Philosophy of Science in Islamic Civilization. There are various ways in which the relationship between science and any religion, including Islam, can be analyzed: as competing structures of power, at the level of ideas, as a matter of the deployment of technologies, etc. Indeed one of the main challenges in discussing this topic properly is that the terms "science," "religion," and "Islam" signify many different kinds of things at the same time. There are problems of terminology to overcome, and these have a huge bearing on questions of substance. It is difficult to discuss fundamental issues related to science in the Islamic world without understanding some of the most important assumptions we make about modern science and how those assumptions can skew our judgment about Islamic science and prevent us from asking the right questions.

Definitions. Like any term of sufficient abstraction and scope, "science" is an equivocal term whose contours are both amorphous and unstable. Any analysis that takes the meaning of "science" as a given and assumes that everyone involved agrees on its various denotations and connotations will be as vague and imprecise as the original assumptions about the central idea. A helpful beginning is provided by Alan Sokal, who points out that science can refer to "an intellectual endeavor aimed at a rational understanding of the world; a collection of accepted theoretical and experimental ideas; a social community with particular mores, institutions, and links to the larger society; and finally, applied science and technology (with which science is often confused)." Indeed it matters a great deal, when we speak of the relationship of religion and science, whether we are speaking of (1) a particular mode of human inquiry into the world, or (2) a worldview and set of assumptions about how the world works, or (3) about a set of human institutions, or (4) physical tools.

Translation. Beyond issues of definition is the problem of the translation when it comes to Islam, namely, what does "science" properly translate in the Islamic intellectual tradition, whose primary language is Arabic? Originating in the Latin *scientia* or "knowledge," the word "science" has been rendered into Arabic as *ʿilm* (itself usually translated in English as "knowledge"). This translation

introduces profound problems. First, whatever its etymology, "science" does not mean simply knowledge or field of study since it is both more narrow and more broad than *ʿilm*, because *ʿilm* includes all levels of understanding on the part of man and also on the part of God, and because *ʿilm*, in traditional Islamic texts, would not include the institutional enterprise or applied science and technology, which are part of the usage of the word "science" in English. Whatever convergence there may have been between the Arabic *ʿilm* and the Latin *scientia* (denoting both the content of knowledge and also the various disciplines) is no longer entirely operative, and we must treat these terms as they are actually used in language today. The modern usage of "scientist" is less than two centuries old, and what we call science typically went under the name "natural philosophy," as it once did in the Islamic world. That is why translating science as *ʿilm* and then proceeding to analyze and explain the understanding of *ʿilm* in light of the term "science" will only obscure important questions. Any serious commentary on the meaning of science in the Qurʾān and *sunnah* must take into account the validity and precision of the translation of "science" as *ʿilm* and vice versa. How many authors have sought to show the harmony between modern science and Islam by quoting the *ḥadīth*, "Seek knowledge, even in China"? To use an example from the Qurʾān, in the statement "My Lord encompasses all things in *ʿilm*," (6:80) is there any conceivable way in which this term could be rendered as "science" or "scientific knowledge" while remaining faithful to the Qurʾānic text? Again is there any sense of the word "science" that could be used instead of "knowledge" in the verse "They encompass nothing of his Knowledge, save as he wills" (2:255)?

Demarcation. Beyond discerning the polyvalence of the word "science," and keeping in mind the problem of translation, one encounters the more substantial problem traditionally referred to as "demarcation," which asks whether an inquiry into the nature of the world, or a theory about the world, is "science" or "scientific." But a cursory glance at the four senses mentioned earlier shows us that the demarcation problem is at least as complex as the polyvalence of the word "science." Those who attempt to define strictly the dividing line between science and non-science—and more specifically, between science and religion—often run into question-begging problems of definition (for example, What is "rational" in the phrase "rational enquiry"? What counts as "evidence" in an "evidence-based" theory?) or create definitions that inevitably exclude ideas and methods that most everyone would wish to count as "science." Anyone who has tried to answer question of demarcation quickly runs into difficulties, and there is no single method or set of conditions that easily accounts for defining what science is and what it is not. Indeed the demarcation question is dependent upon more fundamental questions that will be explored below.

