Creation, Contingency, and Early Modern Science: The Impact of Voluntarist Theology on Seventeenth-Century Natural Philosophy

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CREATION, CONTINGENCY, AND EARLY MODERN SCIENCE:
THE IMPACT OF VOLUNTARISTIC THEOLOGY ON
SEVENTEENTH CENTURY NATURAL PHILOSOPHY

An essay in the history of scientific ideas

Edward Bradford Davis, Junior

Submitted to the faculty of the Graduate School
in partial fulfillment of the requirements
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Gerald Strauss

Frederick Churchill

20 August 1984
To Kathy and Katie
Like many other historians of science, I began my undergraduate education as a science major—physics, in my case—and subsequently discovered that the conceptual development of my field was more interesting to me than the current state of research. Uncertain about my future career plans, I taught secondary science and mathematics for a few years. During this time my interest in the history of science continued to grow, and the interaction between science and religion became the primary focus of that interest. With the advice and encouragement of Professor Richard Rosen, who had first exposed me to the history of science at Drexel, I decided to pursue a graduate degree in the Department of History and Philosophy of Science at Indiana University.

I have never regretted that decision. The faculty at Indiana grounded me solidly in the history and historiography of science, raised my sights, corrected some of my deficiencies, and tolerated my idiosyncrasies. Without their patience and expertise, my life would be far poorer today. I would like to thank them for supporting my first year of study with an Indiana University Fellowship, without which I could not have embarked on what has been for me a great adventure.

Any list of contributors to this dissertation must
begin with Richard S. Westfall, who took to heart the responsibilities he assumed in accepting me as a student. His books and lectures on the personalities, ideas, and institutions of the scientific revolution have been a powerful influence on my own understanding of that period. His expert guidance, constant encouragement, and profound literary instincts have helped this project come to fruition. If he had done half as much for me, he would have done more than enough.

Other members of my doctoral committee have also contributed to this project. Edward Grant, whose familiarity with medieval science is second to none, steered me through the deep waters of Aristotelian natural philosophy after the Condemnation of 1277. Gerald Strauss lent his considerable expertise in religious history and, going well beyond the call of duty, intelligently criticized each chapter as it was written. And Frederick Churchill, more than anyone else, taught me the meaning of historiography. Noretta Koertge, though not a member of my committee, helped me revise my dissertation proposal and was always happy to talk about my research. Another "outsider," James S. Preuss, read drafts of three chapters.

For roughly a generation, historians of science have witnessed a debate within their discipline between "internalist" and "externalist" approaches to historiographical issues. No doubt some will describe this
dissertation as "internalist" because I argue from the
perspective of intellectual history, while others will call
my work "externalist" because I look "outside" of science,
to theology, for an ultimate explanation. Though I do not
object to these labels per se, I reject the debate with
which they are associated--I have no reason to assume that
the one kind of explanation is intrinsically better than
the other. I would prefer that this work, and all others,
be judged on its own merits and deficiencies, without
regard to such historiographical biases. Several scholars
have evaluated some of my ideas in this spirit, and I would
like to acknowledge them here: Dwight Bozeman, William J.
Courtenay, Gary Deason, Richard Greaves, and David C.
Lindberg. Margaret J. Osler, whose work closely parallels
my own, has been gracious and helpful. Because she has
written so thoroughly about Gassendi and Charleton, I did
not include them in my project. Her work on Descartes is
just as good, but does not make my own work superfluous.

A project of this magnitude could not have been
completed without the assistance of cooperative and
knowledgeable librarians. The staff of the reference desk
at the Indiana University Library and their colleagues in
the rare book room of the Lilly Library all meet this
description. They have been, at all times, courteous and
thoroughly professional. Barbara Halporn deserves special
mention for promptly purchasing several dissertations at my
request.

In recent years the history of science, like other areas in the humanities, has suffered from a sharp decline in the amount of funds available to support research. The appearance of any new sources of support is therefore all the more significant. In 1980 the Charlotte W. Newcombe Foundation began to fund dissertations dealing with the influence of religious values on society. I would like to commend the Newcombe Foundation for viewing science as a part of society and for making grants to graduate students in the history of science. As a recipient of a Dissertation Year Fellowship for 1983-84, I would like personally to acknowledge their generous support, without which the completion of this dissertation would have been greatly delayed.

Finally I want to thank my wife, Kathy, whose emotional and financial support made it possible for me to spend five years in Bloomington working toward a goal which often seemed elusive and distant. I owe her a debt far too great to be repaid simply by dedicating this essay, with love, to her.

Bloomington, IN
30 July 1984
Could God have made it true that $2 + 2 = 5$? Was he bound to make the best of all possible worlds? Is he able at this moment to alter the course of nature, either in whole or in part? Questions like these are often associated with medieval theology, not with early modern science. But science is done by people, and people have not always practiced the rigorous separation of science and theology that has come to characterize the modern world. Although many 17th century scientists sought validity for their work apart from revelation, divorcing science from religion was something they never intended. Indeed most natural philosophers of the scientific revolution assumed without question that the world and the human mind had been created by God. This was no small admission, for it meant that both the manner in which and the degree to which the world could be understood depended upon how God had acted in creating it and how he continued to act in sustaining it. Fifty years ago the late British philosopher M.B. Foster identified two different theologies of creation which differ profoundly in their implications for natural science. Rationalist theology, which assigns to God the activity of pure reason, "involves both a rationalist
philosophy of nature and a rationalist theory of knowledge of nature." Voluntarist theology, which "attributes to God an activity of will not wholly determined by reason," implies that the products of his creative activity are contingent and can be known only empirically. By a careful analysis of four natural philosophies of the early modern period--those of Galileo, Descartes, Boyle, and Newton--I intend to show that there was indeed a connection between theological voluntarism and empirical science in the 17th century.
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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BJHS</td>
<td>British Journal for the History of Science</td>
</tr>
<tr>
<td>DNB</td>
<td>Dictionary of National Biography</td>
</tr>
<tr>
<td>JHI</td>
<td>Journal of the History of Ideas</td>
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<tr>
<td>SHPS</td>
<td>Studies in History and Philosophy of Science</td>
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<td>ULC</td>
<td>University Library, Cambridge</td>
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INTRODUCTION:
TESTING THE FOSTER THESIS

