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## LOGIC AND SCIENCE

### Introduction

Logic for Avicenna is primarily a tool for scientific discourse and discovery. It can perform its function, however, only if there is some connection linking the objects of logic, namely, the universal predicables such as, for example, genus, difference, and species, with the objects of which the practitioner of a given science has immediate access, namely, concrete particulars and their causal interactions. Establishing that there is a close association between the objects of logic and science is a necessary part of Avicenna's philosophic enterprise, inasmuch as Avicenna requires that the premises used in logic and the conclusions derived from them accurately capture the way that the world itself is. In this chapter, I focus primarily on how Avicenna envisions the relation between logic and the sciences. Thus, I do not deal with the technical points of Avicenna's syllogistic, that is to say, Avicennan logic considered as a formal language, except insofar as that is necessary for understanding how Avicenna sees logic as a tool of science.<sup>1</sup> One technical point, however, is worth noting here about Avicenna's system of logic: "Every proposition in Avicenna's system is either temporalized or modalized; there is no proposition which directly captures the non-modalized assertoric proposition used in introductory accounts of the categorical syllogistic."<sup>2</sup> So, for example, an assertoric statement such as

“(Every) human is a rational body” is only the implicit way of stating “(Every) possible human is necessarily a rational body.” This fact, I believe, reflects Avicenna’s conviction that the basic ontological structure of the world is inherently modal. In other words, everything, from the lowliest mote to the divinity itself, is either necessary or possible in itself, a point that I turn to in depth in chapters 6 and 7.

For now, however, I begin by sketching what might be thought of as Avicenna’s metatheory of logic, which underlies his philosophy of science and theory of knowledge (*ilm*). Here I consider how Avicenna supports his scientific realism and the theoretical foundation that he provides for the relation between logical notions (such as genus and difference) and the objects of scientific inquiry. Additionally, I look at the role that Avicenna has logical notions play in the scientific enterprise. After a brief consideration of how Avicenna divides the sciences, I turn to two of the most important logical tools that the medieval scientist and philosopher used, namely, definitions and demonstrations, and their relation to causes. In the final section of this chapter, I take up Avicenna’s discussion of some of the empirical methods employed by the scientist for acquiring knowledge of definitions and the first principles of demonstrations, at least as those methods appear in his logical works.

### The Relation between Logic and Science

When one considers the relation between logic and science, one may view logic as standing to science in the way that language, or perhaps better syntax, stands to a body of thought. Avicenna certainly seems to endorse such a view when he writes, “The relation of this field of study [that is, logic] to inner reflection, which is called ‘internal reasoning’ is like the relation of grammar to the explicit interpretation, which is called ‘external reasoning,’ and like the relation of prosody to the poem” (*Introduction*, I.3, 20.14–16). In this respect logic is a tool (*āla*) that guarantees a certain precision in scientific reasoning and even safeguards science against the introduction of hidden assumptions and formal fallacies.

Considered as such, logic, for Avicenna, is essential to a proper and scientific understanding of our world; however, in order fully to appreciate logic’s role in the scientific enterprise, one must first understand what Avicenna means by “scientifically understanding a thing.” “Science” or

“scientific knowledge or understanding” translates the Arabic *‘ilm*, which itself is the common Arabic translation of the Greek *epistēmē*. For Avicenna, scientific knowledge involves two aspects: first, conceptualizing (*taṣawwur*) what is meant when either a term, premise, or even inference or syllogism is presented, and second, verifying (*taṣdīq*, literally “truth-making”) what one is conceptualizing.<sup>3</sup> Avicenna describes these two aspects thus:

Something is scientifically understood (*yu‘lamu*) in two respects: One of them is that it is conceptualized only, such that if it has a name and [the name] is uttered, then what [the name] means is exemplified in the mind, regardless of whether it is true or false, such as when “man” or “do such and such” is said, for when you attend to the meaning of that which you are discussing, then you have conceptualized it. The second is verification together with the conceptualization, and so, for example, when you are told that “all white is an accident,” then from this not only do you conceptualize the meaning of this statement, but also you verify that it is such. As for when you have doubts whether or not it is such, you still have conceptualized what is said (for you do not have doubts about what you have neither conceptualized nor understood); however, you have not verified it yet. All verification, then, is together with a conceptualization, but not conversely. In the case of what this [statement] means, the conceptualization informs you that [both] the form of this composite [statement] and that from which it is composed (like “white” and “accident”) occur in the mind, whereas [in] verification, this form’s relation to the things themselves occurs in the mind, that is, [the form in the mind] maps unto (*muṭābiqa*) [the things themselves] (*Introduction*, 1.3, 17.7–17).

Conceptualization, on the one hand, simply involves understanding the meaning or intention (*ma‘nā*) of a word or a statement or even how statements work together to form an inference, with no reference to whether that term refers, or the statement is true, or the inference is sound. In verification, on the other hand, not only does the conceptualization of the meaning of a word or form of a statement or inference occur in the mind, but also the object of the conceptualization must map onto or “correspond”<sup>4</sup> with the thing itself.

Bearing in mind Avicenna’s distinction between conceptualization and verification let me tentatively distinguish the discipline of logic from the sciences: Logic and the objects of logic, such as genus, difference, and

species (the so-called second intelligibles), focus primarily on that aspect of knowledge that concerns conceptualization and the objects of conceptualization,<sup>5</sup> whereas science and the objects of science, such as extramental things and their causal relations, concern that aspect of knowledge that involves verification.

As for what the objects of conceptualization are, Avicenna mentions definitions, definite descriptions, exemplars, and the signs or terms of things (*Introduction*, I.3. 18.5). Most frequently, these objects of conceptualization are composite in nature. Thus, one first must conceptualize the simple or singular terms from which the more complex is composed in order to understand fully the sense of the term or statement in question (*Introduction*, I.4, 21.1–22.12). For Avicenna, following Porphyry's *Isagoge*, the most logically basic or simple terms are universals represented by the genus (*jins*), difference (*faṣl*), species (*nawʿ*), property (*ḵhāṣṣa*), and accident (*ʿaraḍ*), the so-called predicables.<sup>6</sup> So, for example, when one conceptualizes the term “human” one might recognize that what is meant by it is a composite of the simpler or more logically basic concepts, “animal” and “rational.” Here, “animal” represents the genus, namely, that which is common to several individuals varying in species (*Introduction*, I.9), and “rational” represents the difference, namely that which specifies among the generically common things what kind of animal human specifically is (*Introduction*, I.13). Jointly, the genus and difference constitute the definition of the species “human.” Similarly, one might conceptualize that humans have the capacity to laugh, where “the capacity to laugh” is a property of humans in that it is something unique to humans even though it does not make up part of the definition of “human.” Also, one might conceptualize that “walking” or “black” might belong to humans, where “walking” and “black” are neither constitutive of the definition of human nor unique to humans, but are accidents of, that is, something nonessential to, a human. The propositions composed from the singular terms falling under these universal divisions are in turn constructed into syllogisms or, ideally, demonstrations, which are then used within the sciences.