In general, whenever religious and scientific ways of looking at nature are compared, the scientific perspective that is offered is typically not that of today's actually existing science or even philosophy of science, but some version of the idealized mechanical philosophy that flourished in Europe in the seventeenth century and that continues to this day to have a certain hold upon the imagination of modern people. According to this mechanical philosophy the study of nature was to be the study of Descartes' *res extensa* (the "extended thing" as opposed to *res cogitans* or "thinking thing," the mind), or Galileo's "primary qualities," namely the measurable but quality-less objects of the world whose only real properties were quantitative. According to this way of dividing up the world, the apple "out there" is not the red, fragrant, tasty object; these qualities are in the mind. Rather the apple is the quantifiable and measurable object of such and such size, density, weight, etc.

According to the mechanical philosophy our systematic inquiry into the world would eventually confirm that its nature is a grand and complex machine, as would be each of the objects within it, up to and including animals and human beings. The causal relationships governing that quantitative entity "out there" were to be understood in terms of the everyday physical contact with which we were familiar from our ordinary experience. Even if the objects were invisible, for example, atoms, they interacted with one another in the manner of the mechanical parts of a clock, with no intrinsic relationship to each other. This is what it meant to explain the world rationally. Although Newton was an upholder of this point of view, it was Newtonian mechanics itself that destroyed this conception of the world. Newton's theory of gravity required actions as a distance, in violation of the mechanical philosophy, a fact that was not lost on Newton and that disturbed him greatly, since the founders of modern science had wished to banish from consideration all occult and non-mechanical forces (such as the sympathies and antipathies of scholastic science) and to explain attraction, repulsion, etc. This was done in no small measure as a kind of turning away from the cosmology of traditional Christianity. A giant machine left no room for God except to create it and set it on its way, after which it would move according to the logic of its parts.

Eventually, in trying to explain the inner workings of the natural world, scientists would be compelled to embrace entities such as "forces" and "fields" which did not satisfy the original ambitions of the mechanistic philosophy, and this move away from mechanism was furthered with the advent of twentieth-century physics (relativity and quantum mechanics), when the new standard for scientific theories dropped from intelligibility to consistency and prediction in the face of newly discovered phenomena that simply defied many of the commonsense notions we have of how bodies behave. Indeed philosophers of science today do not argue about the nature of electrons or ask what electrons are really like; rather the range of discussion is about whether it makes sense to even say that there are such things as electrons at all, or if the entities of quantum mechanics are real objects of study like trees and stars. It should be noted that figures such as Newton and Locke did not absorb the idea of actions at a distance such as "forces" or "field" with a shrug, but were open to possibly profound and unsettling implications of a non-mechanical world. Newton noted that scientifically one cannot deny that nature might be alive. Locke wondered whether God might not add to matter the faculty of thinking. Newton's and Locke's remarks about "matter" (which for them, recall, were the quality-less, quantifiable objects as delineated by Descartes and Galileo) are not only as valid today as they were when they were first asked, but are even more relevant, since what physics seems to reveal about the world of nature moves it farther away from the idea of a machine and closer to the ghost from which the scientific revolution initially fled.

Even if professional philosophers of science have abandoned it, the spirit of mechanical philosophy still abides, though much less coherently, in modern scientism, and it is a rough approximation of how many view science today. It is important to note that after Newton's formulation of the law of gravity, modern science no longer had a coherent account of "physical" or "material." It is in a sense inaccurate to critique modern science for wanting to explain everything in terms of physical or material causes, since what is sometimes called scientific reductionism is not so much a reduction of levels of causation to the material or the physical, as it is a reorganization or unification of causation along very narrow lines, incorporating both the perceptible (the objects of our experience) and the intrinsically imperceptible (forces, fields). Indeed according to what defensible

standard is gravity "material" or "physical" as opposed to simply "real"? This is where questions of demarcating between scientific and unscientific become difficult.

