences when those correspondences might have an underlying common cause, second a directive to integrate research on tides into the broader question of whether the earth rotates, and third a list of thirteen observations that are most urgently needed.[62]

By Bacon's inductive method for developing a theory of the tides, a preliminary grouping of observations is made, and a genus—motion of water from place to place on the globe—is identified. By a broad and iterative integration of data not just on tides but on comparable and contrasting phenomena, the tide's differentia within that genus is identified. Thus the essence, or 'form,' or formal cause of the tides is identified. Bacon, that is, was using his own inductive method.[63] Galileo's project was different. He set out not to identify what makes a tide a tide, but to prove the Copernican heliocentric theory.

A long-standing weakness of the Randall thesis that Galileo used Zabarella's system of regressus (mistakenly understood as a combination of induction and deduction) is lack of an example. The tone of the thesis has been that the crucial component of regressus is arguing from observed effects to causes, that Galileo's experiments were aimed at such inference, and that therefore Galileo used regressus. But it has not been shown how the methodology actually applied to

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[62] Spedding, 5:457–58.

[63] He is also using (as James Lennox reminds me) a method strikingly similar to that of *Posterior Analytics* 2. 8-10, 15-18. There too the genus is identified, and the cause serves as the differentia. To know what thunder is is to know that it is a noise in the clouds (genus) caused by the quenching of fire (the cause and the differentia).

specific Galilean theories, such as pendular motion, free fall, or inertia. In a hitherto unexplored way, Galileo's theory of the tides offers such an example. Like Bacon, Galileo did not believe that definitive proof of the Copernican theory had yet been presented. Unlike Bacon, Galileo set out to provide that proof. His proof would be that Copernican heliocentricism provides an explanation for the tides. Thus his theory of the tides would provide the evidence for the Copernican theory, and the Copernican theory would in turn provide evidence for Galileo's theory of the tides. As a postil claims at the beginning of day four of the *Dialogo*, "The tides and the earth's mobility reciprocally confirm one another."[64] This is a straightforward summary of Zabarellian regressus.[65]

Galileo's Zabarellian framework can be seen by examining the argument he presents in the 1616 *Discourse on the Tides* and in the voice of Salviati on the fourth day in the 1632 *Dialogo*. In the *Dialogo*, Galileo announces, in Zabarellian fashion, that one must begin with knowledge of the effects and proceed to discovery of the cause.[66] He admits that he has limited direct evidence about the tides and that the indirect evidence he has is largely unreliable. But, he claims, he does have sufficient sensory experience to know the possible causes for movement of water. These include an inclined plane as of a river bed, motion of surroundings such as wind,

[64] Galilei, *Dialogue Concerning the Two Chief World Systems*, 483.

[65] . . . or more accurately a straightforward application of Paduan regressus. As discussed earlier, Zabarella contributed little that was new to regressus theory, but since he became its leading spokesman, I will continue to associate regressus with him.

[66] Galilei, *Dialogue Concerning the Two Chief World Systems*, 484.

and expansion caused by heat. Galileo brusquely dismisses all of these, as well as the theory that the tides could be caused by an attraction to the moon. The only way the tides could possibly occur, he affirms, is if the earth moves, and moves with a non-uniform acceleration, like the barge slowing down and speeding up. Galileo's argument is a Zabarellian 'resolutio' or 'demonstratio quia,' a 'demonstration of the fact':

> If there are tides, the earth must move in a certain non-uniform way.
> There are tides.
> Therefore, the earth moves in a certain non-uniform way.

Of the two types of Zabarellian resolution, this one is a 'demonstratio a signo,' not an 'inductio.' In the 1616 *Discourse*, Galileo says that the tides are "a sign of and an argument for" the motion.[67] Neither the argument for the major premise (an argument by elimination) nor the 'demonstratio' itself is an induction. Galileo's argument for the earth's motion is a straightforward syllogism.

At this point, Galileo has established that the earth must move in a certain non-uniform way, a way that makes a sea basin act like a barge speeding up and slowing down and throwing its water back and forth. If the earth did not so move, there could not be tides. But Galileo wants more. He said that the tides and the earth's mobility confirm each other, and he has only half of the regressus. He has only the 'demonstration of the fact,' the 'resolutio.' He still needs the 'demonstration of the reasoned fact,' the 'compositio,' the 'demonstratio propter

[67] Galilei, "Discourse on the Tides," 131.

quid.' He has a valid syllogism, but the effect not the cause is the minor premise. This is where one starts in a regressus, but the goal is a syllogism in which the effect is a conclusion, not a premise. To accomplish this, some new insight is required, an insight achieved by what the Paduan Aristotelians called 'consideratio' or 'mentale examen' and Galileo calls "reflection" ("speculazione").[68] After "many days and . . . many more nights"[69] of such reflection, Galileo came to believe that under the Copernican system, the earth has the non-uniform motion necessary to cause the tides.

This insight, he believes, justifies substituting 'according to the Copernican theory' for 'in a certain non-uniform way' and turning the syllogism around as needed. The result is a demonstration of the reasoned fact, a Zabarellian 'resolutio,' a 'demonstratio propter quid,' the second half of a regressus:

> If the earth moves according to the Copernican theory, there are tides.
> The earth moves according to the Copernican theory.
> Therefore, there are tides.

Galileo acknowledges that there is no physical evidence to justify the major premise. In the *Discourse on the Tides*, he says he is building a physical model, but that for now, "let us be satisfied with what each can conceive with his imagination."[70] Galileo's only evidence is the contemplative reflection he has done

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[68] E.g., Galilei, *Dialogue Concerning the Two Chief World Systems*, 487, 516, 518.

[69] Ibid., 518.

[70] Galilei, "Discourse on the Tides," 127. In the 1632 *Dialogo*, Salviati says "I have a mechanical model in which the effects of these marvelous compositions of movements may be observed in detail." There is no evidence for this model, and we do not know what Galileo had in mind. In the

and the earlier demonstration of the fact of the tides. This is all in keeping with regressus methodology. One begins with the effect as a minor premise. By some method outside the regressus, one composes a major premise. The conclusion of the syllogism is the cause. One has argued from effect to cause. Then by some contemplative insight, one gains a clear and distinct idea that the major premise can be inverted. The cause becomes the other premise, and the effect becomes the conclusion. The researcher now has an irrefutable syllogistic proof that the cause causes the effect, in this case, that the Copernican motion of the earth causes the tides. Galileo's basic theory of the tides has been completed.

Though contradicting observed facts, Galileo's theory is a paradigmatic instance of Zabarellian regressus and fits the task Galileo assigned it, that is, confirming the Copernican heliocentric theory. As he said, the theory of the tides and the heliocentric theory mutually confirm each other. Each serves as evidence for the other. The criticism that has always been leveled against regressus methodology—that it is circular and arbitrary—is here on display. Galileo's theory was mutually reinforcing but it was not self-correcting. As is manifest in his failed attempts (added in the 1632 tract) to explain the monthly and annual tidal periods, no further applications of Galileo's Zabarellian regressus method could get him out of the vicious circle he had created. No more disregard for observations and reliance

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dialogue, Salviati continues, "But so far as our present purpose is concerned, what we have grasped intellectually up to this point is sufficient" (500). That is, even if there is such a model, it is superfluous since our mental insight is sufficient.

on contemplative insight and mutually reinforcing syllogisms would get Galileo closer to a correct theory of the tides.[71]

Bacon's theory, on the other hand, was not mutually reinforcing, but it was self-correcting. His theory could not survive the empirical tests of it that he himself set for it. At every turn, Bacon proposed additional observations that would be needed before his theory could be accepted. He explained what parts of his theory would need to be abandoned or modified if investigations he insisted were necessary yielded results different than he expected. He was prepared to abandon his theory, but not his method. The goal of the project, he maintained, was to discover what tides are. The difference between this and the goal of regressus is important. Galileo and other practitioners or theoreticians of regressus speak of causes and effects. Given an effect, they want to find a cause. By their thinking, a cause and an effect are different things. Bacon, on the other hand, speaks of causes and natures. Given a nature, he wants to find its cause, but a particular kind of cause, the formal cause, or 'form.' By this thinking, a nature and its formal cause are the same thing, in the way that a definition and the thing it defines are the same. Bacon wants to learn what causes tides, but only in a specific sense of 'cause.' Fundamentally he wants to know what tides *are*.

[71] This sharp attack on the method Galileo used in developing his incorrect theory of the tides, of course, should not be taken as criticism of his other discoveries, discoveries obtained by other methods.

Galileo suffered opposition to his theory from many quarters—from men such as de Dominis, Matthews, and Bacon who insisted on testing proposals against well-established observations, from Galileo's own followers who recognized an inconsistency with Galileo's own theory of inertia, from Kepler who advocated a lunar attraction, and even indirectly from the Church. Galileo believed his theory of the tides was the clinching evidence validating Copernicus's heliocentric theory, and it was this evidence that he thought justified standing up to the Church's attack on him and on Copernicanism. It is a shame that a natural philosopher so committed to observational research in his other work became so stubbornly committed to a circular method like regressus on a problem so central to his career and life.

Bacon made none of the historic scientific discoveries that Galileo made, and he never returned to in-depth study of the tides. His thoughts on the subject were not lost however. As mentioned, in 1653 the unfinished essay was published, in Amsterdam in a collection with other unpublished works from the period c. 1611–c. 1619. In the *Novum Organum*, Bacon included suggestions for applying his inductive method to research on the tides,[72] and these were extracted for inclusion, under the heading "Ratio inveniendi causas fluxus et refluxus maris," in a book that we will encounter soon, published in Leiden several times starting in 1638. Whether the influence was through one of these publications or by independent application of

[72] *Novum Organum*, 2.36.

the same methodological principles, Bacon's induction came to underlie future science on the tides. One of the great nineteenth-century contributors to tidal theory and a developer of the modern harmonic analysis of tides was Lord Kelvin.[73] In an 1882 lecture, he reflected upon the foundations of the science.[74] His message was that the successful development of tidal theory over the previous two and a half centuries was in effect a project of defining what is and what is not a tide. Successful understanding came when the cause of the tide could become a defining characteristic. As Kelvin did, we nowadays define a tide not just as a periodic rise and fall of the sea, but as a "periodic rise and fall of the sea due to the attraction of the moon and sun."[75] The cause is included in the definition. Bacon's inductive project has been completed, the essence of the tide identified. We do not now ask the inductive question, 'English tides are caused by the attraction of the moon and the sun; so also American tides; so also African tides. Are Chinese tides also caused by the attraction of the moon and the sun?' The answer would be yes, for attraction by the moon and the sun is what makes a tide a tide.[76] A periodic rising and falling of the sea *not* caused by attraction of the moon and sun (as by seasonal winds) is *not*

[73] Cartwright, *Tides: A Scientific History*, 82–84.

[74] William Thompson, "The Tides: Evening Lecture to the British Association at the Southampton Meeting, Friday, August 25th, 1882," in *Harvard Classics*, ed. Charles W. Eliot, vol. 30 (New York: Collier, 1910).

[75] *The Oxford American Dictionary and Language Guide* (1999), s.v. "tide."

[76] We also no longer limit the concept of tides to water. Atmospheric tides are the periodic motion of the atmosphere caused by attraction of the moon and sun, and earth tides, the periodic deformation of the earth caused by attraction of the moon and sun.

a tide. As Kelvin stressed, to determine whether a particular motion of the sea is or is not a tide *is* to determine whether it is caused by attraction of the moon or sun. It was Bacon's method of induction, the method of identifying an essence, that became the model for modern tidal theory.