Although later I shall need to clarify how Avicenna believes that the universal predicables—genus, species, difference, property, and accident—as well as the propositions, and then syllogisms composed from them, relate to the extramental world, let me now explain how he considers them as they exist in conceptualization and how the conceptualization of them is related to logic. To do this I must first consider a topic that might initially

seem to have more to do with metaphysics than logic, namely, essences (*māhīyāt*), a topic, let me hasten to add, that is a recurring theme throughout Avicenna's thought. Still, since Avicenna himself introduces essences in his logical works in order to explain the relation between logic and the sciences, I consider this topic here as well. In his *Introduction* to the *Cure*, Avicenna writes about essences:

The essences of things might be in the concrete particulars of the things or in conceptualization, and so they can be considered in three ways. [One] is the consideration of the essence inasmuch as it is that essence without being related to one of the two [ways] of existence [that is, either in the concrete particulars or conceptualization] and whatever follows upon it insofar as it is such. [Two] it can be considered insofar as it is in concrete particulars, in which case certain accidents that particularize its existing as that follow upon it. [Three] it can be considered insofar as it is with respect to conceptualization, in which case certain accidents that particularize its existing as that follow upon it, as, for example, being a subject and predicate, and also, for example, universality and particularity in predication, as well as essentiality and accidentality in predication, for being essential and being accidental are not in things existing in the external [world] by way of predication, nor is something [in the external world] a logical subject (*mubtada'*) and a logical predicate (*khabar*), nor a premise, a syllogism, and the like (*Introduction*, I.2, 15.1–8).

For now I concentrate on Avicenna's view of essences as they exist in conceptualization. He tells us that when one conceptualizes the essences of things, those essences acquire certain accidental features inasmuch as they are conceptualized, and that these accidental features need not belong to those essences considered either in themselves or as existing in concrete particulars. One of the things that accidentally occurs to essences during conceptualization is that they may be conceptually divided into a part that is a logical subject and a part that is a logical predicate; for example, in the definition of "human," one might consider "human" as the logical subject and "rational animality" as something predicated of that subject. Moreover, Avicenna tells us that during conceptualization essences may be considered as something universal or something particular, although, as will be seen, essences considered in themselves are, for Avicenna, paradoxically neither universal nor particular.

For Avicenna, logic, at least inasmuch as it is relevant to the various sciences, is related to essences precisely insofar as it considers those essences as

existing in conceptualization together with the accidental features that accrue to essences when they are conceptualized. Avicenna, thus, continues:

Now, when we want to think discursively (*natafakḳara*) about things [that is, syllogistically] and know them, we must necessarily take them in conceptualization, in which case they necessarily happen to have states that involve the conceptualization. So, we must necessarily consider the states that they have in conceptualization, especially when we want to come to know things by way of discursive reasoning that were unknown, where that [proceeds] from things that are known. Inevitably, things are unknown and likewise known only in relation to the mind. Now, the state and accident that they happen to have so that we [can] move from what is known about them to what is unknown about them is a state and accident that they happen to have with respect to conceptualization, even if what belongs to them in themselves is also something existing together with that. Thus, it is necessary that we know these states: their quantity, quality, and how they are considered in this accidental [way]. . . . This kind of investigation is called the science of logic, namely, the investigation into the aforementioned things inasmuch as from them it leads to making the unknown known as well as what is accidental to them inasmuch as they are only like that (*Introduction*, I.2, 15.9–16.12).

Logic, inasmuch as it is a tool of the sciences, concerns essences along with the accidental features that follow upon their being conceptualized, and then ordering what is known in such a way that one can move from prior knowledge to a new knowledge about something, which was originally not known. Logic considered as a science in itself, however, is primarily interested in the accidental features that occur as a result of being conceptualized, such as being a logical subject or predicate, universal or particular, and the like. That is because it is the accidental features following upon conceptualization that allow logic to classify things under one of the five aforementioned universal predicables; to construct definitions and propositions from those predicables; and then to arrange those propositions so that they form valid syllogisms that allow one to move from the knowledge conveyed in those propositions to conclusions that convey something that had previously been unknown.

I have now considered how Avicenna envisions logic's relation to conceptualization, but this relation raises the deeper question for him about how logic is related to scientific knowledge in its fullest sense, that is, knowledge involving both conceptualization and verification. To put the

same point slightly differently, the question is "How do the objects of logic—namely, second intentions, which at least for Avicenna are purely mental objects—relate to the objects that the sciences investigate, namely, things in the world and their causal interactions?"<sup>7</sup> In fact, the problem is even more acute; for Avicenna is a realist inasmuch as for him the goal of philosophical and scientific inquiry is ultimately a type of necessary certainty (*yaqīn*) about the way the world in fact is.<sup>8</sup> Thus, if one cannot be certain that the objects of logic and the conclusions derived from logic actually capture the way the world really is, then logic, for all the precision in reasoning it might bring, would fail to be an adequate tool for doing science. If logic is to play a role in the scientific enterprise, as Avicenna believes that it does, then there must be some bridge, or common element, linking the universal predicables treated in logic with the concrete particulars of immediate experience.

In order to answer this deeper question concerning the relation of logic and science, Avicenna returns to his account of essences. Recall that for him essences exist either in conceptualization or in concrete particulars. Inasmuch as an essence exists externally in concrete particulars, it has accidents different from those that follow upon its existing in conceptualization. More precisely, these accidents, at least in the case of the physical and natural kinds that we see around us here on Earth, follow upon the essence's existing in matter,<sup>9</sup> and by existing in matter, that essence becomes the essence of some concrete particular, as, for example, the essence of human that belongs to me. Among the accidents that follow upon an essence's existing in matter are such things as, for example, walking, being white, having this particularly bodily configuration, coming to be at this particular place and time, and the like. In this respect, the essence of human, for example, that exists in individuals such as Socrates, Plato, and Aristotle exists as a particular owing to the material conditions necessary for the existence of those individuals. Perhaps the most significant difference between the essence existing in matter and the essence existing in the mind, and so conceptualized, is that in the latter case the essence exists as something universal or general, whereas in the former case it exists as something particular or individuated.