Creative activity in God, material substance in nature, empirical methods in natural science—how closely each of these involves the other is made clear by an examination of almost any of the great philosophies of the modern period. A defect in the philosophical conception of God is reflected in corresponding defects both in the doctrine of nature and in the theory of natural science. Thus it is a mark of the philosophy of the Rationalist tradition that it is unable wholly to digest the un-Greek element in the Christian theology according to which God is endowed with a voluntary activity in the creation of the world.

--Michael B. Foster, *Mind* 43 (1934), pp. 465f

The one God, the first and only Deity, both Creator and Lord of all, had nothing coeval with Himself, not infinite chaos, nor measureless water or solid earth, nor dense air, nor warm fire, nor refined spirit, nor the azure canopy of the stupendous firmament. But He was One, alone in Himself. By an exercise of His will He created things that are, which antecedently had no existence, except that He willed to make them.

--Hippolytus, *The Refutation of All Heresies* (ca. 230 AD)

[With regard to omnipotence,] the doctrine of Moses differed from that of Plato and of all the Greeks who have correctly approached the study of Nature. For Moses, God has only to will to bring matter into order, and matter is ordered immediately. We do not think that way; we say that certain things are impossible by nature and these God does not even attempt; he only chooses the best among the things that come about.

--Galen, *On the Uses of the Parts* xi, 14 (ca. 190 AD)
 "The relation of science to religion in the seventeenth century," writes Richard S. Westfall, is "the central problem in the history of modern Western thought." With this bold assertion I cannot but concur, yet I must reject the terms in which it is couched. To be sure, the impact of science on religion in the seventeenth century was significant, as Westfall himself has documented so well, yet religion, not science, held the dominant position in seventeenth century Europe. The implied question ought to be turned around: What was the relation of religion to science in the seventeenth century?

Sociological aspects of this question have been the subject of a great body of scholarly research, much of it devoted to the influence of Puritanism on scientific activity in England. A survey of this work—even a survey of surveys—would consume far too much space to justify its inclusion here and, in fact, would lead us away from the issue I intend to explore. Suffice it to say that the relation of religion to science, when understood in social, economic, and political terms, remains unclear, perhaps due to the sheer weight of the evidence which needs to be explained. The definitive account, if such is possible,

1. This remark is found in the preface to the second (1973) edition of Science and Religion in Seventeenth-Century England (New Haven: Yale UP), which was first published in 1958.
The relation of religion to science can also be approached from the standpoint of intellectual history; though religion and science are a great deal more than systems of thought, they are not less. Edwin Arthur Burtt and Alexandre Koyré, those distinguished students of the history of ideas, both showed that early modern science contained a non-trivial metaphysical dimension which often rested explicitly on a strong theological base. As Koyré


once put it, "The God of a philosopher and his world are correlated." Most natural philosophers of the early modern period believed without question that the world and the human mind had been created by the omnipotent God of the Judeo-Christian tradition. For them, both the manner in which and the degree to which the universe could be understood depended on how God had acted in creating it and how he continued to act in sustaining it, profound theological questions indeed. Over the centuries Christian theologians, though reaching a consensus on the reality and goodness of the creation, have differed widely on the precise nature of the created order. The spectrum of views is bounded at one end by the Greek notion of intelligibility via participation in pre-existing archetypal forms and, at the other end, by the biblical notion of the inscrutability of God's arbitrary acts. Thus the Christian doctrine of creation is a dialectic between God's unconstrained will, which utterly transcends the bounds of human comprehension, and God's orderly intellect, which serves as the model for the human mind. This is commonly referred to as the distinction between the

4. From the Closed World to the Infinite Universe, p. 100.

absolute and the ordinary power of God. Individual thinkers typically acknowledge that God has both will and reason, but usually emphasize one at the expense of the other. The question I wish to explore in this essay is inspired by this dialectic: Within the thought of an individual seventeenth century natural philosopher, is there a link between his theology of creation and his philosophy of nature?

Fifty years ago the late British philosopher Michael B. Foster undertook a detailed investigation of the implications of Christian theology for the enterprise of natural science. Among his many claims, some more plausible than others, Foster argued that "the method of natural science depends upon the presuppositions which are held about nature, and the presuppositions about nature [depend] in turn upon the doctrine of God." Foster identified two basic attitudes toward God which, he argued, differ substantially in their implications for scientific methodology. Rationalist theology "is the doctrine that the activity of God is an activity of reason." Since "God

6. William J. Courtenay's forthcoming essay on "The Dialectic of Divine Omnipotence" traces the origin of this distinction to a treatise written in 1067 by Peter Damian. I am grateful to Professor Courtenay for kindly allowing me to see this paper before publication.

is nothing but reason, there is nothing mysterious or inscrutable in his nature." Such a theology, Foster said, "involves both a rationalist philosophy of nature and a rationalist theory of knowledge of nature." As a product of divine reason, the world must embody the ideas of that reason; and "our own reason, in disclosing to us God's ideas, will at the same time reveal to us the essential nature of the created world." A voluntarist theology, on the other hand, "attributes to God an activity of will not wholly determined by reason." The products of his creative activity are thus not necessary, but contingent, and can be known only empirically. This alleged connection between voluntaristic theology and empirical science is what I intend to consider in this essay.