William Harvey and the 'Rule of Socrates'

The discoveries of William Harvey (1578–1657) are often cited as evidence that Baconian induction was not used for the chief scientific advances of the early seventeenth century. I want to claim the opposite and to argue, based on a close reading of *De Generatione Animalium* (1851) and on recent scholarship regarding his studies of the heart,[77] that Harvey's work on generation of animals and circulation of the blood are fine examples of Baconian induction in practice.[78] I believe this is fairly easy to establish; less easy to determine are the lines of influence, that is, whether Harvey got his Baconian induction directly, or even indirectly, from

[77] Especially Andrew Cunningham, "William Harvey: The Discovery of the Circulation of the Blood," in *Man Masters Nature: Twenty-Five Centuries of Science*, ed. Roy Porter (New York: G. Braziller, 1988), 65–76; and Roger French, *William Harvey's Natural Philosophy* (Cambridge: Cambridge University Press, 1994), 71–93.

[78] Useful discussions of possible Baconian influence on Harvey have appeared in J. Pelseneer, "Gilbert, Bacon, Galilée, Képler, Harvey et Descrates: Leurs Relations," *Isis* 17, no. 1 (1932): 203; Geoffrey Keynes, *The Life of William Harvey* (Oxford: Clarendon Press, 1966), 157–161; Walter Pagel, *William Harvey's Biological Ideas: Selected Aspects and Historical Background* (New York: Hafner, 1967), 21–23; William Hale-White, "Bacon, Gilbert and Harvey: Being the Harveian Oration Delivered Before the Royal College of Physicians of London, October 18th, 1927," in *Studies on William Harvey*, ed. I. Bernard Cohen (New York: Arno Press, 1981), 100-200; and French, *William Harvey's Natural Philosophy*, 325–28.

Bacon. Let me first review and then discount the documentary evidence for the conventional view, then demonstrate Harvey's respect for Bacon and use of his method, and then lastly address the question of influence.

The evidence that Harvey dismissed Bacon and his method lies in the material on Harvey in John Aubrey's *Short Lives* (1813)[79] Andrew Wear, in his introduction to a recent edition of Harvey's book on circulation, cites the oft-reported passages from Aubrey in the following way.

> Harvey himself never agreed with the new philosophy. John Aubrey recalled him as saying of Francis Bacon, the philosopher revered by the founders of the Royal Society that '"he writes philosophy, like a Lord Chancellor" saide he to me, speaking in derision'. Aubrey added that 'he bid me goe to the fountain head and read Aristotle, Cicero, Avicen[na] and did call the neoteriques [those who believed in the new philosophies] shitt-breeches.'[80]

This neatly summarizes what many historians believe of Harvey's attitude toward Bacon, but the summary is misleading.[81] It must be remembered that Aubrey's *Lives* were not completed biographies, but haphazard, unsystematic, and often inaccurate notes frequently written decades after the fact and assembled for

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[79] Oliver Lawson Dick, ed., *Aubrey's Brief Lives* (Jaffrey, NH: David R. Godine, 1999), 128–33.

[80] William Harvey, *The Circulation of the Blood and Other Writings*, trans. Kenneth J. Franklin (London: Everyman, 1993), xxv. Bracketed insertions are Wear's.

[81] For development of this theme, independent of but overlapping my own, see Hale-White, "Bacon, Gilbert and Harvey: Being the Harveian Oration Delivered Before the Royal College of Physicians of London, October 18th, 1927."

publication only posthumously. For biographical details, they must be used with caution.[82] Citing them out of context makes them even less reliable. The first part of the remark above comes from three sentences that read in full,

> He had been Physitian to the Ld Ch. Bacon: whom he esteemed much for his witt & style, but would not allow him to be a great Philosopher. Said he to me, he writes Philosophy like a Ld Chancellor, speaking in derision. I have cured him.[83]

It is unclear whether Harvey cured Bacon of some illness or of his bad writing. The first is normally presumed, but the structure of the passage suggests otherwise, and the development of Bacon's style would support the alternate. Bacon's earlier works, such as *Advancement of Learning*, have the tone of a governmental policy paper, and his later works are more like Harvey's own. Harvey's assessment of Bacon's writing style could have been shared by Bacon's staunchest advocates, and many of the same would have acknowledged that Bacon never achieved the status

[82] Andrew Clark, Aubrey's nineteenth-century editor, summarized, "Aubrey's 'Lives' . . . will never be a biographical dictionary. Their value lies not in statement of biographical or other facts." Cited by ibid., 34.

[83] My transcription of John Aubrey, MS Aubrey 6, f. 64v-65r, Bodleian Library, Oxford. In Aubrey's notes, the preceding sentence is about Harvey's attitude toward women, the following one about a trip Harvey made in 1649. To the left is the sentence "He was far from bigotry." As mentioned, the *Lives* are a collection of unrelated recollections. As one example of the imprecision of Aubrey's account, note the tense of the verbs in the quoted passage. Harvey could only have recounted this to Aubrey twenty-five years or more after Bacon's death. Harvey would have said "He wrote Philosophy," not "He writes philosophy," and "I cured him," not "I have cured him." Regarding this inconsistency, see Hale-White, "Bacon, Gilbert and Harvey: Being the Harveian Oration Delivered Before the Royal College of Physicians of London, October 18th, 1927," 32.

of a great 'Philosopher,' having never himself made any great advances in natural philosophy. So these two criticisms cannot ncessarily be taken as dismissal of Bacon's method. Finally, Harvey's comment about the neoteriques being shitt-breeches comes from a completely separate part of Aubrey's notes, in which Harvey offers advice to Aubrey on Aubrey's upcoming trip to Italy. There is no suggestion that Bacon or any Englishmen are among these neoteriques.[84] If other, more reliable, first-hand, evidence indicated that Harvey rejected Bacon's methodological doctrines, then Aubrey's account could add color. But the first-hand evidence indicates otherwise.

For the first evidence that Harvey thought his own views on methodology were similar to Bacon's, we may consult a copy of *De Generatione Animalium* in the Pybus Collection in the library of the University of Newcastle upon Tyne.[85] It belonged to Harvey's nephew, but it includes a few annotations hand-written in Latin by William Harvey himself.[86] They include his thoughts on the practices of the scholastics. The passage ends,

> The elenchic disputations of the scholastics in which they drag truth by the neck to confirm an hypothesis has the result that in this way we can prove or defend anything we choose. So do sophists overthrow

[84] Harvey was probably referring to Italian Paracelsans.

[85] William Harvey, *Exercitationes de generatione animalium* (London: Du-Gardianis, 1651), Newcastle University Library, Pybus Collection Pyb Case 2/iv.

[86] William Harvey, *Disputations Touching the Generation of Animals*, trans. Gweneth Whitteridge (Oxford: Blackwell Scientific Publications, 1981), "Appendix," 456–57.

philosophy and because they are rather useful for shaping the morals and manners of the crowd they may well go unpunished, . . .

This excerpt and the passage leading to it sound eminently Baconian in spirit, like something that Bacon could have written in the *Advancement of Learning* or *Novum Organum*. Indeed, for more on these views, Harvey cites Bacon:

. . . see Bacon, On difficulties, at the beginning.[87]

Now Bacon did not publish anything entitled *On difficulties*, nor was anything published posthumously by that title, so it is unclear to what Harvey is referring. But by including 'at the beginning,' he indicates that he has a particular text in mind. Perhaps he got the title wrong, though I know of no text in which Bacon makes exactly the point Harvey does. Perhaps Harvey is thinking of something written by someone else, but even so, he thinks his own remarks are Baconian. Or perhaps Harvey had access to a manuscript by Bacon now lost, an intriguing possibility. Whatever the explanation for the title *On difficulties*, the passage provides evidence that Harvey believed an explication of his own position on scholastic methodology could be found in the writings of Francis Bacon.[88]

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[87] "Scolasticorum elenctica disputatio qua veritatem ad suppositum obtorto ducunt collo, facit ut eo modo quod licet probare et defendere possimus. Ita sophistae phylosophiam obruunt et quia ad firmandos vulgi mores utiliores inulti sint; vid. Bacon, De difficultatibus, inicio." Ibid., 456.

[88] I have asked Graham Rees, editor of the *Oxford Francis Bacon*, if he can tell what passage Harvey is citing, and he cannot either. It is possible that the transcription is inaccurate, as Harvey's hand-writing is notoriously illegible, but I have reviewed a high-quality facsimile and see no reason to doubt Whitteridge's reading. Presumably, there is also the possibility that Harvey is referring to

For direct evidence of Baconian induction in Harvey's research we turn to the body of *De Generatione Animalium*. Harvey's earlier work, *De Motu Cordis*, was published in 1628 (two years after Bacon died). It is a short work, and Harvey, then fifty years old, said little in it about his method. He probably began work on *De Generatione Animalium* soon thereafter and continued working on it until around 1642.[89] Harvey was not comfortable that he had adequately answered the questions he posed, but he published the work nonetheless in 1651. He wanted to publish it, he says in the preface, in order to show others his method. The short preface describes that method under three headings, "Of the manner and order of attaining knowledge," "Of the same matter according to Aristotle's opinion," and "Of the method to be observed in setting forth the knowledge of generation."[90] What Harvey says here, especially under the heading about Aristotle, and what Bacon says in passages of the *Novum Organum* are so similar in distinctive content and vocabulary that Harvey must be drawing on Bacon's work or the two must have a common source.

Roger Bacon (or even some other Bacon), but the whole passage sounds much more seventeenth century than thirteenth, and I could find no passage in Roger Bacon entitled *De difficultibus*. I follow Whitteridge's judgment that Harvey is referring to Francis Bacon.

[89] Introduction, xix–xxv, in Harvey, *On the Generation of Animals*.

[90] *"De modo, & ardine acquirendae cognitionis," "De iisdem, ad mentem* Aristotelis," *"De Methodo in cognitione Generationis adhibenda."* Preface, Harvey, *De generatione animalium*, B2v, B4v, C2v; Harvey, *On the Generation of Animals*, 10, 14, 17.

Harvey first criticizes those who think "the whole of Truth was . . . colonized by the Ancients"[91] and draws a distinction between discoveries made by chance and those—the "more commendable"[92]—discovered by a methodical investigation of nature. He then cites two conflicting passages from Aristotle, one claiming that knowledge is a rising from singulars to universals, and another that says knowledge is an advance from universals to particulars.[93] The passages introduce the common distinction, 'better known to us' vs. 'better known to nature,' and it seems that Harvey is headed in the direction of proposing a conventional Paduan regressus.[94] But he does not. Instead he begins a discussion about the nature of universals.[95] Knowledge of particulars, he says, is "clear and distinct," that of universals

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[91] "omnen certe veritatem a Veteribus occupatam esse." Preface, Harvey, *De generatione animalium*, B2v; Harvey, *On the Generation of Animals*, 9. Cf. Bacon, *Advancement of Learning*, Book 1. On Harvey's attitude of natural philosophy as progressive investigation of nature, rather than an attempt to recover lost ancient wisdom, see French, *William Harvey's Natural Philosophy*, chapter 3.

[92] "magis laudabile." Preface, Harvey, *De generatione animalium*, B2v; Harvey, *On the Generation of Animals*, 9. Cf. Bacon, *Novum Organum* 1.8 and 1.109.