In addition to essences' being considered as they exist either in concrete particulars or in conceptualization, Avicenna also believes that they can be considered merely in themselves. Considered in themselves, essences for Avicenna are neither universal nor particular, but potentially one or the



other. Thus, Avicenna says, “The animal in itself is a certain thing (*ma ‘nā*)—whether as something existing in concrete particulars or something conceptualized in the soul—but in itself it is neither general nor particular” (*Introduction*, I.12, 65.11–12). Despite the apparently paradoxical nature of claiming that essences considered in themselves are neither universal nor particular, Avicenna believes that to assert otherwise leads to absurdities. To make his point he presents the following dilemma.

If [animal] in itself were general [that is, universal]—so that animality is general because it is animality—then necessarily no animal is an individual; rather, every animal is something general. Again, if the animal—because it is animal—were an individual, then only a single individual [animal] would be possible, namely, that animal that animality requires, and it would be impossible that any other thing is an animal. (*Introduction*, I.12, 65.12–16)

The first horn assumes that animal is something essentially universal, that is to say, animal in itself would be the animality common to many animals. As such, being an animal would apply only to many animals, and so paradoxically being an animal could not apply to any animal taken singularly. In other words, given the assumption that animal in itself is necessarily and essentially universal and so holds only of many animals, and no animal taken individually is many animals, no individual animal could essentially be an animal, which Avicenna takes to be absurd. The second horn assumes that animal in itself is essentially particular and as such is not applicable to many, just as being the individual Socrates is not applicable to many. As such, being an animal would apply only to a single individual and anything other than that individual animal would not be an animal essentially, which again Avicenna finds absurd. Therefore, he concludes that to make animal in itself either universal or particular leads to absurd consequences. Thus, animal in itself cannot be either universal or particular. Since the argument can be generalized to any essence considered in itself, essences in themselves are neither general nor particular.

In fact, it is precisely because essences in themselves are potentially both universal and particular that logic is applicable to the scientific enterprise. That is because logical reasoning, which involves mental existents, maps onto scientific understanding, which involves extramental existents, precisely because the objects of logic and science are partially identical for Avicenna inasmuch as the essences of things considered in themselves are

common to both types of existence. That follows because when, through a process of abstraction (which I discuss more thoroughly in chapter 4), one strips away various accidental features that follow upon essences inasmuch as they exist, either in the mind or the concrete particulars, and then one considers merely the essences in themselves, what exists in the mind exactly equates with what exists in the world. In a very real sense it is the exact same thing in the mind and in the world, namely, an essence in itself. The essence in itself, then, provides the link between the world as it is and the world as we conceptualize it, guaranteeing that the two in very important ways are identical.

Let me briefly summarize the most salient points thus far. For Avicenna essences exist in either one of two ways: They may exist in concrete particulars, that is to say, extramentally, or they may exist in conceptualization, that is to say, mentally. Although essences always and only exist according to one of these two modes of existence, both modes have something in common, namely, the essence considered in itself, which bridges the gap between the extramental and the mental. So, for example, the essence of animal may exist as instantiated in concrete particulars or it may exist as an intelligible in the mind, and yet, despite the difference between these two ways that animal might exist, both modes of existence have in common the essence of animal considered in itself. It is this commonality that guarantees that in salient ways the objects of the intellect map onto things in the world. Logic as a tool used in the sciences is for Avicenna concerned primarily with those accidental features that accrue to essences considered inasmuch as they are conceptualized. These features involve: the logical classification of things into subjects and predicates, as well as into genera, species, and the like; the various logical modes that hold of propositions formed from these predicables,<sup>10</sup> as, for example, being universal or particular, essential or accidental, necessary or possible, always or sometimes, and the like; and likewise the valid inferential structures that hold between propositions so as to lead to necessary conclusions.

### The Division of the Sciences

In contrast with logic, the sciences are not concerned with the conceptual accidents that follow upon essences existing in the mind; rather, the sciences are concerned with the true natures (*ḥaqā'iq*) of things as those things

exist in the world. Consequently, in the *Introduction*, Avicenna divides the sciences according to the various ways that things can be said to exist. The first division Avicenna makes is between “things that either do not exist as a result of our choice and action and those that do exist as a result of our choice and action (*Introduction*, I.2, 12.6–5).<sup>11</sup> Those things over which we have no control belong to the theoretical sciences, while those over which we do have control belong to the practical sciences. Thus, the theoretical sciences seek knowledge simply for knowledge’s sake, whereas the practical sciences seek knowledge for the sake of action.

Avicenna further divides theoretical sciences according to whether the object of the science (1) exists necessarily mixed with or involving motion or (2) is not necessarily mixed with motion. Those things that exist necessarily with motion Avicenna again divides into (1.a) those that neither can exist nor be thought of independent of motion and (1.b) those things that, although necessarily existing together with motion, can nonetheless be thought of as independent of motion. Those things that neither subsist nor are conceived without motion, (1.a), must furthermore exist with matter, claims Avicenna, since matter is required if something is to undergo motion or change. For example, a concrete particular animal cannot exist without flesh and blood, which is the matter from which there is an animal, and similarly one cannot conceptualize what an animal is without considering flesh and blood—one simply is not thinking of an animal if one is conceptualizing a bloodless and fleshless thing. In contrast, other things can be conceptualized without matter, (1.b), for example, square-ness, even though the actual existence of a square for Avicenna requires matter. The natural sciences study, (1.a), those existents that are necessarily mixed with motion and that neither can subsist nor be conceptualized without matter. Those existents, (1.b), that can be conceptualized without matter, even though they are necessarily mixed with motion and never subsist without matter, are the subject of the mathematical sciences.

