

IV

Divine Activity in a Mechanical Universe



Introduction: A Historical Paradox

In 1704 a contributor to a French learned journal observed that a new style of scientific explanation had become all the rage. One heard of nothing else but *mechanistic* physics. Nor was the fashion confined to savants. Ladies familiar with the philosophy of Descartes would blithely reduce animals to machinery. “Please do not bring a dog for Pauline,” a certain Mme. de Grignan begged in 1690: “We want only rational creatures here, and belonging to the sect we belong to we refuse to burden ourselves with these machines.” The universe has become so mechanical, Fontenelle announced in 1686, that one might almost be ashamed of it.

This mechanization of the natural world became such a feature of late seventeenth-century science that historians have sometimes spoken of the death of nature, as organic analogies were displaced by images of clockwork. The impact of mechanical analogies varied from science to science, often proving premature in the study of living systems. In the long run, however, there was scarcely any branch of science that was not affected. Despite the revolution in physics, which in our own century has made the image of a rigidly deterministic universe less secure, the assimilation of natural processes to machinery continues to be a conspicuous feature of scientific investigation. The

legacy of the seventeenth-century mechanical philosophy is apparent in such terms as *genetic engineering* and in the description of computers capable of simulating aspects of human intelligence.

The philosophical implications of the seventeenth-century transformation were profound. A new conception emerged of what was real in the world. Particles of matter in motion defined the new reality. The world of appearances, of colors, odors, tastes was reduced to secondary status – as merely the effect of the interaction of particles on the human sensory apparatus. Moreover, if the real world was that which could be described in mechanical terms, new questions arose concerning the sensitive question of God's relationship to nature. What role could be left for God to play in a universe that ran like clockwork? Would one have to side with those who became known as "deists," who restricted that role to the initial creation of a law-bound system, and who attacked Christian conceptions of a subsequent revelation? Would God's special providence, His watchful concern for the lives of individuals, not be jeopardized if all events were ultimately reducible to mechanical laws?

Such questions will be the main concern of this chapter. They are not, however, as simple as, from a secular vantage point in the twentieth century, they might seem. Certainly to the free thinkers of the Enlightenment a clockwork universe had the great attraction that it could be presented as a universe that ran by itself. But the paradox is that among those seventeenth-century scholars who did most to usher in the mechanical metaphors were those who felt that, in so doing, they were enriching rather than emasculating conceptions of divine activity. Four

examples will serve to illustrate the point. However paradoxical it may appear, the French Catholic Marin Mersenne promoted a version of the mechanical philosophy as a way of defending, not attacking, the miraculous. However paradoxical it may appear, Descartes mechanized the entire animal creation as a way of highlighting the spiritual uniqueness of humanity. However paradoxical it may seem, Robert Boyle compared the physical world with clockwork in order to emphasize, not detract from, the sovereignty of God. And, however strange, Isaac Newton saw in the very laws he discovered a proof, not of an absentee clockmaker, but of God's continued presence in the world.

These paradoxes are easily resolved, but a great irony remains. The philosophy of nature that, during the seventeenth century, was upheld as the most protective of a sense of the sacred in nature was the very one that, in later social contexts, was most easily reinterpreted to support a subversive and secular creed. This is the irony to which reference was made in the Introduction. It must now be explored in greater depth.

The Displacement of Organic by Mechanical Metaphors

The basic postulate of the mechanical philosophies was that nature operates according to mechanical principles, the regularity of which can be expressed in the form of natural laws, ideally formulated in mathematical terms. The contrast with previous approaches to the study of nature can be exaggerated. Indeed, one of the lessons of recent scholarship has been that to identify the mechanical

philosophies with the triumph of rational over occult ways of thinking will not work. It is, nevertheless, useful to consider one or two examples of earlier, organic analogies in order to illustrate the transition.

Aristotle had had this to say in the context of explaining planetary motion: “We are inclined to think of the stars as mere bodies or units, occurring in a certain order but completely lifeless; whereas we ought to think of them as partaking of life and initiative.” The peculiarities of planetary motion could then be understood because, as with a living organism, planets could exhibit different states of health, for which different modes of exercise were appropriate. Even sixteenth- and seventeenth-century critics of Aristotle had continued to imbue physical objects with a life of their own. Giordano Bruno, for example, had been happy to invest the stars with souls. William Gilbert (1540–1603), for all his apparent modernity in the manner in which he experimented on magnets, reproached Aristotle for not going far enough. The Greek philosopher had denied the earth a soul – a deficiency that Gilbert promptly remedied: “We consider that the whole universe is animated, and that all the globes, all the stars, and also the noble earth have been governed since the beginning by their own appointed souls and have the motives of self-conservation.” Governed by souls: not yet by physical laws.

Where such organic analogies prevailed, it was common to suppose that there were sympathies, special affinities, between physical objects. These allowed one body to affect another, even though they were not in contact. The most celebrated examples come from popular belief in the effect of the stars on human destiny, or from the belief of

the alchemists that certain planetary conjunctions were propitious for the success of particular experiments. But a striking example, still much discussed during the first half of the seventeenth century, concerned the efficacy of the weapon salve – a healing balm placed not on the wound but on the weapon by which it had been inflicted. The healing, according to the Englishman Robert Fludd (1574–1637), was effected by a sympathetic power transmitted from the blood on the weapon to the blood of the afflicted. Magnetic attraction was the paradigm for this kind of action at a distance, which contrasted sharply with the contact action on which Descartes would insist as the only means by which causes could produce effects. Scientific explanation for Fludd required a vocabulary of spirits, sympathies, messengers between heaven and earth, and invisible lines. By the end of the century a new vocabulary had been forged, replete with the cogs and wheels of human gadgets.

A contrast between the microcosm–macrocosm analogies of Renaissance philosophy and the new mechanics of the seventeenth century is visible in remarks made by Leonardo da Vinci and Kepler. For all his technical genius and flirtation with flying machines, Leonardo had still envisaged nature as a living organism:

We can say that the earth has a vegetative soul, and that its flesh is the land, its bones are the structure of the rocks . . . its blood is the pools of water . . . its breathing and its pulse are the ebb and flow of the sea.¹

For all his number mysticism and flirtation with animism, Kepler, by 1605, was announcing a mechanistic program:

I am much occupied with the investigation of the physical causes. My aim in this is to show that the Celestial machine is to be likened not to a divine organism but rather to clockwork. . . . Moreover I show how this physical conception is to be presented through calculation and geometry.²

The power of geometry in the analysis of natural phenomena was shown by Kepler's reduction of planetary motions to the shape of an ellipse; by Galileo's study of the relations between speed, time, and distance when a body falls with uniformly accelerated motion; and by his analysis of the parabolic path of projectiles. It was to be supremely demonstrated by Newton when he showed that an inverse-square law of gravitation would explain Kepler's ellipses. As an analytical tool, however, geometry could only be applied to idealized representations of natural phenomena in which the multiple complexities of the real world were temporarily discounted. The geometric model, once constructed, could then be used as a control to see how closely events in the physical world conformed to it. This ability to create two worlds, to relate the real world to an idealized mathematical model, was one of the techniques that made modern science possible. The process of abstraction that was required came more easily in a mechanical than an organismic universe. And the more successful the method, the more it encouraged the view that the most fundamental elements of creation were precisely those amenable to mathematical analysis: the shape, arrangement, and motion of particles. Thus we find Galileo rejecting the notion that heat is a real property or quality residing in a body that feels hot. Rather, heat is a sensation produced in us by "a multitude of minute

particles having certain shapes and moving with certain velocities.”

This predilection for particles, so alien to Chinese philosophies of nature, became a distinctive feature of Western science during the seventeenth century. It can be seen in the efforts of the French philosopher Pierre Gassendi (1592–1655) to grapple with the phenomenon of gravitation, without recourse to action at a distance. Gassendi’s proposal was that the earth emitted a continuous stream of particles from its surface. Like tentacles, these particles could attach themselves to the pores of any body suspended above the earth and so pull it down. The further the body from the earth, the weaker the gravitational pull, because fewer of the emitted particles would reach the object. Wishing to square his explanation with Galileo’s law of falling bodies, he invoked an additional hypothesis – a downward thrust, effected by the air, complementing the effect of the gravitational radiation.

