CLOCKS, GOD, AND SCIENTIFIC REALISM

by Edward L. Schoen

Abstract. Scientists, both modern and contemporary,[1] commonly try to discern patterns in nature. They also frequently use arguments by analogy to construct an understanding of the natural mechanisms responsible for producing such patterns. For Robert Boyle, the famous clock at Strasbourg provided a perfect paradigm for understanding the connection between these two scientific activities. Unfortunately, it also posed a serious threat to his realistic pretensions. All sorts of internal mechanisms could produce precisely the same movements across the face of a clock. Given God's immense creative capacities, Boyle realized that standard epistemological constraints could never ensure, not even to the least degree of probability, that scientific theories about the unobservable mechanisms of nature were descriptively accurate. Like most moderns, he fortified his epistemology theologically in order to retain his realistic stance. John Locke, however, took counsel from Ecclesiastes to repudiate Boyle's realism, while Samuel Clarke mobilized biblical images to dismiss the clockwork paradigm altogether.

A contemporary review of this modern controversy reveals that there is still much to learn from the clock at Strasbourg. Among other things, the realism/antirealism issue is of central importance to understanding today's science, Nancey Murphy's protests notwithstanding. Moreover, the kind of realistic stance that is essential, not only to the truth but to the very intelligibility of certain types of scientific explanation, demands more than the critical realism of Ian Barbour. To be taken seriously, the models used in such contexts must be taken literally.

Keywords: antirealism; Ian Barbour; Robert Boyle; Samuel Clarke; clocks; entity realism; John Locke; models; Nancey Murphy; Isaac Newton; scientific realism; structural realism; John Toland.

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In their study of nature, modern thinkers distinguished two quite different investigative enterprises, the search for patterns of regularity that could be codified as laws, often expressed mathematically, and the quest to understand the natural items thought to be responsible for producing those recurring patterns. Most of the towering figures of early modern science engaged in both theoretical enterprises. Galileo, Kepler, and Newton may be best remembered for their ability to discern lawful patterns. Yet all three also struggled, if less successfully, to discover the nature of the items responsible for producing those patterns. Some such items, like sunspots and comets, were clearly observable, while others, like tiny material corpuscles, were not. But whether they were observable or not, a relatively standardized procedure was used to comprehend them. Typically scientists began with an initial analogy, often crude and obviously inadequate. Then, through a variety of theoretical techniques, including the skillful use of predictions, those analogies were increasingly refined, sometimes to high levels of sophistication (Harré 1970, 33–62). For example, Newton began his analysis of comets by comparing their tails to smoke, then used that analogy to make specific predictions. Depending upon how his assorted predictions were confirmed or disconfirmed, he sharpened his analogical understanding, tightening similarities, discarding dissimilarities, and introducing new analogies to generate fresh predictive tests (Newton [1729] 1934, 522–32).

Lessons from Strasbourg

Clocks, particularly the famous clock at Strasbourg, figured prominently in early philosophical discussions of modern scientific methods. Frequently the regular movements of hands across the face of the clock were taken to represent the observable, recurring patterns of data in nature, while internal clockworks represented the natural mechanisms responsible for producing those patterns. Just as the inner workings of clocks sometimes were hidden behind the face, so the operative mechanisms of nature often were hidden as well. Unlike clocks, however, nature's mechanisms were not always accessible to direct inspection. This, of course, posed an immediate problem, one graphically outlined by René Descartes:

> For just as there may be two clocks made by the same workman, which though they indicate the time equally well and are externally in all respects similar, yet in no wise resemble one another in the composition of their wheels, so doubtless there is an infinity of different ways in which all things that we see could be formed by the great Artificer. . . . (Descartes [1644] 1969, 1:300)

If quite diverse internal clockworks, everything from systems of gears and springs to collections of ropes, weights, and pulleys, could produce precisely the same hand movements, how could anyone be sure of the precise configuration of those internal workings that remained forever hidden behind the observable face of nature's clock?

Recently various historians have traced the way that Robert Boyle and other early leaders of the Royal Society moved away from the Cartesian ideal of achieving demonstrative certainty, replacing it with a more modest goal, often called moral certainty (Van Leeuwen 1963; Shapiro 1983). The result, modern probabilism, might seem sufficient to answer the question posed by Descartes. Laurens Laudan once suggested this possibility (Laudan 1966, 91), backing it with a quotation from Boyle. In a passage that looks much like an early precursor to the contemporary "miracle argument" for scientific realism, Boyle wrote,

> . . . the more numerous and the more various the Particulars are, whereof some are *explicable* by the assign'd Hypothesis, and some are *agreeable* to it, or at least are not dissonant from it, the more valuable is the Hypothesis, and the more likely to be true. For 'tis much more difficult, to finde an *Hypothesis* that is not true which will suit with *many* Phaenomena, especially if they be of various kinds, than but with a *few.* (Boyle [1675–76] 2000, 325)

Though developed in numerous ways, the core of the contemporary miracle argument for scientific realism accounts for the predictive success of advanced scientific theories about unobservables by advocating that the theoretical terms of such accounts genuinely refer. Moreover, at least to some extent, those accounts must accurately depict the characteristics and activities of the unobservables they posit. If there were no such connections, the predictive adequacy of good scientific theories would be utterly inexplicable, nothing short of miraculous, particularly in cases where a wide range of diverse phenomena are encompassed successfully.

Although the passage quoted from Boyle certainly suggests that he correlated explanatory scope, predictive success, or both with the likelihood of being correct in the straightforward way suggested by the miracle argument, the clock at Strasbourg vividly illustrates why he did not, in fact, draw any such direct connection. The internal mechanism of that spectacular clock was responsible for all sorts of phenomena, from the turning of the hands across its face to the plotting of assorted planetary positions, equinoxes, phases of the moon, and eclipses. The Strasbourg mechanism regularly struck the hours and quarter hours. It also animated various figurines, including a mechanical cockerel. Yet any human clockmaker capable of designing that clock could have achieved the same results by using a quite different internal mechanism. No doubt, then, a God of infinite clockmaking skill could produce the same or an even greater range of diverse natural phenomena with all sorts of alternative, equally elegant, efficient, beautiful, and simple internal mechanisms. As Boyle admitted,

> . . . if God be allowed to be, as indeed he is, the Author of the Universe, how will it appear that He, whose Knowledge infinitely transcends ours, and who may be suppos'd to operate according to the Dictates of his own immense Wisdom, should, in his Creating of things, have respect to the measure and ease of Humane Understandings, and not rather, if of any, of Angelical Intellects, so that whether it be to

> God, or to Chance, that we ascribe the Production of things, that way may often be fittest or likelyest for Nature to work by, which is not easiest for us to understand. (Boyle [1663] 1999, 257)

Not only God but even just a couple of centuries of human ingenuity could produce modes of operation beyond anything Boyle might imagine. Today all sorts of combinations of electronic devices, computer chips, electric motors, or gasoline engines can replace wheels and springs or ropes and pulleys. As Boyle realized, no matter how carefully a posit of wheels and springs might be refined, no matter how predictively accurate, simple, elegant, or explanatorily successful it might become, the hands on the face of nature might in fact be driven by something radically different, perhaps something as inconceivably different from gears and springs as a vibrating quartz crystal.