In addition to the objects of the natural sciences and mathematical sciences, there are, (2), those things that are not necessarily mixed with motion. Some of these are necessarily separate from matter and motion, such as God and immaterial substances in general (what Avicenna calls “Intellects,” which are akin to what we might think of as angels), while others can but need not be mixed with motion, such as being, unity, multiplicity, and causality. Although one might expect Avicenna to mark off two theoretical sciences given the difference he notes within this division, he in fact

subsumes all things whose existence does not require motion under the single science of metaphysics, which simply studies being qua being, a point to which I return in more detail in chapter 6.

In short, for Avicenna, there are three major branches of theoretical sciences: the natural sciences, the mathematical sciences, and the science of metaphysics. These divisions correspond respectively with whether the objects investigated by the science must necessarily subsist as well as be conceptualized together with motion and matter; necessarily subsist together with matter and motion but need not be conceptualized as such; or need neither subsist nor be conceptualized together with matter and motion.

As for the practical sciences, Avicenna's comments are brief. He divides them according to the various spheres of human actions, whether at the state, home, or individual level (*Introduction*, I.2, 14.11–15). Thus, city management or generally politics concerns the concerted actions of a general human populace with shared interests. Home management (that is “economics” in the literal sense) concerns the concerted actions of a private group of humans with shared interests. Finally, ethics is concerned with the concerted actions of the single individual with respect to the flourishing of his or her own soul.

### Theoretical Science and the Search for Causes: Definitions

Avicenna's overt interests lie with the theoretical sciences. The goal for Avicenna of these sciences, and what they all share in common, is that they aim at a type of certainty or certitude (*yaqīn*) about the way the world is or why, given the actual makeup of the world, it must be as it is.<sup>12</sup> For Avicenna the only way such certitude about the world can be obtained is through discovering the causes of and causal interrelations among things. Thus, while it is definitions that one conceptualizes, it is that the definitions reflect the true causal natures of things in the world that makes the definitions true, that is to say, the true causal natures of extramental things are the verifiers or truth-makers (*taṣdīq*) of one's definitions of those things. Similarly, while it is syllogisms that can lead one from what is known to knowledge of what was initially unknown, it is only when they map onto or mirror actual causal relations in the world that they are sound and that there is a verification of them. The theoretical sciences for Avicenna are

concerned, then, with various kinds of existents, but even more specifically with the relations of causes to existence. In the case of things that have causes, the sciences are interested in uncovering those causes, whereas, should it turn out that something exists that has no cause, such as God, one would be concerned with it primarily as it is a cause of the existence of other things. Given the centrality of causality to Avicenna's conception of science and knowledge, I consider, first, the relation of causes to definitions, and then in the next section the relation of causes to syllogisms.

Avicenna says of scientific definitions that "the primary aim in defining is to indicate by the expression the essence of the thing" (*Introduction*, I.9, 48.3–4). Now, in the case of something absolutely simple or a singular term, Avicenna realizes that it cannot be defined in terms of essential or constitutive elements more basic than the very thing that is being defined. In these cases, one must appeal to relationships, accidents, concomitants, and necessities that belong to the thing in order to explain it. In contrast, Avicenna continues:

If the account of the thing is something composed of [other] accounts, then it has a definition, namely, the statement that is composed of the accounts from which its essence occurs so that its essence occurs. Because the essential factors (*dhātīyāt*) most proper to the thing are either its genus or its difference . . . the definition must be composed of the genus and the difference. So, when the proximate genus and the differences that follow it are present, then the definition occurs from them, as in our defining human as "rational animal." In the case where the genus has no name, [defining] is equally accomplished by means of the definition of [the genus itself], as, for example, if there were no word for animal, then [the definition of human] would be accomplished by the definition of [animal], namely, a body possessing a sensate soul, to which "rational" is then attached. The same holds on the part of the difference. (*Introduction*, I.9, 48.13–49.2)

Definitions, then, are for Avicenna, statements composed of a genus and difference that indicate a thing's essence. The genus, Avicenna defines, as "that which is said of many things varying in species in answer to the question, 'What is it?'" (*ibid.*, 49.13–14); however, since the species is defined by reference to the genus, Avicenna realizes that there is at least the appearance of a circular definition. Thus, at the end of his chapter in the *Introduction* on the genus, he says that "species" can be replaced in the definition of the genus, in which case genus is defined as "that which is said of many

things varying in true natures, essences, and essential forms in answer to the question, ‘What is it?’” (ibid., 53.13–14).

The difference is the second essential element of a thing’s definition; however, Avicenna observes that logicians have recognized three different sorts of differences: the general difference, the proper difference, and the strict difference (*Introduction*, I.13). A general difference is some distinguishing trait that might belong to something,  $x$ , at one time and so differentiate  $x$  from  $y$ , but that at another time might belong to  $y$ . For example, one might differentiate Peter from Paul at one time by saying, “Peter is the one sitting” and then later distinguish Paul from Peter, by saying, “Paul is the one sitting,” where “sitting” is a general difference. A proper difference is some necessary accident<sup>13</sup> predicated of one sort of thing that differentiates it from another sort of thing, and since “the differentiation occurs by means of an inseparable accident belonging to what is differentiated by it, there never ceases to be a differentiation proper to it” (ibid., 73.9–10). Avicenna gives the example of humans’ having “thin hair covering” (*bādī l-bashara*), for having a (relative) thin hair covering, for example, always differentiates a human (even a hirsute one) from, say, an orangutan.

Neither the general nor proper differences are elements in the definition of some natural kind; rather, only the strict difference is used in forming a scientific definition. Avicenna writes of it:

The difference said in the strict sense constitutes the species, namely, it is that which when joined with the nature of the genus constitutes a species and thereafter whatever necessarily follows on or is accidental to [the difference] necessarily follows on or is accidental to [the species]. So, it is something essential to the nature of the genus constituting a species in existence, namely, it fixes, divides, and individuates [the nature of the genus], for example, like the rationality belonging to human. This difference is differentiated from all the other things that are together with it in that it is that which primarily encounters the nature of the genus and so makes it determinate and divides it; and [in] that the rest of those attach to that general nature only after this [difference] has encountered [the genus] and divides it. Thus, [that general nature] is prepared for the necessity of what necessarily follows upon it and the concomitance of what is concomitant with it, for they necessarily follow it and are concomitant with it only after the specification. This is like rationality’s belonging to human; for after the potency [or “faculty”] called the “rational soul” is joined with the matter—and so at that time the animal becomes rational—[the animal] is prepared to receive scientific and technical knowledge, such as

navigation, husbandry, and writing. It is also prepared to wonder and so to laugh at oddities and to cry and to feel embarrassment and to do the other things that belong to being human. It is not the case that any one of these things was joined with animality in the mind first, and then on account of that the animal came to be prepared in order that it be rational; rather, the universal preparation and the universal human potency are that by which [the animal] is called “rational,” whereas these latter are its nurslings and dependents. You know that by the least amount of reflection. Also, you can discover that were it not that some initial potency is something prepared to distinguish and to understand, which already belonged to the human, then [the animal] would not have these latter particular preparations. That potency is called “reason” and so by it one becomes rational. This is the difference that essentially constitutes the nature of the species. (*Introduction*, I.13, 74.11–75.9)