The particles deployed by seventeenth-century mechanical philosophers varied from one to another. Aristotelian philosophy continued to be one resource, for Aristotle’s theory of matter required the postulation of minute particles, the *minima*, as a substratum. The English physiologist Walter Charleton (1620–1707), having become disenchanted with magical philosophies of nature, reverted to Aristotle before finally adopting an atomic philosophy similar to that propounded by Gassendi in France. Those who favored an atomic theory were, however, committing themselves to the view that matter is not infinitely divisible. For Gassendi’s opponent, Descartes, this was to put constraints on the power of God. Accordingly, in the mechanized universe

of Descartes, the particles were not atoms moving in a void, but were of such different sizes and subtlety that they filled the entire universe. In such a plenum, patterns of roughly circular motion could be established if each particle continually moved into the position that its predecessor was vacating – hence Descartes’s mechanical model for the orbits of planets. Each was carried round in a whirlpool of subtle matter, like a cork floating on water. Despite its mathematical inexactitude, it was a model that was easily visualized, and one that had the virtue of explaining why the planets circle the sun all in the same direction and in roughly the same plane. The model could even be extended to explain the tides, for the earth had its own vortex of swirling matter. This subtle matter, in the vicinity of the moon, would be deflected as it encountered the moon as an obstruction – thereby setting up a downward pressure, which, when transmitted through the ether, compressed the ocean.

With so many different particles to choose from, some exponents of a mechanical philosophy preferred not to take sides, opting instead for the neutral term *corpuscle*. Robert Boyle favored this eclectic approach as he constructed an elaborate, hierarchical theory of matter in order to explain chemical phenomena. His corpuscles could be arranged in different ways, organized into different shapes, and were capable of different patterns of motion. Acids were acids not because they contained some essence, quality, or form of acidity, but because their particles had sharp points and were thus able to attack the surface of metals.

In the work of Newton, the particles of the mechanical philosophy achieved their greatest refinement. His

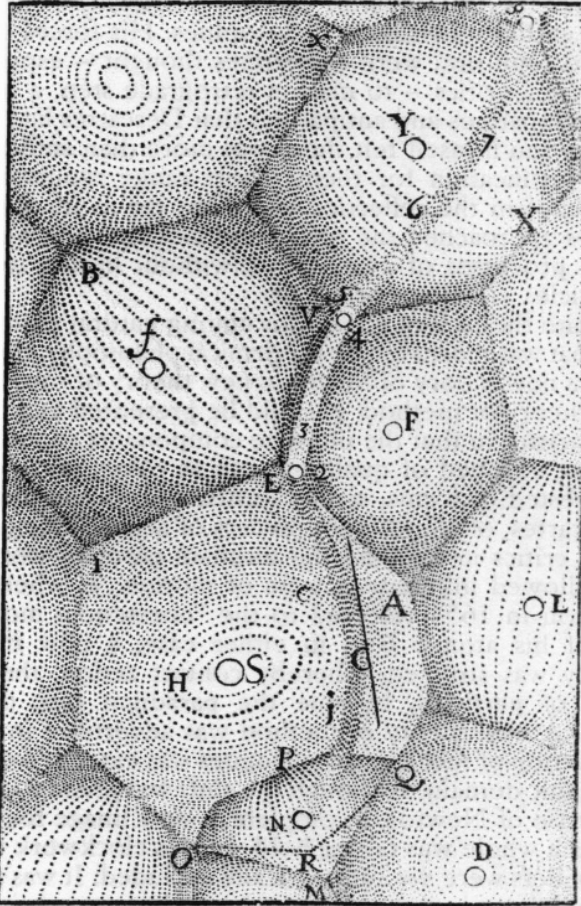


FIGURE IV.1. Illustration from page 92 of Descartes's *Principia philosophiae* (1644). The vortices of subtle matter, swirling in contiguous solar systems, epitomize Descartes's mechanistic universe. The numbers in the diagram identify the path of a drifting comet, formerly a sun but now encrusted and defunct. Bereft of the power to drive its own vortex, it is simply carried along by the impact of particles with which it is at every instant in contact. Reproduced by permission of the Syndics of Cambridge University Library.

theory of matter was explicitly atomic, but each atom was equipped with short range attractive and repulsive forces. These forces, in principle at least, were capable of quantification:

Since metals dissolved in acids attract but a small quantity of the acid, their attractive force can reach but to a small distance from them. And as in algebra, where affirmative quantities vanish and cease there negative ones begin, so in mechanics, where attraction ceases there a repulsive virtue ought to succeed.³

Newton's theory of matter was not a straightforward extension of earlier mechanical philosophies. His forces of attraction and repulsion were sometimes thought – especially by Continental critics – to mark a retrograde step, a reversion to the sympathies and antipathies that Descartes had excised. But Newton himself felt there was more than sufficient empirical justification for them. Short range repulsive forces would explain the reflection of a light ray as its constituent particles approached the reflecting surface. They would also explain processes of evaporation without having to picture air particles as springs or hoops.

Despite the lack of consensus among natural philosophers as to what was meant by the mechanical philosophy, they spoke of it as a new theory of matter, a new theory of causality, and a new theory of method. It could be presented as a new theory of matter in that the ultimate components of things were particles, stripped of qualities such as color, taste, or smell and divested of forms, seeds, spirits, and, in the philosophy of Descartes, of all inherent powers of activity. Among Descartes's critics in England the ultimate particles were sometimes allowed

inherent powers of motion, as when Walter Charleton in 1654 referred to the “coessential motive faculty” of his atoms. But, in either case, a new theory of causality was stressed, whereby contact action, the mutual impact of particles, became the paradigm case of causal agency. A new theory of method was advertised in that the construction of mechanical analogues was extended even into the organic domain. Although the shift was gradual, and even in the case of Newton incomplete, a new image for the universe as a whole was taking hold. In this clockwork universe older beliefs were *not* automatically excluded. It was still possible to believe in the transmutation of base metals into gold, still possible to believe in the efficacy of the weapon salve, still possible to believe in witchcraft. There were, however, changing sensibilities as to what an acceptable mechanism might be in the rationalization of such effects.

Theological Justification for Mechanical Philosophies

However surprising it may seem, seventeenth-century natural philosophers had little difficulty in finding a theological rationale for their mechanical universe. In Chapter II we saw how scientific innovations were often presented in theological terms. In the case of the mechanical philosophies it was necessary to show that divine activity was not excluded by a clockwork universe. The task was all the more pressing because, in the ancient world, the atomic theories of Leucippus, Democritus, and Epicurus had been associated with the belief that nature has no need of gods, that worlds had come into being by the chance

collision of atoms. In their defense of both a mechanical philosophy and divine providence, however, scholars constructed arguments that did more than merely reconcile the two. Advantages were seen in a mechanical philosophy for the defense of the Christian religion, despite the fact that during the course of the seventeenth century it was also seized by those who, like Thomas Hobbes (1588–1679), questioned the immateriality of the soul. Without committing himself to an atomic philosophy, Francis Bacon had insisted that it was *more* conducive to a doctrine of providence than the Aristotelian alternative:

Nay, even that school which is most accused of atheism doth most demonstrate religion; that is, the school of Leucippus, and Democritus, and Epicurus – for it is a thousand times more credible that four mutable elements and one immutable fifth essence, duly and eternally placed, need no God, than that an army of infinite small portions, or seeds unplaced, should have produced this order and beauty without a divine marshal.⁴

For Bacon, as for Boyle and Newton after him, it was simply inconceivable that, from a chance distribution and collision of atoms, a world of such order could have been produced – an order that the progress of science was confirming rather than destroying. It is appropriate, therefore, to examine the theological advantages that were perceived in a mechanized universe.

