

Scientific Methodologies in Medieval Islam

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IBN SÎNÂ'S (LATIN 'AVICENNA') treatise *al-Burhân* (On Demonstration) of his *Shifâ'* closely follows Aristotle's *Posterior Analytics*, but on at least two points it significantly diverges.¹ The context for these differences is the issue of the proper methodology for scientific inquiry and the question "How does one acquire the first principles of a science?" That is to say, how does the scientist arrive at the initial axioms or hypotheses of a deductive science without inferring them from some more basic premises? The ideal situation, Ibn Sînâ tells us, is when one grasps that a *per se* relation holds between the terms, which would allow for absolute, universal certainty. Ibn Sînâ then adds two further, perhaps more interesting, methods used by ancient and medieval scientists for arriving at first principles. These are Aristotelian induction (Arabic *istiqrâ'*, Greek *epagôgê*) and examination or experimentation (Arabic *tajriba*, Greek *empeiria*). Ibn Sînâ severely censures Aristotelian induction as he understood it; for he argues that it does not lead to the absolute, universal, and certain premises that it purports to provide. In its place, though, he develops a method of experimentation as a means for scientific inquiry, and although experimentation cannot provide "absolute" principles, the natural scientist can use experimentation to discover "conditional," universal principles, which can function as first principles in a science.

Concerning the text of Ibn Sînâ's *al-Burhân* itself, with the exception of one chapter, it was not translated into Latin or any modern language, and thus it has

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¹ *Ash-shifâ'*, "al-Burhân," A. Badawi, ed. (Cairo: Association of Authorship, Translation and Publication Press, 1966), I.9, 43–8; henceforth cited as Badawi. Line numbers have been introduced by me and do not appear in Badawi's edition.

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not been accessible to most medievalists and historians of medieval science.² Furthermore, neither has it been the subject of a detailed study by Arabists, despite the treatise's inherent philosophical and historical interest.³ Consequently, the bulk of the present study is an exposition of the content of Ibn Sînâ's discussion concerning induction and experimentation. In addition to commenting on the text, however, the present study further aims at defending two theses about the philosophical and historical significance of this text. First, Ibn Sînâ's attack on Aristotelian induction offers perhaps the most rigorous and technical critique of induction, as later ancient and medieval natural philosophers understood induction, until the modern period. Still, this situation leaves open the question, to what extent is Ibn Sînâ's criticism effective against the historical Aristotle's conception of *epagôgê*, or induction, as opposed to his later followers'? I shall argue that on at least one interpretation of *epagôgê*, Aristotle has the means partially to deflect Ibn Sînâ's critique, but that Ibn Sînâ still offers a much-needed corrective. Second, I maintain that, though Ibn Sînâ's theory of experimentation is by no means modern, it does move one closer to a modern scientific approach; for it emphasizes both the need to set out carefully the conditions under which experimentation or examination have taken place, as well as the tentativeness of scientific discoveries in the face of new observations.

To these ends I divide the current study into two general sections: first, Ibn Sînâ's critique of Aristotelian induction and second, his theory of experimentation. Concerning Ibn Sînâ's critique of induction, I begin with a brief look at Aristotelian induction as it was understood by Ibn Sînâ. Next, I consider Ibn Sînâ's critique of induction, first in broad strokes and then in fine detail. I conclude the first section with an appraisal of the effectiveness of Ibn Sînâ's critique. As for Ibn Sînâ's theory of experimentation, I begin with the distinction that Ibn Sînâ draws between induction and experimentation. Next I consider the conditional, as opposed to absolute, nature of scientific principles obtained through experimentation, and then look at the criteria that Ibn Sînâ lays out for avoiding errors in experimental data. The study concludes with some brief comments about the place of Ibn Sînâ's position in the history of science and philosophy.

I. ARISTOTELIAN INDUCTION AND IBN SÎNÂ'S CRITIQUE

Epagôgê, or induction, is at the heart of Aristotle's theory of science, since only through induction do we seem to acquire or establish the first principles of a

² Marie-Thérèse D'Alverny observes that only II.7 of *al-Burhân* was translated into Latin, perhaps by Dominique Gundisalvi (*Avicenna Latinus: Codices* [Louvain-la-Neuve: E. Peeters, 1994], 5).

³ Several articles, however, have touched on the subject matter of this treatise in varying degrees. Some of the more helpful include F. Jabre's two articles: "Le sens de l'abstraction chez Avicenne," *Mélanges de l'Université St. Joseph de Beyrouth* 50 (84): 281–310, and "al-ʿaql al-faʿʿâl ʿinda Ibn Sînâ," *Millénaire d'Avicenne* (Beirut: Naufal Group, 1981): 13–40. Although he does not develop the arguments, M. Marmura likewise makes references to the treatise in his articles: "The Metaphysics of Efficient Causality in Avicenna (Ibn Sînâ)," in *Islamic Theology and Philosophy: Studies in Honor of George F. Hourani*, M. Marmura, ed. (Albany: The State University of New York Press, 1984), 172–87; "The Fortuna of the *Posterior Analytics* in the Arabic Middle Ages," in *Knowledge and the Sciences in Medieval Philosophy*, vol. 1, M. Asztalso, J. Murdoch, and I. Miiniluoto, eds. (Helsinki, 1990): 89–98, esp. sect. III; and "Ghazâlî and Demonstrative Science," *Journal of the History of Philosophy* 3 (1965): 183–204.

science (*PoA* I 18, II 19; *Metaphys.* A 1). The issue of how to understand the historical Aristotle on induction is a thorny one, and one to which I return in the second part. For now it is sufficient that we understand how induction was used in the later ancient and medieval scientific milieus to which Ibn Sînâ was heir.

According to Ibn Sînâ, induction involves the introduction of a universal through contact with particulars and can be formally represented by a syllogism. Ibn Sînâ summarizes this conception of induction in his smaller encyclopedia of philosophy, the *Najâh*:

Induction is a universal judgment, [which is made] owing to that [same] judgement's [being made] with reference to the particulars of that universal, either all of them, in which case there is the "perfect induction" [or "complete induction"; *al-istiqrâ' at-tâmm*] or most of them, in which case there is the "accepted induction" [or "incomplete induction"; *al-istiqrâ' al-mashhûr*]. Thus [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 [and the like] are gall-less. (*Najâh*, logic: II.34)⁴

At least two points about the nature of induction can be drawn from this passage. First, induction in some way involves acquainting us with universal propositions by means of particular instances. Second, induction can be formally expressed as a syllogism. This point will be clearer if we formalize Ibn Sînâ's example, which he takes from Aristotle's *Prior Analytics* II 23. Thus:

- (1) all humans, horses, oxen and the like are gall-less;
- (2) being long lived identifies humans, horses, oxen and the like;
- (3) thus, all long lived animals are gall-less.

The syllogism is just Barbara, that is, a valid universal affirmative deduction in the first figure. The individuals, humans, horses, oxen, and the like, function as the middle term by which we come to predicate the major term, being gall-less, of the minor term, long lived animals.

One further point must be added to Ibn Sînâ's conception of Aristotelian induction. By Ibn Sînâ's lights, induction was supposed to be a scientific method for discovering and establishing the absolute and necessarily certain first principles of a science. Thus, for Ibn Sînâ Aristotelian induction concerned the acquisition of universal judgments from particular ones, which occurs in a syllogistic manner when through the awareness of particulars an intelligible structure (or form or universal) comes to rest in the soul and the soul judges that the universal is absolute, necessary, and is known with certainty. In this respect, induction for Ibn Sînâ, and in general for Aristotelian philosophers and scientists, does not correspond with the contemporary, Humean understanding of induction, where a greater probability accompanies the increase of observations of events or particulars. Probability plays no role in induction according to these ancient and medieval thinkers.

Ibn Sînâ's critique of induction will surpass those of his Greek predecessors, for instance, the Stoics or empiricist physicians, such as Sextus Empiricus. These

⁴ *an-Najâh* (Tehran: Danishgah-i Tihiran, 1985/86). Cf. Aristotle's *Prior Analytics* II 23.