Avicenna goes on and technically defines the strict difference much as he defined genus, namely, as “the universal singular said of the species in answer to the question, ‘What kind of thing is it in itself within its genus?’” (*ibid.*, 76.8–9). The sciences again are primarily, although not exclusively, concerned with identifying those features of things that correspond with strict differences rather than the other types of differences.

As a general rule, since definitions are supposed to capture the way things actually are in the world, the elements constituting the definition of the species must indicate positive causal factors belonging to things rather than negative aspects.<sup>14</sup> Thus, Avicenna explicitly contradicts Porphyry, arguing that negative differences are not constitutive of a definition, but rather follow upon a consideration of the positive causal features that do in fact constitute the thing itself.<sup>15</sup> “Negations,” Avicenna maintains:

are concomitants belonging to things relative to a consideration of certain (positive) accounts that do not belong to [the things]. So, [for example], “irrational” is something intellectually understood by considering rational, in which case the species, its (positive) account, and its difference that belongs to it are in the thing itself, and thereafter it is entailed of it that it is not described by anything else. (*Introduction*, I.13, 79.3–5)

Predicating a negation, such as “irrational,” of something, then, is subsequent on a consideration of those features or causal factors that actually belong to a thing. In other words, a negation is predicated of something just in case some positive account, such as “rational,” fails to belong to that thing.<sup>16</sup>

The constitutive elements that go into making a definition, namely, the genus and difference, then, must for Avicenna be positive factors that mirror real features of the world. There is also an important corollary that can be drawn from Avicenna's point about the use of negations in defining the essences of things, namely, if something that purportedly has an essence cannot be defined in terms of positive factors, then, in fact, what one is conceptualizing is a vacuous concept. (This point becomes important when Avicenna attacks the notion of a void in his *Physics*, for, as will become clear, a key element in his critique of that notion is that no scientifically adequate definition can be given for a void in positive terms, and thus the name "void" does not refer.)

The positive features in the world with which genus and difference correspond are for Avicenna a thing's material and formal causes respectively. Still, Avicenna argues that one cannot simply identify the logical notions of genus and difference with the material and formal causes that exist in external concrete particulars. Indeed, doing so, observes Avicenna, has led to philosophical confusion. He relates two cases of such confusion.

One of the greatest causes of confusion concerns how animal is a cause of the human's being corporeal, given what we have claimed about that, for as long as the human is not corporeal, then, neither is it an animal. Or, how is [animal] a cause of the human's having sensation, when as long as the human does not have sensation, then neither is it an animal, because corporeality and sensation are both causes of the existence of animal? As long as something does not exist, then the existence of whatever depends upon it does not exist. Also, when the account of the soul is joined with the account of body, such that it is the composite of the two that is an animal, not just one of them, then how can the body be predicated of the animal? In that case, it would be just like predicating the single thing of the two. Similarly, how can being animate be predicated of the animal, in which case it would be just like predicating the single thing of the two? (*Book of Demonstration*, I.10, 49.4-10)

Here, Avicenna notes two puzzles. The first puzzle arises from the fact that Avicenna believes that being an animal is a cause, of, and so prior to, the human's body, but if one considers the logical relations between "animal" and "body" it would seem that "body" is the cause, and so prior to "animal," for "animal" is defined as "a *body* having sensation," where "body" functions as the genus and "having sensation" functions as the difference. "Body" and "having sensation," then, seem to be explanatory and so prior



to the species "animal" rather than animal's somehow being their cause. In the second puzzle, since again "animal" is defined as "a body having sensation," to predicate "body" of "animal" is logically equivalent to saying "sensate body is body." In this case the concern is that a certain whole, namely, "sensate-body," is being identified with a part, namely, "body," whereas a whole clearly cannot be identical with one of its parts.

The puzzles are resolved, claims Avicenna, once one distinguishes the body qua matter from the body qua genus, and similarly once one distinguishes sensation qua form and sensation qua difference.<sup>17</sup> In general, the distinction between matter/form and genus/difference concerns whether what is signified is taken in an exclusive way or nonexclusive way respectively. I focus primarily on Avicenna's discussion of body qua matter and body qua genus, although similar remarks can be made about form and difference.

The body as matter is for Avicenna body insofar as only length, breadth, and depth are signified and nothing else. It is, as it were, that which has bare corporeality. Any other qualifications are additional to the body as matter. In this respect, one might think of the body qua matter as the thinnest possible account of what it is to be a body, for, as will be seen in the next chapter, being three-dimensional is for Avicenna the hallmark of being a body. In contrast, the body considered qua genus is an account that signifies not only three dimensions, but also, according to Avicenna, every other possible description or account that one might associate with the term "body" when one conceptualizes various corporeal things. Indeed, Avicenna invites his reader to include within the meaning of "body," understood as genus, every possible account compatible with being a body, even if those accounts might mutually exclude one another in reality, such as being animate or inanimate, sensate or insensate, and rational or irrational. In this respect, one might think of the body qua genus as the thickest possible account of body that is still compatible with the notion of body.