That is to say, in the popular and even scholarly imagination it is thought that modern science really did accomplish its goals of explaining the world in terms of physical causes, but the original ambition of the modern scientific revolution of exposing the world as a giant machine failed utterly. From Newton's theory of gravity onward science had to be content to exchange one set of invisible causes for another set of similarly invisible causes. Indeed the acceptance of gravity, electromagnetism, and quantum entanglement demonstrate the readiness of science to accept unperceived and intrinsically unperceivable (and indeed unimaginable) realities underlying the world of ordinary perception. The ultimate question between religion and science would thus become: What parameters of causation are allowed when constructing a unified theory of how the world works?

Did Islamic Theology Destroy Science? How do these questions of definition, translation, and demarcation relate to Islamic science? Let us turn to the example of the famous theologian Abū Ḥāmid al-Ghazālī, whose work is said to have been so destructive to the spirit of scientific inquiry in the Islamic world. In a now proverbial illustration of the principle of divine causality, al-Ghazālī and other theologians said that fire does not itself burn cotton but that we observe that whenever fire is brought into contact with cotton God makes the cotton burn, and that God could make it burn without fire, or not burn at all even in the presence of fire. Many have argued that by destroying the idea of "horizontal" or secondary causality al-Ghazālī and like-minded theologians forever crippled science in the Islamic world.

This conclusion is a total non-sequitur. One could just as easily argue that al-Ghazālī's burning cotton example would motivate greater investigation, since pious Muslims should be interested in what God is up to in the world of nature because occasionalism invests the world of nature with more, not less, meaning. Why would the belief that God is the immediate cause of all reality dissuade anyone from studying nature? Does anyone blame David Hume's arguments against induction and the discovery of causal relations—the latter being generally considered crucial to the practice of science—as having harmed the progress of Western science? Why did al-Ghazālī's argument against induction have a devastating effect on science, but Hume's argument did not?

Much more relevant than al-Ghazālī's metaphysical doctrine, sometimes called occasionalism, are his comments about the practical effects of those who study mathematics, logic, and natural philosophy (what we would call "science"). Al-Ghazālī argues emphatically that the findings of mathematics neither confirm nor deny any truth of religion, since they are matters of rational demonstration that are impossible to deny. However he observes that while the subject matter of mathematics is totally unobjectionable, those who have a high opinion of philosophers because of their knowledge of mathematics will follow their opinion in other matters where their knowledge is suspect. Al-Ghazālī is quite explicit that this is not a judgment about the content of mathematical knowledge but a judgment regarding human trust, authority, and even vanity. Another danger with mathematics is that of religious believers attacking mathematics on the assumption that it contradicts faith, since this would amount to a denial of that which is not objectionable in itself and can even be beneficial. Al-Ghazālī has similar views regarding systematic logic, which he says neither affirms nor denies religion. Here again he directs his warning not against the subject matter but against the pitfalls of those who study it. He objects to those philosophers who establish certain

standards for logical demonstration, which he agrees produce certainty at their own level, but he argues that when it comes to certain questions of religion the philosophers fall short of these very standards. Indeed one of al-Ghazālī's main criticisms of Avicenna (Ibn Sīnā) was not so much that he held incorrect doctrines (he did believe this), but that those doctrines are not arrived at using the logical and rationalistic methods philosophers claim to espouse. When it comes to natural philosophy or physics al-Ghazālī again limits his objections not to the subject matter, which he sees as neutral, but to the philosophical and a priori decision to exclude God from the workings of the cosmos.

Al-Ghazālī's arguments are neither pro-science nor anti-science as such (at least not in all the senses mentioned above), but rather are sociological and philosophical. His warning about the application of mathematical precision to other realms prefigures contemporary criticisms leveled at the some social sciences that attempt to buttress their findings using quantitative methods, in order to give their field the certainty and precision typically associated with physics and chemistry. The pitfalls associated with the use of statistical regression, for example, in fields as nonquantitative as international relations is a topic of serious debate today. The desire by economists to incorporate the methods and theories of physics into their discipline is well known and reaches back to the nineteenth century.