Greek thinkers criticized induction on the grounds that either (1) one could not be certain that the relevant similarities have been observed or (2) one could never be certain that either all the individuals of a species or all the species of a genus have been considered. Ibn Sînâ, on the other hand, as we shall see, offers a much more subtle analysis of the underlying philosophical considerations concerning induction.⁵ Moreover, Ibn Sînâ's critique in *al-Burhân* is broader in scope than his own critiques of "accepted" or "incomplete induction" that scholars have observed in his *Najâh*, *al-Ishârât wat-Tanbihât*, *Danesh Nameh* and other short treatises.⁶ The objections found in these works indicate the dangers of moving from limited observations to a generalization; for example, one might move from the observation that most animals masticate by using their lower jaw to the generalization that all animals do so. This generalization, Ibn Sînâ notes, as did earlier Greek critics, is falsified by the crocodile, which chews with its upper jaw.⁷ The critique in *al-Burhân*, however, is not merely limited to accepted or incomplete induction, but also is applicable to perfect or complete induction. Let us, then, begin examining Ibn Sînâ's criticism of induction first by presenting his critique in broad strokes and then returning to its various moments in detail.

Prior to presenting his critique, Ibn Sînâ had explained how a demonstration makes evident the necessary and universal relationship between a subject and a predicate when a middle term links the two, that is, when a proposition is the conclusion of a demonstration. He now asks "how is the necessary and universal relationship between the subject and predicate explained or made evident, when there is *no* middle term that links the two?" In other words, how do we come to know the propositions that are not the conclusion of a demonstration, but are the initial, non-demonstrable posits of a science? The explanation, we are told, must either be *per se* or *per alia*. We can exclude *ex hypothesi* that the relation is explained *per alia*, since this other thing would be a reason why. As for when there is a *per se* relation between the predicate and the subject, Ibn Sînâ continues, that relation may be either already evident, or explained through the predicate's belonging to the various particular instances of the subject. In this latter case we have induction. Concerning induction, knowledge of the necessary relation between subject and predicate may come either through (sensible) perception or through intellection (*bil-'aql*; literally "through the intellect"). On the one hand, perception does not afford necessary knowledge. On the other hand, if the intellect recognizes the necessary relation of the subject to the predicate, then the intellect either grasps an essential constitutive factor in the particulars, or some accident (necessary or otherwise), and through grasping one of these comes to know the universal proposition. Ibn Sînâ contends that an essential constitutive factor can

⁵ For a summary of Stoic critiques of induction, see R. J. Hankinson, *Cause and Explanation in Ancient Greek Thought* (Oxford: Clarendon Press, 1998), 234–6. Also see Sextus Empiricus's *Purrôneiôn Hupotupôseôn*, or *Outlines of Pyrrhonism*, II.xiv.195–7 for an ancient empiricist critique of induction.

⁶ See J. R. Weinberg, *Abstraction, Relation, and Induction: Three Essays in the History of Thought* (Madison: University of Wisconsin Press, 1965), 133–4; and H. Davidson, *Alfarabi, Avicenna, and Averroes on Intellect: Their Cosmologies, Theories of the Active Intellect and Theories of Human Intellect* (New York: Oxford University Press, 1992), 88.

⁷ This counterexample is already found in Aristotle (*Historia Animalium* I 11, 492b23; III 7, 516a24–5) and Sextus Empiricus (*Outlines of Pyrrhonism*, II.xiv.195).

never be an object of scientific inquiry and thus induction cannot make it evident. As for the intellect's knowing an accident, one of two situations will occur. One, the accident necessarily belongs to the particular and as such the relationship is due to the essence of the particular kind, in which case the relation of accident to particular is on account of the essence and so explained *per alia*, which we excluded. Or two, the relation is not necessary, in which case the knowledge is not suitable as a first principle of a science. Therefore, having argued that all the possible ways of explaining how induction might work fail, Ibn Sînâ concludes that induction cannot explain the necessary, universal relation that holds between the subject and predicate in scientific first principles.

Let us return to the various moments of Ibn Sînâ's argument in detail. Ibn Sînâ initiates his critique with a question: "If there is no *reason why* (*sabab*) between the predicate and the subject, then how is the relation between them made evident?"⁸ That is to say, how do we come to know the initial assumptions or hypotheses of a science? Two options present themselves: either the relation is evident *per se* or it is not. If the relationship is not evident *per se*, then that which explains the relation between the subject and predicate is either a *reason why*, that is, a middle term that causally links the subject and predicate, or it is not. On the one hand, if that which makes the relation clear is not a *reason why*, then the predicate belongs to the subject by happenstance; for there is no necessary relation between the two terms. Thus the predicate need not belong to the subject with necessity or certainty; however, the relation between the subject and predicate in scientific propositions is supposedly one of necessity and certainty. On the other hand, the explanation that makes the relation between the subject and predicate evident cannot be a *reason why*, since we assumed that no *reason why* links the two terms. Therefore, concludes Ibn Sînâ, "it appears that all the examples of [our knowing a relation between a subject and predicate, when a *reason why* is absent] are either evident *per se* or their explanation is through induction" (44.6–7).⁹

Although Ibn Sînâ does not clarify the distinction between "evident *per se*" and "evident through induction," I would suggest that these two are not wholly distinct; rather, they are two different modes of *per se* explanation. Thus we might distinguish between a "universal mode" of *per se* explanation and a "particular mode" of *per se* explanation, where induction corresponds with this latter division. According to what I call "the universal mode of *per se* explanation," the relation of

⁸ Badawi suggests that *sabab* is translating the Greek *aition*, or cause (Badawi, op. cit., 260). More likely, I believe, the Arabic *sabab* translates Aristotle's *to dioti*. First, by the time Ibn Sînâ is writing, the Arabic *'illa* is the common translation for *aition*. Furthermore, if we consult the Arabic translation of the *Posterior Analytics*, *sabab* translates *dioti*, or "reason why." Either translation works though, since the root meaning of *sabab* is "rope" and so by extension that which ties or links two things together. *Sabab* here, then, is intended to indicate an explanatory link, in the way that a middle term links subject and predicate. Both cause (*aition*) and reason why (*dioti*) can play the role of this explanatory link. Consequently Ibn Sînâ's question may be rendered: "If there is no middle term linking subject and predicate, then how do we explain or throw light on the relation between the two terms?"

⁹ The Arabic here—*hâdhihi bayyinatun binafsihi kullahâ au yakuna bayânahâ bil-'istiqrâ'* (44.6–7)—is setting up an opposition between some form of *per se* explanation and induction; for the conjunction "au" with the following subjunctive "yakuna" might be understood as "unless." Thus our passage may rightly be rendered "this is an explanation *per se*, unless it is through induction."

the predicate to the subject is made evident when the predicate is included in the essences of the universal subject. In induction, that is, what I call “the particular mode of *per se* explanation,” the relation is explained when the predicate belongs *per se* primarily to each of the particulars of the subject and only derivatively to the universal.

For example, if we wanted to explain why “all humans are rational” we might say, using the universal mode of *per se* explanation, that the predicate “rational” is included *per se* within the concept human. Or to be more exact, we should say that we come to know that what it is to be rational belongs to what it is to be human. This initial concept or essence, in turn, would be known through the assistance or mediation of the active intellect, when it imprints or illuminates the form in the human intellect.¹⁰ In contrast, according to the particular mode, or induction, the necessary judgment “all humans are rational” is evidenced by the fact that Socrates, Plato, Aristotle, etc. are rational. That rationality belongs *per se* and primarily to all the particulars explains the universal judgment “all humans are rational.”¹¹ Thus we have the following inductive syllogism:

- (1) Socrates, Plato, Aristotle, etc. are rational;
- (2) the kind human identifies Socrates, Plato, Aristotle, etc.;
- (3) therefore, the kind human identifies rational.

From knowledge of some feature of the particulars we come to know some feature of the kind.

Although all scientific propositions must be necessary and universal, Ibn Sînâ, if I am correct, is suggesting two possibilities as to how such propositions might be made evident, namely, either through an illumination of the universal, for example, the kind human in the human intellect, or through a consideration of the particulars, for example, Socrates, Plato, and Aristotle. Such an understanding would exhaust the possible ways *per se* explanations could make the relationship between the subject and predicate of a scientific proposition evident, namely either on account of considering the universal or the particulars.