Given this distinction between matter and genus (and the analogous one for form and difference), Avicenna claims that "whatever is in the sense of the matter or the form is simply not predicated and is not taken as middle terms in their essence and definition, but as causes are taken as middle terms,"<sup>18</sup> namely, in the way we shall explain latter" (*Book of Demonstration*, I.10, 49.12–14). He argues for this point thus:

Since the body in the first sense [that is, as matter] is a part of the substance composed of body and the forms that are posterior to the corporeality

that is in the sense of matter, it is not something predicated, because that whole is not some abstract substance possessing only length, breadth, and depth. This second [that is, body as genus], however, is something predicated of whatever is a composite of matter and form, whether one form or a thousand, among which will be [having] three dimensions. Thus, [the body qua genus] is predicated of what is composed of corporeality (which is like matter) and soul, because the whole of that is a substance. (*Book of Demonstration*, I.10, 50.4–8)

Body qua matter, and similarly sensation qua form, cannot be predicated of animal since both are constitutive parts or elements that jointly cause the animal, and so stand to the animal as constitutive or essential parts stand to the whole. Thus, to predicate body qua matter or sensation qua form of the animal is tantamount to making the part equivalent to the whole, which it obviously is not. In contrast, when one considers the body qua genus, one considers body in its thickest sense and as such it contains every possible account that is included in one's conceptualization of body. In other words, for Avicenna the logical notion of a genus implicitly contains all the ways that the genus can be differentiated and so implicitly contains all of its species. It is precisely because body qua genus does implicitly contain the species "animal" that "body" can be predicated of "animal," for such predication is similar to saying that the whole includes one of its parts. A similar account holds for difference as well.

Although Avicenna believes that one must distinguish the causal notions of matter and form from the logical notions of genus and difference, I noted in the first section of this chapter that he also insists that there is, nonetheless, a close relation between them as well, for he believes that the causal elements in the essences of concrete particulars furnish the content of the universal predicables conceptualized in the mind. It is precisely because one has discovered, for example, that animal body and rationality are the matter and form respectively of the essence of concrete particular humans that the essence of human conceptualized in the mind in terms of the genus "animal" and the difference "rationality" provides the scientific definition of "human" as "rational animal." In other words, because the logical ordering mirrors the causal ordering, logical definitions in terms of genus and difference map onto the true natures of thing, and thus can function as proxies in logical inferences. Since any given determinate kind existing in the physical world has certain material and formal causes, the effect of this mirroring of the ontological ordering by the logical ordering is that that kind must likewise have a definition in terms of the logical counterparts of

matter and form, namely, in terms of genus and difference. Avicenna observes, “These differences, though trivial in themselves, are useful in the sciences, and should not be undervalued” (*Book of Demonstration*, I.10, 52.22). How they can be useful becomes clear in the next chapter when I consider one of Avicenna’s refutations of the existence of a void.

### Theoretical Science and the Search for Causes: Demonstrations

A second aspect of Avicenna’s theory of science concerns how causes are related to the syllogism and more specifically to the demonstrative syllogism (*burhān*), which according to Avicenna is “a syllogism constituting certainty,” (*Book of Demonstration*, I.7, 31.11). As such it begins with necessary and certain premises from which is deduced not only that the conclusion is the case, but also that the conclusion cannot not be the case (*ibid.*, I.7, 31.7–8).<sup>19</sup> The demonstrative syllogism, then, makes clear the necessity or inevitableness obtaining between the subject matter designated by the syllogism’s major and minor terms.

Avicenna divides demonstrative knowledge itself into two categories depending upon the type of demonstration employed. Thus, he distinguishes between what came to be known in the Latin tradition as the demonstration *propter quid*, that is, the demonstration giving “the reason why” (*burhān lima*) or simply the demonstration-why, and what was known as the demonstration *quia*, that is, the demonstration giving “the fact that” (*burhān al-inna*), or simply the demonstration-that.<sup>20</sup> The demonstration-that is further divided into two subspecies: a demonstration-that which leads from one correlative effect to another correlative effect, called an “absolute demonstration-that” (*burhān al-inna ‘alā l-iṭlāq*), and a demonstration-that which leads from an effect to the cause, called an “indication” (*dalīl*).

Concerning the two types of demonstration-that, Avicenna suffices himself with providing definitions and examples of both. Thus, the absolute demonstration-that “accords with the existing middle term’s neither being a cause nor an effect of the major’s existing in the minor; rather, [the middle term] is something related to or coextensive with [the major term] in relation to its cause, where [the middle term] accidentally accompanies it or something else simultaneous with it in the nature” (*ibid.*, I.7, 32.7–10). He gives the following syllogism as an example: Whoever exhibits cloudy

viscous urine is feared to have encephalitis; this individual (who is suffering from a fever) has exhibited such symptoms; thus, this individual is feared to have encephalitis. In this case, notes Avicenna, neither the symptoms nor having encephalitis is the cause or the effect of the other; rather, they are both effects of some unstated cause, which Avicenna identifies with the motion of heated humors toward the head and their evacuation from it. What is important to note about the absolute demonstration—that is that even though the syllogism neither proceeds from nor leads to a cause, there nonetheless is a necessary, natural causal relation between the two terms, namely, they both are effects of some common cause, even if that cause is not made explicitly clear in the syllogism. Had there been no such causal relation, and the two terms had been merely coincidental accidents, then there would have been no demonstration.

The second of the two demonstrations—that, namely, an indication, “accords with [the middle term’s] existing as the effect of the major’s existing in the minor” (ibid., I.7, 32.10). Here Avicenna provides several examples. For instance, every recurring tertian fever is a result of bile’s putrefaction; the individual has a recurring tertian fever; therefore, his fever is a result of bile’s putrefaction. Similar examples are given concerning the Moon’s relative position in relation to the Sun and the Moon’s various phases; the Moon’s being eclipsed when it passes between the Earth and the Sun; and wood’s burning when put into contact with fire. What is common to all of these examples is that one starts from some effect and then concludes to the effect’s cause.

Demonstration in the most proper sense according to Avicenna is the demonstration-why. This demonstration is a syllogism “that gives the cause with respect to both issues [namely, *that* such and such is the case as well as *why* such and such is the case], such that [the syllogism’s] middle term is like the cause that verifies (*taṣdīq*) the major’s belonging to the minor (or its denial),<sup>21</sup> and so it is a cause of the major’s belonging to the minor (or its denial)” (ibid., I.7, 32.5–7). In his examples of the demonstration-why, Avicenna returns to his earlier examples used in clarifying an indication, but now he converts the examples such that the middle term is the cause of the effect. So, for example: Whoever suffers from a putrefaction of bile owing to the congestion of bile and the pores’ being obstructed is suffering from a recurring tertian fever; this individual is suffering from such putrefaction of the bile, therefore, this individual is suffering from a recurring tertian fever. Here, the major premise should be understood as a definition of “tertian fever,” namely, as a “putrefaction of bile” (genus) brought about by “a congestion and obstruction of the

pores" (difference), where these are the causes of a tertian fever. In short, the demonstration-why, like the demonstration-that, inherently involves necessary, natural, causal relations. Unlike the demonstration-that, however, the demonstration-why makes clear exactly what that causal relation is.