Foster was not an historian of science, but a Christian philosopher with an apologetic aim: those many contemporary thinkers who admire modern science also ought to admire its source, Christian theology. In this respect, of course, Foster was not particularly original—Duhem had said much the same thing forty years before. I have no intention of following their line; it is history, not apologetics, that I have in mind, and this brings me to the most serious problem in Foster's work, his lack of

historical documentation. Although he went a long way toward showing what a consistently pursued theology of creation ought to have entailed for natural philosophy, he did very little to show that this had actually been the case historically. However, other scholars with a greater sensitivity to history have laid the groundwork for an historiography that incorporates Foster’s essential insights. Foremost among these are Reijer Hooykaas, Eugene Klaaren, J.E. McGuire, Francis Oakley, and Margaret J. Osler. Considered individually, their studies generally lack the scope and detail required for an adequate test of the Foster thesis. Only Osler has looked closely at more than one person, and her excellent work on the foundations of the mechanical philosophy has by no means exhausted the

9. This is one of many objections raised by Rolf Gruner, "Science, Nature, and Christianity," Journal of Theological Studies 26 (1975), 55-81. This is not the place to refute Gruner’s arguments, many of which are valid but have no bearing on the validity of this essay.

subject. Oakley and Hooykaas have managed to cover a wide range of figures, but only summarily: Hooykaas, for instance, devotes less than twenty pages to voluntaristic elements in the works of Kepler, Galileo, Descartes, Pascal, Boyle, Newton, and several others. Klaaren, on the other hand, focuses almost exclusively on two men, Van Helmont and Boyle, one of whom (Van Helmont) was neither a voluntarist nor a rationalist, and his account of Boyle is marred by imprecise language and a convoluted argument. I am unable to say what it is that he intended to prove. McGuire's paper on Boyle is quite clear, but it confines itself almost entirely to just two of his many treatises, the *Free Inquiry into the Vulgarly Received Notion of Nature* and *The Christian Virtuoso*.

Taken together, however, these scholars have demonstrated the explanatory power of the Foster thesis as applied to early modern science. Without their successes, this dissertation probably would not have been contemplated and certainly would not have been completed. With their

11. Klaaren says (p. 1) that his "chief purpose" is "to show that religion was conducive to the advent of modern science, specifically that belief in creation was a major presupposition in the emergence of natural science in seventeenth-century England." I do not know how to take this. One hardly needs to prove that belief in creation was a major presupposition of 17th century English scientists—it can be taken almost as axiomatic. And I do not see how studying Van Helmont can have anything to tell us about English scientists. Klaaren seems to have more than this on his mind, but I am at a loss to say what that may be.
help, I will now clarify further the issue I intend to discuss in this essay.

It will be important always to keep in mind the dialectic nature of Christian theology, according to which God has both will and reason, not just will or reason. To assert the one to the exclusion of the other would be an error. As Foster put it, "It is Christian to ascribe to God an activity of will, but it is not Christian to deny to God a theoretical activity or to ascribe to him a blind activity of will." Thus the doctrine of creation implies "that the created world must contain an element of contingency, not that it must be nothing but contingent."12

Thinkers in the voluntarist tradition, McGuire has observed, "do not usually deny that God is bound by the laws of logic; rather they are concerned to emphasize the power of God--PANTOKRATOR--and the inscrutability of Divine Will."13 Both voluntarists and rationalists agree that the world is created and intelligible; they differ on the role of the divine will in creation and on the manner in which the world is intelligible. For rationalists, God's will is bound to the dictates of his reason, and therefore the world is open to human reason at every point, for human reason is the image of the divine. Voluntarists, on the other hand, begin by stressing God's absolute power to do

as he pleases, apart from any rational constraints, and account for intelligibility by appealing to God's ordained power. This view, in the words of Oakley and Daniel O'Connor, "rejects an a priori deduction of rational and necessary order." It claims instead "only a de facto intelligibility directly dependent on the Divine Will." Hooykaas has argued similarly: "the biblical conception of a world fabricated and created by a free act of [the] will of God implies a science subject to data and facta, things given and things made, whether they are rational or not." Theology and science, he has also said, "have a common enemy in philosophical rationalism, which refuses to accept things it cannot explain."

I therefore propose to test the validity of these ideas, which for simplicity I will refer to as the "Foster thesis," by a careful examination of four great natural philosophers of the seventeenth century: Galileo Galilei, René Descartes, Robert Boyle, and Isaac Newton. Both pragmatic and methodological reasons led me to select this particular group and not another. First of all, because each one played a leading role in what is often called the scientific revolution, they constitute a stiff test for the Foster thesis; if it has no validity for them, it probably