Mersenne and the Defense of the Miraculous

Mersenne has an important place in the history of seventeenth-century science because, through an extensive correspondence, he probably did more than anyone

to coordinate the efforts of the early mechanists. He was particularly conspicuous in popularizing Galileo's physics. A French Catholic, and member of the Order of Minims, he was aware that his faith was under attack from two directions. First, Protestants and deists were drawing a distinction between religious truth and religious tradition that he, as a Catholic, felt bound to resist. Second, philosophies of nature had been emerging from Renaissance Italy that, explaining nature's marvels in purely naturalistic terms, threatened to explain away the truly miraculous. In seeking to combat both these threats, Mersenne found a mechanical philosophy useful.

In the preceding chapter we showed how religion could have an indirect effect on science. Continuing debates between Catholic and Protestant Christians helped to turn controversial scientific innovations into sensitive issues. But such debates also created issues of their own. Mersenne was wounded by Protestant allegations that the Catholic priesthood manufactured miracles in order to convert the masses. He therefore believed that it was in the best interest of his Church to tidy up the borderland between natural marvels and genuine miracles. A mechanical philosophy provided the means of doing so because it could assist in defining the boundaries of natural order. Miracles, after all, presupposed a natural order against which they could be judged to be miracles, against which they could be differentiated from mere marvels.

Mersenne's response to the second of the two threats helps to clarify the point. The challenge of a purely naturalistic philosophy had been issued by Pietro Pomponazzi (1462–1525), who had preserved the Aristotelian deity as a prime mover but at the same time rejected both

providence and miracles. It was one thing to attack popular credulity as Pomponazzi had done, but to reject miracles altogether was, for Mersenne, going too far. For every prodigious effect in nature, Pomponazzi and his devotees had insisted there must be some explanation in terms of natural forces. But the forces he employed were precisely those that would offend the mechanists – forces whose causal agency was vested in stars, names, signs, images, thoughts. He frequently invoked intelligences associated with the stars. Nature knew no miracles but, in Pomponazzi's system, it had become a chaos of natural wonders. A mechanistic physics arguably appealed to Mersenne because it injected a ray of light, a sense of order and restraint into a naturalistic fantasy. The desire to discriminate between natural marvels and true miracles was religiously motivated and eventuated in a mechanical and less magical view of nature. If the ringing of church bells could disperse a storm, for the credulous masses it was a miracle; for Pomponazzi it was through the will of an astral intelligence; but for Mersenne it was through the will of God, which had expressed itself in the laws of fluid mechanics.

The coherence of Mersenne's position depended on an important, and long-established, distinction between God's power as displayed in the order of nature and His absolute power by which He could act in any manner He chose. A mechanical philosophy appealed to Mersenne, as it did later to Boyle, because it seemed the perfect way of expressing the manner in which God normally chose to act in the world. Physical laws were an expression of the divine will, the ultimate source of order. But they were in no way binding on God, who was always free to act in

other ways if He chose. The possibility of miracles was not excluded. It was rather that the means of recognizing a true miracle was clarified. An event could be deemed a miracle if it was not explicable in terms of physical laws.

Descartes and the Defense of Human Dignity

In Chapter II we saw how Descartes promoted his mechanical philosophy in theological terms. The quantity of motion that God had put into the world at creation was conserved at every moment by His sustaining action. Other theological issues arose, however, in the context of applying mechanical analogues to the analysis of living things. Whereas organismic analogies had been habitually applied to physical processes, Descartes turned the procedure upside down, interpreting animals as pure machinery. This was a highly controversial move, but Descartes protested that his doctrine of the beast-machine was not so much cruel to animals as it was favorable to humans. It was favorable in that it emphasized a superiority over the whole of creation that had a parallel – the exactness of which continues to be a source of debate – with the reference in Genesis to a dominion over nature that was a human privilege and responsibility.

Descartes underwrote the privilege by insisting that humans are machines with a difference: They alone have the gift of an immortal soul. Descartes could see advantages in a mechanical philosophy because it helped to sharpen up the difference between the world of matter and the world of spirit. In the rationality of the human mind was evidence of a spirit world, but it was confined to

humanity. The uniqueness of humankind, as alone made in the image of God, was not merely protected but positively enhanced.

Historians have hit on some grand explanations for why the mechanization of nature occurred when it did. It has been observed that it followed the establishment of absolute monarchies in Europe, which may have facilitated the projection of a divine sovereign, legislating for the universe as the monarch legislated for society. On the basis of such analogies, it has even been suggested that a mechanical philosophy could serve to undermine papal opposition to the divine right of kings. It is also argued that the experimentalists of the English Royal Society adopted mechanical metaphors as a way of legitimating their use of instruments, traditionally the preserve of the artisan. In the case of Descartes, one suspects that the universe had begun to seem self-evidently mechanical as he reflected on sophisticated machinery (clocks, looms, pumps, and fountains) of sufficient ingenuity to match some of nature's more recondite operations.

A smattering of hydraulics was already in the curriculum of the Jesuit college at which Descartes had received his education. As a youth he had planned mechanical models to simulate animal activity: a flying pigeon, and a pheasant hotly pursued by a spaniel! But what justification was there for regarding real animals as machines, for depriving them of their animal souls? From the very perfection of animal actions, Descartes observed, we suspect that they do not have free will. Compared with men and women who are often indecisive in their actions, animals behave in an apparently determinate manner, as if programmed to respond to external stimuli.

The idea that animal activity is determined by mechanical reflexes was sustained by a comparison with much that is involuntary in human behavior. A child placing its hand close to a fire would withdraw it without thinking. In fact the great majority of bodily movements appeared not to depend on the mind at all. Descartes listed the beating of the heart, the digestion of food, and respiration while asleep. Even walking and singing could be performed without the mind attending to them.

In the animal kingdom, the sheer regularity of instinctive behavior suggested a programmed mechanism. To speak of the birds and the bees was to speak of clockwork: "Beyond question when the swallows come in the Spring they act in this regard like clocks. All that is done by the honeybees is of the same nature." Why, Descartes asked, was it necessary to suppose that the essence of life consists in some special soul? Why could it not consist in the warmth of the heart? But the fundamental argument was derived from the fact, as Descartes perceived it, that pheasants and spaniels did not talk. Dogs were not devoid of vocal apparatus, but no dog had yet spoken French. Not a single brute speaks, Descartes declared; and this absence of communication implied an absence of rationality, an absence of a rational and immortal soul. Given that one would not even be tempted to attribute mind to a sponge or jellyfish, why confer it on more complex creatures? Man's self-consciousness in the perception of his self-consciousness made him the one exception.

What theological advantages were there in this rigid demarcation? To deprive the brutes of free will, Descartes observed, was no more than scholastic philosophers had already allowed. To deprive them of a sensitive soul might

be to deprive them of feelings; but would it not be unjust if they did feel pain? It was humanity, not they, that had sinned and paid the price. To deprive the animals of an immortal soul was favorable to man in one final respect: Heaven would surely be more blissful in the absence of bites and stings. Applying his mechanical principles to the study of reproduction, he even absolved God of immediate responsibility for monstrous births. Physical deformity could be ascribed to some failure in the mechanism of generation.

It is tempting to ask why Descartes did not go the whole hog and turn men and women into robots. But that was a possibility he could never seriously entertain. He claimed that he had a clear and distinct idea of himself as a conscious being, from which he deduced that there was a sense in which he could be said to exist independently of his body. His mind was radically different from matter in that it exhibited the powers of imagination, understanding, and volition, each of which was foreign to matter. Consequently, there was a special substance in man, a thinking substance, in addition to the machinery of which his body was made. With some justice, later critics would object to the smooth transition from thinking substance to spiritual substance to immortal soul. But the transition was justified in Descartes's own mind because, once a unique immaterial substance was conceded, it became impossible to conceive how it could be destroyed by any physical cause. The existence of a soul, interacting with the body, and yet independent of it, was corroborated by the fact that different parts of the body could be affected by external agents without necessarily affecting the mind at all.

Descartes's most powerful argument, still entertained in some quarters, derived from the indivisibility of the human ego. One could conceive of the indefinite divisibility of matter, but not of the divisibility of the self-conscious personhood corresponding to the use of the word *I* in everyday speech. By way of clarification, Descartes insisted that he was not lodged in his body like a pilot in a ship. If he were, he would feel no pain when wounded. Despite the rigidity of his dualism between matter and spirit, he confessed to being "very intimately connected" to his body – so intermingled with it that he constituted "an entire whole with it." He pressed mechanical analogies so far, even in human physiology, that he has been called the father of neurophysiology. But his reasoning pointed toward, not away from, an eternal destiny for the human race.