[93] Preface, Harvey, *De generatione animalium*, B2v-r; Harvey, *On the Generation of Animals*, 10. The first Aristotelian passage Harvey cites is *Physics* 1.1. The second passage is a misquotation. It comes from an edition by Guilio Pace, a Paduan Aristotelian and regressus theoretician. See the citation of Charles B. Schmitt, *The Aristotelian Tradition and Renaissance Universities* (London: Variorum Reprints, 1984), 305, by French, *William Harvey's Natural Philosophy*, 40.

[94] French, *William Harvey's Natural Philosophy*, 59n34, 63.

[95] James G. Lennox, "The Experimental Basis of Conceptual Innovation in William Harvey's *De Motu Cordis*" (paper presented at the Meeting of the Philosophy of Science Association, Austin, TX, November 18–20, 2004), 1–2.

"obscure and indistinct."[96] The passage sounds more like English Aristotelians we have encountered, such as Everard Digby and John Case than like regressus theoreticians Harvey would have met in Padua. The treatment is rather eclectic and not fully clear, but in the end Harvey says, "To conclude, sensible objects are of themselves and prior to things in the mind; these things of the mind are after them and derive from them."[97] The most important part of natural philosophy, Harvey is arguing, is to get the concepts right, that is, to make sure the abstract notions of natural philosophy are properly formed from sense observations. This, of course, is Bacon's project, and here Harvey's language turns recognizably Baconian. If notions are not formed properly, Harvey says, "we make judgements entirely on phantoms and apparitions inhabiting our minds"[98] and "will arrive at a floating and nebulous opinion."[99] To refer to these false representations, Harvey uses the distinctive terms that Bacon used: phantasmata, apparitiones, inania, falsae imagines, and Idola, i.e., Idols.[100]

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[96] "clarum et distinctum" and "obscurum et indistinctum." Preface, Harvey, *De generatione animalium*, B3v; Harvey, *On the Generation of Animals*, 11, replacing Whitteridge's "confused" with "indistinct."

[97] "Denique, sensibilia sunt per se, & priora: intelligibilia autem, posteriora, & ab illis orta." Preface, Harvey, *De generatione animalium*, B3r; Harvey, *On the Generation of Animals*, 12.

[98] "de phantasmatis & apparentiis mente nostra comprehensis, perperam judicabimus." Preface, Harvey, *De generatione animalium*, B3r; Harvey, *On the Generation of Animals*, 13.

[99] "opinionem quidem tumidam, & fluctuantem acquires." Preface, Harvey, *De generatione animalium*, B3r; Harvey, *On the Generation of Animals*, 13.

[100] Preface, Harvey, *De generatione animalium*, B3r, C1r; Harvey, *On the Generation of Animals*, 12-3, 16.

To describe the proper method of proceeding, Harvey first cites and summarizes Aristotle's *Posterior Analytics*. In this work, Harvey says, Aristotle poses and then finally solves a problem. The problem is how we come to know the premises upon which syllogism and demonstration are based and, moreover, to know that these premises are true and necessary. Harvey then quotes a long passage from the final chapter (2.19) of the *Posterior Analytics*, the passage in which Aristotle describes the rise from sense perception to memory to experience to, in Harvey's words, "universal reason, definitions and maxims, or common axioms."[101] This, recall, is the passage that Aristotle says is a description of induction. If this method is followed, Harvey says, men "by the aid of their own senses [may] abstract therefrom true representations of the things themselves," and will avoid "false Idols."[102]

Harvey concludes with a preview of how he has applied his method to the current case of the generation of animals. A wide range of animals must be investigated, he says, but some are unavailable in sufficient quantities, are too small, or are inaccessible to dissection. He has therefore, to the extent possible, chosen to examine

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[101] "ratio universalis, definitions, & maxima, sive axiomata communia." Preface, Harvey, *De generatione animalium*, B4r; Harvey, *On the Generation of Animals*, 15.

[102] The full sentence: "Qui enim Autorum verba legentes, rerum ipsarum imagines (eorum verbis comprehensas) sensibus propriis non abstrahunt, hi non veras Ideas, sed falsa Idola, & phantasmata inania mente concipiunt." Preface, Harvey, *De generatione animalium*, C1r; Harvey, *On the Generation of Animals*, 16. Cf. Bacon, *Novum Organum*, 1.1–38, especially 1.23 and 1.38 for some of the distinctive vocabulary.

> certain races of oviparous creatures, hens, geese, pigeons, ducks, fish, crustaceans, testaceans, soft-bodied fish, frogs and snakes; of insects, bees, wasps, butterflies and silkworms; of viviparous creatures, sheep, goats, dogs, cats and cloven-hoofed cattle, and in chief, the most perfect of them all, man himself.[103]

The variety is directly in keeping with a Baconian approach. Harvey continues, "Having thoroughly examined and understood all these things, we may next contemplate the hidden nature of the vegetative soul, and apprehend the manner and order of generation in *all* creatures, and its causes."[104] That is, by identifying the essence of the things under investigation, we may extend our conclusions to all creatures, not just those investigated. This kind of inference was central in the *Novum Organum*. Harvey closes by noting that there may not be words for all the things he may come upon. If so, he may need to reuse common words and give them more precise definitions, or he may need to form entirely new words. He asks the reader's indulgence, for identifying the essential characteristics of things named will repay the effort.

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[103] "in oviparorum quidem genere, gallina, anser, columba, anas, pisces, crustata, testacea, mollia, ranae, serpents; insecta, ut apes, vespae, papiliones, bombyces: in viviparorum autem censu, oves, caprae, canes, feles, jumenta bisulca; &, prae caeteris, animalium omnium perfectissimus, homo ipse." Preface, Harvey, *De generatione animalium*, C3v; Harvey, *On the Generation of Animals*, 19.

[104] "His perspectis, & cognitis, naturam animae vegetativae abstrusam contemplari; & in omnibus animalibus, generationis modum, ordinem, atque caussas intelligere licebit." Preface, Harvey, *De generatione animalium*, C3v; Harvey, *On the Generation of Animals*, 19, substituting "nature" for Whitteridge's "account." Italics mine. Cf. Aristotle, *De Partibus Animalium*, 1.1 641a15–25.

In this preface, though Harvey has described a process like that of the *Novum Organum*, using distinctively Baconian vocabulary, Harvey has not named Bacon. That changes at a key point in the body of *De generatione animalium*. The book has seventy-two chapters. Chapter 25[105] forms a clear break between a first section and a second. In the first section, Harvey provides an account of "where and how an egg is made . . . and by what means, in what order and by what stages the foetus or chick is fashioned and perfected in the egg."[106] His account is lengthy, detailed, and based on careful observations. Although the account is structured around the hen's egg and the growth of the chick, along the way Harvey makes comparisons to the reproduction of the hawk, pigeon, ostrich, pheasant, butterfly, worm, snake, bee, wasp, shrimp, crayfish, tortoise, mole, hare, deer, horse, man, and many other animals. He has organized his analysis differently, but he has done the work Bacon does using three tables. Harvey then writes, "All this has perhaps been too wordy and long drawn out . . . . And so I think it convenient to explain here what fruit my labour has born and, to use the words of our most learned Verulam [i.e., Francis Bacon], proceed to my 'second harvest.'"[107] A 'harvest' ('vindemiatio'), recall, is

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[105] Mislabeled "24" in the 1651 London edition, corrected in the 1653 Latin and English editions.

[106] "unde, & quomodo oriatur. . . . quo pacto, & ordine, quibusque gradibus, foetus, sive pullus in ovo, & ex illo formetur, & perficiatur." Chapter 1, Harvey, *De generatione animalium*, D1r; Harvey, *On the Generation of Animals*, 22.

[107] "Prolixe forsitan nimis. . . . Quare, quem fructum diligentiae nostrae consequuti simus, hic adjungere consentaneum arbitror: atque (ut doctissimi *Verulamii* nostri verbis utar) *vindemiatio*

Bacon's unusual word for a definition drawn from whatever observations have been made up to that point of the investigation. Harvey has been discussing the egg for seventy-four pages and twenty-four chapters, and only now does he get to the topic one might have expected at the beginning. The title of the next chapter is "What an Egg is."[108] The first twenty-four chapters have been directed toward identifying the essence of an egg, at identifying what makes an egg an egg, at identifying what Bacon would call the form of an egg. Harvey's procedure has followed the pattern of Baconian induction, and at the critical transition in that procedure, Harvey confirms for us that he is self-consciously following the model that Francis Bacon presented in his treatise on induction.

It thus seems that by 1642, when Harvey finished writing *De generatione animalium*, he believed that to some extent he was using Baconian induction. But it is not clear whether he thought the method was exclusively Baconian and whether he learned it from the *Novum Organum*. That is, did Harvey learn his Baconian induction from Bacon? To answer that question, let us review Harvey's career.[109]

When he was fifteen, Harvey entered Gonville and Caius College, Cambridge, a college with a strong tradition of medical study. After six years there,

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secunda instuenda est." *Harvest* for Whitteridge's *vintage* for Harvey's *vindemiatio*. Italics in original. Harvey, *De generatione animalium*, N2v; Harvey, *On the Generation of Animals*, 134.

[108] "Quid fit Ovum." Harvey, *De generatione animalium*, N2v; Harvey, *On the Generation of Animals*.

[109] Roger French, "Harvey, William (1578–1657)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

he moved to the University of Padua, where he studied for two and a half years with Fabricius of Aquapendente (1537–1619). Fabricius believed that he was continuing Aristotle's anatomical research project and understood the core of that project to be the determination of what causes any particular bodily organ to be the kind of organ it is.[110] Fabricius proceeded methodically. He first acquired a comprehensive historia based on dissections and observations of the widest possible variety of animals possessing that organ. By comparing and contrasting, he distinguished which common features were only accidentally or coincidentally so and which were essentially so. He held that all four Aristotelian causes have a causal role, but the most important is the organ's function—its action and use. The function is the essential characteristic that makes, for example, a stomach a stomach or an ear an ear. Fabricius demonstrated the validity of his identification by using the function to explain why the organ differed in different animals. By his process he used similarities and differences to identify the essence—the function—of the organ, and then the function to explain the differences between different kinds of the organ. Fabricius faulted his predecessors for focusing on structure instead of function and for not considering a sufficiently wide variety of animals. To understand the structure of the human stomach, for example, Fabricius held, it was necessary to first understand the function that makes any stomach a stomach. This

[110] Andrew Cunningham, "Fabricius and the 'Aristotle Project' in Anatomical Teaching and Research at Padua," in *The Medical Renaissance of the Sixteenth Century*, ed. A Wear, R. K. French, and I. M. Lonie (Cambridge: Cambridge University Press, 1985), 195–222; French, *William Harvey's Natural Philosophy*, 66–68.

was a theme in Aristotle's biological works: to know the function is to know the essential cause and to have scientific knowledge. Harvey will later adopt the same doctrine in *De Generatione Animalium*, in his research into the function that causes an egg to be an egg.

Harvey was back in England in 1603 and was granted permission by the College of Physicians to begin practicing medicine. King James was now on the throne, and Francis Bacon had a position in the new adminstration, but few official responsibilities. In that year he began the notes toward what would later become the *Novum Organum*. Harvey had made no noteworthy investigations into the heart. In 1604 Harvey married a daughter of the king's physician. In 1605 Bacon published the *Advancement of Learning*. Separated in age by seventeen years, both Bacon and Harvey were seeking their place at court in the same years of James's reign, and both succeeded admirably. In early 1618, Bacon was named Lord Chancellor, and at nearly the same time, Harvey was appointed the king's physician. Even without Aubrey's testimony, we can safely assume Harvey and Bacon, both serving the king directly, knew each other.