has no validity for others in the same period. Because they were important figures, their works are readily available, either separately (Newton) or in essentially complete collected editions (the others). Boyle wrote entirely in English, and most of the treatises of the others have been translated reliably into English. Although I have consulted the original languages to check key passages, I have done most of my reading in various translations. The secondary literature on each of these figures is enormous—one could easily read for twenty years and not digest the half of it. Fortunately only a fraction centers on science-religion issues, and only a fraction of that on the question I have in mind. Of course I have had to become familiar with the salient features of the vast scholarship devoted to each of these men and to the social and intellectual contexts in which they worked. Secondly, the four men I have chosen represent a cross section, albeit a limited one, of the seventeenth century scientific community: one Italian, one Frenchman, and two Englishmen; two Catholics and two Protestants; two physicists, one chemist, and one philosopher with a strong interest in biology; two who spent time as university professors and two who did not; and, in terms of this study, two rationalists and two voluntarists. Together they span the seventeenth century both chronologically and symbolically. Certainly a larger group would make a better test of the Foster thesis, but time has not allowed me that luxury—
'Tis better to do a little with certainty (I hope) and leave the rest for others. I would like to have included a Catholic voluntarist such as Pascal, Gassendi, or Malebranche, and a Protestant rationalist such as Leibniz (who does in fact put in an appearance in connection with Newton), since the group I have selected suggests misleadingly that voluntarists were English Protestants and rationalists were Continental Catholics. It is true that voluntarism is an outstanding feature of the Augustinian tradition, on which Protestants drew perhaps more freely than Catholics. It is also true that it was especially attractive to the English—just as a voluntarist God had the power to reorder his creation in whole or in part, so the English strove to reorder their society into a new creation. But neither the Protestants nor the English had a monopoly on the will of God and the doctrine of creation. All of Christendom shared in the rich inheritance of Greek philosophy and biblical theology which flowed together in the deep river of Christian thought.

A full history of voluntarism, then, requires a full history of the doctrine of creation. Obviously that is

impossible for me to attempt here. However I do need to say something about the tension between rationalism and voluntarism in the late Middle Ages following the Condemnation of 1277, for only in light of its historical background can we accurately weigh the influence of voluntarism on the scientific revolution. In the first chapter therefore I summarize the Condemnation and its effects on late medieval natural philosophy. In the next four chapters I consider in detail the role of divine will in the natural philosophies of Galileo, Descartes, Boyle, and Newton. In the conclusion I offer my assessment of the impact of voluntaristic theology on seventeenth century natural philosophy.

CHAPTER ONE:

THE CONDEMNATION OF 1277:

NOMINALISM AND VOLUNTARISM IN THE LATE MIDDLE AGES

Of course, what really mattered to Tempier was only the full recognition of the sovereignty and freedom of God, but in rejecting any limits to these, he unintentionally took away limitations to scientific theorizing as well. Not only the theology of necessity was at stake, but also the natural science of necessity. Among the theses he condemned were those that suggested that God could not make an empty space; that He could not create new species; that He could not make more than one planetary system, and that He could not give other than circular motions to the heavenly bodies. All these prohibitions hampered the freedom of scientific research; all of them in the long run turned out to be false.

--R. Hooykaas, Religion and the Rise of Modern Science, p. 32

The nominalists were not, therefore, abandoning the Greek notion of "science"; they were setting more realistic limits to its applicability. But one can see here the beginning of a new realization: if "science" is to be the best attainable knowledge of some domain, then the "science" of nature cannot be described in the traditional Euclidean terms. This will ultimately involve a modification in the notion of science itself. But the nominalists were not yet ready to make this modification. "Science" in the sense of unchanging necessary truths still seemed to them the goal of man's desire to know; the fact that he could not know nature in this way was simply an unhappy circumstance. So Buridan would say, characteristically: there is no true "science" of nature; not: there is a "science" of nature, but it has to be differently defined qua "science."

On 7 March 1277, exactly three years after the death of Thomas Aquinas, the bishop of Paris, Stephen Tempier, condemned on pain of excommunication "certain obvious and loathsome errors" circulating at the university entrusted to his care.¹ The "outcome of doctrinal, philosophical, and personal animosities that rocked Paris in the 1260s and 1270s,"² this condemnation of 219 propositions has been called "the central event" of thirteenth century thought because of its far reaching effects on the philosophy, theology, and natural science of the late middle ages.³ Because it represents the assertion of divine freedom against the staunch rationalism of Aristotelian thought, it is worth investigating why the Condemnation of 1277 took place and how it influenced the subsequent development of

1. The text of the condemnation can be readily found in P. Mandonnet, O.P., Siger of Brabant et l'averroïsme latin au XIIIème siècle, 2me partie, Textes inédits (2nd ed: Louvain, 1908), pp. 175-191. Mandonnet has arranged the prohibited theses into categories; his edition is the basis for the English translation by Ernest L. Fortin and Peter D. O'Neill, found in Ralph Lerner and Mushin Mahdi, editors, Medieval Political Philosophy: A Sourcebook (Toronto: The Free Press of Glencoe, 1963), pp. 335-354. All of my citations are from this translation, but I have numbered the propositions as they were ordered in the Latin original. The fact that Aquinas died on 7 March 1274 is noted by R. Hooykaas, "Science and Theology in the Middle Ages," Free University Quarterly, 3 (1954), p. 89.


natural philosophy.

Christianity has always been openly cautious, if not deeply suspicious, of pagan philosophy. Most Christian theologians have agreed with Clement of Alexandria that philosophy is best treated as a handmaiden to theology, not as a noblewoman worthy of praise in her own right. This was particularly true of the first millennium of Christian thought. For seven hundred years after the fall of Rome, theology's claim to the throne of knowledge was unchallenged, her reign as queen of the sciences unbroken. Philosophy, impoverished by the loss of her ancient treasures in the Latin West, could do no more than give passive obedience to her lord. Even in the early universities—Paris, Oxford, and Bologna all flourished before 1200—the arts faculties were geared exclusively to the preparation of students for higher studies in law, medicine and, above all, theology. In keeping with this aim, the curriculum emphasized grammar and logic, not philosophy, and the theologians, "themselves not greatly interested in philosophy," were determined "to keep the masters of arts within the fixed bounds of their province. Their function was, in the phrase of Van Steenberghen, to train the mind, not to feed it or fill it."4