Boyle and the Defense of God's Sovereignty

In the previous chapter it became clear that an unresolved dispute exists between those historians who see a correlation between puritanism and science in seventeenth-century England and those who insist that the correlation was rather between science and religious moderation. One way out of the impasse is to deny the value of attempts to assign natural philosophers to one or the other of such religious types and to recognize instead that the events of the civil war period could transform the perceptions of reformers who, from having been sympathetic to the early stages of revolution, eventually found themselves recoiling against the excessive demands of more radical campaigners. The demands of the extremists, which included

disestablishment of the Church, abolition of tithes, the admission of lay preachers, the equality of women, extension of the franchise, property redistribution, and even sexual libertinism, were such that many who had once favored reform found themselves saying thus far and no further. To understand the relations between science and religion in mid-seventeenth-century England, it is well to recognize this continuing dialogue between conservative and radical reformers, the form of which could change as social and political circumstances changed.

One advantage of this approach is that it is more sensitive to the details of historical change than alternatives that aim to correlate an interest in science with some archetypal religious, or even hedonist, mentality. Another advantage is that it helps one to understand how certain strands within Descartes's mechanical philosophy could become attractive to the more conservative reformers who, like John Wilkins and Robert Boyle, were concerned about the threat to a stable society posed by puritan extremists. Because Descartes had poured a cold douche on those who claimed a hot line to God, his philosophy could be used against radicals who claimed the illumination of the Holy Spirit as their authority. Because he had also demonstrated the immortality of the soul, his dualism proved attractive in the assault on those who, like the Leveller Richard Overton, were arguing that the soul was mortal.

This does not mean that every aspect of Descartes's philosophy found favor in England. His reduction of animals to machines was generally considered eccentric. His reluctance to admit final causes into natural philosophy was often censured, as it was by Boyle, who felt that the French

philosopher was unnecessarily depriving Christianity of one of the strongest arguments for God's existence. The vocabulary of English mechanical philosophers suggests that they found Descartes's emphasis on the complete passivity of matter too restrictive. But Descartes's vision of a universe running according to mechanical principles certainly took hold of the scientific imagination.

When Boyle spoke of the excellence of the mechanical philosophy, he produced many arguments in its favor. It would be wrong to imply that its advantages were purely theological or that Boyle adopted it merely for polemical purposes. Intelligibility and clarity were two intrinsic virtues he claimed for it. The case for reinterpreting traditional concepts, like that of *form*, in mechanical terms, had been developing over several decades. Some thirty years before Boyle pressed the case, the French chemist Etienne de Clave had already complained that the word *form* had come to mean at least ten different things. Versatility, in addition to clarity, was claimed for mechanical analogues as Boyle presented his corpuscular philosophy as a comprehensive alternative to that of Aristotle. Comparing his different corpuscles with the letters of the alphabet, Boyle was more than satisfied that there were letters enough to compose the book of God's works.

The case for a mechanical philosophy was not exclusively a theological one. Indeed, it was often justified in straightforward empirical terms. When the microscope revealed the compound eye of a fly, or the microstructure of small grains of sand, it gave a considerable boost to particulate theories of matter. The theological justification was nevertheless of fundamental importance, for Boyle found in his corpuscular philosophy the perfect

antidote to all those heretical systems in which Nature (with a capital *N*) was seen as self-sufficient, as an active and productive source of all things. By stressing that his corpuscles behaved according to rules that God had freely chosen, he retained a central role for divine activity in the world. Nature was to be looked upon not as a distinct or separate agent but as a “system of rules, according to which those agents, and the bodies they work on, are by the great Author of things, determined to act and suffer.”

We saw in Chapter II how Boyle used the mechanical philosophy to differentiate sharply between nature and God. But how exactly was God supposed to act in a world of whirling particles? Boyle gave an answer in an essay expressly directed against those who, in his own phrase, “would exclude the deity from intermeddling.” Because the laws of nature, the “system of rules,” were of God’s devising, they were themselves an expression of divine activity. Because mechanistic explanations relied on the fact that matter exhibited certain properties, Boyle could argue that the choice of which properties to bestow on matter had been God’s. Furthermore, for a viable universe, it was not enough that matter should have certain properties rather than others. The ultimate particles had to be put into certain situations and given certain motions. Divine activity was required to achieve that initial configuration. The phenomena that the divine will intended to appear would then follow in an orderly manner, but only through the assistance of His “ordinary preserving concourse.”

Drawing on Descartes’s definition of matter as extension, Boyle could make the further point that motion was in no way necessary to the essence of matter, for “matter

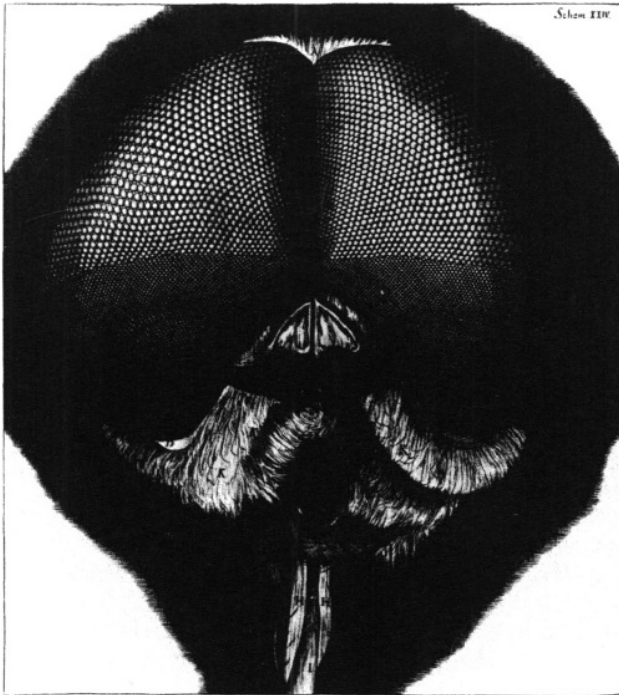


FIGURE IV.2. Plate from opposite page 175 of Robert Hooke's *Micrographia* (1665); "Eye of a fly." The granular structure of a fly's eye was typical of microscopic phenomena that seemed to confirm an underlying reality of minute particles out of which the many edifices of nature had been constructed. Knowledge of mechanical structure, of nature's architecture, became a new form of active knowledge – knowledge by modeling and mechanical reconstruction rather than by reflection. In the preface to his *Micrographia*, Hooke declared that the "mechanical philosophy" alone was truly grounded in experiment and capable of giving access to physical reality. Reproduced by courtesy of The Bodleian Library, Oxford; Shelfmark Lister E. 7.

is no less matter, when it rests, than when it is in motion." It could gain or lose motion; but no man, Boyle reported, had yet made out how matter could move itself. This had been an unwarrantable assumption, along with others such

as the eternity of matter, on which the atomists of old had relied. The mechanical philosophy properly understood was supportive of divine activity. How, Boyle asked, could “so curious an engine” as this world possibly be produced by a “casual concurrence of the parts it consists of”? The design argument was reinforced, not overridden, by a philosophy of mechanism.

So far so good. But the argument from design was as compatible with the absentee god of the deists as with Christian theism. Among all these arguments, has Boyle yet produced one in favor of divine “intermeddling”? No; but he had one up his sleeve. Descartes once again came to his aid in establishing a powerful analogy, which Newton too would embrace. If there was a spiritual substance in man, then every voluntary human action was proof that an incorporeal and intelligent being could work upon matter. By analogy, why should God not do the same? There was no reason to discount the possibility that “there may be a spiritual deity, and that he may intermeddle with, and have an influence upon the operations of things corporeal.”