Over the last couple of decades, philosophers of science have devised more chastened forms of scientific realism. Structural realists have abandoned the hope of identifying the specific nature of unobservables, claiming only that the basic structural relationships among them are discernible. In good theories, those relationships are represented in mathematical formulations or, perhaps, reflected in accurate classification schemes, as natural kinds. Once properly identified, such mathematical formulas or classifications remain fixed as scientists replace their theories with better ones or substitute one interpretive model for another. Entity realists are even more modest in their claims. They disconnect scientific realism from all theoretical commitments, even structural ones. They argue that theories, models, interpretations, classification schemes, and even laws may change drastically over time. Consequently, scientists construe unobserved entities realistically, not on the basis of any conceptual consideration but only when such items can be manipulated in experimental contexts. For entity realists, a realistic stance is a practical matter: if you can do something with it, it must be real, no matter how you understand it.

Even these more attenuated realisms run afoul of the clock at Strasbourg, however. That clock could be driven equally well by wheels and springs, ropes and pulleys, or, today, by electric motors and quartz crystals. Structurally, such internal mechanisms are quite different. The classification schemes and mechanical laws that govern wheels and springs share nothing in common with those displayed by electric motors or quartz crystals. The more practical hands-on approach of entity realists reveals nothing of interest, either. An external crank might be used to tighten a spring, spool a rope, or oscillate a fresh battery into position. More to the point, the crank might be just for show, connected to nothing at all inside. According to Boyle, God originally created the material world, then directly produced the first motion to get nature's clockwork going. In principle, however, God could have chosen to dispense with natural mechanisms altogether, divinely producing not just the first natural motion but every subsequent one as well. A mixed bag also was a possibility. God could have permitted natural mechanisms to operate in some contexts but chosen to produce other items in the flow of natural events by direct divine action. If any of these were the divine choice, then even the most sophisticated experimental procedures would amount to nothing more than the convincing illusion of manipulation and control. To modern ears, such thought experiments were devastating, every bit as convincing as present-day antirealistic arguments built on detailed, cumbersome examples drawn from the actual history of recent science (Carrier 1991, 23–36; Elsamahi 1994, 173–80).

The Standard Modern Solution

The Cartesian solution to universal skepticism is famous, perhaps infamous. Out of the sea of doubt stirred up by the Demon Deceiver, a slender, precarious perch of certainty arose from the *cogito*. From there, Descartes discerned a beneficent God, a trustworthy divinity who would never sink to the wicked trickery of deception. So long as humans refrained from the sin of pride and did not overstep the natural bounds of their cognitive faculties, this God would not lead them astray. Within these parameters, people could know a surprising number of things with certainty, including "mathematical demonstrations, the knowledge that material things exist, and the evidence of all clear reasoning that is carried on about them" (Descartes [1644] 1969, 302). Such certainties were "founded on the metaphysical ground that as God is supremely good and cannot err, the faculty which He has given us of distinguishing truth from falsehood, cannot be fallacious so long as we use it aright, and distinctly perceive anything by it" ([1644] 1969, 301–2). Because Descartes believed that the fundamental principles governing the material world could be "derived in a continual series from the first and most simple principles of human knowledge" (p. 302), he was convinced that it was possible both to identify and to know with certainty fundamental laws of nature. Indeed, he believed that he himself had discovered some of those laws, although he conceded that other laws remained enticingly elusive (Descartes [1637] 1960, 95–97).

In the case of the unseen mechanisms of nature, Descartes believed not only that such mechanisms were genuine but that careful scientific investigation could result in their accurate description. Here, however, his thought experiments about alternative clockworks suggested a measure of epistemic humility. Divine trustworthiness still supported his realistic stance, but with a lesser degree of epistemic commitment, what he termed "moral certainty . . . a certainty that suffices for the conduct of life" ([1644] 1969, 301). After all, he reasoned, in the case of highly successful explanations covering wide ranges of phenomena, even if a theorist had "taken up these principles at random and without good grounds, . . . it could hardly happen that so much would be coherent if they were false" (p. 301).

Boyle did not share the Cartesian confidence about deducing fundamental laws of nature from first principles. Instead, he believed that such laws stemmed from divine choice, not necessity, since "the most free and powerful Author of those Laws of Nature, according to which all the *Phaenomena* of Qualities are regulated, may (as he thinks fit) introduce, establish or change them in any assign'd portion of Matter" (Boyle [1675] 2000, 312). Nevertheless, he and later members of the Royal Society did use Descartes' distinctively theological strategy to anchor their more modest, probabilistic realism. While the skeleton of their theological defense was simple, the details were fleshed out with the help of the clockwork paradigm. With Boyle's concession that God could move the hands of a clock directly, he had to admit that there might be no natural mechanisms at all behind the face of nature's clock. If there were any hidden natural mechanisms to be found, even the most empirically adequate, predictively accurate, epistemically impeccable scientific accounts might be wildly off the mark. After all, anything from wheels and springs to weights and pulleys, regulated by all sorts of different possible laws, could produce precisely the same movements on the hands of a clock. Indeed, clockmakers with a taste for causal redundancy could easily cram several mechanisms into the same case. If gripped by a similar fit of extravagance, God might have supplied more than one hidden mechanism to govern the patterns of nature.

This flow of skeptical reasoning drove the problem of scientific realism along two distinct lines, one referential and the other descriptive. The referential problems were two. First, why should anyone believe there were any unseen natural mechanisms at all to which scientific theories might refer? Second, if there were such mechanisms, why should theorists be content to refer to only one rather than to several diverse causally redundant mechanisms? When it came to matters of description, how could there be even the least degree of probability that the best, indeed epistemically impeccable, scientific accounts described those natural mechanisms at all accurately?

Although reflections about clocks and clockworks blocked any purely epistemic justification of modern scientific realism, they pointed quite directly toward an appropriate theological solution. Like so many other modern writers, Boyle viewed the natural order as a clockwork of the finest imaginable quality. Accordingly, he wrote,

> As in the . . . Clock of *Strasburg*, the several Pieces making up that curious Engine, are so fram'd and adapted, and are put into such a motion, that though the numerous Wheels, and other parts of it, move several ways, and that without any thing either of Knowledge or Design; yet each performs its part in order to the various Ends for which it was contriv'd, as regularly and uniformly as if it knew and were concern'd to do its Duty. (Boyle [1663] 1999, 248)

If nature were a clockwork, then there could be no doubt that the Creator was the finest of clockmakers.