Ibn Sînâ now begins the substantive part of his critique. Induction would make evident the relation of the predicate and subject either through perception of the particulars or the intellect’s grasping something in the particulars. These two options exhaust the possible ways that induction could lead from the particulars to the universal.

¹⁰ See H. Davidson, *op. cit.*, 83–94 for the traditional interpretation of the relation between the active and human intellect and the acquisition of knowledge. Also, see the section “l’Interprétation Avicennienne de l’ἀφαιρέσις d’Aristote” in Jabre’s article “Le Sens de l’Abstraction chez Avicenne,” 297–304 for a discussion of the limited role sense perception of the particulars plays in Ibn Sînâ’s noetics. Dag Hasse, on the other hand, has argued in a recent article (“Avicenna on Abstraction,” in *Aspects of Avicenna*, R. Wisnovsky, ed. [Princeton, NJ: Markus Wiener Publishers, 2001], 39–72) that for Ibn Sînâ the human intellect plays a more active role in the acquisition of knowledge. Also see D. Gutas’s article, “Intuition and Thinking: The Evolving Structure of Avicenna’s Epistemology,” *ibid.*, 1–38, which traces the development of Ibn Sînâ’s thought concerning the relation of the human and Active intellects. I am grateful to Robert Wisnovsky for allowing me to see the unpublished versions of these last two papers.

¹¹ Cf. Aristotle’s *Categories* 5, 2a35–b6.

Perception, Ibn Sîna says, “neither necessitates the permanence nor the elimination of a factor capable of passing away, and so there is no certitude from [the premises obtained via perception]” (44.11–2).¹² Despite the peculiarities of Ibn Sîna’s language the argument is clear enough. The scientist seeks what is necessary and universal; however, one does not perceive necessity, or in Ibn Sîna’s terms “permanence.” As far as sensible perception is concerned, anything we recognize may be eliminated. If one were to come to know a necessary connection between subject and predicate through perception, then the necessary connection would be a perceptible feature, but necessary connections are not perceptible features. Induction, then, cannot make clear the relation between subject and predicate through perception alone.

If induction makes clear this relation by way of the intellect, then the intellect grasps that the predicate belongs to the subject either (1) as an essential or constitutive factor of the particulars or (2) as an accident in the particulars (whether necessary or otherwise). Once again these two possibilities exhaust our options. Ibn Sîna denies that induction makes clear an essential or constitutive factor, namely, the genus or differentia, for example, rational or animal, that constitutes the essence of human. “[T]his predicate cannot be an essential . . . [since] the essential in the sense of the constitutive factor is in truth not an object of scientific inquiry; rather [the predicate’s] existence is evident because of what is essential to it” (44.12–4). Both Ibn Sîna’s argument and his Arabic are obscure here, but an argument can be made out, especially in light of comments made later at *al-Burhân* IV.1. Again, the view being criticized claims that the intellect grasps some essential constitutive feature belonging to each individual of a certain kind and then predicates it of the kind as a whole. For example, the intellect recognizes that Socrates, Plato, Aristotle, etc. are all rational animals, and that the kind human identifies Socrates, Plato, and Aristotle. Consequently, induction seemingly has made clear that being a rational animal essentially belongs to the kind human.

Ibn Sîna criticizes this position at *al-Burhân* IV.1, where he observes that in order to identify Socrates, Plato, Aristotle, etc. as humans we must already know that they are humans. Moreover, we can only identify that they are humans if we already know what a human essentially is, namely, a rational animal. In other words, the relation between human and rational animal, which the induction purportedly made clear, must already be assumed, or given, in order to carry out the induction.

The force of Ibn Sîna’s critique becomes clearer if we again consider the formalized syllogism:

- (1) (Major Premise): Socrates, Plato, Aristotle, etc. are rational animals;
- (2) (Minor Premise): the kind human identifies Socrates, Plato, Aristotle, etc.;
- (3) (Conclusion): therefore, the kind human identifies rational animal.

Ibn Sîna’s objection concerns how we come to know the minor premise, or more specifically, which particulars to include in the minor premise. If one identifies

¹² Cf. *Posterior Analytics* I 31.

the particulars merely on the basis of shape or function, then one might be tempted to include department store mannequins or automata among the particulars identified with the kind human. Clearly, one would want to respond that the particulars must be animals, but then there is no principled reason for excluding other higher primates such as chimpanzees, orangutans, and the like. Again, one might want to specify that the identification criteria include rational. Now we see the thrust of Ibn Sînâ's objection. In order for one to recognize that the kind human identifies Socrates, Plato, Aristotle, and the like, one must first recognize that the kind human identifies rational animals; and yet it was this latter claim that an appeal to the particulars was intended to make clear.

Indeed, Aristotle himself constructs a similar objection, albeit in a different context, at *Posterior Analytics* II 4, where he argues that definitions cannot, without qualification, be the conclusion of a syllogism. Moreover, Aristotle explicitly asserts in several places that the essential account of what it is to be a certain kind of thing must be assumed (*lambanetai*, *APo.* I 10, 76a31–6) or a posit of a science (*thesis*, *APo.* I 2, 72a14–24) and cannot be deduced. In short, it would seem that even for Aristotle essential constitutive factors should not be objects of scientific inquiry. Thus Ibn Sînâ has merely indicated that the view that sees induction as seeking out the essential features of a thing is incompatible with other elements of Aristotelian science.

Ibn Sînâ now considers the suggestion that induction involves the intellect's grasping some accidental feature of the particular. Induction, on this account, purportedly makes the relation between the subject and an accidental predicate clear. If induction makes clear that the predicate is an accident belonging to the subject, then that accident is either a necessary accident (for example, as risibility is for humans) or not (for example as white or black is for humans). That the accident might not be necessary can be rejected, since scientific propositions involve necessary and apodictic knowledge of the predicate's relation to the subject, whereas one's knowledge of a non-necessary accident's relation to its subjects is not necessary and apodictic.

If the accident is a necessary accident, Ibn Sînâ continues, it must belong to the subject on account of one of the subject's essential formulae or intentions (*al-mâ'ânî adh-dhâtîya*).¹³ For if the accident did not flow from the very essence of the thing—from what the thing is—then it would be possible for this accidental predicate not to belong to the subject. However, if it were possible for this accident not to hold, then it would not be necessary and we have seen that this option is unacceptable. Hence, necessary accidents belong to their subject on account of the subject's essence. "Now if that is so," reasons Ibn Sînâ,

¹³ The technical term *mâ'ana*, like its Greek equivalent *logos*, has a complex of meanings in Arabic philosophy and theology. Consequently, it is difficult to find one word that covers its varieties of and nuances in meaning. Ibn Sînâ seems to be using it here to indicate a defining element of a thing, such as "rational" and "animal" said of human. See R. Frank, "Al-Mâ'ana: Some reflections on the Technical Meanings of the Term in the Kalâm and Its Use in the Physics of Mu'ammâr," *Journal of the American Oriental Society* 87 (1967): 248–59; also see D. Black, "Estimation (*Wahm*) in Avicenna: The Logical and Psychological Dimensions," *Dialogue* 32 (1993): 219–58 for a discussion of *mâ'ana* as the proper object of the estimative faculty.

then predicating [the accident] of each particular is because of an essential formula [or intention] belonging to it and the rest [of the particulars]. However, that, that is, the essential, would be a common *reason why* belonging to the being of this accident in the individuals, but we posited it without a *reason why*. (44.17–8)

Simply put, induction cannot make clear the relation of the subject to a necessary accident in the way the defender of induction wants, since one of the essential formulae or constitutive factors always plays the role of a *reason why* that explains the relation of the predicate to the subject. Therefore, this relation, with respect to necessary accidents, is always *per alia*, but the relation with which Ibn Sînâ is concerned is a *per se* relation. Consequently, we cannot grasp that an accident belongs necessarily and *per se* to its subject through induction.