This analogy with human voluntary activity may help to explain why Boyle’s theology (and that of Newton) is sometimes called “voluntarist.” It emphasized the freedom of God’s will to create whatever world He wished, and His freedom to manipulate and dispose things as He saw fit. He was not bound by any kind of logical necessity, nor by the laws of nature, for they were simply expressions of the way He normally chose to act. The analogy may also suggest that what Boyle meant by “intermeddling” was not necessarily miraculous intervention. It did not require a miracle for a man to shift his leg or pick up his pen. Why should it require a miracle for God to shift matter?

Not that Boyle wished to exclude the miraculous. Quite the contrary: for he believed that the New Testament miracles were the surest proof of Christian doctrine:

For the miracles of Christ (especially his Resurrection) and those of his disciples, by being works altogether supernatural, overthrow atheism; and being owned to be done in God's name, and to authorize a doctrine ascribed to his inspiration; his goodness, and his wisdom, permit us not to believe that he would suffer such numerous, great miracles, to be set as his seals to a lie.⁵

In Boyle's clockwork universe there was therefore room for God's general providence, His particular providence when He chose to intermeddle, and His miraculous intervention when extraordinary effects were wrought by supernatural means.

Such distinctions were not purely academic. They helped to define the scope of mechanical philosophies. One could not define the province of mechanistic explanation without, tacitly at least, defining the province of "spirits." And this of course had been the preserve of priests more than experimental philosophers. Boyle himself would consult friends in the priesthood if his conscience told him that the investigation of phenomena commonly associated with the dark world of spirits might be illicit. He was inclined to divide the cosmos into "supernatural, natural in a stricter sense, that is, mechanical, and natural in a larger sense, that which I call suprimechanical." The question of which processes should be placed in the suprimechanical category produced a range of competing answers, with experimental programs in both pneumatics and chemistry designed to capture and reproduce the agency of subtle spirits. Boyle certainly

made room for what he described as a “very agile and invisible” sort of fluid, for which the term *spirit* was commonly used. For this reason, it may be more accurate to see the English mechanical philosophers as capturing the domain of spirits with their experiments rather than discarding it. Boyle’s contemporary John Mayow (1641–79) affirmed that there was an ingredient in the air, vital to human life. At times he would call it a nitro-aerial spirit. At times he would call it a nitro-aerial particle. But whatever its label, its very existence was proof of providence. It restored the atmosphere spoiled by respiration. Without it, “there would be no society at all . . . for we should be obliged to spend our lives single and separate, namely where a ration of nitro-aerial spirit sufficient for sustaining life might be obtained for each.” There would be perpetual strife between mortals as they sought to partition their tracts of air. One could not implement a mechanistic program without confronting the continuum of meanings that the word spirit connoted. Boyle did not even demur from the view that experimental evidence in favor of intelligent and invisible beings might be useful in remonstrating with atheists, whose way of life implied a negligence of higher spiritual demands.

Newton and the Defense of God’s Omnipresence

To say that mechanical philosophies had their origins in a voluntarist theology would be going too far, but the latter undoubtedly provided a convenient metaphysics for their promotion. In Newton, as in Boyle, one finds the same allowance made for a God whose sovereign will had not only dictated the properties bestowed on matter but

was also capable of immediate action, whether directly or through the agency of natural causes. The irony is that it was only necessary to restrict the sources of activity to powers within matter itself to tear the veil and reveal a material universe in which divine activity was reduced to an initial act of creation and legislation. The irony runs deeper because Newton's gravitational force, and the short range forces of attraction and repulsion that he associated with atoms, were seen by later interpreters as just such inherent sources of activity. But not by Newton himself.

An extract from an early essay suggests that one of Newton's objectives had been to develop that analogy between human and divine volition that had been of central importance to Boyle:

I have deduced a description of this corporeal nature from our faculty of moving our bodies, so that all the difficulties of the conception may at length be reduced to that; and further so that God may appear (to our innermost consciousness) to have created the world solely by the act of will just as we move our bodies by an act of will alone; and, besides, so that I might show that the analogy between the Divine faculties and our own is greater than has formerly been perceived.⁶

In pursuing that theological goal, Newton was not merely philosophizing. His concern with the question of divine activity in the world was deeply informed by his study of the Bible. At a critical stage in his Cambridge career, he had had to come to terms with the moral demands that the divine ruler made of His servants. To retain his fellowship at Trinity College he expected that he would have to

follow the usual pattern and take Holy Orders. But that would have meant swearing an allegiance to the thirty-nine articles of the Anglican Church, which in conscience he could not do. He had already come to reject the doctrine that Christ is of one substance and coeternal with the Father. In the event, he was let off the hook with a special dispensation (which may well have seemed like a special providence) allowing him to continue his work without being ordained. But he had lived through a pending crisis in which he must have weighed the cost to his soul were he to perjure himself.

Newton's philosophy of nature is sometimes discussed as if his conception of God were a mere appendage – a hypothesis to explain what his science could not, a god-of-the-gaps. But this is a superficial view, for Newton was deeply concerned with the action of God in human history. Fascinated by the history of ancient kingdoms, he would trace their degradation as they lapsed from monotheism into idolatry. His historical researches were designed to show that biblical prophecies had been fulfilled. They also reflected his conviction that he belonged to a faithful remnant whose Christianity, unlike that of the established churches, had not been defiled through centuries of political machination and doctrinal corruption. His aversion to the Roman Catholic Church was apparent in his treatment of Revelation 12:6, where 1,260 years of the reign of Antichrist were identified with the years of papal domination. Newton's adage that "the end of prophecy is not to make us prophets" was directed against enthusiasts who were forever predicting dates for apocalyptic events. But prophecies already and unmistakably

fulfilled were evidence of the divine arm in human affairs. A belief in God's omnipresence even penetrated his analysis of space.

In Newton's mind, space was associated with the intimate presence of God, who knew and perceived all things, who knew when his servants disobeyed Him, who knew that Newton himself had once eaten an apple in Church, had once made a mousetrap on the Sabbath, had once lied about a louse to his roommate in Cambridge. His overbearing sense of a divine presence has been analyzed in psychological terms as a consequence of his having been a posthumous child. Never having known an earthly father, he found a heavenly substitute on whom every absolute was conferred. But whatever its origins, Newton's conviction that "God was everywhere from eternity" had implications for how space and time were to be conceived. They, too, became absolute rather than relative constructs. For Descartes there had been no space without matter; for Newton there was no space without God. It was not that space was an attribute of God, or the Body of God, or the sensory apparatus of God. But there was a sense in which space was constituted by God's omnipresence.

To help in defining God's relation to space, Newton employed the Hebrew word *maqom*. The Hebrews, he wrote, "called God *maqom* place, the place in which we live and move and have our being and yet did not mean that space is God in a literal sense." In an early essay, *De gravitatione*, he argued that space is eternal in duration and immutable in nature precisely because it is "an emanative effect of eternal and immutable being." The most perfect idea of God, he declared, is one in which

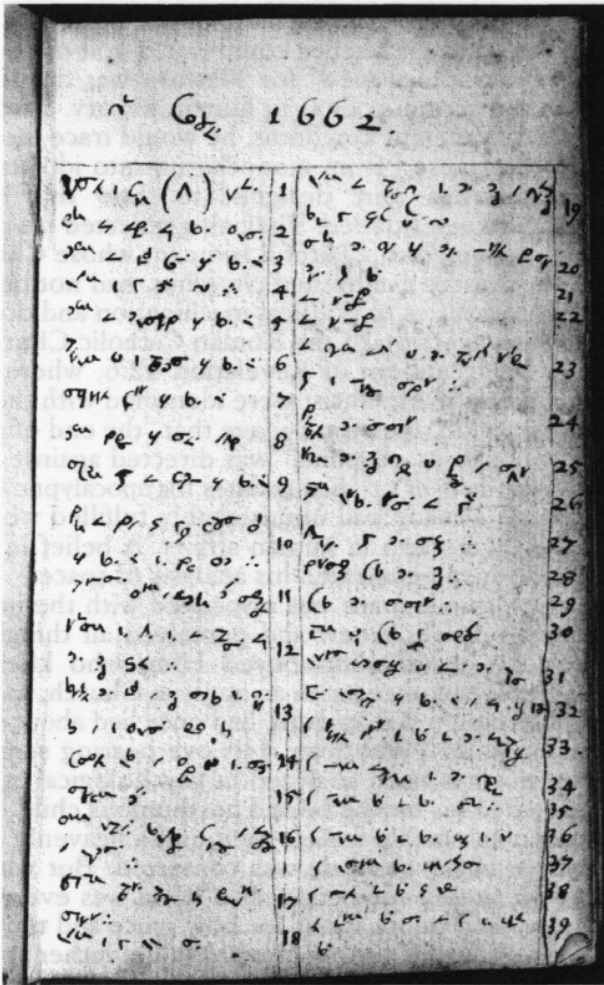


FIGURE IV. 3. A page, dated 1662, from Newton's "accounts book" in which he listed the sins of his youth. Recorded in shorthand, Newton's numerous sins included swimming in a tub on the sabbath, having "unclean thoughts words actions and dreams," and even threatening his mother and stepfather "to burn them and the house over them." Reproduced by courtesy of the Fitzwilliam Museum, Cambridge.