More generally, if al-Ghazālī argued that following the ways of the natural philosophers could be dangerous, was he not in some respect right? If one were to study physics during the heyday of mechanical philosophy, would it not be correct to say that believing such doctrines would be dangerous to one's faith in a responsive God of Providence and Grace, especially since the prevailing mechanistic interpretation of observed phenomena (which was taken to contradict the religious view of the cosmos) turned out to be itself utterly wrong? Should religious doctrines subordinate themselves not only to scientific doctrines but to the amorphous spirit of science, its institutions, and its personalities? Taking a dispassionate look the changing nature of modern science over the centuries, would not a theologian be wise to advise believers about the danger of placing one's belief at the mercy of ideas (and people) that are so unstable and liable to fundamental misinterpretation? Is there to be no reasonable limit or standard by which a person of faith might take care in drawing inferences from the study the natural world, or must they submit to professional scientists whose interpretations of the data will almost inevitably change and cause the theoretical ground under one's feet to move? Newton believed in the mechanical philosophy, and many believed in it based upon the prestige Newton acquired from his work in mathematics and physics, but this belief turned out to be unjustified by his own discoveries. Is that not a textbook case of what al-Ghazālī warned against, namely extending the authority of a particular natural philosopher beyond his domain of competence? What good would it have done for a believer to reject everything except mechanical causation only to have this doctrine overturned soon after?

Four Senses of Science in Islamic Civilization. If one looks at the handful of senses in which one can say "science" and proceeds to investigate Islam on that basis, one realizes that what "Islam" says about "science" in each of these categories is quite different and that the level of opposition and disagreement between Islamic science and modern science differs significantly from category to category.

Science as an intellectual endeavor. One must avoid the easy mistake of beginning from the popular conception of what science is and then go digging in the Qurʾān and *sunnah* to find ways

in which it agrees with those assumptions. To even quote from the Qurʾān to "show" how it is pro-science already gives the argument away to those operating from an unjustified assumption about the nature and limitations of modern science. Only after settling matters of definition, translation, and demarcation can questions such as "Is Islam against science?" even reasonably be asked. It is noteworthy that the most famous argument against what we call science, that of al-Ghazālī, was not made against the content of science but against the excesses of scientists and the abuse of their prestige to attack religion on philosophical, not scientific, grounds. As for an argument against the study of the natural world, or against attempting to understand how the world works, has such a thing been discovered anywhere in the history of Islamic civilization in any form?

Moreover, because of the equivocality of the word "Islam," in commentaries on the place of science in Islam it is often unclear whether one means Islam the religion or Islam the civilization; this difference, which scholars have tried and failed to enshrine in English usage (e.g., Islamdom or Dār al-Islām) as akin to that between Christianity and Christendom. If we are asking whether "Islam" in the former sense stifles or promotes science, we will naturally go looking in sacred texts, the writings of theologians, and legal dicta to see what they have to say about science. If we ask about "Islam" in the latter sense, we will ask about wealth, institutions, power structures, local conditions, and accidents of history in order to see how they affect the history of science. These two senses and areas of inquiry have been and continue to be conflated and confused, and even though they are intimately related, they are not the same and cannot be investigated on the same terms.

Indeed the history of science in the Islamic world shows case after case of the most illustrious practitioners of science who did not see any contradiction between their religion and their activity as natural philosophers (these are too numerous to list individually and one can peruse this volume to see many such examples). This is not only true of the more famous figures such as Avicenna, but post–al-Ghazālī figures in various fields such as astronomy who were simultaneously authorities in the religious sciences as well as trailblazers in astronomy or *ʿilm al-hayʾah*. George Saliba has written persuasively that the heyday of Islamic science, especially astronomy but also in other areas such as scientific instruments and medicine, was not pre–al-Ghazālī as is often claimed by Muslims and non-Muslims alike. In fact almost all of the most important astronomers doing the most sophisticated work, who lived after al-Ghazālī and not before, were not only religious but were religious authorities in their own right. Saliba locates the decline of Islamic science no earlier than the fifteenth century, and attributes the disparity between Western science and Islamic science not to Islamic theology or clerical obscurantism but to the new economic fortunes of the West and the institutions of science that they were able to sustain.