The same years which saw the rise of the first

universities also witnessed the recovery of a significant part of Greek science and philosophy: works which had been unknown in the Latin West for nearly a thousand years began to reach European scholars from their counterparts in the Islamic empire.\(^5\) Of all the manuscripts which appeared at this time, the most important were the scientific books of Aristotle, the greatest natural philosopher before the scientific revolution. His systematic synthesis of scientific thought and common sense observation possessed remarkable explanatory power and depth of insight. Its impact on the arts masters was nothing short of spectacular--here was a body of knowledge which cried out for attention, which deserved to be studied for its own sake. Alas, Aristotle had been a pagan, a fact which had affected his works and which Christians dared not forget. His uncompromising assumption of naturalistic determinism was unacceptable, and his opinions on certain matters, if adopted by believers, would surely lead them to perdition.\(^6\)

In the face of such a challenge to their authority, theologians could only be expected to react with severe


\(^6\) For example, Aristotle had taught the eternity of the world, the total regularity of nature and the impossibility of miracles, and that the soul does not survive the body. And his rejection of the Platonic notions of form and creation in time implied that God could not have known all species of things that he would eventually create. See Edward Grant, *Physical Science in the Middle Ages* (New York: John Wiley & Sons, 1971), p. 24.
disapproval. A series of official decrees beginning in 1210 stirred the smoldering embers of disagreement, which burst in 1267 into the open flame of confrontation. Addressing a convocation of monks at Paris, St. Bonaventure decried the dangers of a new paganism and denounced those arts masters who taught the eternity of the world, the unicity of the human intellect, and the mortality of the soul. The latter two points were also the target of St. Thomas Aquinas' 1270 treatise *On the Unicity of the Intellect against the Averroists*, in which he attacked those philosophers who presumed to discuss theological matters and showed his annoyance with those who held that reason could affirm one truth while theology affirmed another. Then on 10 December of the same year, Tempier officially "condemned and excommunicated with all who taught or asserted . . . knowingly" thirteen articles as follows:  

1. That the intellect of all men is one and the same in number.
2. That this is false or inappropriate: Man understands.
3. That the will of man wills or chooses from necessity.
4. That all things which are done here below depend upon the necessity of the celestial bodies.
5. That the world is eternal.
6. That there never was a first man.
7. That the soul, which is the form of man as a human being, is corrupted when the body is corrupted.
8. That the soul separated from death does not suffer

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7. The original document is in *Chartularium universitatis Parisiensis* I, 486f; the translation here is that of Lynn Thorndike, *University Records*, pp. 80f.
from corporeal fire.
9. That free will is a passive power, not active; and that it is moved necessarily by appetite.
10. That God does not know things in particular.
11. That God does not know other things than Himself.
12. That human actions are not ruled by divine Providence.
13. That God cannot give immortality or incorruptibility to a corruptible or mortal thing.

Four of these propositions (numbers 1, 5, 6, and 8) are found in treatises by Siger of Brabant, a radical Aristotelian. The others are not directly attributable to Siger or to anyone else, but we may assume their currency in the arts faculty on other grounds.

Yet the Condemnation of 1270 was apparently not enough to silence the radical Aristotelians, or there would have been no need for further action against them. On 1 April 1272 the conservatives, under Alberic of Rheims, passed a

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9. At around this time--perhaps in 1270, but not later than 1276--Giles of Lessines sent a letter to Albertus Magnus in which he listed fifteen theses then being held by arts masters at Paris; all thirteen of the above are included. See Wippel, pp. 182-183. The treatise _Errores philosophorum_, by Giles of Rome, dates from the same period. A member of the Order of the Hermits of St. Augustine, Giles studied under Aquinas at Paris from 1269 to 1272. _Errores philosophorum_ catalogues the various "errors" of Aristotle, Avicenna, Averroes, Algazel, Alkindi, and Maimonides, and castigates those Christians who held the erroneous views. Josef Koch's edition of the text is published with John O. Reidl's translation in _Errores philosophorum_ (Milwaukee: Marquette University Press, 1944); a translation by Herman Shapiro appears on pp. 386-413 of his _Medieval Philosophy_ (New York: Random House, 1964).
regulation forbidding arts masters to treat theological questions. The following year Bonaventure saw fit to repeat his attacks on the followers of Aristotle and the Peripatetics in his Easter Collationes in Hexaemeron. A university decree of 2 September 1276 prohibited all private teaching except for logic and grammar, a move which prevented any rebellious masters from promulgating heretical doctrines in secret. Less than three months later, on 23 November, Siger and two of his colleagues, Bernier of Nivelles and Gosvin de La Chapelle, were called before the French office of the Inquisition to answer charges of heresy, of which they were subsequently convicted. Someone must have informed the new pope, John XXI, of the dangerous ideas circulating at Paris, for on 18 January 1277 he ordered Stephen Tempier to investigate certain errors and to make a report. Rarely has a command been executed with greater zeal. Assembling a committee of sixteen theologians, Tempier orchestrated the identification and wholesale condemnation of 219 propositions on 7 March. Ten days later in a related event, the Archbishop of Canterbury, Robert Kilwardby, condemned 30 propositions circulating at Oxford. Although there is no evidence that the Holy Father saw Tempier's decree before it was issued—indeed on 28 April he wrote to him, asking for the names of those perpetrating errors but