No one captured the implications of the clockwork ideal more vividly than Gottfried Leibniz when he claimed that God cherished the same distinctively human values as properly trained clockmakers. Consequently,

> . . . it is possible to make some general remarks touching the course of providence in the government of things. One is able to say, therefore, that he who acts perfectly is like an excellent Geometer who knows how to find the best construction for a problem; like a good architect who utilizes his location and the funds destined for the building in the most advantageous manner, leaving nothing which shocks or which does not display that beauty of which it is capable; like a good householder who employs his property in such a way that there shall be nothing uncultivated or sterile; like a clever machinist who makes his production in the least difficult way possible; and like an intelligent author who encloses the most of reality in the least possible compass. (Leibniz [1686] 1951, 295–96)

According to Leibniz, in preparation for creating the universe, God surveyed all of the logical possibilities, then produced the best of all possible worlds, a world that would gladden the heart of any mechanical engineer. Surpassing even the clock at Strasbourg, God's creation met the highest possible standards of construction. Consequently it operated in the most efficient, economical, fruitful, and beautiful way imaginable. In fact, even beyond that exemplary Strasbourg clock, the clockwork machinery of nature was so finely crafted and smoothly lubricated that Leibniz believed "*it is not even possible to conceive of events which are not regular*" (Leibniz [1686] 1951, 296).

Boyle did not press the clockwork image to the Leibnizian extreme. He was convinced neither that God was constrained to create the best of all possible worlds nor that natural irregularities were utterly inconceivable. In fact, he used the clockwork analogy to counsel epistemic humility on both points (Boyle [1685] 2000, 251–52; [1686] 2000, 493–96). Moreover, he believed that "by Miraculous Operations [God] hath some times Suspended the Laws of Nature, and sometimes Over rul'd them, upon account of Man" (Boyle [1688] 2000, 109). Nevertheless, when it came to the ordinary course of natural events, Boyle did share the Leibnizian taste for engineering excellence. As he confessed, "it seems very suitable to the Divine Wisdom, that is so excellently display'd in the Fabrick and Conduct of the Universe, to imploy in the World, already fram'd and compleated, the fewest and most simple Means, by which the *Phaenomena*, design'd to be exhibited in the World, could be produc'd" (Boyle [1686] 2000, 556). Since the best human clocks need the least adjustment or repair, Boyle saw no reason for natural philosophers to appeal to divine interventions in their accounts of the ordinary course of natural events. Accordingly, he said, "I ascribe to the wisdom of *God* in the first Fabrick of the universe; which He so admirably contrived, that, if He but continue his ordinary and general concourse, there will be no necessity of extraordinary interpositions, which may reduce him, to seem as it were to Play *After-games*" ([1686] 2000, 448). Because God was the supreme craftsman, divine dabbling in the everyday workings of nature was not necessary. As in the finest clocks, the machinery of nature ticked along without the need for constant tinkering.

Like other modern clockwork corpuscularians, Boyle explicitly transformed the traditional, medieval role of God as final cause into a form of first causality. He believed that the Creator originally produced matter and dictated the laws of nature. Then, instead of serving as a cosmic, divine lure, God became a crafty, manipulative engineer, providing matter with its initial push but in such a way as to achieve specific anticipated results. This did not mean, however, that divine manifestations were precluded from the natural order of things. On the contrary, as with the handiwork of the best clockmakers, God's precise workmanship was evident everywhere in creation. Divine unity was demonstrated in the tight interworkings of nature's parts. While God's power was manifest in the sheer immensity of the world, divine intelligence was displayed in the intricacy as well as the complexity of natural design (Boyle [1663] 1999, 220–33). Indeed, almost paradoxically, Boyle believed that God's apparent absence from the natural causal nexus was in fact one of the most powerful imprints of God's hand on the natural order of things. As he explained,

> . . . *as* it *more* recommends the skill of an Engineer, to contrive an Elaborate Engine, so as that there should need nothing to reach his ends in it, but the contrivance of parts . . . So it *more* sets off the Wisdom of God in the Fabrick of the Universe, that he can make so vast a Machine perform all those many things which he design'd it should, by the meer contrivance of Brute matter, managed by certain Laws of Local Motion, and upheld by his ordinary and general concourse; *than* if he imployed from time to time an Intelligent Overseer . . . to regulate, assist and controul the Motions of the Parts. (Boyle [1686] 2000, 447)

For Boyle there could be no more eloquent display of the lasting genius of the divine clockmaker than the proper functioning of his natural clock, day after day, with no need for ongoing maintenance.

Newton openly doubted the possibility of explaining the full range of natural phenomena naturalistically. In particular, he suspected that reference to direct divine action might be needed to account for all sorts of things, including the symmetry of animal bodies, the role of instinct in animal life, and the orbital planes of the planets (Newton [1729] 1934, 544; [1730] 1952, 369–70, 400, 402–6). Pressing the ideal of an absent clockmaker, Leibniz rejected any such places for God in the natural scheme of things. Mockingly, he wrote,

> Sir *Isaac Newton*, and his Followers, have also a very odd Opinion concerning the Work of God. According to their Doctrine, God Almighty wants to *wind up* his Watch from Time to Time: Otherwise it would cease to move. He had not, it

seems, sufficient Foresight to make it a perpetual Motion. Nay, the Machine of God's making, is so imperfect, according to these Gentlemen; that he is obliged to *clean* it now and then by an extraordinary Concourse, and even to *mend* it, as a Clockmaker mends his Work. . . . (Leibniz [1738] 1978, 587)

For those who embraced it, the image of engineering excellence, epitomized in the ideal of an absentee clockmaker, provided a straightforward line of reasoning for solving the referential problems of modern realists. A perfect clockmaking God would not move the hands of nature's clock directly, manually dragging them around the face, as it were. Instead, the cosmic clockmaker would provide a natural, hidden mechanism so excellent in design that it would run the observable world perfectly on its own. Causal redundancy, a sure sign of inferior craftsmanship, was equally inconceivable. Elegance, efficiency, beauty, and simplicity were the true marks of quality engineering. Because God's splendid designs could never fail, there would be no need for backup machinery.

Unfortunately, while this line of argumentation might ensure the presence of one and only one elegant, efficient, beautiful, and exquisitely simple mechanism for each natural task, appeals to God's perfect clockmaking skills did not solve any descriptive problems. Human clockmakers, though drastically inferior to the divine Clockmaker, are fully capable of producing quality clocks of diverse internal design. The finest concoctions of weights and pulleys may be every bit as elegant, efficient, beautiful and simple as the best systems of gears and springs. Given God's infinite capacities and, one might add, God's knowledge of so many natural principles unknown to early modern science, Boyle had no reason to believe that even his most empirically adequate and predictively accurate descriptions of hidden mechanisms were at all probably correct, even to the least degree.

Here it was necessary to take solace in another of God's attributes, divine goodness. Although Boyle himself did not delve into the theological details in his published writings, the standard line of argumentation shows up in bits and pieces in the writings of a surprising diversity of modern thinkers. It is perhaps most explicitly developed in John Toland's *Christianity Not Mysterious*. Like Descartes, Toland maintained that because God was no deceiver, humans must be held responsible for their errors. Also like Descartes, Toland believed that human culpability for error resides in pride, the urge to overestimate human cognitive powers and consequently to go beyond what the evidence warrants. On the other hand, God gave humans their reasoning powers, and, for Toland, truth was correspondence. So, because God is no deceiver and the human mind is designed to attain truth, the conformity of ideas to things as they really are, Toland believed that the rule of evidence could be trusted to guide investigators toward a right understanding of the actual workings of those hidden mechanisms. Consequently, the ultimate lesson to be learned from the possibility of diverse internal clockwork mechanisms was not one of intellectual despair but only epistemic modesty. As long as theorists eschewed prideful claims to certainty, they could progress confidently to the probable knowledge that their best theories accurately described, at least to some degree of approximation, the actual workings of those items lurking in the darkest caverns of nature (Toland [1696] 1984, 12–21, 33, 43, 79–80, 132–42).