Science as a collection of accepted theoretical and experimental ideas. Here the differences between modern science and Islam are stark and profound. The unification of causation under the parameters of modern science leaves no room for God, angels, spirit, soul, and indeed any sacred reality at all. The various forces and invisible entities of science have meaning only as mathematical forms that provide intelligibility and coherence sufficient to make experimentation and induction possible.

However even when discussing theories there can be quite a wide gap between the immediate set of assumptions and expectations governing one's inquiry into the world on the one hand, and what might be called one's overall worldview,

even one's metaphysics, on the other; both of these are called "theories." The working theory of Islamic astronomy (*ʿilm al-hayʾah*), for example, was the mathematics, trigonometry, and algebra of the day. The metaphysical commitments of the astronomers did not have a direct bearing on their working theories of angles, degrees, etc., any more than the faith of an archer might determine the most effective way to hold an arrow.

Modern biologists, to cite another example, rarely bring questions of the origin of life into their actual work. When investigating an organism, working biologists first attempt to understand how the organism actually works, and it is not altogether relevant which overarching theory brought the biologist to his or her object of study. One can discover the nature of a DNA molecule in searching for a common ape-human ancestor, but one could just as easily discover it because one is investigating God's design of the human cell. In actual science we first understand how DNA works in terms of physics and chemistry (the immediate theory) and only then do we place it in some overarching metaphysical theory (Darwinism), which is a descriptive theory. If the fact that Muslim astronomers all believed in God while carrying out their observations and constructing their theories does not support the existence of the God in which they all believed, then the fact that successful biologists happen to believe that organisms originated in the "primordial ooze" does not count as evidence in favor of Darwinism either, since this ooze has nothing to do with the day-to-day work of biologists.

Science as a social community with particular mores, institutions, and links to the larger society. Conflict also arises between science and Islam (or any religion) regarding how and whether authority and trust are invested in the opinions and views of those who specialize in the study of the natural world. For example, most people "know" that the earth follows an elliptical orbit from the point of view of the sun not because they have checked the observations and mathematics themselves but because of their judgment and moral assessment about the trustworthiness of certain institutions and individuals. The process by which such trust and authority is granted is complex and it is not always clear how rational or evidence-based it is. As al-Ghazālī noted, human beings often follow the ideas of people based on the credibility they have in other fields, or they do so for reasons of vanity or other negative reasons. To believe that professional scientists are more credible on matters relating to intrinsically non-scientific questions is by definition a non-scientific judgment, since the scientific layman has no means available to him to judge the truthfulness of a scientist other than his judgment about human nature and the institutions in his life.

Science as applied science and technology. Finally an important area of conflict is the impact of technology in human life and its effect on the natural environment. Significantly what technology a society decides to produce and use depends entirely upon the previous three senses. There is nothing morally self-evident about technology, as a civilization will make judgments about what is worth making and what is not. If Islamic civilization did not produce the steam engine, railroads, or computers, it is entirely a philosophical question as to whether this is a good or bad thing. Can one look at the horrors of the twentieth century and not wonder, if only for a moment, whether it might not have been better for the state of human technology to have remained stable at the Middle Ages? Do we rationally weigh the benefits of modern emergency medicine against the horrors of mass murder and the destruction of the natural environment, or do we assume that our employment of technology is always worth the real costs? Do we consider the unprecedented power of the surveillance state when enjoying the benefits of computers? Each technological invention is also

an acquisition of power by some people over others. The conquest of nature by technology is also and always a conquest by those who wield the technology of those who do not wield it. The benefits of technology are never enjoyed equally and always create new types of privilege and disadvantage. Do advances in technology create a more just situation of winners and losers than what existed before?

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