10. See Chartularium I, 499f, and Thornkike, University Records, pp. 85f.
making no mention of the condemnation itself—there can be little doubt that it pleased him, for he never made any attempt to revoke the decree or to limit its force. All the evidence points to a hasty job. Allowing time for Tempier to receive the papal letter and to gather around him a sizeable group of men, not more than four weeks could have been devoted to the preparation of the document. The prohibited articles were not listed in a logical order, they contained both repetitions and contradictions, and they included some perfectly orthodox opinions, among them several upheld by Aquinas.11 The fact that 7 March was the anniversary of Thomas' death has already been mentioned. Surely this was no coincidence; Thomas had not endeared himself to Bonaventure and his followers, who were only too anxious to heap coals on the memory of the Angelic Doctor. As Peckham understood it, Thomas' system "despises the doctrines of the Fathers and bases itself almost completely on the doctrines of philosophers, so that the house of God is filled with idols."12

But Aquinas was not the main target. The Condemnation of 1277 was "the brutal resolution of a crisis whose first symptoms had been manifest since the first years of the

11. Some of these are identified by Armand A. Maurer, Medieval Philosophy (New York: Random House, 1962), p. 206. One such proposition was that the action of the will naturally follows upon the judgment the of reason.

century: the crisis of the Christian intelligence, shaken by the wholesale invasion of pagan learning."13 It was Aristotle and his Arabian commentators who had shaken the Christian intelligence, and it was they who received the full brunt of the blow. Both the content and the spirit of profane philosophy were directly impugned. Each of the thirteen articles condemned in 1270 was condemned again, in one form or another, and many other opinions met the same fate. Some propositions were clearly counter to Christian doctrine14: others encouraged immorality or denied its consequences.15 Several propositions betray a bitter professional rivalry between the theologians and the arts masters16, a situation clearly evident in these statements from Boethius of Dacia, one of those targeted by the Condemnation: "It is easier for the philosopher to be virtuous than anyone else": "When a man is engaged in [philosophical] activity he is in the best state possible

13. Van Steenberghen, p. 103.

14. Number 1: "That God is not triune . . ."; number 189: "That creation is not possible, even though the contrary must be held according to faith."

15. Number 183: "That simple fornication, namely, that of an unmarried man with an unmarried woman, is not a sin"; number 178: "That death is the end of all terrors.--The statement is erroneous if it excludes the terror of hell, which is the last"; number 19: "That the separated soul in no way suffers from fire."

16. Number 40: "That there is no more excellent state than to study philosophy"; number 154: "That the only wise men are philosophers"; number 152: "That the teachings of the theologian are based on fables"; number 153: "That one does not know anything more by the fact that he knows theology."
The preface of the decree explicitly banned the licentious book *De deo amoris* by one Andre le Chapelain, a work on geomancy by an unnamed author, and other occult writings. Some sharp words were reserved for those who held the doctrine of the double truth. But above all, the Condemnation of 1277 was a declaration of God's absolute free will to do as he pleases, apart from rational and physical necessity. As Hooykaas has observed, the Parisian theologians were defending the "core of religion, namely, that creation depends on God and not God on creation." "That God of necessity makes whatever comes immediately from Him" (number 53); "That God cannot be the cause of a newly-made thing and cannot produce anything new" (number 48); "That what is impossible absolutely speaking cannot be brought about by God or by another agent" (number 147)—these and propositions like them were banned because they placed limitations on God's power or subjected His will to some external requirement. Such a step was wholly in keeping with the emphasis on voluntarism in Augustinian theology.

Tempier's decree had several significant effects, but the most important was that medieval philosophy reaped a

17. Quoted by Maurer, p. 204.


harvest of nominalism, which emphasized the inscrutability of the divine will and the contingency of all created things.20 William of Ockham (ca. 1285-1349), the chief representative of this movement, taught that God was not obligated to any action.21 Thus he opposed all attempts to deduce the world a priori. The knowledge that one thing exists, he said, does not allow us to infer the existence of any other thing, for there is no guarantee that ideas correspond to reality. Relations between objects can only be detected a posteriori, through the senses. Even then, we can have no certain knowledge of causal connections, for God can produce an effect in any way he pleases.22

The impact of this "radical empiricism" on medieval natural philosophy has been the subject of considerable debate by historians of science.23 Pierre Duhem, the great Catholic apologist for medieval science, saw the birth of


23. I am relying here on the excellent summary accounts in Hooykaas, "Science and Theology," pp. 78-81, and Edward Grant, "Late Medieval Thought, Copernicus, and the Scientific Revolution."
modern science in nominalism and in certain propositions
condemned in 1277, notably articles 34 ("That the first
cause cannot make more than one world") and 49 ("That God
could not move the heaven in a straight line, the reason
being that He would then leave a vacuum"). In his opinion
the Condemnation freed medieval science from its
Aristotelian prejudices and stimulated the discussion of
novel hypotheses about the physical world. Some of these
hypotheses, he argued, particularly those about the motion
of the world, fostered the development of a new mechanics
which foreshadowed the work of Galileo and his
contemporaries.24 On the other hand, Alexandre Koyré has
insisted that the only effect of the condemnation on
natural philosophy was to force the concession that God
could do things in any manner that he chose, yet natural
philosophers still seemed to assume that the world God had
chosen to make was Aristotelian.25 Thus they pursued their
studies within the traditional world picture. Reijer
Hooykaas prefers a more moderate line: "medieval theology
did not hamper the development of science," but "in some
respects it gave scope for [the] free development of
science by liberating it from philosophical constraint,"
although "it did not directly stimulate scientific

24. See volume 6 of Le système du monde (10 Vols.; Paris,
Hermann, 1913-59).

25. See "Le Vide et l'Espace Infini au XVIe Siecle,
Archives doctrinale et litteraire du Moyen Age 24 (1947),
45-91.
research."26 Who is correct? What were the actual effects of the Condemnation of 1277 on late medieval science? In an attempt to answer these questions I will briefly consider the problems of the plurality of worlds and the motion of the earth as they were discussed in the thirteenth and fourteenth centuries.