Ibn Sînâ's critique of induction is complete. He began with the question "How can we come to know that some predicate term necessarily belongs to some subject term when a middle term does not link the two?" Induction was then offered as a possible answer. Through induction one purportedly comes to recognize, for example, that all humans are rational because rationality belongs *per se* to each individual human. If induction leads one from the particulars to the universal, then, Ibn Sînâ observes, either (1) one must sensibly perceive some necessary feature in the particulars, or (2) the intellect grasps this necessary feature. On the one hand, perception does not provide the requisite certainty. On the other hand, if induction works through the intellect, the intellect must recognize either (2a) an essential, constitutive factor of the particular or (2b) some necessary accident of the particular. Essential constitutive factors are not objects of scientific inquiry and thus cannot be established by induction, demonstration, or any other means, whereas necessary accidents belong to their subjects *per alia*, but it was assumed that the explanation is *per se*. However one construes induction, it simply cannot bring one to an understanding of the necessary and universal propositions required by science.

Ibn Sînâ's argument is, I believe, a devastating critique of later ancient and medieval accounts of induction. Still, the historical Aristotle seems to have resources by which he could avoid at least some of the thrust of Ibn Sînâ's argument. An Aristotelian defense might begin by observing a distinction found in contemporary philosophy of science, namely, between the "mode of discovery" and the "mode of establishment." The "mode of discovery" concerns the historical, sociological, and psychological factors that came to bear on a scientist's actually hitting upon some scientific "fact," relation, or law. For example, Friedrich August Kekulé relates that his discovery of the structure of the benzene ring came in a dream while on a London bus. Clearly, Kekulé's dream is irrelevant to establishing the fact that benzene is a six-membered ring of carbon atoms, each with one hydrogen atom bonded to it. Kekulé's discovery would in turn need to be explained by some formal, rigorous mode of establishment. The mode of establishment, then, provides the formally valid presentation and justification for some scientific discovery.

Bearing this distinction in mind let us consider Aristotle's conception of *epagôgê*, or induction. Modern interpreters of Aristotle are divided as to Aristotle's primary meaning of *epagôgê*. Some scholars emphasize those passages, particularly

Prior Analytics II 23, where Aristotle treats *epagôgê* as a type of proof or justification that some universal statement holds, where the justification will be through the many observed particulars.¹⁴ On this interpretation of *epagôgê*, induction might be seen as providing the mode of establishment in science. Other scholars, however, emphasize those passages such as *Posterior Analytics* II 19 and *Metaphysics* A 1, where Aristotle treats *epagôgê* as a generative psychological account of how we acquire concepts or universal scientific principles.¹⁵ In this respect, *epagôgê* might be seen as belonging to the mode of discovery. This is not the place to attempt a reconciliation of these two views.¹⁶ It suffices for our purposes that there are at least two ways to understand Aristotelian *epagôgê*, one as a “mode of establishment” and the other as a “mode of discovery.”

Ibn Sîna’s critique is effective against induction considered as a mode of establishment, or a means of making clear or formalizing scientific discoveries. Indeed, Ibn Sîna begins with the question “How is the relation between [a predicate and subject, where there is no middle term] made clear [*tubayyanu*]?” which at least suggests that Ibn Sîna is concerned with induction as a mode of establishment. His critique need not, however, apply to induction considered as a mode of discovery, which focuses on those factors of human psychology required for concept formation. The way our minds work when we grasp first principles need not be syllogistic at all, even though we can subsequently formalize this psychological process as a syllogism. Since Ibn Sîna’s critique required that one formalize induction as a syllogism, but our psychological processes need not have a syllogistic structure, Ibn Sîna’s criticism would not necessarily apply to induction as a psychological process.

Still, Ibn Sîna’s critique offers an important corrective. First, it shows that the conception of induction as understood by later ancient and medieval natural philosophers was inadequate and thus needed to be modified. Second, and similarly, to the extent that Aristotle himself thought that inductive syllogisms could clarify or provide a formal explanation of how we acquire the first principles of a science, that is, insofar as he considered induction an adequate mode of establishment, he erred. Some other mode of establishment or clarification is needed, and, as we shall see, it is just such an account that Ibn Sîna’s theory of *tajriba*, or experimentation, is intended to provide.

¹⁴ D. W. Hamlyn, “Aristotelian Epagoge,” *Phronesis* 21 (1976): 167–84; T. Engberg-Pedersen, “More on Aristotelian Epagoge,” *Phronesis* 24 (1979): 301–19; and to a lesser extent 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 (esp. 11–2).

¹⁵ Thomas Upton, “A Note on Aristotelian *Epagôgê*,” *Phronesis* 226 (1981): 172–6; Jaakko Hintikka, “Aristotelian Induction,” *Revue Internationale de Philosophie* 34 (1980): 422–39; Simo Knuuttila, “Remarks on Induction in Aristotle’s Dialectic and Rhetoric,” *Revue Internationale de Philosophie* 47 (1993): 78–88.

¹⁶ Greg Bayer in his article “Coming to Know Principles in *Posterior Analytics* II 19,” *Apeiron* 30 (1997): 109–42 provides an excellent interpretation of Aristotle’s account of *epagôgê*, which does justice to both of the intuitions motivating these two camps’ readings of Aristotle, while avoiding many of their pitfalls.

2. AVICENNIAN EXPERIMENTATION

Ibn Sîna distinguished experimentation (*tajriba*) from induction (*istiqrâ*).¹⁷ The claim made for induction, we recall, was that it could purportedly provide (or establish) the absolute, necessary and certain first principles of a science, whereas Ibn Sîna argued that in fact induction either cannot guarantee the necessity or cannot provide the primitiveness required of the first principles of a science. In contrast, *tajriba*, or experimentation, Ibn Sîna believed, does not suffer the same fate; for it is more modest in its claims about what it can accomplish. Unlike induction, experimentation does not aspire to provide *absolute* necessary knowledge, but only *conditional* necessary knowledge, albeit knowledge that can function as a first principle in a science. To appreciate this distinction between induction and experimentation we must first better understand Ibn Sîna's account of experimentation. Ibn Sîna described it as follows:

[It] is like our judgement that the scammony plant is a purgative for bile; for since this [phenomenon] is repeated many times, one abandons that it is among the things which occur by chance, so the mind judged that it belongs to the character of scammony to purge bile and [the mind] gave into it, that is, purging bile is an intrinsic characteristic (*'arad lâzim*) belonging to scammony. (45.15–8)¹⁸

This description needs to be clarified and Ibn Sîna attempted to offer just such clarification.

The first issue that Ibn Sîna raises concerns experimentation and certainty. For one may ask, if one does not know the reason why which explains some characteristic of a thing, for example, scammony's power to purge bile, then how is experimentation to provide certainty? Or simply stated, how does experimentation produce certainty that scammony necessarily purges bile? Ibn Sîna's response moves in two steps. The first is to show that a certain power to purge belongs to the very nature of scammony. The second step uses this knowledge of scammony's nature in a syllogism to show that scammony necessitates purging.

The first stage begins with a distinction already used by Aristotle and a commonplace among ancient physicians, such as Galen.¹⁹ One may either (1) repeat

¹⁷ *Tajriba* is the Arabic counterpart of the Greek *empeiria*. Thus there is some reason for wanting to translate *tajriba* as "experience" and reserving "experimentation" for such Arabic terms as *'tibâr*. *Empeiria* in the Greek philosophical and medical literature, however, came to be associated with a "knack" one acquires through accumulated experience and this is clearly not the sense that Ibn Sîna wants to convey with *tajriba* as he technically defines it. *Tajriba*, as we shall see, involves a very close and critical examination of the phenomena, taking special care to note the antecedent conditions surrounding the observations. Perhaps, then, one might want to translate *tajriba* as "examination"; nonetheless, I prefer the translation "experimentation," flawed though it might be. See A. I. Sabra, *The Optics of Ibn al-Haytham: Books I–III, On Direct Vision*, Vol. II (London: Warburg Institute University of London, 1989), 14–9, for a discussion of *tajriba*, *'tibâr*, and *istiqrâ*' as used by Ibn Sîna's contemporary, Ibn al-Haytham.