From this theologically fortified epistemological point of view, it is possible to reconcile the apparently conflicting claims of modern scientific realists like Boyle. Given God's exceptional clockmaking skills, natural mechanisms must be supremely elegant, efficient, beautiful, and simple. Still, given God's extraordinary creative capacities, there is no telling what hidden mechanisms the divine clockmaker may have chosen. This line of thought counsels epistemic humility, especially in cases where there is no perceptual access to the inner recesses of nature's clockworks. On the other hand, because God created the human mind to understand the truth about things and truth is the mental representation of things as they really are, neither instrumentalism nor extreme skepticism is warranted. Since God is no deceiver, humans can expect to achieve a right understanding of how things truly are so long as they do not pridefully overstep the limits of human reason, limits that are delineated by the nature of the evidence available. Only a deliberately deceptive God would mislead humans into believing what is false, particularly if sincere investigators had devised a theory for which all the evidence they were humanly able to gather pointed in the direction of its truth. So, even though Boyle could admit that God was fully capable of designing a natural mechanism in a way that was the "fittest or likelyest for Nature to work by, which is not easiest for us to understand" (Boyle [1663] 2000, 257), he could also affirm, without the slightest hint of contradiction or conflict, that

> . . . the more numerous and the more various the Particulars are, whereof some are *explicable* by the assign'd Hypothesis, and some are *agreeable* to it, or at least are not dissonant from it, the more valuable is the Hypothesis, and the more likely to be true. For 'tis much more difficult, to finde an *Hypothesis* that is not true which will suit with *many* Phaenomena, especially if they be of various kinds, than but with a *few.* (Boyle [1675–76] 1999, 325)

Despite having the power to create in a way that would systematically mislead even the best human reason, God, being beneficent, had not chosen to do so.

Modern Dissent

Though widely embraced, the standard modern defense of scientific realism was not universally endorsed. At least two prominent thinkers, Samuel Clarke, who defended the views of Newton against Leibniz (Koyré and Cohen 1962, 64–66, 79), and John Locke, who was deeply influenced by his friend Boyle, rejected it, but for quite different reasons. In his correspondence with Leibniz, Clarke did not question the modern confidence in human reason. Nor did he quibble over the realistic potential of arguments by analogy. Instead, he fixed upon the theological suitability of clockwork analogies. For Descartes, Boyle, Leibniz, and Toland, all of whom prized the skills of a clockmaker, the absence of divine tinkering in the world of everyday affairs was the clear mark of brilliant design. For Clarke, this looked like Deism in danger of slipping into atheism (Clarke [1738] 1978a, 600–601). If the clockwork analogy were replaced by the more biblically accurate model of God as king, a preference Clarke shared with Newton (Koyré and Cohen 1962, 72–73, 114; Newton [1729] 1934, 544–46), then what seemed to be a virtue from the mechanistic perspective would be transformed, quite suddenly, into a vice. On the kingship model, God's absence from the everyday world amounted to dereliction of duty. Moreover, on a mechanistic, clockwork understanding of the natural world, not only would God as active Governor disappear, the immortal human soul, which was created in the image of God, would evaporate as well (Clarke [1738] 1978b, 599; [1738] 1978c, 697).

Attracted neither to corpuscularian ideals nor to the professional standards of clockmakers, Clarke aggressively challenged the scientific prejudices of his day. Following Newton, he believed that many important natural phenomena, such as gravitational attraction, magnetism, and the reflective behavior of light, could never be understood mechanistically. He took no delight in repeatable, regular patterns. Clarke believed that the God of the Bible, rather than providing a static, mechanistic plan whereby history monotonously ticked along in a rigidly predictable way, had framed a dynamic world of constant change. Like an energetic king, the true God was always building, revising, tearing down, and renovating the natural world. The very idea that the natural world was self-contained, self-sufficient, or self-regulating was a silly delusion (Clarke [1738] 1978b, 599; [1738] 1978c, 697). To the contrary, "if *God* or *Man*, or *any living* or *active Power*, ever *influences* any thing in the *material World*; and every thing be not *mere absolute Mechanism*; there must be a continual *Increase* and *Decrease* of the *whole Quantity of Motion in the Universe*" (Clarke [1738] 1978c, 697).

Locke took a different tack. He focused not on the biblical or scientific shortcomings of the clockwork model but on the modern theological defense of scientific realism originally introduced by Descartes, the kind of appeal to divine goodness that was elaborated so explicitly in the writings of John Toland. Locke believed that God had designed human minds not as instruments for probing the theoretical mysteries of the universe but merely as tools appropriate to the practical, everyday needs of finite, earthly life. Consequently, human understanding could never pierce to the true nature of things, not even with the aid of divine beneficence. Where Descartes had invoked the goodness of God as a ground for eliminating the problem of skepticism, Locke appealed to the goodness of God as a basis for endorsing skepticism. God had imposed severe limitations on human cognitive capacities, even perceptual ones, not out of stinginess or any malicious desire to deceive but out of compassion. Human hearing was a case in point. No doubt God could have made human ears more acute, but such acuity would have come at a steep price. Distracted by the slightest noises, people never would have been able to sleep properly. Fortunately, God had recognized the need for human well-being and at Creation had sacrificed a measure of human hearing for the sake of a good night's sleep (Locke [1700] 1959a, 402–3).

Not that this was, in fact, much of a sacrifice. Locke warned against correlating acuity with representational accuracy. As human senses become more acute, the information they gather does not converge toward any particular ideal limit. When sensory abilities are strengthened, appearances change in unanticipated and quite unpredictable ways. To the unaided eye, blood looks uniformly red. When visual acuity is enhanced with the help of powerful microscopes, blood does not appear redder. Surprisingly, it appears to be an almost completely clear liquid laced with occasional red globs. Were human sight strengthened even further, there is no telling what blood might look like.

Locke did believe, of course, that primary qualities were essential to substances and that blood and other substances could be known to possess various primary qualities. He also believed that the sensory impressions of primary qualities resemble the qualities themselves. This did not imply, however, that such resemblances were sufficient to ensure representational accuracy. To the contrary, even optimal perceptions of primary qualities could not be trusted to represent those qualities as they truly were in themselves. Consider the motion of solid parts, which Locke considered to be one of the primary qualities of bodies. For Locke, human perception of motion is not one of continuous, flowing change. Instead, the perception of true motion is simulated by a quick succession of individually static ideas, similar to the way that a quick succession of static images flashed on a movie screen depicts the fluid motion of a trotting horse. So according to Locke, the resemblance enjoyed by sensory ideas of motion does not accurately portray motion as it truly is. Perceived motion is nothing more than a cheap imitation, a simulation produced not by approximation but by a trick of illusion. This must not be construed as a shortcoming, a failure of human perceptual powers, but only as an indication that God did not design humans to be mirrors of nature. The point of human perception, even the most veridical of human perceptions, was never to produce high quality facsimiles of anything (Locke [1700] 1959a, 173–81, 242–44, 401–3).