According to orthodox Aristotelian thought, there could only be one world. The arguments for this position are given in a commentary on the Sphere of Sacrobosco attributed to Michael Scot and written well before 1277.27 If another world existed, the author said, it would have to be in a place different from that of our world, but then intermediate space would exist between the two worlds, space which would not be body but which could not be void because a void is impossible. Furthermore, the elements in another world would have to be the same as those in our world; they would possess similar properties and would have the same natural motions. But this would cause confusion, for the element earth would tend to move both toward the center of our world and toward the center of the other world; hence it would both fall and rise naturally, an absurdity. Michael therefore concluded that although God could have made other worlds, he obviously had not really done so, since nature lacked the capacity to receive them.


After Tempier had condemned the proposition that God could not make more than one world, some continued to follow Michael's line of reasoning, holding that such an act on God's part, while possible in an absolute sense, would be utterly unintelligible. But others "took seriously the possibility that God could create other worlds than our own and, on the assumption that he did create them, sought to counter those of Aristotle's arguments that had previously been accepted more or less routinely." 28 In his French commentary (1377) on Aristotle's *De caelo*, Nicole Oresme admitted that "there never has been nor will there be more than one corporeal world," yet he tried to make sense of the claim that "God can and could in his omnipotence make another world besides this one or several like or unlike it." 29 Oresme allowed that this created difficulties for the idea of natural place, but instead of denying the existence of other worlds, as Michael had done, Oresme redefined "heavy" and "light" in relative terms which made no reference to natural places. A "heavy" body was said to be "down" simply when it was surrounded by "light" bodies which were said to be "up." In intercosmic void space, a body would not be surrounded by others and hence would be neither "heavy" nor "light." It would not seek to move in any direction, but would come to rest. Therefore if an

28. Ibid., p. 220.

29. Quoted in ibid., p. 223.
earthy body from our world were to rise through the sphere of the stars, it would not continue to move toward the center of another world; being neither "heavy" nor "light," it would stay in the void between the worlds. As for this void--its very impossibility one of Michael Scot's objections against the plurality of worlds--Oresme simply assumed its possibility. Robert Holkot took a stronger stance. In his *Four Books of Questions on the Sentences* he assumed that God really could make another world, in which case he could put it anywhere. But what is now in the place where God could put such a world? Either a body or nothing; if nothing, as Holkot preferred to assume, then we must conclude that a vacuum presently exists beyond the world, for God can really put something there, and any place in which a body could be but is not constitutes a vacuum. It is significant that Holkot phrased this not in the customary subjunctive mood, but in the indicative: "extra mundum nihil est, et extra mundum potest esse corpus; ergo extra mundum est vacuum, quia ubi potest esse corpus, et nullum est, ibi vacuum est. Ergo vacuum modo est." For him, the real possibility that God could create another world led to the actuality that a vacuum presently exists beyond the world. Although he did not directly refer to any condemned articles, one can hardly avoid hearing the footsteps of 1277 in Holkot's deliberate

30. Quoted in ibid., p. 224 n46.
The impact of the Condemnation is equally apparent in late medieval discussions of the possible motion of the earth, something which was impossible in Aristotelian natural philosophy for several reasons. Since every rectilinear motion was necessarily from place to place and since the last heaven had no place, the world could not be moved in a right line. But suppose that it were to be moved; how could we know it, with no stationary body for our reference point? Again, if the earth were to move, a vacuum would be left behind, since a vacuum is a place where a body could be but is not, and a vacuum is impossible. Two of the many natural philosophers who responded to these arguments in an attempt to make the earth's possible motion intelligible were Jean Buridan and Nicole Oresme. Each undertook to redefine motion, and each cited article 49 of the Condemnation as a reason for doing so. If God can move the world in a straight line, said Buridan, then he can certainly move it circularly. Now such a motion would be undetectable if it were shared by all parts of the world; nevertheless it would in fact be motion because God would be causing it and, presumably, he would know this. The same applies to the case of rectilinear motion. If all parts of the world were to be moved together by God in a straight line, there would be no

31. These arguments are given in *ibid.*, pp. 226-228.
relative motion to observe, yet the world would still be moving. Thus for Buridan, God functioned as the absolute reference for the motion of the world. There was no need to postulate places between which motion could occur. Oresme's answer was much the same. The motion of the world could occur in an imaginary space beyond the world, an absolute space not defined by reference to any body, a real space over which God ruled at his pleasure and through which he could transport the world if he so desired.32

I have cited only a few examples of the impact of the Condemnation on late medieval science. There are many, many more. As Grant has observed,

> Frequent citation of, and implicit allusions to, numerous articles of the Condemnation of 1277 should convince us that it was taken seriously throughout the fourteenth century and that it encouraged innumerable invocations of God's absolute power in a variety of hypothetical physical situations. The supernatural alternatives which medieval scholastics considered in the wake of the condemnation conditioned them to consider possibilities outside the ken of Aristotelian natural philosophy, and usually in direct conflict with it. So widespread was the contemplation of such hypothetical possibilities in the late Middle Ages that it is no exaggeration to view them as an integral feature of late medieval thought.33

God's absolute power, Grant goes on to say, was "a

32. See ibid., pp. 229-32. As we shall see in a later chapter, Newton used the same arguments against Descartes' conception of relative motion, in defense of an absolute space in which God was omnipresent.