Harvey had begun taking a vigorous role in the College of Physicians and would continue to do so for the rest of his career. In 1616, at the age of thirty-eight, he began delivering lectures there. His lecture notes survive and are a valuable source for understanding Harvey's methods.[111] In their introductory section, Harvey says that the anatomist should proceed "secundum Socratis regulam," i.e., "according to the rule of Socrates."[112] What he means by that emerges from an examination of the notes, Harvey's later additions to them, and the tract on the circulation of the blood that he later published.[113]

Harvey's assignment is to lecture not on animals in general, but on man, yet on the title page of his notes, he writes, quoting Aristotle, that "The inner parts of man are uncertain and unknown wherefore we must consider those parts of other animals which bear any similarity to those of man."[114] Harvey is lecturing while he and his students look at a dissected human cadaver, yet Harvey says that to understand what they are looking at, they must consider not only the same organ in other cadavers but the same organs in other animals, too. Only then can one know the essence of the organ. To understand the human heart, for example, one must determine what makes any heart a heart. Harvey holds, with Aristotle, that it is not its color, shape, size, or structure but its function that makes a biological organ the kind of thing it is. We point to a certain organ in man, a certain organ in deer, and in dogs, cats, frogs, fish, and snakes, and we call each of those organs a 'heart.'

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[111] Gweneth Whitteridge, *The Anatomical Lectures of William Harvey* (Edinburgh and London: E. & S. Livingstone, 1964).

[112] Quoted and translated in French, *William Harvey's Natural Philosophy*, 83.

[113] Cunningham, "William Harvey: The Discovery of the Circulation of the Blood"; French, *William Harvey's Natural Philosophy*, 71–93.

[114] *History of Animals*, 1.16 494b19–24, and *Parts of Animals*, 2.10 656a9–14. Quoted and translated in French, *William Harvey's Natural Philosophy*, 84.

Harvey says we do this not because the individual organs have the same color or structure, but because they perform the same function. After a series of comparisons, experiments, dissections, and vivisections with the most diverse creatures, Harvey concluded that that function is to eject blood into the arteries of the organism. Every organ, if it is a heart, has that function. If it does not have that function it is not a heart. Discovery of the essence, the function, of the heart—not the circulation of the blood—was Harvey's fundamental discovery. He obtained it by considering his subject to be not the heart of man but the heart in all animals that have one. Note the full title of his seminal book is *Anatomical Exercise On the Motion of the Heart and Blood in Animals*.[115] Once the function, the essence, of the heart (any heart) is identified, it become a straightforward question to ask where all the blood goes and where it all comes from. It was a small step to conclude, through a combination of observation and reasoning, that the blood is circulating out from the heart and back again. What Harvey means by the 'regula Socratis' is the compare-and-contrast process by which he surveyed the widest possible variety of hearts and determined what makes a heart a heart.

By the time Bacon published the *Novum Organum*, Harvey was well on his way to discovering circulation, if he had not discovered it already. Bacon died in 1626, his *Sylva Sylvarum* was published in 1627, and Harvey's *De Motu Cordis* was published in 1628. By the mid-1640s, a group of talented physicians and natural

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[115] Harvey, *De generatione animalium*.

philosophers, moving in circles in London and Oxford, had come to admire both men. In 1642, Harvey at age sixty-four moved to Oxford. By 1650 an informal group of his followers had organized themselves into the Experimental Philosophy Club.[116] They met first at the lodgings of William Petty, then of John Wilkins, and then of Robert Boyle. Some members of this evolving club moved to London and formed the Royal Society.[117] The Society conspicuously adopted the methods of Francis Bacon and half of its members were Harveian physicians. Harvey died before the Society was founded, but he remained an active leader in the College of Physicians nearly till his death. In these years of Harvey's leadership and influence, the College became what his friend and fellow physician William Charleton called "Solomon's House in reality,"[118] referring to Bacon's *New Atlantis*. In the 1660s, Bacon and Harvey were often mentioned together (along with Gilbert) as the founders of modern English science.[119] Their work was considered of a type. Baconians were Harveians, and Harveians were Baconians.

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[116] Robert G. Frank, Jr., *Harvey and the Oxford Physiologists: A Study of Scientific Ideas* (Berkeley and Los Angeles: University of California Press, 1980).

[117] Webster, *The Great Instauration: Science, Medicine and Reform 1626–1660.*

[118] Walter Charleton, *The Immortality of the Human Soul, Demonstrated by the Light of Nature* (London: 1657), 34.

[119] Several examples appear in Robert G. Frank, Jr., "The Image of Harvey in Commonwealth and Restoration England," in *William Harvey and His Age: The Professional and Social Context of the Discovery of the Circulation*, ed. Jerome J. Bylebyl (Baltimore and London: Johns Hopkins University Press, 1979), 103–44.

There is a small but potentially important difference between what Harvey wrote in *De Generatione Animalium* and what Bacon wrote in the *Novum Organum*. Harvey says that the words 'second vintage' are those of 'our most learned Verulam.' But in his published work Bacon never uses the phrase 'second vintage.' He discusses the first vintage, but never the second, and the omission is a valid source of criticism. A first implies a second, but Bacon says the conclusion reached by his induction is certain. How could the first conclusion be certain if it is to be superseded by a second? Passages in the *Novum Organum* and elsewhere suggest how Bacon might answer this, but they are only suggestions. Characterization of a second vintage is simply not part of the orthodox Baconian doctrine as it survives in Bacon's own writings. Why did Harvey, writing in the 1640s, believe his definition of the egg was a second rather than a first vintage, and why did he believe the words 'second vintage' were those of 'our most learned Verulam'?[120] I do not yet see how to answer the first question, but to answer the second, it is fair to hypothesize first

[120] It is possible that the passage in chapter 25 is being misread. By his Latin statement, Harvey might mean, 'I will explain here what fruit my labour has born and, *after doing so*, proceed to my second vintage.' In this case, the definition of an egg presented in chapter 26 is a first vintage, and the second vintage does not appear until chapter 62, where Harvey summarizes, integrates, and refines the intervening developments. If this is his intent, and if he really is following Baconian doctrine, then chapter 62 could indicate what Bacon himself had in mind for a 'second vintage.' But regardless whether Harvey thought the second vintage was the definition of an egg in chapter 26 or the broader integration in chapter 62, we still want to know why he thought he was using Bacon's phrase. I do not think that Harvey meant Bacon knew only how to get to the first vintage, but that he, Harvey, knew how to go beyond that. If he did, I doubt Harvey would have said that 'second vintage' was Bacon's phrase.

that an (at least slightly) amplified version of Bacon's doctrine of induction circulated among Bacon's followers of the early 1640s, second that this version was either passed on from Bacon orally or in lost texts or was developed by followers who believed it was a justified extension, and third that Harvey was familiar with and believed he was using this amplified version. Perhaps Harvey himself was the conduit passing knowledge of this version of Baconian induction from Bacon himself to the natural philosophers who gathered around Harvey in the 1640s. Maybe Harvey and Bacon discussed natural philosophy at length—maybe Harvey cured Bacon of writing natural philosophy like a government bureaucrat, and Bacon taught Harvey how to develop a 'second vintage.' Harvey's use of the phrase deserves further study.

To Harvey, Baconian induction probably looked like just a systematized, codified, even formulaic version of the Aristotelian method that Harvey learned from Fabricius through countless dissections and vivisections, just a restatement of the 'regula Socratis' that Socrates had used to identify the essence of love and that Harvey used to identify the essence of the heart.[121] Harvey probably thought of Bacon as a dilettante, sitting in his barrister's office telling real natural philospher's like himself how to go about their business. But he did not dismiss Bacon. He appreciated Bacon's ability to capture an idea with words like *idol* and *harvest*. Harvey recognized his own method in Bacon's. In 1654, the same year Webster

[121] That Harvey had Socrates' discussion of love in the *Republic* in mind, see French, *William Harvey's Natural Philosophy*, 84–85.

attacked Cambridge and Oxford professors for not teaching Bacon's induction and Ward and Webster insisted they did, Harvey was elected president of the College of Physicians. He was seventy-six and decided he was too old to serve. To the new generation of physicians at the college and to natural philophers at Oxford, he was now admired—along with Bacon and Gilbert—as one of the founders of their revolution. But of these founders, it was Bacon who was the methodologist. Until 1651 Harvey had published nothing on method. When he did, he implored the young not to abandon Aristotle and to look to the *Posterior Analytics* for how to avoid idols. Men in their twenties and thirties were probably glad to learn their methods instead from the more practical *Novum Organum*. Baconian induction was a systematized version of Aristotelian and Socratic induction. Although Harvey accepted and used Baconian induction, he had already been introduced to its essentials before meeting Bacon or reading anything Bacon wrote. Harvey learned the essentials of Baconian induction not from Bacon, but from Fabricius, Aristotle, and Socrates.

Robert Boyle on the Nature of Chemical Qualities

One of the most influential of this younger generation and one more likely to encounter induction in Bacon than in Aristotle was the natural philosopher Robert Boyle (1627–1692). Though Francis Bacon's influence on Boyle is and has been for a long time widely accepted, Boyle's acceptance of Bacon's induction has received little attention. It is well recognized that Boyle accepted Bacon's insistence on the material benefits of knowledge, Bacon's insistence on the need for a sound observational foundation, and Bacon's explanation of the role of experiments, but what Boyle thought of the specific process that Bacon considered his induction has not been studied. In her defense of Boyle's Baconianism, Rose-Mary Sargent explicitly sets induction to the side, and in his study of Bolye's philosophy, Peter Ansley never mentions it.[122] I will here propose that Boyle's most important work is an excellent example of Baconian induction in practice.

In late 1655 or early 1656, Boyle, aged twenty-nine, arrived in Oxford and joined the community of natural philosophers, now led by John Wilkins. While there, Boyle, with Robert Hooke (1635–1703), constructed an air pump that was an improvement over the one that Otto von Guericke invented in Germany in 1650. With their pump Boyle and Hooke tested existing hypotheses and came up with several of their own involving the nature of air and the behavior of materials and objects in a vacuum. Boyle published the results in 1660. Though the pump and experiments using it have been the object of considerable scholarly interest in the last twenty-five years, Boyle's *New Experiments Physico-Mechanical Touching on the Spring of the Air*[123] was only the first of dozens of works on natural philosophy that Boyle published and not the most important. He and Hooke were proceeding along a line of inquiry already well scoped by Torricelli, Mersenne, and others. That the

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[122] Rose-Mary Sargent, "Robert Boyle's Baconian Inheritance: A Response to Laudan's Cartesian Thesis," *Studies in History and Philosophy of Science* 17, no. 4 (1986): 473; Peter R. Ansley, *Philosophy of Robert Boyle* (London: Routledge, 2000).