Locke found the representational resources of human theories to be as paltry as those of human perception. Unlike Clarke, he was happy to sanction exclusively mechanistic construals of the material world (Locke [1700]

1959a, 402–7). This endorsement did not imply any commitment to representational realism, however, not even so much as the attenuated commitments of contemporary structural realism. As Locke explained,

> The workmanship of the all-wise and powerful God in the great fabric of the universe, and every part thereof, further exceeds the capacity and comprehension of the most inquisitive and intelligent man, than the best contrivance of the most ingenious man doth the conceptions of the most ignorant of rational creatures. Therefore we in vain pretend to range things into sorts, and dispose them into certain classes under names, by their real essences, that are so far from our discovery or comprehension. (Locke [1700] 1959b, 65)

Here Locke described his skeptical stance in terms reminiscent of Boyle. Unlike Clarke, however, who often represented the views of Newton, sometimes even to the extent of using Newton's own words (Koyré and Cohen 1962, 121), Locke pressed the skeptical implications of his position beyond the stance taken by Boyle, at least in his published writings.

Like Locke, Boyle regularly emphasized the vast gulf between the human capacity for understanding and the mysterious ways of God. Nevertheless, as a committed corpuscularian, he recommended the mechanical philosophy, not just for utilitarian reasons but because he believed that mechanical action, one local motion effecting another, was the only truly intelligible form of natural causality. Of course, as a sincere Christian, Boyle was convinced of the reality of God and other active spiritual agents. He also readily conceded the possibility of natural but nonmechanical causation. Still, no matter how real any of these other forms of causality might be, Boyle argued that "their way of working being unknown to us, they can but help to constitute and effect things, but will very little help us to conceive *how* things are effected; so that, by whatever Principles Natural things be *constituted*, 'tis by the Mechanical Principles that their *Phaenomena* must be clearly *explicated*" (Boyle [1674] 2000, 113). Indeed, Boyle seemed so convinced of the paradigmatic intelligibility of mechanical action that he wrote, even "if an Angel himself should work a real change in the nature of a Body, 'tis scarce conceivable to us Men, how he could do it without the assistance of Local Motion; since, if nothing were displac'd, or otherwise mov'd than before, . . . 'tis hardly conceivable, how it should be in it self other, than just what it was before" ([1674] 2000, 110).

Superficially, Locke agreed that corpuscularian accounts seemed more intelligible than appeals to nonmechanical agents (Locke [1700] 1959b, 203–7). Nevertheless, he also insisted that the heart of corpuscularianism, the impact model, gave only the impression of true understanding. One thing pushing another is certainly commonplace in everyday life. Still, familiarity must not be confused with intelligibility. How one material substance actually pushes another remains utterly beyond human comprehension. "For, in the communication of motion by impulse, wherein as much motion is lost to one body as is got to the other, which is the ordinariest case, we can have no other conception, but of the passing of motion out of one body into another; which, I think, is as obscure and inconceivable as how our minds move or stop our bodies by thought" (Locke [1700] 1959a, 413).

For Locke, there simply was no paradigmatically intelligible instance of one thing influencing another ([1700] 1959a, 413–14). Accordingly, he emphasized rather than minimized the antirealistic import of the clock at Strasbourg.

> Our faculties carry us no further towards the knowledge and distinction of substances, than a collection of *those sensible ideas which we observe in them*; which, however made with the greatest diligence and exactness we are capable of, yet is more remote from the true internal constitution from which those qualities flow, than, as I said, a countryman's idea is from the inward contrivance of that famous clock at Strasburg, whereof he only sees the outward figure and motions. . . . When we come to examine the stones we tread on, or the iron we daily handle, we presently find we know not their make; and can give no reason of the different qualities we find in them. It is evident the internal constitution, whereon their properties depend, is unknown to us. . . . (Locke [1700] 1959b, 64)

Along with the intellectual mainstream of his day, Locke agreed both that God was no deceiver and that the material world was best construed as a vast machine. Ultimately, however, his skepticism was more radical than Clarke's or Newton's and quite possibly even deeper than Boyle's. In his reflections on the clock at Strasbourg, Boyle rooted his skepticism in the hiddenness of nature's mechanisms. While he shared Locke's doubts about the true essences of things, he persisted both in his convictions regarding the intelligibility of mechanical explanations and in his realistic aspirations to provide at least probably true descriptions of the secret operations of nature (Boyle [1674] 2000, 104–16). In his discussions of the usefulness of natural philosophy, he invariably acknowledged that God had created the human mind for something more elevated than simply finding ways of exploiting the natural world. God had equipped humans with a capacity, even a passion, to comprehend nature. Consequently, despite considerable obstacles, posed not merely by the hiddenness of nature's mechanisms but also by the Fall of Adam, Boyle remained optimistic about the potential for human understanding. Humans should aspire not only to find ways of using nature but to honor God by using their minds to achieve a true understanding of the way nature actually operates (Boyle [1674] 2000, 70; [1675–76] 2000, 325; [1663] 1999, 218, 235–37). Indeed, these two intellectual enterprises were more than compatible; they were linked. As Boyle explained, of all the "Number of Plants, Animals, Metals, Minerals, &c . . . there is not any one, of which Man might not make an excellent use, had he but an insight into its Nature" (Boyle [1663] 1999, 229).

By contrast, Locke's skepticism was driven not by concerns about hiddenness but by his conception of the function of the human mind. God had not designed human minds to grasp the true nature of reality. Consequently, even the best corpuscularian analogies could never be used to fashion accurate descriptions of the hidden workings of the natural world. This was not because the mechanisms of nature remained hidden. In many cases, the inner workings of the paradigms themselves, including the famous clock at Strasbourg, were open to direct inspection. Even so, their internal mechanisms remained utterly mystifying. If anything, they were paradigms of incomprehensibility. According to Locke, God had provided humans with sufficient intellectual resources to build, maintain, and use such clockworks but had not equipped anyone, not even the finest clockmakers, with the ability to understand how those mechanisms worked as they did.