He necessarily exists everywhere, a substance in which all other substances are contained – a substance “which by His own presence discerns and rules all things.” When he wrote that “in Him are all things contained and moved,” the supporting references included eight from Scripture, most notably St. Paul’s speech in Acts 17:28. The analogy that Newton reiterated, between the power of God and our ability to move our bodies, was embedded in a long tradition of Jewish and Christian speculation concerning God’s relation to space.

This might be considered of minor importance were it not for the fact that Newton’s association of space with the omnipresence of God provided one justification for regarding his inverse-square law of gravitation as a universal law. In Query 31 of his *Opticks* Newton explained that, because God is present in all places, He is *more* able by His will to move bodies (and thereby to form and reform parts of the universe) than we are to move our limbs. The link with the universality of the laws of motion was, however, made explicit in an earlier, unpublished draft of that Query:

If there be an universal life and all space be the sensorium of a thinking being who by immediate presence perceives all things in it . . . the laws of motion arising from life or will may be of universal extent.⁷

This may help to explain how Newton became so committed to the universality of his law of gravitation, despite the existence of some evidence that could have told against it. The stability of the fixed stars, for example, was all the more remarkable in a universe governed by gravity: One might expect that the most peripheral would experience

a resultant “pull” inward. If the universe were finite, a devastating implosion would eventually occur.

Mechanical Philosophies and Religious Apprehension

The association of a mechanical philosophy with a voluntarist theology served its exponents well – not least because it helped to justify experimental methods. If the workings of nature reflected the free agency of a divine will, then the only way to uncover them was by empirical investigation. No armchair science, premised on how God *must* have organized things, was permissible. This meant that theological moves could be made in criticizing any science that seemed too conjectural. And this might include the very mechanical models favored by one’s predecessors! One of the claims made on Newton’s behalf was that he had discovered the laws of motion that God had actually implemented, by contrast with Descartes whose mechanical models, by his own admission, could never provide more than a plausible account of how the clockwork worked.

The promotion of a mechanical philosophy on religious grounds was not, therefore, without its problems. And there were to be more. The clockwork analogies of Boyle or Descartes, though lodged in theologies of nature that remained Christian in inspiration, were to appear perfectly at home when lodged in deistic philosophies – in the anti-Christian literature of the Enlightenment. For Voltaire, in the eighteenth century, the clockmaker God was to be an attractive alternative to the gods of established religions. It would be surprising if such tendencies

had not been discerned in the seventeenth century and religious apprehension expressed. But what form did such apprehension take?

Although Mersenne had seen value in a mechanical philosophy that would help preserve the miraculous, it soon became apparent that if the mechanistic explanations he favored were imported into the naturalistic philosophies he was attacking, they could so encroach on holy ground that they might exclude the miraculous. This soon became a problem with Descartes's account of how the solar system originated. His detailed account of how the material vortices had assumed their present form was construed in some quarters as disrespectful to the Bible. In England, in 1662, a future bishop of Worcester, Edward Stillingfleet, complained that atheists were busily exploiting "the account which may be given of the origin of things from principles of philosophy without the Scriptures." Five years later, a Cambridge tutor was complaining that his students were deriving from Descartes "notions of ill consequence to religion."

The nature of a mechanical philosophy might be theistic in tone, but its nurture was liable to be otherwise. Given a certain arrangement of atoms, argued the French eccentric Cyrano de Bergerac, some object or other was bound to be formed. It was not in the least marvelous, he suggested, that among them would be trees, frogs, monkeys, and men. So, too, with Thomas Hobbes, a mechanical philosophy was associated with belief in a material soul, with a critical attitude toward the Scriptures, with an explanation for the origins of religious belief in an ignorance of natural causes, and with his discomfiting emphasis on self-interest as that which had to be accommodated in a social

contract. Although Hobbes was not an atheist, he was commonly despised as one. He stood for a set of meanings that the term *mechanical philosophy* might denote, and from which Boyle and other Christian virtuosi had to distance themselves.

The beast-machine doctrine of Descartes was another source of apprehension. To regard God's creatures as no different in kind (however much Descartes might protest that they differed in degree) from human artifacts caused offense to Gisbert Voet, rector of the University of Utrecht. Another critic saw how the beast-machine could become the thin end of a wedge: "If one suppresses the vegetative and sensitive soul in brutes, one opens the door to the atheists, who will attribute the operations of the rational soul to a cause of the same kind and will give us a material soul to replace our spiritual soul." And he was right. Material souls, made of fiery particles, had made many an entry by the close of the seventeenth century. For thoughts to be produced, it was argued, all that was necessary was for fine particles to flow through the filigree ducts of the brain. This mechanization of the mind was to be a familiar theme in the clandestine literature of the Enlightenment. The ultimate fear was that it might strip humanity of free will. Further anxieties were raised by the beast-machine. It was often said that the test of a good Cartesian was whether he would kick his dog. Descartes's doctrine provided ample justification for a widespread cruelty to animals. For the English naturalist John Ray it was an indictment of Descartes's system that it was so viciously anthropocentric.

The question of divine activity in a mechanized universe became even more urgent in the context of Christian

worship, and especially for the Roman Catholic Church, which took a distinctive view of the presence of Christ at the celebration of the Eucharist. With an Aristotelian theory of matter and form, it was possible to understand how the bread and wine could retain their sensible properties while their substance was miraculously turned into the body and blood of Christ. Drawing on the categories of St. Thomas Aquinas, it was said that the accidents of color, odor, and taste could continue to exist without their original substance. But if, as the mechanical philosophers argued, the sensible properties were dependent on an ulterior configuration of particles, then any alteration to that internal structure would have discernible effects. The bread and wine would no longer appear as bread and wine if a real change had occurred. From a recently discovered document in the Vatican archives, it is clear that the atomism of Galileo was suspect for precisely this reason. If, following the consecration, the particles of the bread no longer remained, then, as Galileo's critic observed, no accident of the bread could remain. Substance and accident were no longer separable as the miracle of transubstantiation required.

Descartes barely admitted the difficulty. As long as the surface texture of the bread and wine remained the same, they would continue to generate the same perceptions in us. As long as the real presence of Christ was confined within those surface boundaries, the transubstantiation could occur without perceivable effects. But Descartes's critics were not so easily appeased. After all, the Council of Trent had stipulated that *all* the substance of the bread was transmuted into the body of Christ. The theologian Antoine Arnauld (1612–94) warned Descartes that the

derivation of qualities merely from extension and motion would prove impossible to reconcile with Catholic doctrine. The efforts of Claude Clerselier to promote the Cartesian reinterpretation were duly rewarded with censorship from Louis XIV and the archbishop of Paris. By September 1671 Descartes's doctrines were condemned by royal authority and by the University of Paris. Persecution was the word used by the Cartesians to describe their harassment. There was no comparable problem for Protestants, who often ridiculed the doctrine of transubstantiation as the epitome of Catholic mystification.