[123] Robert Boyle, *New experiments physico-mechanicall, touching the spring of the air* (Oxford: Tho. Robinson, 1660).

air had 'spring' had been discussed since the late 1640s. The important discovery known as Boyle's Law, itself the result of a project well advanced by others, came a couple years after *New Experiments Physico-Mechanical* and was made with the sealed-end J-tube, not the air pump.[124] Boyle's most important and fundamental work for the history of chemistry was on the nature of chemical qualities, such as heat, cold, color, porosity, odor, taste, volatility, corrosiveness, and many others, and the method by which any quality should be investigated. Two-thirds of his publications were on these subjects. Peter Ansley was correct to write recently,

> When it comes to an assessment of the significance of Boyle's thought for the history of philosophy and the history of science, it is the theory of qualities that motivated much of his most important experimental work and where he made his most significant contributions to human knowledge.[125]

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[124] I. Bernard Cohen, "Newton, Hooke and Boyle's Law; Discovered by Power and Towneley," *Nature* 204 (1964): 618–21; Charles Webster, "The Discovery of Boyle's Law, and the Concept of the Elasticity of Air in the Seventeenth Century," *Archive for History of Exact Sciences* 2 (1965): 441–502; Joseph Agassi, "Who Discovered Boyle's Law?" *Studies in History and Philosophy of Science* 8 (1977): 189–250.

[125] Ansley, *Philosophy of Robert Boyle*, 17. Ansley's volume is an important contribution to the recent scholarship on Boyle. It shares with my analysis a respect for the centrality of qualities in Boyle's natural philosophy. Ansley, however, gives little attention to 'form,' (consciously so, p. 12). On conceptions of form in early seventeenth century, see Norma E. Emerton, *The Scientific Reinterpretation of Form* (Ithaca and London: Cornell University Press, 1984).

If Boyle deserves to be called the father of modern chemistry, it is not for the discovery of Boyle's Law, but for the radical reconceptualization of qualities that he effected.

By 1661, the year after *New Experiments Physico-Mechanical* was published, Boyle was familiar with some but not all of Bacon's works.[126] In *Certain Physiological Essays* of that year, he wrote that he had "purposely refrained"[127] from reading large systematic treatments of natural philosophy until he had made a sufficient number of experiments and observations of his own. He said that he had not read, for example, Gassendi's *Syntagma* or Descartes' *Principia*, and not even Bacon's *Novum Organum*. Boyle's phrasing suggests that a natural philosopher might be excused for having not read the first two but would be expected to have read the third. He is only now, he says, allowing himself to read these "excellent Books."[128] Yet by this time Boyle knew and knew well at least three other books by

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[126] On Boyle's intellectual development in his mid-twenties (1648–1653), see Michael Hunter, "How Boyle Became a Scientist," in *Robert Boyle (1627–91): Scrupulosity and Science* (Woodbridge, Suffulk, UK: Boydell Press, 2000), 15–50. The question of when Boyle read which of Bacon's books has also been researched by Hideyuki Yoshimoto at the Tokyo University of Foreign Studies. http://members3.jcom.home.ne.jp/hist_science/BaconF.html.

[127] Robert Boyle, *Certain physiological essays, written at distant times, and on several Occasions* (London: Henry Herringman, 1661), 6; Robert Boyle, *Works of Robert Boyle*, ed. Michael Hunter and Edward B. Davis, 14 vols. (London: Pickering & Chatto, 1999), 2:13. As here, citations to Boyle are to the original (if published) and occasionally to the corresponding passage (sometimes from a different edition) in the *Works*, edited by Hunter and Davis.

[128] Boyle, *Certain physiological essays*, 7; Boyle, *Works of Robert Boyle*, 2:13.

Bacon. The first is the *Sylva Sylvarum*, published in 1627 and printed at least a dozen times by 1661. Of his *Physiological Essays*, Boyle writes,

> I must inform you that many of the Particulars which we are now considering, were in my first Designe collected in order to a Continuation of the Lord *Verulam's Sylva Sylvarum*, or Natural History. And that my intended Centuries might resemble his, to which they were to be annexed.[129]

Recall that the *Sylva Sylvarum or a Naturall History in Ten Centuries* was to form most of the third part of the *Instauratio*. In the editor William Rawley's introductory epistle, he explains that Bacon intended the *Natural History* to be the foundation upon which a true philosophy would be erected and that the *Novum Organum* sets down the directions by which it would be. At this point in his career, Boyle is intentionally digesting and extending the *Sylva Sylarum* before proceeding to the *Novum Organum*. Boyle's study of the *Sylva Sylvarum* is not superficial. In describing a particular experiment involving gold, sulphur, and quicksilver, he recalls that Bacon had reported on a similar experiment, though he could not recall where.[130] By this time, Boyle also knew at least some of *De Augmentis Scientiarum*, for he cited it in an unpublished essay written several years earlier.[131]

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[129] Boyle, *Certain physiological essays*, 14; Boyle, *Works of Robert Boyle*, 2:17.

[130] Boyle, *Certain physiological essays*, 68; Boyle, *Works of Robert Boyle*, 2:58. In the *Sylva Sylvarum*, the experiment is entry 327 in century IV.

[131] "Of the Study of the Booke of Nature," Boyle, *Works of Robert Boyle*, 14:157. This essay was written c. 1650.

Also by this time, Boyle appears to have read a work of Bacon's that Boyle calls *De Forma Calidi*. The work left quite an impression on Boyle, for as we will see, he later cites it in a crucial context. But, surprisingly, Bacon never published a work by this name. What Boyle is referring to is an essay that appeared in a pocket-sized duodecimo volume first published in Leiden in 1638, reprinted in 1648, and regularly bound with the 1650 Leiden edition of the *Novum Organum*.[132] The volume was an odd collection. The title page called it *Historia Naturalis & Experimentalis de Ventis &c*. It included Bacon's natural and experimental history of the winds, published first in 1622 as one of the natural histories that would comprise the third part of the *Instauratio Magna*. But to it, the publisher, Franciscus Hack, added three other pieces, all written by Bacon but never intended as independent essays. The third was on the proper method for investigating tides, the second was on motion, and the first—the one Hack entitled "De Forma Calidi"—was on the form of heat. All three were excerpted from the text of the *Novum Organum*. "De Forma Calidi" was the important section of book 2 in which Bacon presents an investigation into the nature of heat as an example of a proper induction. The

[132] Francis Bacon, *Historia Naturalis & Experimentalis De Ventis &c.* (Leiden: Franciscus Hack, 1648); Gibson, *Francis Bacon: a bibliography of his works and Baconiana to the year 1750*, #109. Boyle was once in Leiden, presumably during his trip to the Netherlands from February to April, 1648. Michael Hunter has remarked on how little attention this important visit has received from Boyle scholars. Hunter, "How Boyle Became a Scientist," 44. Events and optical experiments Boyle witnessed there made a lasting impression (Boyle, *Certain physiological essays*, 7, 25). I do not know when in 1648 that year's edition of this duodecimo came out, but it is tempting to speculate that it came out while Boyle was in Leiden.

reason to believe that Boyle read this example of induction before reading the treatise on induction itself comes from *Certain Physiological Essays*.[133] In that 1661 volume, Boyle makes two references to passages that appear in the *Novum Organum*. The first is, "It has been truly observ'd by a great Philosopher, That Truth does more easily emerge out of Error than Confusion."[134] Bacon makes this point in *Novum Organum*, 2.20. The second is, "Another Experiment much of the nature of this is said to be delivered by Sir *Francis Bacon*, who teaches to coagulate whites of Eggs with Spirit of Wine."[135] Bacon discusses this experiment in the *Novum Organum* 2.2.24. This second reference appears in an essay on fluidity and firmness written a few years earlier, and the first appears in the same Proemial Essay in which Boyle says he has not yet read the *Novum Organum*. It is not impossible that he picked up the first from outside of his reading, but that is even less likely for the second. Much more likely is that he read both in the Leiden duodecimo. This little volume and "De Forma Calidi" will be important again. For now we may simply note that in 1660–61, Boyle knew Bacon as a "profound Naturalist,"[136] the author of experimental and natural histories on a wide range of

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[133] If my supposition is correct, it partly explains why Boyle seldom uses the word *induction*. He first learned the method by example and tends to refer to it as the method of "De Forma Calidi" rather than the method of induction.

[134] "Proemial Essay," in Boyle, *Certain physiological essays*, 9; Boyle, *Works of Robert Boyle*, 2:12–14.

[135] "The History of Fluidity and Firmness," in Boyle, *Certain physiological essays*, 209; Boyle, *Works of Robert Boyle*, 2:170. Italics in original.

[136] Boyle, *Certain physiological essays*, Sect. 13, p. 115; Boyle, *Works of Robert Boyle*, 2:170.

natural phenomena,[137] histories that Boyle himself sought to emulate, and that Boyle knew Bacon's proposal for a new and true induction from the *Novum Organum*'s example of heat.

Direct references to Bacon's methodological writings began to appear in Boyle's works the following year. In *Defence of the Doctrine Touching the Spring and Weight of the Air* (1662), Boyle cites Bacon as the source for the concept of the "experimentum crucis" ('crucial experiment'), an experiment that would determine which one of alternate hypotheses is true.[138] Bacon had presented this idea, at length, in book 2 of the *Novum Organum*, where he called such evidence not a 'crucial experiment,' but a 'crucial prerogative instance.'[139] Of all Bacon's prerogative instances, this has been the most influential, and has become known by Boyle's modified title. The following year, in 1663, in the *Usefulness of Natural Philosophy*, Boyle cites another Baconian concept, again credits Bacon, and again gives it a slightly different name. In book 1 of the *Novum Organum* (in a passage not in the Leiden excerpts) Bacon draws a distinction between *fructiferous* experiments

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[137] In an unpublished essay written 1652–4, Boyle included Bacon in lists of the leading modern natural philosophers. Also in the lists were Bernardino Telesio (1508–88), Sebastiano Basso (fl. 2nd half 16th century), Nicholas Copernicus (1473–1543), Pierre Gassendi (1592–1655), Henricus Regius (1598–1679), Athanasius Kircher (1602–80), J. B. van Helmont (1579–1644) Daniel Sennert (1572–1637) and Tommaso Campanella (1568–11639). Boyle, *Works of Robert Boyle*, 13:190, 197.

[138] Robert Boyle, *A defence of the doctrine touching the spring and weight of the air propos'd by Mr. R. Boyle in his New physico-mechanical experiments, against the objections of Franciscus Linus* (London: Richard Davis, 1662), 48; Boyle, *Works of Robert Boyle*, 3:50.

[139] *Novum Organum*, 2.36.

and *luciferous* ones, those that yield immediate practical results and those that may not have immediate practical use but allow us to identify a cause. Boyle calls the first ones *lucriferous* instead of *fructiferous*, yielding the pair *luciferous* and *lucriferous*.[140] In this same 1663 text, Boyle also quotes at length from Bacon's *Advancement of Learning*.[141] Boyle did not regularly put quotations on the title pages of his natural philosophy books, but when he did, starting in 1664, the quotes were usually from Bacon.[142] In unpublished notes, written in the 1660s and relating to the *Usefulness of Natural Philosophy*, Boyle shows an increasing and increasingly sophisticated appreciation of the content of *Novum Organum* and of his own adoption of its method.[143] In *Reason and Religion* (1675) and *Things Above Reason* (1681), Boyle cites Bacon in discussions of 'Idols' and uses the term in the same distinctive way that Bacon does, for 'notions' improperly formed.[144] In summary,

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[140] Robert Boyle, *Some considerations touching the usefulnesse of experimental naturall philosophy* (Oxford: Ric. Davis, 1663), 45; Boyle, *Works of Robert Boyle*, 3:229. Boyle returns to Bacon's 'fructiferous' and 'luciferous' in *Usefulness of Natural Philosophy*, II sect. 2 in 1671. It is easy to speculate that Boyle picked up *lucriferous* from his colleagues, before having read the *Novum Organum* itself.

[141] Boyle, *Usefulness of natural philosophy*, 104–5; Boyle, *Works of Robert Boyle*, 3:271.