Realism and Intelligibility

In recent years, Nancey Murphy has complained about the lack of convergence among contemporary participants in various realist debates. Linking modern realism with referential theories of language, correspondence theories of truth, and representational, or "picture," theories of meaning, she dismisses contemporary critical realists as "chastened moderns" (Murphy 1997, 41) and recommends breaking from the modern thinking patterns of the past by switching to a postmodern agenda. She explains,

> . . . from a postmodern point of view neither the assertion nor the denial of modern scientific realism makes sense. No single theory of scientific language should be expected to fit everything from continental plates to quarks and ids. . . . the best solution to the realist debate in philosophy of science is simply to drop the issue and to attend instead to very pressing questions regarding the justification of scientific claims. (Murphy 1997, 48)

John Toland provides a textbook example of the correlations suggested by Murphy. No doubt they can be found in other modern writers as well. Nevertheless, it would be a mistake to read too much into them. For modern scientists like Boyle, scientific realism was not a general conclusion regarding the referents of successful scientific theories. It was a localized analysis of the metaphysical implications of one highly specific but widely popular strategy of formulating scientific hypotheses. This strategy began by positing the existence of responsible entities. Subsequently, it shaped an understanding of those entities by using initially crude analogies further refined in a variety of ways, most importantly, by using predictive tests. So, during the modern period, as now, it was perfectly reasonable to adopt a realistic stance regarding the output of this particular reasoning strategy yet remain antirealistic or uncommitted about the output of other styles of scientific reasoning. For example, modern scientists could easily share Newton's realism regarding the nature of comets but take an instrumental stance regarding celestial orbits or the laws of motion. Indeed, as was noted above, even with respect to the implications of this one particular style of analogical reasoning it was quite possible to split along two separate lines, one referential and the other descriptive. Theorists might straightforwardly agree, say, that comets were real, but repudiate the accuracy of even the best descriptions of their true nature. Locke fell into this category, agreeing that there were substances but denying any understanding of their real essences.

Moreover, as the modern discussion of the clock at Strasbourg reveals, scientists like Boyle were driven toward their realistic stance more by theological concerns than epistemological ones. None of the main figures on either side of the debate discerned any significant connection between scientific realism and their commitments regarding linguistic reference, meaning, or truth. To the contrary, they explicitly recognized the disconnection between their epistemological positions on such topics and any particular realist or antirealist conclusions. That is why they felt compelled to bring theological considerations into play. Those who correlated God's goodness with honesty or fancied that God cherished the values of human clockmakers tended to come down on one side of the fence, while those who disputed such theological positions tended to come down on the other.

The analogical reasoning pattern picked up by modern scientists was nothing more than a powerfully refined version of a commonplace strategy. Living in a forest cabin, I occasionally notice scattered droppings, ragged holes in cereal boxes, and bits of cheese on the floor. I suspect a mouse has gotten in—a real mouse. So I set a trap, catch myself a mouse, and, sure enough, the suspicious patterns disappear. I blame the trapped mouse for the damage done. My "realistic" stance, both with respect to my original hypothesis regarding the source of the damage and my subsequent explanation of that damage, is demanded not by my theories of reference, meaning, or truth but by the structure of my explanatory intentions. I am looking for a culprit, something that could have produced the suspicious patterns.

This particular style of reasoning, whether used in everyday life or sophisticated scientific contexts, reduces to unintelligibility without the realistic suppositions. To do the explanatory job, the something I am seeking not only must be real but also must have the right sort of characteristics, those needed to produce the relevant damage. If I were to take an antirealistic stance regarding the mouse or perhaps dismiss the whole realism-antirealism issue as irrelevant to my concerns, my proposed explanation, not to mention my subsequent trapping behavior, would degenerate into incomprehensibility. What could it possibly mean to explain the droppings or the tooth marks on the cheese as produced by a mouse yet deny the existence of the mouse or perhaps shrug off the whole question of existence as a nonissue? What could motivate me to set the trap? Without a mouse—a real mouse with a real digestive tract and teeth—I have no explanation, not to mention any impetus to look for anything.

With everyday, observable items like mice, justifying the legitimacy of this particular explanatory strategy is straightforward. Induction seems quite sufficient. People who live in the woods have been suspecting and successfully trapping mice for centuries. In scientific contexts, however, where the posited culprits are not observable, the induction has been more problematic. Over the past few centuries, various items, from undetected planets to microbes, have been posited to explain assorted patterns of phenomena. With the invention of powerful microscopes or telescopes, such items have actually been observed. So, at least in cases where unobservables subsequently have become observable, particularly with the aid of technological advances, some inductive evidence to support the practice has been forthcoming. But when it comes to posited entities that not only are currently unobservable but remain forever unobservable, there neither is nor ever will be any such basis for constructing an inductive defense of the practice (Harré 1996).

This latter case, of course, was the one that so exercised modern writers and for which the thought experiments stimulated by the clock at Strasbourg proved so devastating. Whether inductive or otherwise, neither modern nor contemporary scientists could generate any sufficient, purely epistemic reason to justify their belief that such unobservables exist. Nevertheless, in order to be even minimally intelligible, this particular explanatory practice demands their existence. Indeed, if such entities are to explain anything at all successfully, they not only must exist but must exist as so described. This was the pressure that compelled Boyle and others to close the justificatory gap theologically.

Not all of the reasoning patterns used by scientists demand such a trenchantly realistic stance. Many mathematically formulated laws apply strictly only to items like perfectly reversible heat engines or point masses. Scientists refer to such items constantly in their specification of various sorts of ideal systems, then explain the actual behavior of real things in terms of how closely they conform or fail to conform to the envisaged ideal systems. For this particular explanatory strategy to work, it does not seem necessary to take any position at all on the realism-antirealism issue. Most scientists do not believe that perfectly reversible heat engines or point masses really exist. Indeed, there seem to be strong scientific reasons to reject the existence of such items. Nevertheless, if perfectly reversible heat engines or point masses did exist, the intelligibility of such scientific explanations would remain entirely unaffected (Ellis 1990, 57–61). So, with respect to this specific kind of scientific reasoning, perhaps Murphy's lack of interest in the realism issue would be appropriate. Unlike the analogical strategy of concern to Boyle, the intelligibility of explanations by reference to the behavior of idealized systems does not seem to depend on whether any such items really exist.

One reason, though not the only one, for the lack of convergence in the contemporary realism-antirealism debate is that many writers join Murphy in her conviction that the issue is a global one associated with a certain family of general philosophical positions. In most scientific contexts, however, the concern is typically localized, demanding different answers relative to different explanatory strategies. As such, it can be disjoined from broader philosophical positions, which is why all sorts of interesting, if unusual, blends can be found among contemporary philosophers. For example, there are now proponents of realism who reject correspondence theories of truth, embrace referential indeterminacy, and acknowledge the underdetermination of theories by evidence (Ellis 1990; McGowan 1999; Grimes 1998). In this respect, the contemporary scene is similar to the modern one, which manifested an equally interesting diversity of blends.

If, as Murphy contends, human belief systems are more like spider webs than buildings with firm foundations, then this is exactly what we should expect to find—all sorts of blends and associations, even in the fabrics of belief systems endorsed by foundationalists. After all, their systems, like any other system of human beliefs, must be webs, too. The inner weavings and connections among their beliefs, even their most cherished philosophical ones, should therefore assume all sorts of variegated forms in the overall patterns of their thinking. No doubt many modern or contemporary webs of belief share common strands of thought, similar internal patterns, or perhaps the same overall global shapes. Still, if human belief systems are webs, then specific doctrines about reference, meaning, language, or indeed anything at all, must not function as relatively basic or foundational assumptions supporting other, less basic, realist or antirealist commitments. In genuinely weblike systems of belief, there are no higher levels to collapse when underlying foundational assumptions are withdrawn. Indeed, there are no underlying foundations at all. Instead, all people, including avowed foundationalists, may hold fast to any belief or, for that matter, combination of beliefs by making sufficiently radical adjustments elsewhere in their fabrics of belief (Quine 1961, 43). If the modern discussion of the significance of the clock at Strasbourg is any indication, this is in fact just what people do.