As Avicenna's examples suggest, he believes that there is an inherent relation between demonstrations and causes; for demonstrations make clear the causes of a given phenomenon, while a knowledge of a phenomenon's causes guarantees necessary, perpetual certainty, which Avicenna takes to be the goal of scientific knowledge. In fact, argues Avicenna, this certitude is ensured only when one comes to know the causes of the phenomenon. As for defending the existence of such causal relations, in a very real sense Avicenna simply takes the reality of natural causality for granted as part of his realism. Indeed, for Avicenna to deny natural causal relations (as certain Islamic speculative theologians in fact did) would make the events in the world matters of mere happenstance and arbitrary and so would leave unexplained the manifest regular and orderly occurrence of events. In effect, for Avicenna to deny causal relations would undermine the very possibility of science understood as an investigation and explanation of the world's order, a position that Avicenna simply will not countenance.<sup>22</sup>

To summarize this section briefly, for Avicenna the goal of science is to obtain a type of certitude about the way the world is. One way such certitude can be reached is through demonstrations, that is, sound syllogisms, which provide necessary and eternal knowledge. In order to provide such knowledge, maintains Avicenna, the propositions used in demonstrations must mirror the actual causal relations in the world, ideally by direct causal relations, as in the case of demonstrations-why, or at the very least involving indirect causal relations, as in the two cases of demonstrations-that. In subsequent chapters (especially chapters 3 and 7), I discuss the various types of causal relations investigated in scientific research, but for now the most important ones are formal and material causation, since it is these causes that are reflected in the definitions that give the essence of a thing.

### Acquiring the Definitions and First Principles of Science

As has been seen, demonstrations can provide certitude according to Avicenna because they reflect the actual causal structure of the world; however,

like Aristotle before him, Avicenna denies that everything can be demonstrated (*Book of Demonstration*, II.1). That is because, argues Avicenna, who is himself following Aristotle's *Posterior Analytics*, I 3, such a position would require that in order to know anything, either one must have gone through an infinite number of demonstrations (for the principles of any demonstration would then themselves need to be demonstrated ad infinitum) or one has given a circular demonstration (for one and the same premise would have to be a principle and conclusion of itself to stop the regress). Both alternatives Avicenna complains would undermine the practice of science itself. In order to avoid either of these two outcomes, Avicenna maintains that demonstrative knowledge must proceed from prior knowledge or the so-called first principles of a science. These first principles are the existence claims and definitions of a given science and are not demonstrated within the science itself—though in some cases, although not all, they may be demonstrated in a “higher science.” Instead, relative to a given science, its first principles must simply be posited by that science without demonstration (*Book of Demonstration*, I.12, 58.14–17).

Avicenna frequently states throughout the *Book of Demonstration* that a discussion of how the first principles of a science are acquired belongs properly to the science of psychology, for an account of how one acquires such principles for Avicenna ultimately involves describing the various (proper-functioning) psychological and cognitive processes involved in human thought, as well as any natural posits required to explain what we as human cognizers in fact do. Indeed, in chapters 4 and 5, I consider in some detail the psychology underlying Avicenna's theory of concept formation and the acquisition of scientific knowledge. For now, however, I merely focus on Avicenna's discussion of two possible methodologies for acquiring first principles, namely, induction, or, more specifically, certain criticisms and limitations Avicenna imposes on its use, and methodic experience.<sup>23</sup>

### *Induction*

While like Aristotle before him Avicenna takes a staunchly empirical approach to the sciences (or at least the natural sciences),<sup>24</sup> it is on the subject of induction, which is frequently considered a cornerstone of empiricism, that Avicenna most notably parts way with Aristotle and his epistemology and philosophy of science. Here it should be noted that the conception of induction with which Avicenna takes issue is not the naïve notion of

induction that simply involves making a generalization from a limited number of observations; rather, Avicenna is critiquing a technical Aristotelian notion of induction (Gk. *epagōgē*, Ar. *istiqrā'*), which I discuss more fully below. This technical Aristotelian sense of induction involves, not only generalizations, but also a formal syllogism, and is intended to establish the first principles of a science. In contrast with Aristotle, Avicenna is overall skeptical of the merit of induction as an adequate tool for scientific inquiry (at least as Aristotle presented induction in *Prior Analytics*, II 23). Avicenna describes induction in the following lackluster terms:

When the particular instances [of the first principle] are considered inductively, they call the intellect's attention to the belief of the universal; however, the induction that proceeds from sensory perception and the particulars in no way makes belief of a universal necessary, but only draws attention to it. For example, [when] two things both touch a third thing, but not each another, they require that that [third] thing is divisible. This aforementioned claim, however, may not be something established in the soul as well as it is sensibly perceived in its particular instances, which the intellect does notice and believes. (*Book of Demonstration*, III.5, 161.14–18)

For Avicenna, induction is at most merely a pointer that draws one's attention to the pertinent facts surrounding some state of affairs. Induction, then, does not make clear what the cause of that state of affairs is or even that there must be a cause. Although Avicenna's reservations toward induction might incline one to think that he is being anti-empirical in his approach to science, such an assessment would be wrong.

Both in the *Book of Demonstration* (I.9) and the *Book of Syllogism* (IX.22), Avicenna lays out what he finds problematic about induction. Induction as described by Aristotle in his logical works has two elements: One involves the sensible content of induction, and the other the rational structure of induction, namely, the syllogism associated with induction. If Aristotelian induction is to provide one with the necessary and certain first principles of a science, then the necessity and certainty of the conclusion of an inductive syllogism must be due either to its sensory element or its rational element.

Avicenna begins his critique of induction by first noting that the purported necessity and certainty that induction is supposed to provide about causal relations cannot be known solely through induction's sensory element, for, in good empirical fashion, Avicenna recognizes that the necessity

of a causal relation and the certainty about it are not direct objects of sensation. If the necessity and certainty are due to induction's rational component, continues Avicenna, the syllogism associated with induction should not be question begging. Yet, complains Avicenna, in the scientifically interesting cases of induction one of the premises of the inductive syllogism is always better known than its conclusion, and so the induction is neither informative nor capable of making clear a first principle of a science.