[142] Galen was the only other source. Boyle used the Bible and Seneca for his non-scientific works.

[143] Boyle, *Works of Robert Boyle*, 13:351, 3.

[144] Robert Boyle, *Some considerations about the reconcileableness of reason and religion* (London: Henry Herringman, 1675), 29–30; Boyle, *Works of Robert Boyle*, 8:256; and Robert Boyle, *Experiments, notes, & c. about the mechanical origine or production of divers particular qualities* (London: R. Davis, 1676), 58; Boyle, *Works of Robert Boyle*, 9:382. Boyle attributes the quotation on the title

during the early 1660s, Boyle gained a more sophisticated understanding of what Bacon had presented in the *Novum Organum* and from then on prominently cited distinctive passages from Bacon's text. Boyle continued to cite observations from the *Sylva Sylvarum*,[145] but now, in addition to recognizing Bacon as 'a profound Naturalist,' Boyle recognizes him as a methodologist and calls him "that Great and Solid Philosopher," "that great Ornament and Guide of Philosophical Historians of Nature," "so Judicious a Friend to Philosophie and Mankind," and "Great Restorer of Physiks, . . . who trac'd out a most useful way to make discoveries."[146]

After *Certain Physiological Essays*, the next book of Boyle's to be published was the book often cited as marking the historical break between medieval alchemy and modern chemistry, *The Sceptical Chymist, or Chymico-Physical Doubts & Paradoxes*, published in August 1661. Though Lawrence Principe has shown that

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page of *Reason and Religion* to the *Novum Organum* but the passage does not appear there. Its source has not been identified. Could it too be from unpublished and now lost Baconian material?

[145] On an experiment involving metals, Century IV, 327; Boyle, *Certain physiological essays*, 68; Boyle, *Works of Robert Boyle*, 2:58. On a getting rose bushes to bloom in autumn, Century V, 13; Boyle, *Certain physiological essays*, 70–71; Boyle, *Works of Robert Boyle*, 2:59. On freezing of apples and eggs, Robert Boyle, *New experiments and observations touching cold* (London: John Crook, 1665), 52; Boyle, *Works of Robert Boyle*, 4:542. On "many particulars in husbandry," including the fertilization of vegetables, Century 5, 444; Robert Boyle, *Some considerations touching the usefulnesse of experimental naturall philosophy*, vol. II, sec 2 (Oxford: Ric. Davis, 1671), 5; Boyle, *Works of Robert Boyle*, 6:409.

[146] Boyle, *Usefulness of natural philosophy*, 104; Boyle, *Works of Robert Boyle*, 3:271; Boyle, *Experiments touching cold*, b7v; Boyle, *Works of Robert Boyle*, 4:213; Boyle, *Usefulness of Natural Philosophy, II.2*, 43; Boyle, *Works of Robert Boyle*, 6:433; Robert Boyle, *The excellency of theology compar'd with natural philosophy* (London: Henry Herringman, 1674), 170; Boyle, *Works of Robert Boyle*, 8:75.

the text is less a break with the past than once thought,[147] it is still revolutionary—maybe not for the affirmations it makes, but for the issue it raises. Boyle proposes no firm resolution of the issue until *Origine of Formes and Qualities* of 1666. Let us first consider the problem and then Boyle's proposed solution.

The *Sceptical Chymist* attacks the two prominent competing theories of chemistry,[148] the Aristotelian doctrine that there are four elements, earth, water, air and fire, and the main doctrine of medieval and Renaissance alchemy, the Spagyrical doctrine that there are three elements, salt, sulfur, and mercury. Boyle's attack begins on experimental grounds and proceeds to more abstract and fundamental issues. In countless experiments, recounted over nearly three hundred pages,[149] Boyle found no evidence for a small number of elements. It was clear that the chemists' proposal that fire could be used to decompose any material into common component elements was wrong.[150] Upon separation (by fire or otherwise), different materials yielded different numbers of materials. There was no evidence that the results were even elements or pre-existing ingredients not created by the separation process itself. Some materials, such as many metals, were impervious to

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[147] Lawrence M. Principe, *The Aspiring Adept: Robert Boyle and His Alchemical Quest* (Princeton: Princeton University Press, 1998), 27–58.

[148] Though rightly this should read "alchemy/chemistry" or "chymistry," (see ibid., 8–10), I believe little harm is done in the current context by using the more familiar term.

[149] Robert Boyle, *The Sceptical Chymist, or Chymico-Physical Doubts & Paradoxes.* (London: J. Crooke, 1661), 1–298. In what follows, I will paraphrase more than might be preferred. Already in the *Sceptical Chymist*, Boyle's style had become maddeningly prolix.

[150] Bacon too thought decomposition by fire was a fruitless approach. *Novum Organum*, 2.7.

any separation. Although elements were supposedly homogenous, always and in all cases the same material, and insusceptible of further decomposition, many supposedly elemental materials could in fact be further decomposed. Moreover, many supposedly elemental ingredients of different experiments were themselves quite different. The salt, for example, that resulted from one separation was plainly different from the salt that resulted from another.[151] Salt, therefore, was not a common, universal, homogenous element. Boyle concluded that there was no evidence for a small number of elements out of which all materials are composed.

These experimental results led Boyle to a more fundamental problem, a problem involving the very nature of material properties. Under both the ancient Aristotelian doctrine and the medieval chemist's doctrine, each element has distinctive properties, and the presence of these properties in constituent elements accounts for the presence of those properties in mixed bodies. In the Aristotelian view, if something is wet, that is because it has water in it. It if is heavy, it has earth in it. But what accounts for something having, say, flavor?[152] The difficulty in accounting for properties beyond hot and cold and wet and dry led over time to the replacement of the Aristotelian tetrad with the medieval triad. But the underlying principle was retained: properties of mixed bodies are properties of their constituent elements. Under the medieval triad, if something is flavorful, it contains salt, if fluid or ponderous, it contains mercury. Boyle's experimental results led him

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[151] Boyle, *Sceptical Chymist*, 247.

[152] Ibid., 245.

to challenge not just the Aristotelian tetrad and the medieval triad, but the underlying principle as well.[153] He stressed that many materials change properties without any addition or removal of elements. For example, with time or heat, materials within an enclosed chamber can acquire or lose properties. Opaque sand and ashes can, without the addition of any other materials, become transparent glass. Ice, snow, and hail all melt and become water.[154] Silver, when hammered becomes springy, when heated becomes flexible.[155] The sound of a plucked string changes if the string is tightened.[156] Egg whites, when beaten, harden. In all these cases, no elements are added, none removed, yet the properties changed. Moreover, how does one account for qualities such as the sound of a plucked string? Which element is sonorous? How does one account for color or motion?[157] It cannot be the case, Boyle concludes, that the qualities of mixed bodies are simply those of the constituent elements, whether earth, water, air, and fire, or mercury, sulfur, and salt—at least not if those elements are to be understood as the common and real materials that go by those names.

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[153] Ibid., 283–346.

[154] Ibid., 385.

[155] Robert Boyle, *The origine of formes and qualities, according to the corpuscular philosophy* (Oxford: R. Davis, 1666), 168.

[156] Robert Boyle, *Of the imperfection of the Chymist's Doctrine of Qualities* (Oxford: R. Davis, 1675), 31.

[157] Boyle, *Sceptical Chymist*, 313.

Throughout the Middle Ages, this presumption that elements were common materials was increasingly weakened.[158] Mercury, for example, came to be thought of as something other than the common silvery gray liquid metal. Instead it was conceived to be a special, pure, even non-material element, a unique combination of properties rather than something one can touch and feel. Elemental sulfur was no longer common brimstone, but simply the carrier of the properties of odorousness and inflammability. To have sulfur as an element came to mean simply that the material was odorous and inflammable. But what of all the qualities of perceived bodies—transparency, brittleness, particular colors, and so on—that are not characteristic of any of the elements? And how could a few elements combine to create all the combinations of properties that existed? If elemental sulfur were odorous and inflammable, how could there be a material that was odorous but did not burn? Boyle described the recent solution to this problem offered by Daniel Sennert (1572–1637).[159] According to Sennert, there is one element for each possible quality. "Where the same Quality is to be met with in many Bodies, it must belong to them upon the Account of some one Body whereof they all participate."[160] If something is heavy, that is because it has the heaviness element in it, fluid because

[158] Ibid., 299–346.

[159] Ibid., 309, 325. For recent research on this understudied figure, see Christoph Lüthy, "Daniel Sennert's Slow Conversion from Hylemorphism to Atomism," *Graduate Faculty Philosophy Journal* 26, no. 2 (2005): 99–121; and William R. Newman, *Atoms and Alchemy: Chymistry and the Experimental Origins of the Scientific Revolution* (Chicago: University of Chicago Press, 2006), 85–153.

[160] Boyle, *Sceptical Chymist*, 310. Each property has its own "δεκτικον προτον," its own "Native receptacle." Boyle, *Sceptical Chymist*, 329.

it has the fluidity element in it, sonorous because it has the sonorous element in it. By this doctrine, qualities are substantial. Properties are not properties *of* something; rather they are self-sufficient elements from which material things are composed. The basic building blocks of all material things are thus blueness, inflammability, heaviness, sweetness, transparency, and so on. All elemental qualities have a self-sufficient existence independent of the material things that manifest them as properties. Elements thus are not common or even uncommon materials, indeed not things of any sort, but attributes. By Sennert's proposal, elements are reified, non-material, independently existing qualities. Boyle thought Sennert was taking to a logical extreme the underlying error shared by both the Aristotelian advocates of four elements and the Spagyricist advocates of three, the principle that the qualities of something are the qualities of its constitutent elements. Boyle found both "the Aristotelian and divers other Theories incompetent to explicate the Origine of Qualities."[161] He ended *The Sceptical Chymist* with only a tentative suggestion for an alternative proposal.

Boyle deepened his attack and advanced his own solution in *The Origine of Forms and Qualities*, *According to the Corpuscular Philosophy*, published five years later, in 1666. Although a continuation of topics broached in *The Sceptical Chymist*, it is different in character, vocabulary, and confidence. In his earlier work, Boyle confidently provided exhaustive experimental results that indicated the

[161] Boyle, *Sceptical Chymist*, 333.

conventional approaches were wrong, but he was hesitant to name their essential problem and to propose an alternative. He said that he did not use the term *Form* in discussing his own ideas because it might be understood as *Substantial Form*, something he rejects.[162] Boyle did not yet have enough experience with any other kind of form, such as the Baconian. In the *Origine of Formes*,[163] he has shed his reservations. He now holds that the nature of forms is the unavoidable and fundamental issue, that the doctrine of substantial forms is the incorrect and harmful position, and that the correct position is one based on a corpuscularian philosophy. When Boyle wrote the first work, he was just beginning to read the *Novum Organum* and other systematic treatises, though he had already read book 2 aphorisms 11–20 excerpted in "De Forma Calidi." The difference between the *Sceptical Chymist* and the *Origine of Forms* is a much more confident understanding of Scholastic doctrine of substantial forms and a proposal virtually the same as the one Bacon presented in book 2, aphorisms 1–10 of the *Novum Organum*. Let us look first at Boyle's criticism of substantial forms and then his proposal.

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[162] Ibid., 379.