¹⁸ The example no doubt strikes modern readers as odd at best, and thus must be understood against the background of ancient and medieval humoral medicine. (Cf. the Pseudo Aristotelian *Problêmata* I 41 and 43.) Health and illness for many early physicians was understood in terms of a balance or imbalance of one of the four basic humors—blood, phlegm, yellow or black bile. Yellow bile was seen as a substance essentially possessing the active powers hot and dry. When one ingests scammony, the scammony apparently always causes a yellowish burning diarrhea, where the yellowish burning characteristics were thus ascribed to a preponderance of yellow bile in the patient.

¹⁹ Cf. Aristotle, *Physics* II 5; *Metaphysics* E (VI) 2, 1026b27–1027a28. Also compare Galen, *Outline of Empiricism*, II ("Subfiguratio empirica" in *Die griechische Empirikerschule*, K. Deichgräber, ed. [Berlin:

edly observe two things always (or at least for the most part) together, or (2) one may sometimes observe them together and sometimes not together.²⁰ If, as in the latter case, one only sometimes observes two things together after multiple observations, then the two things are just as likely to happen together as not. When two things are just as likely to happen as not, however, they occur according to chance or by accident. If *ceteris paribus* the occurrence of the two is not just as likely to happen as not, and thus one observes that the two things occur together always or at least for the most part, then the relation is not a mere chance or accidental relation.²¹ Hence, since one always observes scammony's purging bile, one can infer that the relation between purging and scammony is not a mere chance or accidental relation. Thus Ibn Sînâ claimed:

since after all chance is not always or for the most part . . . it is known that the [scammony's characteristic of purging] is something which the scammony necessitates by [its] nature, since it does not turn out that there is anything arbitrary about it. (46.2–3)

One can understand Ibn Sînâ's move from the regularity of observations to the claim that a certain necessary power inheres in the nature of the scammony in one of two ways. On one interpretation, since one observes scammony's purging bile always or at least for the most part, the sheer volume of positive cases might be thought "to verify" that a necessary relation holds between scammony and purging. On a second interpretation, one could emphasize the absence of "falsifying instances"; or in Ibn Sînâ's words, the fact that "it does not turn out that there is anything arbitrary [*ikhhtiyâr*]." ²² In both interpretations the judgment that it belongs to the nature of scammony to purge is made against the backdrop of numerous observations. In the second option, however, the number of positive cases does not convince one of the necessary relation; rather, the lack of any negative cases or falsifying instances indicates a non-accidental power belongs to scammony to purge. If the relation between scammony and purging were not essential, and thus only accidental, then at least occasionally one should observe scammony's not purging bile, which Ibn Sînâ believes that we do not.

That Ibn Sînâ intended the second interpretation is intimated by his later claim that induction treats the cases exhaustively, while experimentation does not (46.12–3), as well as his claim that multiple observations alone are not sufficient to produce necessary knowledge (46.19–20). Thus, we might understand one difference between induction and experimentation along the following lines. Induction attempts to engender a necessary judgment through the enumeration of positive instances, whereas experimentation involves in part seeking falsifying cases.²³

Weidmann, 1930], 44–6; an English translation is available in *Galen: Three Treatises on the Nature of Science*, M. Frede, ed., R. Walzer and M. Frede, trans. [Indianapolis, IN: Hackett Publishing Company, 1985].

²⁰ Ancient physicians also indicated a third option when two things are seldom, if ever, observed together; however, we need not consider this option here.

²¹ Concerning chance and necessity, see Aristotle's *Posterior Analytics* I 30 and *Physics* II 5, 196b10–3.

²² My translation of *ikhhtiyâr* as "arbitrary" is itself a bit arbitrary. The term in Arabic actually means "choice, preference or free will." Since none of these translations seems suitable for objects lacking volition, such as scammony, I have used "arbitrary," which at least is etymologically linked to the Latin verb *arbitor* ("to decide") but has taken on a broader meaning in its English cognates.

²³ Sari Nuseibeh argues in his article, "*al-aql al-Qudsî: Avicenna's Subjective Theory of Knowledge*," *Studia Islamica* 69 (1989): 39–54, that Ibn Sînâ conceives of knowledge as fundamentally "sub-

A brief aside is warranted here, since Ibn Sînâ's use of the phrase "for the most part" (*akthariyan*) appears to present a significant challenge to the interpretation proffered above. For if scammony is only observed to purge bile "for the most part," then there would have been at least one falsifying instance. There are two responses to this objection. First, the phrase "for the most part" (Grk. *hôs epi to polu*), as noted above, was a commonplace both in Aristotle's writings and later Greek medical works, such as Galen's, all works which Ibn Sînâ had clearly read.²⁴ Thus, Ibn Sînâ may just have included the phrase here in deference to the tradition, even though he himself believed that in all legitimate cases of causal connection the relation would always and necessarily obtain, and so one would not observe any falsifying instances.

A second, and I believe more philosophically satisfying response, is also available. Ibn Sînâ clearly does not mean by "for the most part" merely that two things have been observed together greater than fifty percent of the time; rather, the exceptions would be extremely rare, perhaps observed only once or twice. These rare exceptions might indicate that there is not a causal relation, but they might also indicate that the causal circumstances were more complex than initially supposed. For instance, some contributing factor may be absent or some impediment may be present. And indeed Ibn Sînâ makes this very point later in the text (48.47), which we shall consider below. Consequently, when the observation is only for the most part, the experimenter should first investigate whether there are any "hidden variables," which might explain the seemingly falsifying instance.

In fact, something like this is what scientists do. To take an example from modern physics, Newtonian mechanics predicted a particular path for the motion of Uranus, which Uranus did not follow. This fact should have counted against the Newtonian hypothesis; however, since the hypothesis had been so successful, another planet, Neptune, was postulated to explain the error. J. C. Adams and U. J. J. Leverrier calculated the location of this "hidden" planet based upon Newtonian mechanics and Neptune was discovered in 1864 by Johann Galle. Such a technique is, I believe, in keeping with the spirit of Ibn Sînâ's scientific methodology. In the rare cases of exceptions, the experimenter should first investigate whether any other factors might explain the failure of the observation. Only when no satisfactory explanation can be found does the scientist begin to consider whether the exception is a genuine falsifying instance.

Returning to the issue of how Ibn Sînâ believes that experimentation produces certainty, he next turns to the question of what it is about scammony that produces purging (46.3–7). This power to purge cannot belong to scammony insofar as a scammony plant is a body; for then all bodies would purge bile, which is clearly false. Moreover, we might add, the power to purge cannot belong to scam-

jective and unverifiable" (39). Nuseibeh's argument is based upon a string of passages drawn from the metaphysical and psychological sections of the *Shifâ'*. Such a thesis, I believe, simply cannot stand up in view of our passage here. Moreover, Nuseibeh's position adopts the traditional conception of Ibn Sînâ's psychology as its starting point, a position which Dag Hasse (op. cit.) has successfully challenged.

²⁴ For a discussion of the phrase in Aristotle, see M. Mignucci, "Ὅς ἐπὶ τὸ πολὺ et nécessaire dans la conception aristotélicienne de la science," in *Aristotle on Science: The Posterior Analytics*, E. Berti, ed. (Padua: Editrice Antenore, 1981), 173–203.

mony merely insofar as it is a plant; for then all plants would be purgatives, which again is clearly false. Thus, the power to purge must belong to scammony insofar as it is the certain kind of plant that it is. That which makes something to be the kind that it is is the thing's nature. Consequently, the power to purge bile must belong to scammony's nature. Ibn Sînâ specifies that this characteristic of scammony belongs to it either as its *proprium* or something related to the *proprium* (46.4).²⁵ Since a power or potential to purge belongs to scammony's nature, then if the scammony is placed in the right situation, namely, when it is properly administered to a ready patient, "then the activity [of purging] and the affection [of being purged] occur" (46.6–7).²⁶

Thus experimentation allows one to judge that "some power" essentially belongs to scammony that produces purging. Experimentation, however, has not provided one with the underlying causal explanation for *why* scammony necessitates the purging, merely *that* scammony necessitates purging.²⁷ Now in ancient medicine there were debates about the underlying causes that explained why certain medicines function the way they do. Some physicians argued that a drug has the effect that it does because it involves a hot/wet mixture, for example, of a certain proportion; others claimed that the drug's substance is composed of "atoms" of a certain configuration; and still others held that the drug blocks or clears certain pores. Experimentation, then, has not told us *what* the reason why is, but only *that* there is a reason why. Ibn Sînâ, thus I suggest, uses the phrase "the power to do *x*" merely as a place holder to indicate that an essential relation holds between the subject and predicate, even though one might not know what the causal explanation for that relation is.²⁸

²⁵ In L. Bakhtiar's English adaptation of Book I of Ibn Sînâ's *al-Qânûn fi-t-tibb* (Chicago: KAZI Publications, 1999), 7.3.7 there is an interesting discussion of the difference between "proprium" and "nature." Unfortunately, the corresponding passage is not found in either of the Arabic editions of the *Qânûn* that I have consulted: New Delhi: Institute of History of Medicine and Medical Research in association with Vikas Publishing House, LTD, 1982 (on which Bakhtiar's adaptation is based); and Beirut: Dâr al-Kutub al-'ilmiyah, 1999.