Of course, the web metaphor permits the possibility for some beliefs to be held more dearly than others. Nevertheless, it is not always clear which beliefs are most precious or influential, or even whether the same set of privileged beliefs remains constant over time. Leibniz and Clarke, along with many other moderns, shared many of the same epistemological convictions yet spun out quite different webs. Clearly, then, their differences did not stem from specific philosophical theses regarding language, reference, or meaning. Instead, they parted company theologically. Citing the need for biblical accuracy, Clarke replaced the scientifically fashionable clockwork model with a kingship image. Superficially this would seem to indicate that he cherished scriptural teachings more deeply than Leibniz did. A closer look, however, reveals that this was not really the heart of the matter. After all, not every king meddles in the daily affairs of the kingdom. Sometimes sovereigns devise systems of laws to govern their kingdoms or delegate tasks to subordinates or local functionaries. So it would not have taken much effort to integrate the kingship image into the overall thinking of Leibniz. Something more important to Clarke than his or Newton's biblical passion for kings must have been at stake.

Perhaps Clarke's reaction to Leibniz's mockery of Newton hits closer to home. Whereas Leibniz prized a God who was causally remote from everyday concerns, Clarke saw this as tantamount to no God at all. Whereas Clarke delighted in a God who was constantly engaged in the everyday world of natural events, Leibniz saw only a meddling, bungling, incompetent Craftsman. Here, surely, was a crucial divergence in rudimentary religious affections, a preferential split that seems perennial, neither distinctively modern, particularly Christian, nor, for that matter, even especially Western. Homer relished gods that readily mixed with humans. His world brimmed with the possibility of divine encounters. Whatever may have been the faults or foibles of the grey-eyed goddess Athena, the prospect of actually crashing into her one day certainly added spice to common life. Even so, some temperaments did not embrace such exciting possibilities. Xenophanes condemned the Homeric vision as scandalous, claiming that it was not fitting for the true god to "come and go, first to one place then to another" (Robinson 1968, 53). Writing from a very different cultural perspective, Lao-Tzu marked the same division, expressing his own preference for Xenophanes' side of the fence.

> The best [rulers] are those whose existence is [merely] known by the people.
> The next best are those who are loved and praised. . . .
> [The great rulers] . . . accomplish their task; they complete their work.
> Nevertheless their people say that they simply follow Nature. (Lao-Tzu 1963, 130)

While this particular split in religious values may not be the whole story, it certainly seems closer to the core than anything distinctively epistemological. After all, Clarke's epistemological commitments, his specific views about language, reference, and meaning, were almost identical to those of Leibniz and Toland. Yet the latter two shared a common contempt for the kind of Newtonian theology endorsed by Clarke. By contrast, the ancient epistemologies of Xenophanes or Lao-Tzu bore little resemblance to the modern ideas of Leibniz or Toland. Yet these four shared a common religious thread, a singular preference for gods that stood causally remote from everyday affairs.

Many others, of course, both before and after the modern age, have felt the tug of both directions. Boyle may be a case in point. Despite sharing the ideal of an absent cosmic clockmaker with Leibniz and Toland, he compromised that ideal by leaving room for occasional direct, divine actions. According to Boyle, in order to instruct or benefit human beings God sometimes intervened quite deliberately in the natural world (Boyle [1663] 1999, 215). On such occasions, God would perform miracles that suspended or even conflicted with the regular functioning of natural laws. By contrast, Toland's conception of miracles fit the absent-clockmaker ideal more snugly. For Toland, God performed miracles not by disturbing ordinary natural processes or violating natural laws but simply by exceeding the powers of nature in such a way as to leave the ticking of nature's clock undisturbed (Toland [1696] 1984, 150–57; Burns 1981; Dear 1990).

Perhaps, then, if the complexity and dynamics of the modern dispute is any indication, it might be better to construe the contemporary rift between conservative and liberal Protestants as nothing more exotic than the latest reflection of this ancient divide among religious affections. No doubt, this diagnosis is less ingenious than Murphy's analysis. Still, it enjoys the merit of taking the Protestant division at face value as a distinctively religious rather than a peculiarly philosophical one.

Seriously Is Literally

According to Ian Barbour, "Models . . . are to be taken seriously but not literally; they are neither literal pictures nor useful fictions but limited and inadequate ways of imagining what is not observable. They make tentative ontological claims that there are entities in the world something like those postulated in the models" (Barbour 1990, 43). In scientific contexts, models play a variety of roles, some realistic, some not. Idealizations, like perfectly reversible heat engines or point masses, often are used to simplify calculations. Sometimes idealized models function as standards against which real systems may be compared in order to understand better the array of factors that prohibit real systems from realizing such ideals. When used in these ways, idealized models are taken very seriously, not as literal pictures of reality but as useful fictions. Normally they are not conceived as being limited or inadequate ways of imagining unobservables. In many cases, such idealized items are easily imagined and, if they existed, would be readily observable.

When used as ideal standards or to simplify calculations, ontological claims about such models rarely come into play. Sometimes there are scientific reasons to deny the existence of things like perfectly reversible heat engines or point masses. At other times, questions about their realizability may be less determinate. Although real items might be like idealized models, they need not be. Some real heat engines might be almost perfectly reversible. On the other hand, planets are not anywhere near being the point masses that are used to simplify the calculation of celestial orbits.

Of course, idealized models probably were not on Barbour's mind when he wrote the passage just quoted. Closer to his target are the scientific uses of models discussed by Boyle and others in their concerns about clocks and the hidden mechanisms of nature. Even here, however, it is difficult to embrace all that Barbour has to say about models. His analysis correctly recognizes that when Galileo, Newton, Boyle, and many other scientists, both modern and contemporary, used models to fashion their understanding of the mechanisms responsible for natural patterns of phenomena, their realistic stance was absolutely essential. As the mouse-in-the-house example illustrates, construing the relevant entities as nothing more than useful fictions reduces this particular explanatory procedure to nonsense. Because convenient fictions, no matter how useful, do not produce real crumbs or droppings, reference to fictional entities cannot explain the occurrence of such patterns of phenomena. Similarly, scientists presume that something real must be responsible for producing the vapor trails in Wilson cloud chambers. Undoubtedly, then, scientists who employ this style of reasoning are at the very least making "tentative ontological claims that there are entities in the world something like those postulated in the models" (Barbour 1990, 43).

Nevertheless, despite using this explanatory strategy to understand items that have not been and perhaps never will be observable, scientists do not limit their use of this procedure to such items. In fact, this particular explanatory strategy has been so popular, among both moderns and contemporaries, as to be almost ubiquitous. Galileo exploited it to understand sunspots ([1613] 1957, 90–97). Newton used it to describe the nature of comets ([1729] 1934, 522–32). It also has been used to understand everything from mountains on the moon to microbes, items that once were unobservable but later became observable, thanks to technological advances (Galileo [1610] 1957, 31–39; Harré 1996).