[163] Nowadays, the book's full title is usually shortened to *Forms and Qualities*. This partly masks the Aristotelian and Baconian pedigree as well as Boyle's emphasis. Boyle himself calls the work the *Origine of Forms*, as for example at "History of Particular Qualities," 15, and "Of the Systematicall or Cosmicall Qualities of Things," 3 in Robert Boyle, *Tracts written by the Honorable Robert Boyle about cosmical qualities*. (Oxford: Ric. Davis, 1670).

In *Origines of Forms*, Boyle rejects the doctrine of substantial forms for three reasons: it is unnecessary, useless, and inconsistent.[164] First, Boyle says, there is no need to appeal to reified, immaterial, unobservable qualities when appeals to observed matter and properties of that matter serve all needed purposes. Second, the doctrine is useless, even on its advocates' own terms. For they admit that "true Knowledg of [Substantial] Forms is too difficult and abstruse to be attain'd."[165] The only thing that can be said about a substantial form is it produces the observed property: the rock is heavy because it has heaviness, or earthiness, in it; the log is porous because it has porosity; but true knowledge of heaviness, earthiness, and porosity are unobtainable. Boyle summarizes, "I do not remember, that either Aristotle, (who scarce ever attempted it,) or any of his Followers, has given a solid and intelligible solution of any Phenomenon of Nature by the help of substantial Forms."[166] The doctrine was intended to help explain but in the end explains nothing. Third, Boyle notes, the doctrine is logically inconsistent. For example, consider a block of brass cast or turned into some other shape, say, a sphere.[167] The raw material has the substantial form of cubicity and the result has the substantial form of sphericity. The new may have the material of the old, but has a new form. "If they will not allow, as indeed they do not, that the substantial Form is made of

[164] Boyle, *Origine of formes*, 146–8. In Boyle, *Chymist's Doctrine of Qualities*, 33, a fourth is added: the doctrine of substantial forms fails to make reliable predictions.

[165] Boyle, *Origine of formes*, 146.

[166] Ibid., 185. See also the introductory material before page 271.

[167] Ibid., 150–52.

any thing that is Material, they must give me leave to believe, that tis produce'd out of Nothing,"[168] but advocates of substantial forms cannot accept that a substance could be produced out of nothing. Boyle recounts several examples in which these advocates try to claim that forms and their associated properties are independent of matter but end up claiming they are dependent on matter.[169] Boyle concludes, "Again, what they call a Substance they make indeed an Accident, and . . . contradict their own vulgar Doctrine."[170]

In *Origine of Formes and Qualities*, Boyle offers an alternative proposal. Qualities of things, he claims, are produced "by virtue of the Motion, Size, Figure, and Contrivance of their own Parts."[171] A cave has the ability to produce echoes because of the arrangement of its walls. A watch can tell time because of the "the number, the figure, and the coaptation of the Wheels and other parts."[172] A prism displays colors because of its shape.[173] In some explanations, the relevant parts may be small, maybe imperceptibly so. Surfaces, for example, have a certain color

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[168] Ibid., 152–53.

[169] Ibid., 154.

[170] Ibid., 156. In Boyle, *Chymist's Doctrine of Qualities*, 33, a fourth is added: the doctrine of substantial forms fails to make reliable predictions.

[171] "Preface," Boyle, *Origine of formes*, [xii]. The point is made in many places in the *Origin of Forms*, but the specifics of the list vary. "Number, bigness, proportion, shape, motion, (or endeavour,) rest, coaptation and other mechanical affections" is used (195). 'Size,' 'shape,' 'motion' and 'texture' are the most common.

[172] Ibid., 7. Also, Boyle, *Sceptical Chymist*, 341.

[173] Boyle, *Sceptical Chymist*, 334.

because of their texture.[174] Ground glass is poisonous because the fine particles cut the intestinal lining. Boyle often called his natural philosophy the 'Mechanical Philosophy,' for he held that properties were produced by mechanical, physical means. He also called it the 'Corpuscularian Philosophy,' for he hypothesized that ultimately, all properties could be explained by the physical properties—the size, arrangement, and motion—of very fine, imperceptible particles that he called corpuscles,[175] and he described many experimental results that could be explained by such an hypothesis.[176] He considered the proposal for corpuscles merely an hypothesis, albeit an increasingly well-supported one.[177] He was certain, however, that qualities are qualities *of* something and can be explained by the size, arrangement, and motion of the thing's parts. Qualities, that is, are not substances.

The 'form' of a natural body, Boyle proposes, is

> but an Essential Modification . . . of its Matter, or such a convention of the Bigness, Shape, Motion (or Rest,) Scituation and Contexture, (together with the thence resulting Qualities) of the small parts that

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[174] Ibid., 328.

[175] Boyle did not call his fine particles 'atoms' and did not claim to know how similar these corpuscles were to what others called atoms. He considered this an empirical question not yet answered. Lack of empirical evidence for atoms was more important to him than a concern with atheist implications of atomism, as is sometimes reported. Cf. *Novum Organum*, 2.8.

[176] The earlier Boyle, *Spring of the Air* and last part of Boyle, *Sceptical Chymist* provide notable examples.

[177] Boyle, *Sceptical Chymist*, 330–31; Preface, Boyle, *Mechanical origine of divers qualities*.

compose the Body, as is necessary to constitute and denominate such a particular Body.[178]

By 'denominate[s],' he means "discriminates it from all other sorts of Bodies."[179] In other words, the Form is a "convention of essential accidents,"[180] a union of qualities, that make something the kind of thing it is. Boyle stressed that he "would be understood to mean by it [the word *Forme*], not a Real Substance distinct from Matter, but onely the Matter it self of a Natural Body, consider'd with its peculiar manner of Existence."[181] This doctrine of an alternative to that of substantial forms was, Boyle held, the "summe of the Controversy betwixt Us and the Schools."[182] Boyle considered his break with past theories of chemistry to be this doctrine that qualities of a body are caused by the size, shape, arrangement, and motion of the body's (possibly imperceptible) parts and that the form or essence of something is the union of qualities that make the thing the kind of thing it is.

Boyle considered discovering the nature of such forms and qualities to be the "noblest," "most important," "most useful," "most fundamental," and "most perplexed" part of natural philosophy.[183] In the mid-1660s he embarked on a project

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[178] Boyle, *Origine of formes*, 189.

[179] Ibid., 102.

[180] Ibid. See also Robert Boyle, *The origine of formes and qualities, according to the corpuscular philosophy*, 2nd ed. (Oxford: R. Davis, 1667), 318. For which of something's many attributes are the characteristic and essential ones, see Boyle, *Origine of formes, 2nd ed.*, 294, 353–5.

[181] Boyle, *Origine of formes*, 66.

[182] Ibid., 145.

[183] Ibid., B1v, r, 143; "Author to the Reader, Boyle, *Origine of formes, 2nd ed.*, b2.

to identify the essence of important chemical qualities. The project would result in a general inventory that Boyle would call a *Chymia Philosophica*.[184] The project was never completed as envisioned, but the pursuit remained the core of Boyle's scientific work for at least twenty years. He went on to publish research on many material qualities, including colors, heat, cold, rarefaction, volatility, fixity, taste, odor, alkalinity and acidity, corrosiveness and corrodibility, solubility, porosity, magnetism, electricity, and various qualities of gems, medicines, blood, the air, and the seas. In the second edition of the *Origine of Forms and Qualities* (1667), Boyle wrote that the book should be taken as an introduction to all of his works on qualities.[185] In all these works, his criticism of what had gone before was the same: There are no substantial forms, and the accepted notions for chemical qualities are poorly defined if not meaningless. A different method must be used to identify forms than had been used in the past.

The proper method for discovering the form of qualities Boyle called "experimental induction."[186] In the Preface to the *Origine of Forms*, he dismissed nearly all prior work on the nature of qualities. He did, however, acknowledge an exemplar of the correct procedure, "our illustrious Verulam . . . in his short Essay,

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[184] "Advertisements about the experiments and notes regarding chymical properties," Robert Boyle, *Experiments, notes, &c., about the mechanical origine or production of divers particular qualities* (London: R. Davis, 1675), 3; "Author to the Reader, Boyle, *Origine of formes, 2nd ed.*, b2.

[185] "Author to the Reader," Boyle, *Origine of formes, 2nd ed.*, b2. See also introductory note from the publisher in Boyle, *Experiments touching cold*.

[186] "Reflections upon the hypothesis of alkali and acidum," Boyle, *Mechanical origine of qualities*, A3.

De Forma Calidi,"[187] the example that Bacon had given for 'true induction.' The goal of the *Origine of Forms*, according to the publisher's introduction, is "to see the noble Project of the famous Verulam . . . receive its full and perfect accomplishment."[188]

Bacon's example was Boyle's model, but Boyle did not follow it in a mechanical or rote way. Bacon had presented experiments first and then the 'harvest,' the proposal for the essence of the quality under investigation. Boyle often presents the harvest first. The experiments follow, rather like a supporting appendix. "On Corrosiveness and Corrosibility" (1675) is a good example.[189] The four differentiae that define the essence of corrosiveness are presented on three pages before twenty experiments are presented on forty pages. Boyle also arranges his experimental evidence differently. In "De Forma Calidi," Bacon presented his evidence, let us say, vertically. That is, he first presented all instances. He then returned to the top of the list and identified corresponding absences for each instance. He then returned again to the top and identified corresponding variations. Boyle, on the other hand, tends to present his evidence horizontally, as for example in *New Experiments Touching Cold*. He treats expansion of liquids, then contraction,

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[187] Preface, Boyle, *Origine of formes*, B3.

[188] Richard Davis, "The Publisher to the Reader," in ibid. Davis was a major, important, and knowledgeable publisher of scientific works in Oxford in 1646–86. He published many of Boyle's mature works and was on good terms with Royal Society members and the Society itself. Margaret Forey, "Davis, Richard (1617/18–1693x1700)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004).

[189] In Boyle, *Mechanical origine of qualities*.

then the measure of expansion and contraction before proceeding to instance, absence, and measure of the transmission of cold. Finally, Boyle's works are always incomplete, and he apologizes for that incessantly. The nature of cold he found particularly difficult to research. In the preface to his treatise on the subject, he writes, "Though a 150 or 200 Experiments . . . allow me to have *begun* the natural History of Cold; yet . . . I look upon what I have done but as a *Beginning*. . . . I look upon these as things, that do rather Promise then Present a Harvest."[190]

In the first ten aphorisms of book 2 of the *Novum Organum*, Bacon had insisted that conventional natural philosophy was unable to provide directions that with certainty and liberty would allow someone to effect a desired quality in some object. The problem was that the concept for the quality was corrupt. The essence—the form—had not been properly identified. "Separation and dissolution of bodies . . . through fire"[191] were the wrong method. What was needed was "reason and true induction."[192] To show the proper method Bacon used the example of heat and concluded that heat is a certain kind of motion not of atoms as previously understood, but of "true particles as they are found to be."[193] The example began in aphorism 11, and this is where Boyle began reading. He returned to the earlier part of the text years later, only after reading and digesting the example. Boyle came to see that Bacon's understanding of form and how to identify

190 "The Preface Introductory," Boyle, *Experiments touching cold*, d4r. Boyle's italics.

191 "corporum separatio et solutio . . . per ignem." *Novum Organum*, 2.7.

192 "rationem et Inductionem veram." *Novum Organum*, 2.7.