²⁶ Cf. Aristotle's *Metaphysics* Θ (IX) 5, 1048a5–8.

²⁷ Cf. Aristotle's *Posterior Analytics* I 13 for a discussion of the difference between demonstrations *quia* ("that") and *propter quid* ("on account of what").

²⁸ Ibn Sînâ is not clear here whether experimentation can only tell us *that* a necessary relation holds without telling us why, or whether further experimentation could reveal the "reason why." For two reasons, I think that Ibn Sînâ believes that experimentation can only show *that* a relation holds. First, Ibn Sînâ is clear that experimentation is only a means of providing certainty about some relation when the *reason why* is not known (45.19–20). To investigate into what belongs to the nature of a thing such that it must act in a certain way, that is, the reason why, is to inquire into the very essence of a thing; however, essentials, as we have seen above (44.13–4), are not the proper objects of scientific inquiry for Ibn Sînâ. Consequently, to use experimentation as a tool to discover the reason why is to employ it in a way beyond which it is capable.

Second, experimentation concerns only that which is observable, for example, scammony's bringing about purging; however, that which explains the causal power, that is, the reason why, whether the substance's mixture, atomic structure, ability to block pores, etc., is a theoretical posit and not observable. Consequently, the raw data required for experimentation would not be available to undertake an experimentation with respect to the reason why.

This point is explicitly made in the questionable passage on "proprium" in Bakhtiar's adaptation of the *Qânûn fi-t-tibb* (7.3.7). See n. 25 for my concerns about this text. Also the thesis that for Ibn Sînâ experimentation cannot uncover the *reason why* fits well with a similar and well-argued point made by Sari Nuseibeh in his article "Avicenna: Medicine and Scepticism," *Koroth* 8₁₋₂ (1981): 9^{*}–20^{*}; however, I am skeptical about Nuseibeh's further claim that Ibn Sînâ was a "rational skeptic."

I mention this Aristotelian distinction between knowing *that* there is a reason why and knowing *what* that reason why is, since the distinction is needed to understand the second stage in Ibn Sînâ's discussion of experimentation.²⁹ In this stage Ibn Sînâ wants to explain how the knowledge that scammony essentially has the power to purge can function in a syllogism to produce necessary and certain knowledge that scammony causes purging.³⁰ Thus we read:

[W]e discovered [that] the major [term] belongs to the minor by means of the middle term, which is the purgative power and is the *reason why*. And when you analyze the remaining syllogism, you find every explanation is only an explanation through an intermediary that is a cause owing to the existence of the major because of the middle, even if it is not a cause for knowledge with [respect to] the major term. Consequently, this variety of certainty through a reason why does occur to us. (46.7–10)

On the basis of experimentation one discovered that a power to purge (whatever that might be) essentially belongs to scammony. Moreover, having the power to purge is necessary in order to cause purging. Thus, maintained Ibn Sînâ, one can construct the following syllogism:

- (1) having the power to purge causes purging;
- (2) scammony has the power to purge;
- (3) thus, scammony causes purging.

“Having the power to purge” is the middle term and “scammony” and “causes purging” are the minor and major terms respectively. From the syllogism, one learns that “the major term belongs to the minor,” namely, scammony causes purging. Moreover, the conclusion follows, from a necessary middle term. Consequently, one knows the conclusion with necessity or certainty, even though one does not know *what* the middle term is qua the underlying cause.

Because we do not know *what* the causal explanation is, but only *that* there is one, Ibn Sînâ makes a qualification about the variety of certainty that the above syllogism occasions. It does not provide scientific knowledge (*‘ilm*) in the rich sense described by Aristotle at *Posterior Analytics* I 2; for there we are told that scientific knowledge (Grk. *epistêmê* = Arb. *‘ilm*) must be *both necessary and explanatory* (71b10–2). The knowledge produced by the above syllogism, although necessary and certain, does not explain *why* the scammony purges, only *that* scammony in fact does purge. Consequently, with respect to causing purgation, one does not have a causal explanation why scammony occasions this effect. The middle term “is not a cause for knowledge with [respect to] the major term” (46.10). Nonetheless, since one knows that scammony necessarily purges one can use this knowledge in making various subsequent scientific demonstrations.

Experimentation, with its accompanying syllogism, then, occasions certainty. It does so because the syllogism is based upon necessary premises obtained when the scientist observes that some phenomenon occurs regularly without any falsify-

²⁹ J. R. Weinberg (op. cit., 127) suggests that perhaps Aristotle also only intended *epagôgê* to reveal *that* certain kinds have certain powers and not *why* they had those powers.

³⁰ Cf. Aristotle's *Posterior Analytics* II 1–2.

ing instances. One may feel that Ibn Sînâ's argument has moved too fast; for merely observing something very many times hardly seems capable of guaranteeing necessary knowledge. Indeed, Ibn Sînâ was aware of the unsettling effects of moving from multiple observations to a conviction of necessity. He even presents a significant counterexample to the technique of experimentation.

If we were to imagine that there were no people except for Sudanese, then on the basis of sense perception there is no repetition of a person except a black person. Thus, would not that [situation] necessitate occasioning a conviction that all people are black? And if it does not occasion [such a conviction], then on account of what does [one instance of] repetition occasion [a conviction], while [another instance of] repetition does not occasion [such a conviction]? On the other hand, if [only seeing black people] does occasion [the conviction that there are only blacks], then it has occasioned an error and falsehood; and if experimentation occasions error and falsehood, then it leads to what is untrustworthy and does not function properly for obtaining from it the principles of demonstrations. (46.14–8)

The objector asks us to think of a person who has only seen black humans. Thus, for every observation of a human there has likewise been the observation of black. Consequently, for the observer there are no falsifying instances of the proposition "all humans are black." Therefore, on the basis of experimentation the observer should be able to conclude with necessity that it belongs to the nature of humans to be black.

Ibn Sînâ is now confronted with a dilemma. Either the above example of experimentation (1) occasioned a conviction of necessity or (2) it did not. On the one hand, if, (1), experimentation in the case of observing black humans did occasion conviction, it occasioned conviction about what is false and not necessary. Hence, experimentation is an unsuitable technique for acquiring scientific premises; for any scientific method that creates conviction that some premises are necessary when they in fact are not necessary undermines the very project of ancient and medieval science, at least in its Aristotelian form. On the other hand, if, (2), in the case where one has only observed black humans the experimentation does not occasion a conviction of necessity, then either (2a) there is something different between this case and the scammony case above, where necessity was legitimately inferred, or (2b) there is nothing different between them. If, (2b), there is no difference between the two cases, then necessity could not have been occasioned in the scammony case as well. As for (2a), that there is a difference between the two cases, it is not clear what the difference might be. In both instances, there are multiple observations of some relationship and no observed falsifying instances. In short, even if experimentation occasions a conviction of necessity in some cases, there appears to be no clear way of identifying the legitimate cases of conviction from illegitimate ones. Thus, experimentation would appear to be a broken reed when it comes to science.