There was, however, another problem, which Protestants were not spared. This arose in the context of explaining what was meant by laws of nature. Despite Boyle's assurance that they were not binding upon God, that they merely reflected how He normally chose to act, there were occasions when Boyle implied otherwise. The pressure to do so came not so much from his scientific endeavors, as from a desire to say something constructive about the existence of suffering in the world. It was perhaps unreasonable, Boyle suggested, to expect God to intervene in every case when an individual was at risk. Was it not conceivable that God should subordinate the welfare of individuals to His "care of maintaining the universal system . . . and especially those catholic rules of motion and other grand laws, which He at first established among the portions of the mundane matter"? This may sound callous, but could one reasonably suppose that the deity would suspend a law of gravity just because someone fell over a cliff?

Whatever Boyle's intentions, it was possible to read into his remarks a diminution in the scope of God's particular providence. Again, for all his insistence that nature is not

autonomous, that the clockwork has an external source of power, he was driven on occasions to use a terminology that gave the impression that the Almighty had created the world and then retired. He wanted to show that a world seemingly running by itself would be just as indicative of design, if not more so, than one requiring constant attention. But his references to a “self-moving engine” could be read as an invitation to deism. In fact, that is precisely how they were read, even by as sympathetic a scholar as John Ray, before he realized his mistake and duly apologized. That initial misreading is highly instructive because it shows how a mechanical philosophy designed to uphold the sovereignty of God could so easily turn Him, and literally so, into a *deus ex machina*.

The analogy between divine activity and human voluntary action was designed to prevent that from happening. But, as employed by Boyle and Newton, it too ran into difficulties. It is perhaps a measure of the problem with which they were wrestling that they were driven to this essentially organismic analogy to explain how God could be active in a mechanical universe. The real source of apprehension, however, was located in the inferences that might be drawn if the analogy were taken too literally. Newton did sometimes seem to be saying that space *is* the sensorium of God, inviting the objection that he was regarding the physical universe as the body of God. In other words, the analogy designed to protect God’s freedom to act how He wished could be a slippery slope that led to pantheism. Newton’s critic Leibniz was uneasy for that very reason. Newton might say that God, by His presence, perceives all things; but, for Leibniz, it was more appropriate to say that God knows all things because He produces them.

Such metaphysical squabbling shows how difficult it was to construct a model for divine activity in the world. In one respect the mechanical philosophies merely reinforced an ancient paradox: how God's foreknowledge of events could be squared with human freedom. For a Christian theist like Boyle, such problems belonged to a domain of "things above reason." They constituted paradoxes that could not be resolved by single analogies. Indeed he said as much when discussing the *nature* of God. Because it comprehended all perfections in their utmost degree, it was "not like to be comprehensible by our minds." For Boyle, the failure of analogies to explicate divine activity in the world was only to be expected. But for later generations less tolerant of paradox, less tolerant of things above reason, less tolerant of a realm of grace in addition to the realm of nature, a clockwork universe demanded nothing more than an original clockmaker.

Divine Activity in Newton's Universe: A Dilemma, an Ambiguity, and an Irony

Apprehension lest a fully mechanized universe might cripple divine activity was felt by no one more keenly than Newton. His disenchantment with the cosmology of Descartes was partly due to the boldness with which the French philosopher had presumed to show how an organized solar system could develop from a disorganized distribution of matter. Newton insisted that organization could not result from disorganization without the mediation of an intelligent power. As if to defuse the deistic tendencies of Cartesian philosophy, Newton scrutinized the universe for evidence of divine involvement. As

he did so, however, he placed himself on the horns of a dilemma.

Because his voluntarist theology allowed events in nature to be explained *both* as the result of mechanism *and* of the divine will, there was a difficulty in determining what kind of event would most demonstrate divine involvement. The most spectacular evidence would surely come from extraordinary as distinct from ordinary phenomena. And yet, on a voluntarist theology, extraordinary events could still be envisaged as resulting from a divinely instituted mechanism. In which case, if a mechanism were specified for the extraordinary event, would not a skeptic say that references to divine activity are superfluous? Newton experienced this dilemma and there were respects in which his strategy proved self-defeating. By speculating, for example, on the mechanism by which God reformed the solar system, he drew attention to the role of providence in nature – but at a price. Those who did not share his religious sensibilities would look at the mechanism and see no further.

We shall consider this example in a moment, but it is necessary first to identify some of the ambiguities that arose in the interpretation of Newton's science. Because his own remarks left options open rather than closed, his references to divine activity in the world proved as rich a resource for Anglican clerics as for the deists they were attacking. Take the gravitational force itself. Though Newton had calculated how it varied with distance, he had little idea of *how* it acted. No fewer than four possibilities were explored, none of which he definitively abandoned. At times he toyed with the mechanism of an ether

consisting of the most tenuous matter, the particles of which were associated with short-range repulsive forces. At other times he revealed his Platonist heritage, seeing in the diffusion of light a model both for divine activity in the world and for gravitational phenomena. On other occasions he used a vocabulary of “active principles” drawn from an alchemical tradition. These were sources of activity in nature, associated with matter but not inherent in it. Finally, the invisibility and immateriality of the gravitational force allowed him to write as if it were a direct expression of God’s continual activity.

Newton’s dilemma arguably arose from his resolute determination to avoid a fifth possibility, a possibility vetoed by his voluntarism but having the merit of clarity – namely that the source of activity *was* inherent in matter. But because he resisted that option, and because he left open the possibility of direct divine activity, his philosophy provided succor to theists as well as deists. In a letter to the Reverend Richard Bentley, who was pumping him for advice on how to turn the latest science to theological advantage, Newton admitted the ambiguity:

Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent be material or immaterial I have left to the consideration of my readers.⁸

That different readers would draw different conclusions is clear from the remarks of two other contemporaries. William Whiston (1667–1752), who succeeded Newton in the Lucasian Chair of Mathematics at Cambridge, identified the gravitational force with the interposition of God’s “general, immechanical, immediate power.” By

contrast, the deist Anthony Collins (1676–1729) invoked Newton’s authority to declare that gravity proved the activity of matter.

In his quest for evidence of divine involvement, Newton created a God in his own image, a divine intelligence “very well skilled in mechanics and geometry.” He could do so because a gravitational force directed to the center of bodies was arguably insufficient to explain the origin of planetary orbits. A body falling toward the sun would have to acquire a transverse component of velocity if it were to go into orbit rather than fall into the sun or drift past it. Because the inverse-square law of gravitation was compatible with parabolic and hyperbolic paths, the planet’s assumption of a closed, elliptical orbit depended on its receiving exactly the right “flick” at exactly the right time. It was an exquisite calculation on the part of the deity who had to consider the “several distances of the primary planets from the sun and secondary ones from Saturn, Jupiter and the Earth, and the velocities with which these planets could revolve at those distances about those quantities of matter in central bodies.”

Newton had no difficulty, then, in arguing for the existence of an intelligent Being involved in the original creation. But a degree of ambivalence was still possible because few deists would have objected to a role for God at creation. To accept that initial role need not imply a continuing providence thereafter. And there were times when Newton seemed to hint as much. In Query 31 of the *Opticks*, after dismissing the view that the world could have arisen out of chaos by the mere laws of nature, he added that “once formed, it may continue by those laws for many ages.”

Clearly, further evidence was required if divine activity since creation was to be affirmed. Newton found it in the stability of the fixed stars. Even in an infinite universe one would expect stellar movement because it was inconceivable that the resultant gravitational force acting on every star was zero. Newton's answer to the question What hinders the fixed stars from falling upon one another? involved divine providence. But once again an ambiguity arose. Was it that God directly held them in place? Or had He the foresight to place them so far apart that any resultant force would be negligible? Newton's contemporary David Gregory opted for the former, noting that "a continual miracle is needed to prevent the Sun and fixed stars from rushing together." But Newton's conjecture that the problem might have been minimized at creation could again attenuate the argument for God's constant involvement. Newton's position has been described as one in which God had taken every precaution to minimize the destabilizing forces and yet had willed a world in which His intervention would also be required. There was no contradiction in such a view, but it smacked of an ambivalence that was always liable to be resolved in favor of divine foresight rather than divine intervention. For, as Leibniz objected, if God had to remedy the defects of His creation, this was surely to demean His craftsmanship.