193 "particulas veras, quales inveniuntur." *Novum Organum*, 2.8.

it was the correct alternative to substantial form as presumed by Aristotelians, Spagyrists, and Sennert alike. He asked that his attack on substantial form and his proposal that all qualities should be explained in terms of the size, shape, motion, and texture of corpuscles be the preface to all the publications on qualities that formed the backbone of his life's work. He considered the identification of the form of qualities in terms of corpuscles the most noble, useful, fundamental, and important work of a natural philosoper. We now take this for granted. Whether the quality under investigation is the color of a laser beam, the adhesiveness of a glue, the scent of a flower, the gain of a transistor, or the efficacy of a drug, we seek to explain it in terms of the essential characteristics and arrangements of imperceptible parts that we now call molecules, atoms, and electrons. Boyle called the process for doing this 'experimental induction,' and took as a model Bacon's example of the induction of the form of heat. Boyle's commitment to that model and his understanding of it increased after reading, around 1661, that 'excellent book,' the *Novum Organum* by 'that Great and Solid Philosopher' 'who trac'd out a most useful way to make discoveries.'

Conclusion

Seventeenth-century natural philosophers have made it difficult for us to known what they thought of Baconian induction. John Wilkins and Seth Ward insisted that it was taught at Oxford but provided no details on what they understood it to be or what exactly was taught. William Harvey published the last major work of his career to demonstrate his research method. In the middle of that treatise, in a way suggesting his readers would not be surprised, Harvey included a reference to Bacon that indicated Harvey thought he was using the method of the *Novum Organum*. Analysis of Harvey's text indicates that he really was. Yet Harvey was a staunch Aristotelian who admonished his readers to follow the method of *Posterior Analytics*, and he completed his most innovative work before the *Novum Organum* was published. Robert Boyle probably presents the most straightforward case of Baconian influence, but that influence must be teased from a mass of prolix writing. Only once does Boyle call his method 'experimental induction,' and it is in a context suggesting the reader would already know what that means. Boyle's first exposure to Baconian induction was not the treatise in which it was discussed by name, but in illustrative examples extracted therefrom.

Other practicing natural philosophers of the time can be equally unhelpful. John Wallis, though himself more a mathematician, was from 1645 through the 1660s a leader in the community of natural philosphers that founded the Royal Society. In 1655, he published *Arithmetica infinitorum*, a seminal text in the history of infinitesimal mathematics.[194] He achieved remarkable mathematical results using a method he called 'induction,' a method he used without explanation or justification. Thirty years later, in *Institutio logicae* (1687),[195] Wallis seems to have virtually forgotten his own method. His long chapter on induction is remarkably

[194] John Wallis, *The Arithmetic of Infinitesimals*, trans. Jacqueline A. Stedall (New York: Springer, 2004).

[195] Wallis, *Institutio logicae ad communes usus accommodata*.

scholastic, explaining the relationship between induction and the syllogistic moods Barbara, Darapti, and Felapton.[196] Just at the end of the chapter, however, he mentions, "There is, however, another [form of inductive] argument . . . of indeed great and frequent use. It is the primary instrument of investigation, whenever, by examining and observing particulars we arrive at a universal cognition." It is used in "what is called Experimental Philosophy,"[197] and its essence is the identfication of causes. This induction is "however uncertain on account of the uncertainty of the material."[198] In Wallis alone we thus find three conceptions of induction. In those on the periphery of natural philosophy, such as the educational reformers John Webster and Samuel Hartlib or the historian of the Royal Society Thomas Sprat, there is deep commitment to various aspects of Baconian thought, but little evidence of any precise understanding of or commitment to Baconian induction.

We may thus conclude that it is not enough to distinguish the Baconianisms of different groups and different times. We must also distinguish varying understandings and commitments within those groups. Some within the communities of natural philosophers had only a loose understanding of Baconian induction and associated it with a general commitment to observation, experiment,

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[196] Ibid., bk. 3, ch. 15, pp. 167–72.

[197] Utraque tamen Argumentatio . . . magni tamen usus est & frequentis. Investigationis, praecipuum est Instrumentem; ubi particularia examinando & observando, pervenimus ad universalium cognitionem . . . . (quae dicitur) *Experimentalis Philosophia*." Ibid., 172. My translation, italics in original.

[198] "(utut incerta propter incertitudinem materiae)." Ibid. My translation, italics in original.

natural histories, the rejection of past authority, the reform of learning, the usefulness of knowledge, or peaceful cooperation among scholars. For many, the theoretical and practical details of the *Novum Organum* 'flew over men's heads.' Others, however, understood Baconian induction well and applied it in their research. We must include William Harvey and Robert Boyle among them. There are likely others. It is also likely that sophisticated and subtle understanding of Baconian induction passed among the community without always being associated exclusively with Bacon himself. Someone developed standards by which Harvey could refer to his proposal as a Baconian second harvest, even though Bacon only promised and never published anything on a harvest past the first.

It is also likely that some of those who understood Bacon's induction in all its theoretical subtlety did not see it as a doctrine sui generis. The Aristotelian John Case had already used the term *idols* to refer to those floating and poorly formed concepts endemic to philosophies like those of Everard Digby. Ramists such as William Temple and various humanists had already proposed that there was a kind of induction unlike that of the scholastics, that there was a kind of induction that went back to Cicero and Socrates. It was from Socrates that Aristotle got his idea of induction, and it was from principles Bacon found in Aristotle that he developed his own. In the end, Francis Bacon's induction is a systematization and codification of regula Socratis. A natural philopher steeped in Aristotelian and other ancient study such as William Harvey probably realized that. Maybe academicians like Wilkins and Ward did, too. Many talented researchers of the next generation, such as Robert Boyle, probably did not. To them, the search for the essence of something by a methodical process of comparing and contrasting was simply the fundamental way to gain certain and practical knowledge about the natural world.

Epilogue

This study has examined the history of the concept of induction from Aristotle to Francis Bacon and taken a preliminary look at the practice of Baconian induction afterwards. It has not discussed the practice of induction in the earlier period or theories of induction in the later. The first topic is a subject for further research, research which will greatly benefit from the historical understanding of induction presented here. Let me close by offering a small outline of the second topic.

The history of the idea of induction from late antiquity to early modern England has been largely a story of the misreading or selective reading of Aristotle. Such misunderstanding did not stop after Francis Bacon. It is, for example, still common today to treat *Prior Analytics* 2.23 as the chief Aristotelian passage on induction and to interpret that passage as saying an induction gains force by being converted into a deduction through a complete enumeration of particulars. That Aristotle held another view of induction in which inductively reached conclusions can validly and certainly apply beyond the observed particulars is attributed to Aristotle's being imprecise, confused, or inconsistent. But as we have seen, it was not that Aristotle was being inconsistent; it was that *Prior Analytics* 2.23 was being misread. In the history of induction, moreover, not only was Aristotle misread. So too was Bacon.

William Harvey and Robert Boyle understood Baconian induction to be the discovery of what makes some property or thing the kind of property or thing it is, i.e., the discovery of its formal cause. Not all natural philosophers understood Baconian induction so well. It became widely accepted—and remains so among practicing scientists, engineers, and technicians—that to ensure the certainty of an inductive inference, one must identify a cause. But Bacon's insistence on finding a formal cause and not merely the material and efficient cause was lost. What Boyle feared would happen happened. He was reluctant to use the term *form* because it had become equated with the medieval *substantial form*. With his theory of qualities, he successfully banished *substantial forms*, but with it went *form*. Henceforth the only causes considered appropriate for scientific inquiry were efficient and material causes.

At some level and for some time, this loss did not much matter. Bacon and Boyle had insisted that properties are to be explained by the size, shape, arrangement, and behavior of material parts (often imperceptibly small ones). So in a sense formal causes could be reduced to material and efficient ones, and to identify the latter was to identify the former. But this shift of emphasis eventually destroyed the foundation of Baconian induction. Bacon held that a property and its formal cause are one and the same thing. What is caused is not something else, but the very property itself. As Bacon stressed, heat is not *produced* by a certain kind of motion; heat *is* that kind of motion and that kind of motion *is* heat. By the new thinking, on the other hand, a cause and what is caused are two separate things, a cause and its effect. Causes came to be compared to the motions inside a clock. A clock could be made of several different materials (it could have different material causes) and have any of several mechanisms (it could have different efficient causes) yet still display the same time. If all we see is the clock's face, we cannot know the material and efficient causes of the hands' motion.

In an influential debate over the nature of induction in the mid-nineteenth century, William Whewell, in his three volumes *The History of the Inductive Sciences* and three volumes *The Philosophy of the Inductive Sciences*,[1] took Bacon's position, while John Stuart Mill insisted on the opposing principle, the 'plurality of causes.'[2] Whewell believed with Bacon—and with Socrates, Aristotle, Cicero, Harvey, and Boyle—that the fundamental role of induction is to determine what uniquely makes something the kind of thing it is. Mill took the position that, as when we look at a clock face, we can never be sure which of several causes are at work in making things appear as they do. Mill's insistence on the plurality of causes helped erode not only the understanding of but the respect for Baconian induction. It now became easy to treat Baconian induction as an inference on the following model: 'The cause is either A, B, or C; it is not A or B; therefore the cause is C.' The conclusion of this syllogism follows if it is certain that the only candidates are A, B,

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[1] William Whewell, *History of the inductive sciences, from the earliest to the present times* (London: J.W. Parker, 1837); William Whewell, *The philosophy of the inductive sciences founded upon their history*, 2 vols. (London: J.W. Parker, 1840).

[2] John Stuart Mill, *A system of logic, ratiocinative and inductive: being a connected view of the principles of evidence, and methods of scientific investigation* (London: J.W. Parker, 1843), bk. 3, ch. 9.

and C. Philosophers observed that Bacon said nothing about how to ensure this was the case. Thus Baconian induction came to be treated as Aristotelian induction was in medieval Scholasticism—as a usually defective form of deduction that could be perfected only by a complete enumeration of particulars, and since the particulars can rarely be fully enumerated, induction is at best a special case and more commonly simply incapable of providing important and certain scientific knowledge.

On induction, Aristotle and Bacon have been misread. So too even has David Hume. He is the man most associated with induction, yet he wrote virtually nothing on the subject that in his day was known by the term *induction*. He used the word only a few times, always incidentally, never skeptically, and even once or twice to support an argument of his own.[3] None of the great British theoreticians of induction in the mid-nineteenth century, such as Richard Whately, John Herschel, Whewell, and Mill, gave Hume much attention. In English, Hume's name was not connected to induction until the late nineteenth or early twentieth century. Credit for fully making the association may go to John Maynard Keynes. Hume may not have said anything about induction, but he surely said much about causality, including that causes cannot be known with certainty. In 1921, Keynes pointed out this implication: If causes cannot be known with certainty, then inductive inferences cannot be drawn with certainty, and thus the real object of Hume's

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[3] For the two uses in the *Treatise*, see Hume, *A Treatise of Human Nature*, 1.2.1.2 p. 23 and 1.3.7.7 p. 68.

attack, even if Hume did not realize it, was induction.[4] Once Hume's attack on causality was accepted, the implications for induction were read back into Hume and he became known as the great inductive skeptic, even if he did not think of himself that way.

The whole history of induction seems beset with misreading and selective reading. Yet we should not conclude that induction is inherently prone to being misunderstood. Aristotle's view went little challenged for eight hundred years. Bacon's was understood by many for at least two hundred. It is rather that the acceptance of certain more fundamental premises drives interpreters to force induction into a framework the authors did not share. In the case of the misinterpretation of late antiquity, those premises were those of Alexandrian Neoplatonism. The premises that led Bacon's induction to be misunderstood remain a subject for future research.

[4] Keynes, *A Treatise on Probability*, 272.

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