Ibn Sînâ has two responses to this puzzle. The first solution he presents is almost a throwaway line, while he goes to lengths to develop the second solution. His first response, which I believe is wanting, is based upon the syllogism that accompanies experimentation and it runs in its entirety as follows.

In response to [the above objection] we say that experimentation does not report (*tufîd*) knowledge from the frequency of what is witnessed on the basis of that judgement alone, but because of an association to a syllogism together with [the judgment]. (46.19–20)

There is a difference between the scammony case and the Sudanese case, Ibn Sîna maintains; namely, a syllogism is associated with the former case, but not with the latter. Thus, the certainty that was occasioned by the scammony case, Ibn Sîna tells us, was not due merely to the repetition of cases or the absence of any falsifying instances; rather, the premise obtained from the multiple observations was used in a syllogism and it was the syllogism that brought about the certainty. Consequently, Ibn Sîna's rejoinder is to identify a principled difference between the two cases and thus take the above dilemma by horn (2a).

This response will not do as it stands. For one could seemingly construct a syllogism for the Sudanese case that is analogous to the scammony syllogism. Thus, the objector could counter with the following syllogism:

- (1) whatever has the power to produce black progeny produces black progeny (self-evident);
- (2) all humans have the power to produce black progeny (purportedly known through experimentation);
- (3) therefore, all humans produce black progeny.

Thus Ibn Sîna would again find himself confronted with horn (2a); namely, there is no principled difference between the scammony and Sudanese cases. Obviously, if Ibn Sîna's comments here were intended as an argument against the objector's counterexample, they fail. More likely, Ibn Sîna meant his remarks as a warning against simply taking multiple repetitions of some phenomenon as guaranteeing necessity. In this respect, his comments anticipate his more fully developed argument that immediately follows. In short, experimentation involves more than just seeing something very many times.

Ibn Sîna's preferred solution to the puzzle concerns how experimentation only occasions conditional knowledge, where the conditions state the domain surrounding which the observations were made.

[Experimentation] does not report universal, absolute syllogistic knowledge, but only universal conditional (*bishart*) [knowledge], that is, this thing which is repeated to the senses adheres to its nature as an ongoing thing with respect to the domain in which it is repeated to the senses, unless there is an obstacle. Thus the knowledge is universal through this condition, but not absolutely universal. (46.20-3)

In other words, when using experimentation, the scientist must note the variables or various antecedent and background conditions surrounding the observations. Once the experimenter has taken these conditions into account, then if he regularly observes one thing's following another and so no falsifying instances, he can be certain that a necessary causal relation holds between the two under these conditions. Otherwise, there would only be an accidental or chance relation between the two that cannot explain the regular occurrence of the two together.

Bearing this basic rule (*qânûn*) in mind, Ibn Sîna readily resolved the above dilemma concerning the Sudanese and the production of black progeny.

In general, when the producing of children is taken *qua* the producing of children from black people or the people of such a country, then the experimentation from [this base of data] turns out true. As for taking the producing of children *qua* from people only [that is,

unconditionally], it is not the case that the experimentation through a consideration of the mentioned particulars results, since after all that experiment was with respect to black people, whereas people absolutely speaking are not [only] black. Because of this experimentation often errs. (47.7–11)

Simply stated, once the background conditions are noted, then experimentation, even in the Sudanese case, is successful; for the progeny of blacks are indeed always black.

Although Ibn Sînâ feels confident that experimentation for the most part occasions certainty, he adds the caveat that it is not an absolute “safeguard against error.” Error can occur through experimentation when one mistakes what is merely an accidental relation for an essential one. This mistake clearly underlies the erroneous conclusion that all humans are black. One had observed an accidental feature of humans, namely, color, and then drew a conclusion about humans absolutely speaking or essentially.

To help scientists avoid this pitfall of experimentation, Ibn Sînâ listed three cases where accidental features can be mistaken for essential ones and thus where scientists must be on their guard.³¹ The first case where one can make a mistake is “when one [relation] is from a common attribute; however, the thing with its common attribute is associated with the differentia (*al-khâṣṣ*) and the differentiating attribute (*al-waṣf al-khâṣṣ*) is in addition associated with the judgement” (47.18–9). In other words, assume that a certain necessary relation belongs to some species on account of its genus. Since when one observes the species, one observes both the genus and differentia, one could accidentally (and consequently, erroneously) explain the relation by appeal to the species’ differentia instead of the genus. For example, one observes that all humans are mortal. Essentially humans are rational animals and it is because all animals are material composites and all material composites are corruptible that humans are corruptible, that is, mortal. Nonetheless, since one’s initial observations concerned the mortality of rational animals and associated with these observations is the repeated death of something rational, one could wrongly infer that all humans die on account of being rational. In this case, humans are mortal essentially because they are animals and only accidentally because they are rational.

A second way one can mistake an accidental feature for an essential one, and thus err in experimentation, is when two properties are coextensive. To use a hackneyed example, having a heart is coextensive with having kidneys. Hence, one observes both that all animals having hearts are warm blooded and that all animals having kidneys are likewise warm blooded. Consequently, one could wrongly conclude that having kidneys is the cause of being warm blooded, when in fact, at least according to ancient anatomy, having a heart explains being warm

³¹ Galen relates in *On Medical Experience*, VI (in *Galen on Medical Experience*, R. Walzer, ed. [London: Oxford University Press, 1944], 9–11) and in *Galen: Three Treatises on the Nature of Science*, op. cit., 55–6 that one of the rationalists’ arguments against the empiricists’ experimental approach was that it could not distinguish between accidental and essential features of the observed phenomena. Hankinson (op. cit.) observes that the Stoics leveled the same complaint against induction in general. Ibn Sînâ, thus, might be seen as providing guidelines for discovering the essential as opposed to the merely accidental features of some substance.

blooded; for the heart is the source of an animal's innate heat. Here one has mistaken a coextensive accidental feature for the essential one.

The third way that an accident may be confused with something essential is "when the [relation] is due to a particular attribute, indeed more narrow than the nature that belongs to the thing" (47.20–1). This case is just the one we saw with respect to the Sudanese and the production of black progeny. The objector, on the basis of a peculiar feature belonging to the observed cases, generalized about the entire kind; namely, since black humans produce black progeny, all humans produce black progeny.

In light of these warnings Ibn Sînâ observed that even with respect to the scammony case the scientists have to qualify their claims:

Thus, we also do not disallow that in some country a disposition (*mizâj*) and *proprium* (*khasṣiya*) is associated with scammony not to purge (or there is absent in it a disposition and *proprium* [to purge]); however, it is necessary that the experimental judgement we possess is that the scammony commonplace to us and perceived [before us], either from its essence or from the nature (*tabʿ*) in it purges bile, unless it is opposed by an obstacle. (48.4–7)

In short, one can feel confident in the results obtained through experimentation, provided that one avoids mistaking what is accidental for what is essential and that one carefully sets out the conditions surrounding the observations that are the basis of the experimentation.³² Ibn Sînâ is under no delusion that these tasks are easy. Still, he is presenting an ideal toward which the scientist should strive.

In conclusion, I would like to make a few brief comments about the significance of Ibn Sînâ's experimental methodology within its philosophical and historical context.³³ Ibn Sînâ's ideas did not arise in a vacuum. Both certain Stoics and various ancient physicians, specifically the empiricists, as well as certain Is-

³² The three criteria given here are intended as general constraints on experimentation and the discovery of causal powers. In Ibn Sînâ's *Qânûn*, II.1.ii, he expands this list to include seven conditions specific to experimenting on cures and seeking their causal powers.