That objection was directed toward Newton's belief that the solar system would require an occasional "reformation." If the planets were moving through an ether, however tenuous, they would surely be retarded by friction. Motion, in Newton's memorable phrase, was more apt to be lost than got. The intrusion of foreign bodies into the system could induce irregularity, pulling

on any planet that might be in their vicinity. The sun, too, might lose mass through vaporization. The long-term security of the system needed a safeguard in the shape of divine providence. Without it, planets would stray or implode into the sun. But what provision had providence made? The same dilemma remained. Was this reformation achieved by direct fiat? Or was there a divinely controlled mechanism? The former might be the more spectacular, if the effects were visible. But, in a letter to Thomas Burnet, Newton had stated that “where natural causes are at hand God uses them as instruments.” And Newton believed there were such causes at hand in the shape of comets. The irony is that, once a natural cause was found, the exponents of a thoroughgoing naturalism could claim it as an argument for dispensing with providence.

There is a popular view that, by reducing the paths of comets to regular laws, Newton divested them of religious significance. Formerly signs of divine displeasure, portents of catastrophe, they were stripped of that superstitious gloss once their return could be predicted. In fact, Newton reinvested comets with religious significance when they were already losing it. In 1683, four years before Newton’s great book, the *Principia*, was published, the Congregational minister Nathaniel Mather wrote to his brother Increase in a manner that shows that divines were already questioning a former superstition. Of comets, Nathaniel wrote they “do no more portend than eclipses, and eclipses no more than the constant conjunctions of the sun and moon, that is, just nothing at all, save only as they may be natural causes of alteration of air or weather.” He did not deny that they were symbols of God’s power, as

were thunder and lightning. But no way were they “teachers from God to ourselves.”

Newton reinvested comets with religious significance precisely because they were instruments of providence. Matter from their tails could replenish matter lost by planets, as he suggested in the first edition of *Principia*, or by the sun, as he suggested in the second. The comet would lose its matter through gravitational attraction as it passed close to the sun. Accordingly, “fixed stars, that have been gradually wasted by the light and vapors emitted from them for a long time, may be recruited by comets that fall upon them.” The masses of suns and planets could be kept in balance, the orbits of the latter preserved.

With hindsight, Newton’s strategy is apt to appear self-defeating. If comets fulfilled this ulterior purpose in a synchronized manner, was there any point, from the standpoint of natural philosophy, in trying to distinguish between ordinary and extraordinary providence? Could not the latter always be subsumed under the former? Were the reformations not, as it were, preprogrammed? For those who thought that a natural mechanism was sufficient, Newton had supplied it. By stressing periodic reformation Newton also invited the inference that a series of earths may have arisen, each from the ruins of its predecessor. If the processes of decay and reformation were cyclic, *might* they have been in operation from eternity? Hence the paradox and the irony, for it had been the fear of such a notion that had prompted Newton to underline a continuing providence. By the end of the eighteenth century there would be an additional irony when the French mathematicians Laplace and Lagrange showed that irregularities induced in planetary orbits could be self-correcting.

That did not have to mean that the universe was any less the work of design, but it was an embarrassing exposé of what could go wrong when a religious apologia was rooted in fallible science.

To that later generation of French secularists, Newton's religious interests were essentially pathological. Even today, one sometimes encounters surprise that the man who laid the foundations of classical mechanics could have been so absorbed by biblical prophecy and the religious dimensions of alchemy. In his historical studies he did have prejudices that, if not idiosyncratic, were certainly lagging behind contemporary scholarship. The notion, for example, that any pagan civilization might have preceded the Jewish was anathema to him. Greek, Latin, Egyptian, and Persian chroniclers had "made their first kings a little older than the truth." But Newton was not schizophrenic. The rationalism characteristic of his scientific work was not so much *deflected* as *reflected* in his biblical studies. The same mind that set up rules for interpreting nature did the same for the correct interpretation of Scripture. With supreme self-assurance, he hoped to eliminate disputation both in natural philosophy and in biblical exegesis by achieving definitive truth. The existence of competing, speculative hypotheses was a symptom as distressing in natural philosophy as the existence of idolatrous deviation from a true, original monotheism in religion.

Newton formalized no fewer than fifteen rules for biblical interpretation. Just as one paid attention to the analogy and uniformity of nature, so one respected the analogy of prophetic style. A prophetic symbol such as the "beast" of the Apocalypse always signified a kingdom or

similar body politic. Just as one sought certainty in the mathematization of nature, so one should choose interpretations of Scripture that converged on a unique and literal meaning. Just as, in debate with Leibniz, Newton would invoke a principle of simplicity to eliminate subtle matter from the heavens, so he insisted that constructions placed on Scripture were to reduce matters to the greatest simplicity. In his ninth rule, he drew the parallel himself: “It is the perfection of all God’s works that they are done with the greatest simplicity And therefore as they that would understand the frame of the world must endeavour to reduce their knowledge to all possible simplicity, so it must be in seeking to understand these visions.”

If one is looking for Newton the rationalist, one can still find him. He is visible in the manner with which angels, spirits, and devils were treated in his biblical study. There was a certain reductionism in his reading whereby the “cherubim” and “seraphim” became hieroglyphs of ordinary social groups. Evil spirits became mental disorders, and devils became the imaginary ghosts of the departed. In his treatment of the six days of Genesis, a certain rationalism intruded. But – and this is crucially important – it was directed toward the protection of a literal, not a figurative, meaning. The first two days could be made as long as one wished – if the earth had not yet begun its rotation! The mechanization of nature may have given the sciences a higher profile in theological debate, but it would be quite wrong to imagine that God had yet been ousted from His universe. For Newton’s successor, William Whiston, it was a matter of great excitement when he realized that the

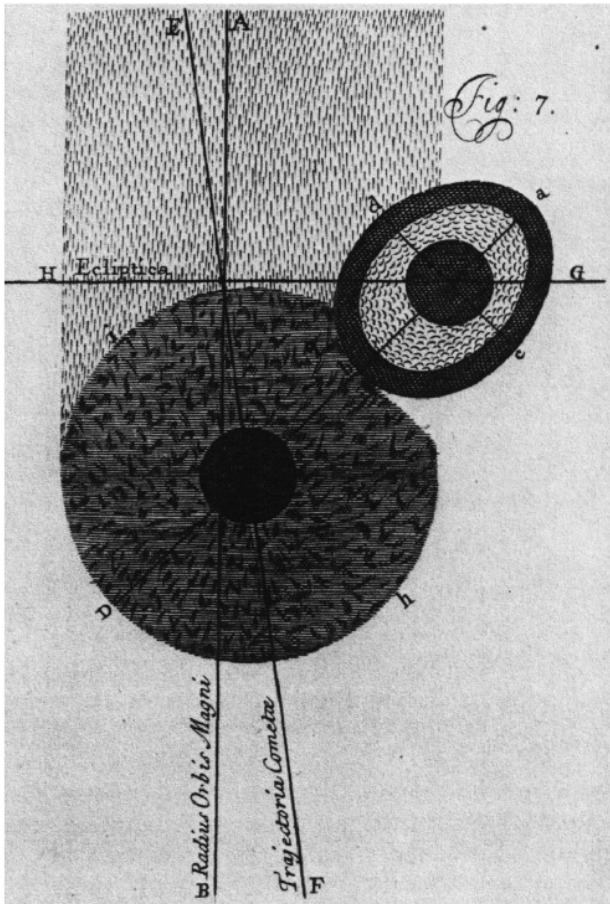


FIGURE IV.4. Figure 7 from William Whiston's *New theory of the earth* (1696). Whiston proposed that, at the time of Noah, gravitational attraction between a passing comet and the earth had resulted in deformation of the latter, with a consequent cracking of its surface crust. Material from the comet's tail had then rained down. As in the scheme of Thomas Burnet, however, subterranean fluid also poured up through the cracks in keeping with the description that "the fountains of the deep burst forth." Reproduced by permission of the Syndics of Cambridge University Library.

Genesis flood could be confirmed by retrospective calculations showing that a particular comet, actually seen by himself, would have been in the right place at the right time to have triggered it.