More important, the serious use of this style of reasoning demands that models be taken literally. Even in the earliest stages of development, if this kind of explanation is to be fully effective, the referentially realistic stance must always be coupled with a core of literal ascriptions, no matter how provisional, tentative, or partial they may be. Consider again the mouse in the house. If I hope to explain successfully the scatterings of cheese, ragged boxes, and droppings, I must posit a real culprit. Here, of course, is my referentially realistic stance. My actual culprit, however, cannot be just anything. It must be the sort of thing that could actually produce the phenomena in question. Moreover, if my account is to be genuinely explanatory, I must understand how my culprit produces such phenomena. If I do not understand how my analogical source produces its range of phenomena, I cannot describe how it generates its pattern of phenomena, either. Because the intelligibility of my new explanation feeds off the intelligibility of my analogical source so directly, my newly hypothesized account can explain the phenomena under investigation only insofar as my culprit enjoys the very same relevant characteristics as my analogical source.

Thus, as I cast about for my own fertile source of analogy, I must find something that has the right features to produce the phenomena in question, something whose operation is already intelligible. This is where my familiarity with mice and their behavior enters the scene. I understand enough about their teeth and digestive tracts to know how mice produce the kinds of items I am finding in my home. Hence, I posit a mouse or at least something with the relevant mouse characteristics as responsible for the phenomena in question. Realizing that other things with quite different features, like my jokester wife, are fully capable of scattering bits of cheese, ragged boxes, and droppings around the house, my analogical commitment at this stage is certainly tentative and provisional. I know that I may be heading down the wrong track. Since I also know that my hypothesized culprit need not have all the characteristics of a mouse to fulfill its explanatory role, my analogical commitment is only partial. To explain the slashing grooves on the cheese and the droppings, my culprit need only have parallel upper incisors and a small digestive tract.

Still, it must actually have these features, quite literally, to fulfill its explanatory task. If it does not actually have the right kind of teeth or digestive tract, then it might still be producing the phenomena in question, but I certainly do not understand, nor can I explain, how it is doing so. No doubt, features merely analogous to mouse incisors or digestive tracts could produce the phenomena in question. But then again, so could my crafty wife, who is not equipped with anything like these features. Hence, if my particular explanatory proposal rather than some other one is to be taken seriously, it must be taken literally. If I were to claim merely that my culprit has features something like the needed ones, I would not be providing a genuine explanation at all. Instead, I would be substituting a thinly veiled confession of ignorance, an admission that I cannot actually explain the genesis of the phenomena in question. Insofar as my descriptive attributions cannot be taken literally, my account degenerates into a hollow, but perhaps hopeful, promise of some future explanation.

Process must be distinguished from product here. In formulating my initial hypothesis, I depend on an analogy, something that may be dissimilar from my hypothesized culprit in many ways. Overall, then, my culprit need not actually be a mouse. It need only be mouselike. My goal, however, is to mine the analogical source for characteristics that can be carried over in attribution to my culprit, features that actually could produce the phenomena I hope to explain. In this respect, my culprit must be more than mouselike. It must genuinely possess the requisite features, since those specific features are pivotal to the success of my explanation. Ultimately, then, although my initial mining process involves the crucial use of an analogical source, my intended product is a literally accurate depiction of the responsible culprit, at least in the relevant respects.

In most cases, of course, my first hypothetical ascriptions will need to be modified, refined, or even rejected altogether. Here again, however, literalism is crucial. It yields the kind of precision necessary for predictive testability. If I attribute parallel upper incisors to my hypothesized culprit, I know precisely what kinds of evidence to look for in seeking confirmation of my hypothesis. I need twin, parallel tracks in the cheese. If I find such tracks, I will be encouraged. If I do not find such tracks, I know something is amiss. Then I can fall back on my understanding of the analogical source to decide my next step. Single slashing tracks might direct me toward a mouse with a missing tooth. Fingerprints might counsel abandoning my mouse hypothesis altogether; maybe I need to start looking more carefully in the direction of my wife.

Wherever I may go in my subsequent investigations, my literalism guides me. If I were to follow Barbour's advice to repudiate such literalism and only commit myself to claiming that my culprit is something like a mouse, something that I can only imagine in limited and inadequate ways, I would not have sufficient precision to know what to look for in my attempts to confirm, modify, refine, or disconfirm my hypothesis. Without some specific, literal attribution, I would not know what to make of my findings, whatever they might be. If my culprit is equipped with features that are only something like mouse incisors, they may not be sufficiently like mouse teeth to produce twin slashes. Still, they might be sufficiently like mouse incisors to produce single slashes. On the other hand, they might be only so vaguely akin as to be able to produce humanlike fingerprints. Without the precision of literal attribution, I cannot tell what the evidence indicates. Whatever I may find, I cannot decide whether my hypothesis is acceptable, unacceptable, or in need of refinement or modification.

This is not to deny, or even to devalue, the place of approximation in this kind of explanatory enterprise. Unlike my mouse-in-the-house project, the introduction, evaluation, and refinement of sophisticated scientific hypotheses often is slow, tedious, riddled with pitfalls, and in the end relatively unsuccessful. Frequently, after years of effort, scientists remain saddled with vague, approximate, even conflicting models, particularly in areas where they are trying to understand items beyond the range of human observation. In such cases, however, theorists construe vagueness, approximation, or conflict as defects or symptoms of failure, not signs of success. Such defects spur research toward something better. Ultimately, that something better is trenchantly realistic, ideally the literally accurate depiction of things as they actually are.

Unfortunately, reflections on the clock at Strasbourg reveal that even the most epistemically irreproachable explanations of this sort may be wildly off the mark. Nevertheless, this particular way of constructing explanations demands realism, both referential and descriptive, not merely to ensure truth but for the very intelligibility of the outcome. That was why Descartes, Boyle, Toland, and so many other moderns felt constrained to place their intellectual fate in the hands of God. Contemporary science, for all its sophisticated trappings, is no better situated. Whenever they use this common strategy for understanding the hidden operations of nature, scientists still cannot rely solely on their own intellectual prowess. Even their best efforts may not be intelligible, much less true, but for the grace of God. And what a place to find a need for God—in those icons of human technological sufficiency, modern clocks.

NOTES

The present version of this article has benefited from the comments of participants at the Spring 2000 meeting of the Institute for Liberal Studies at Kentucky State University and the Spring 2001 meeting of the Society for Philosophy of Religion, as well as from the criticisms and suggestions of two anonymous referees for *Zygon*. The weaknesses and mistakes that remain are my own.

1. Here, the terms *modern* and *contemporary* are used in the same rough yet focused way familiar to the history of Western philosophy. *Modern* roughly designates seventeenth- and eighteenth-century British and European thinkers, with particular focus upon those who influenced or were influenced by the scientific developments of that period. *Contemporary* is roughly equivalent to "current," though it stretches to encompass the middle and perhaps even the early twentieth century. For the purposes of this discussion, the focus of *contemporary* remains upon Western thinkers deeply respectful of the continuing growth of the sciences.

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