³³ Both the philosophical and historical context are considerably more complex than I have suggested heretofore. First, I have said nothing about the various occasionalist critiques of induction (as well as experimentation) raised by certain Islamic speculative theologians. See al-Baqillani (who was roughly a contemporary of Ibn Sînâ), *at-Tamhîd*, R. McCarthy, ed. (Beirut: Librairie Orientale, 1957), 43.4–14; and also al-Ghazâlî (who is chronologically later than Ibn Sînâ), *The Incoherence of the Philosophers*, M. Marmura, ed. and trans. (Provo, UT: Brigham Young University Press, 1997), discussion 17. In short, their argument is that repeated observations only reveal a constant conjunction, but not a causal connection. Repeated observations need only indicate God's habit (*âda*) or custom (*sunna*) of producing two things together, not that the two things are naturally and necessarily linked. Since both al-Baqillani and al-Ghazâlî were occasionalists, their critiques of Aristotelian induction (as well as Avicennian experimentation) were directed against the metaphysical underpinnings of those theories, namely, the theory of natural causality. Since Ibn Sînâ's criticism of induction (as well as his subsequent development of a theory of experimentation) is made within an Aristotelian metaphysical system and attempts to show the internal difficulties of induction with Aristotle's overall theory of science, I have not discussed these various occasionalist critiques. See M. Marmura's "The Metaphysics of Efficient Causality in Avicenna (Ibn Sînâ)" and "Ghazâlî and Demonstrative Science."

Similarly, I have not mentioned al-Fârâbî, who was chronologically before Ibn Sînâ and who argued that the acquisition of first principles is due to an emanation from the Active Intellect. Consequently, the question of how one acquires the first principles of a science was for al-Fârâbî a metaphysical issue and not merely one of possessing a proper method of scientific discovery. Also, al-Fârâbî marks a difference in his *Kitâb al-Burhân* between induction and experimentation that is an inchoate version of Ibn Sînâ's distinction (al-Fârâbî, *Kitâb al-Burhân*, *al-Manṭiq ʿind al-Fârâbî*, M. Fakhry, ed.

lamic speculative theologians, had attacked Aristotelian induction. They argued that one could not be certain that one has observed the relevant similarities nor that one observed a sufficient number of cases to justify a necessary generalization. In its place they claimed that *empeiria*, the Greek term that almost certainly underlies the Arabic *tajriba*, was sufficient for the physician or scientist in general. Hence, one may want to claim that Ibn Sînâ's account of experimentation is just a continuation of a long-established doctrine. Similarly, most of the arguments and caveats that Ibn Sînâ used when discussing his theory of experimentation were already present in Aristotle. Given this indebtedness to ancient Greek sources one may be tempted to conclude that at best Ibn Sînâ is just a synthesizer, and at worse that he merely repeats the Greeks and thus he contributes to neither philosophy nor science.

One would be wrong in this judgment. As Galen himself observes concerning the ancient empiricists, they reduce medicine, and science in general, to a mere "knack" (*tribê*). *Empeiria*, for these thinkers, neither provides necessary nor causal explanations, both hallmarks of ancient (Aristotelian) science. Ibn Sînâ's methodology intended to provide both necessary knowledge, albeit conditionally necessary knowledge, and causal explanations, albeit only *that* there is a causal explanation and not *what* that explanation is. In this respect, Ibn Sînâ's account of experimentation goes beyond its Greek predecessors. Moreover, in Ibn Sînâ's list of rules to avoid errors in observation, he attempted to provide guidelines that ensure one is observing the relevant features. Thus, in contrast to the Stoics and Empiricists, who primarily provide negative arguments concerning scientific method, Ibn Sînâ is offering a decidedly positive account of scientific method.

As for Ibn Sînâ's relation to Aristotle, Aristotle nowhere brings all the disparate elements mentioned by Ibn Sînâ together to form a viable alternative method to induction. For Ibn Sînâ, Aristotelian induction failed as a means of scientific establishment. Thus a new method was needed. That Ibn Sînâ drew on already existing elements to create this new methodology in no way detracts from the creativity and originality that went into shaping it. Indeed, when one turns to certain Medieval Latin philosophers' conception of the scientific enterprise, most notably Robert Grosseteste's, it is as much Ibn Sînâ's view of experimentation as Aristotle's view of induction that is motivating their projects.³⁴ Furthermore, as we have already seen, Ibn Sînâ's critique of induction and his subsequent discussion

[Beirut: Dâr al-Mashriq, 1987], 24); I am grateful to Deborah Black and Thérèse-Anne Druart for pointing out to me the parallels between Ibn Sînâ and al-Fârâbî. For the metaphysical underpinnings of al-Fârâbî's thought see al-Fârâbî's *Mabâdî' arâ' ahl al-madîna al-fâdîla* (*Principles of the Opinions of the Inhabitants of the Virtuous City*), R. Walzer, ed. and trans. (Oxford: Oxford University Press, 1985), ch. 13; also see Thérèse-Anne Druart, "Al-Fârâbî, Ethics, and First Intelligibles," *Documenti e Studi Sulla Tradizione Filosofica Medievale* 8 (1997): 403–23.

Ibn Sînâ would certainly agree that the acquisition of the first principles of a science does require an emanation from the Active Intellect or some sort of intuition (*hads*). Still, since this metaphysical issue has been the topic of several studies, while the empirical and methodological element of Ibn Sînâ's theory has received far less attention, I have limited myself to these later components.

³⁴ Cf. Robert Grosseteste, *Commentarius in Posteriorum Analyticorum Libros* (Firenze: Leo S. Olschki, 1981), I 14, 251–91. See A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100–1700* (Oxford: Clarendon Press, 1953), 79–81 for Ibn Sînâ's influence on Grosseteste. Also, if I might hazard a guess, it is possible that some of the content of our text, even if not the text itself, was known to Grosseteste. Such a suggestion would explain certain structural similarities between the

of experimentation provided a corrective to certain problems in Aristotle's theory of science.

Finally, although by no stretch of the imagination could Ibn Sîna's account of proper scientific method be identified with our modern conception of science, it does anticipate certain salient features of it. First, unlike the modern conception of science, Ibn Sîna held up as an ideal that science should provide necessary, apodictic knowledge. Still, he also recognized that scientific claims could be tentative. That is to say, in the light of new discoveries and observations one must be willing to modify one's claims. New varieties of scammony, for example, might be found, which are not purgatives. Second, Ibn Sîna gives a significant role to conditional claims in science, or what we might now call "scientific laws." Obviously, an Aristotelian universal affirmative proposition, such as "All *A*s are *B*," could also be a scientific law. Such propositions, however, allow little room for incorporating the conditions under which the observations were made that gave rise to the law. For example, the categorical claim "all scammony purges" might turn out false for certain unexamined varieties of scammony or under other conditions. Ibn Sîna's view, in contrast, requires that the scientist explicitly state the conditions under which the law obtains. Thus the "scientific law" concerning scammony, for example, would look something like this: if the scammony is (1) one of the varieties examined, (2) administered to a ready patient, and (3) any other conditions that surrounded the experimentation are satisfied, then scammony necessarily has the power to purge. Finally, Ibn Sîna's theory of science, like Aristotle's, finds a significant place for empirical observation. There has been a tendency for many Avicennian scholars, such as F. Jabre, S. Nuseibeh, and H. Davidson, to emphasize the role Ibn Sîna gives to the Active Intellect's illuminating the human intellect in the acquisition of knowledge to the exclusion of the role of the senses. On this reading, the role of empirical observation is either an obstacle to knowledge acquisition or at best a fifth wheel. The present study has hopefully shown that empirical observations play a crucial part in Avicennian science. In fact, the findings of our study fit nicely with the recent research into the psychology of Ibn Sîna by Dag Hasse and Dimitri Gutas.

In summary, Ibn Sîna offered perhaps the most trenchant criticism of induction during the ancient and medieval period. His purpose, though, was not purely negative. His critique was intended to provide a corrective to the excesses that were claimed for induction at his time. Furthermore, Ibn Sîna's critique opened the way for him to develop a different, and perhaps better, method of scientific explanation in the form of experimentation. The account of experimentation that Ibn Sîna develops, though by no means modern, has certain elements that are definitely heading in the right direction. These elements include the experimental method's willingness to allow tentative claims, which can be modified in the light of new observations, as first principle of a science; its explicitly taking into account the conditions under which an experiment was made; and the significant role it gives to empirical observations.

Burhân text and Grosseteste's commentary on the corresponding passages of the *Posterior Analytics* (ad I 18). Even if the content of our text was not available, many of the same points, especially concerning the rules for correct observation, would have been available in Latin via the Latin translation of Ibn Sîna's *Qânûn* (see n. 32).