Let us consider Avicenna's argument for this last claim. At IX.22 in the *Book of Syllogism*, Avicenna claims that induction in fact is successful in those cases where its divisions are exhaustive, as, for example, when animal is divided into mortal and immortal, or rational and irrational. The difficulty arises when one uses some other type of division that does not involve contradictory pairs. So, to take an example from Aristotle's *Prior Analytics*, II 23, assume one divides long-lived animals into horses, oxen, humans, and the like, and then one wants to use this premise to make clear inductively the cause of these animals' longevity. Thus, one might reason (as Aristotle in fact did) as follows:

1. all horses, oxen, humans, and the like are gall-less (major premise);
2. long-lived animals are horses, oxen, humans, and the like (minor premise);
3. therefore, long-lived animals are gall-less.

Avicenna's earlier point concerning exhaustive division was that the induction works only if one can be certain that one has correctly identified all and only long-lived animals in the minor premise. One could be certain of this identification, Avicenna however maintains, only if one knew what it is about this set of animals that guarantees that they and only they are the long-lived ones, but this knowledge would simply be to know the cause of these animals' longevity, the very premise one wanted to make clear. Thus, it cannot be induction's rational element, at least in the scientifically interesting cases of induction, that explains the purported necessity and certainty of its conclusion; for, complains Avicenna, the syllogism is question begging.

The necessity and certainty required by scientific knowledge, then, cannot arise from either induction's sensory or rational elements. Again, Avicenna is not dismissing Aristotelian induction outright; it certainly has its place in science for him as a means of drawing one's attention to pertinent facts. Still, if induction is intended to establish the facts about some causal



relation and so provide the first principle of a science, Avicenna contends that it simply fails.

### *Methodic Experience*

Avicenna instead wants to replace the technical Aristotelian notion of induction with his own conception of methodic experience (*tajriba*), which like induction has both a sensory and rational, or syllogistic, component. Unlike induction, however, methodic experience does not purport to explain *why*, that is, what the causal relation is between two terms of a first principle, but only to identify *that* there is a causal relation between those terms.

[Methodic experience] is not like induction, for induction, in chancing upon the particulars, does not occasion universal certain knowledge, even if it might be something drawing attention [to it], whereas methodic experience does. Indeed, methodic experience is like the observer and perceiver seeing and sensing that certain things belong to a single kind upon which follows the occurrence of a given action or affection. So, when that is repeated numerous times, the intellect judges that this is an essential feature belonging to this thing that is not some mere chance occurrence, since that which is by chance does not occur always. An example of this is our judgment that a magnet attracts iron, and that scammony purges bile. (*Book of Demonstration*, III.5, 161.20–162.3)

In methodic experience, there is the regular observation that two things always occur together without any falsifying evidence to the contrary. The regularity of the observation provides the basis for a hidden syllogism, claims Avicenna, namely that whenever two things always occur together without any falsifying instance there must be a cause relating those two things, and since these two things regularly occur together, there must be a cause relating them. So, for example, one always observes a magnet's attracting iron. Given the regularity of this occurrence, there must be some causal relation, maintains Avicenna, that exists between the magnet's attraction and the iron, otherwise the attraction would not always occur. Avicenna's general idea is that if there were absolutely nothing linking two regularly joined events or things to one another, then the laws of probability would dictate that the two should on occasion not occur together, which is contrary to observation. Methodic experience has not explained what this

causal relation is, but it has established that there is such a relation. Thus, given the fact that propositions obtained from methodic experience must involve some causal relation between the terms, such propositions, claims Avicenna, can still be used as first principles of a science in order to explain other phenomena.

As for the knowledge acquired through methodic experience, Avicenna is quite insistent that although the knowledge so obtained is necessary, the necessity in question is only conditional necessity and applies only to the domain under which the examination was made.

[Methodic experience] does not provide *absolute* universal syllogistic knowledge, but only *conditional* universal [knowledge], that is, this thing that 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 with this condition but not absolutely universal. (*Book of Demonstration*, I.9, 46.20–23)

It is because knowledge of the first principles acquired through methodic experience is limited to the domain under which the examination took place that Avicenna further warns us that in light of new empirical data one may need to revise one's claims. For example, he considers the case of the scientist who has repeatedly observed that on administering scammony there is always an accompanying purging of bile.

We also do not preclude that in some country a disposition and special attribute are associated with scammony not to purge (or there is absent in it a disposition and special attribute); however, it is necessary that our judgment based upon methodic experience is that the scammony commonplace to us and perceived [before us], either from its essence or from the nature in it, purges bile (unless it opposed by an obstacle). (*ibid.*, I.9, 48.4–7)

Thus, the only thing that one can legitimately conclude from methodic experience, according to Avicenna, is that those varieties of scammony that have been tested always lead to this expected result; however, should new varieties of scammony become available that do not conform to the earlier findings, the initial hypothesis must be revised, and of course this point can be extended to all cases of knowledge acquired through methodic experience. In the end, while it is true that Avicenna was critical of the notion of induction that he inherited and wanted to replace it with his own conception of methodic experience, his conception of methodic experience

is perhaps closer to our own understanding of what induction is than the earlier account of it that he wanted to replace.

To conclude this chapter, for Avicenna scientific knowledge involves two facets: conceptualization and verification. Logic treats those universal features of essences that follow upon their being conceptualized and so existing in the mind, whereas the various sciences focus on verification, namely, discovering and making clear those causal relations among essences inasmuch as they exist concretely in the world. The two most important logical tools used in the various sciences are for Avicenna definitions and demonstrations, both of which are closely related to the causes sought in the various sciences. Thus, the genus and difference that constitute a definition reflect, but are not wholly identical with, the material and formal causes of a thing's essence, while the middle term of a demonstration either expresses, or in some sense is connected with, the causal relation linking the terms of a demonstration. In his works specifically dedicated to philosophy of science, Avicenna outlines a number of methods that the scientist uses to discover these causal relations. What should be emphasized about these methods, as well as about Avicenna's general attitude toward science, are the strong empirical or naturalistic elements as opposed to so-called rational or a priori elements. In the next chapter, I consider how Avicenna uses a number of the logical points developed in his *Book of Demonstration* to tackle and to resolve problems in natural philosophy, that is, the science of physics.