33. Ibid., p. 239.
convenient vehicle" for the consideration of original physical hypotheses. But if the Condemnation caused some to challenge certain fundamental Aristotelian principles, he points out, it did not result in a new science of nature. The possibilities entertained by the nominalists were put forth secundum imaginationem, according to the imagination, not according to the truth. In spite of the vigor with which a few scholastics pursued the possibility of a moving earth, none of them, as far as is known, ever actually believed that the earth moves. The scientific revolution did not begin until Copernicus proclaimed the earth's motion as the true explanation of the phenomena. If the nominalist "atmosphere of uncertainty" had prevailed, Grant concludes, the scientific revolution probably could not have happened.34

I find myself in agreement with Grant's main thesis, that medieval nominalism did not produce the scientific revolution. It will be my chief purpose in this essay, however, to demonstrate that the theology associated with the Condemnation of 1277 did in fact play a major role within the scientific revolution; to wit, it encouraged the development of a new view of scientific knowledge as deriving from phenomena rather than from propositions. In a provocative essay on "Empiricism and the Scientific

34. This interpretation is developed in "Late Medieval Thought" and "Hypotheses in Late Medieval and Early Modern Science," Daedalus 91 (1962), 599-616.
Ernan McMullin has argued that "the history of science, from its Greek beginnings right down to the present, has been marked by a tension between two views concerning the nature of science, which we can call the conceptualist and the empiricist views." Where the conceptualist assumes "that a direct access to the essence or structure of natural objects is available," the empiricist believes "that evidence for a scientific statement" can be found "only in the singular observations on which the statement rests." Conceptualist science "will be certain and definitive"; empiricist science "will be tentative, approximate, progressive." McMullin offers the following historical analysis in terms of these categories: Although challenged by the positivism of the later nominalists, "the dominant medieval theory of science was conceptualist." The science of the early seventeenth century "was still largely conceptualist," but it "became more and more empiricist in tone" as the century continued. This is precisely the pattern which emerges from the four case studies in the following pages: the conceptualism of Galileo and Descartes belonged to the first half of the seventeenth century, the empiricism of Boyle and Newton to the latter half. What I intend to show

35. In Art, Science, and History in the Renaissance, ed. Charles S. Singleton (Baltimore: Johns Hopkins UP, 1967), pp. 331-69. This article contains a brief rejoinder to Grant's view of Copernicus and nominalism. See pp. 341-44.

36. Pages 332-34.
is that this change in philosophy of nature from conceptualism to empiricism was accompanied by a change in theology of creation from rationalism to voluntarism. What the medieval nominalists were unable to accomplish—the construction of a science of contingent truths deriving from phenomena—the seventeenth century voluntarists successfully carried out.
The possibility of an applied mathematics is an expression, in terms of natural science, of the Christian belief that nature is the creation of an omnipotent God. This belief is what replaced the Greek conception of nature as the realm of imprecision with the Renaissance conception of nature as the realm of precision. The Platonism of Renaissance natural science is not fundamentally Platonic, it is fundamentally Christian. Christian thought is adapting Platonism to its own ends, or begetting upon Platonism an idea which Platonism proper would never have originated or even tolerated.


By his free use of the word "nature," he [Galileo] does not mean to deny an ultimately religious interpretation of things. God, by his immediate creative knowledge of nature, thinks into the world that rigorous mathematical necessity which we reach only laboriously through resolutions and demonstrations--God is a geometrician in his creative labours--he makes the world through and through a mathematical system. . . . It was this religious basis of his philosophy that made Galileo bold to declare that doubtful passages of scripture should be interpreted in the light of scientific discovery rather than the reverse. God has made the world an immutable mathematical system, permitting by the mathematical method an absolute certainty of scientific knowledge. The disagreements of theologians about the meaning of scripture are ample testimony to the fact that here no such certainty is possible.

--E.A. Burtt, The Metaphysical Foundations of Modern Physical Science, pp. 82f
Giorgio Spini's remark that "our sources of information about Galileo's religiousness do not always allow us to reach a certainty beyond all reasonable doubt" greatly understates the case. Apart from his letter to the Grand Duchess Christina, which was hardly a spontaneous effusion of deep religious conviction, Galileo never wrote at length on any religious topic, and some of the little that he did say—for example, the pious platitudes scattered sparingly throughout his works—can only be taken with a grain of salt. From all appearances, Galileo reflected his civic heritage: religion, while necessary for salvation, need not be an important part of one's private life; public worship, not personal piety, was the rule for Florentine society.


2. See Gene A. Brucker, Renaissance Florence (New York: John Wiley & Sons, 1969), pp. 172-212. An ambivalent attitude toward the Church was a characteristic feature of Renaissance Florence. A host of cults and confraternities and periodic revivals gave Florentines ample opportunities to display their public religion. Yet Florence suffered heretics quite readily, and was more than once under the threat of an interdict; anticlericalism was virtually a sign of good citizenship. In financial matters the cittadini looked after their own interests first; if a number of hightborn women ended up in nunneries, it was largely because their families could not afford to provide them with dowries. Galileo, who sent both of his daughters into cloisters, himself studied at a Vallombrosan monastery.
It would be a serious mistake, however, to assume that Galileo had no faith at all. Too often he is depicted as a martyr for the church scientific, or a saint who strode forth like David to slay the Goliath of Catholic theology with his smooth stones of critical reasoning. Such accounts only serve to obscure the complexities of the historical reality: Galileo had his supporters in the Church, and some of his staunchest intellectual foes were Latin Averroists like Cesare Cremonini, Fortunio Liceti, and Antonio Rocco, outspoken libertines who had no time for Christianity. The fact is that Galileo never repudiated his Catholicism publicly or privately—indeed he saw himself as saving the Church from error by championing the truth of Copernicanism. Furthermore, in confronting the virtual identification of mathematics with physics, and the justification he provided was couched in the language and concepts of theology. Some scholars, clinging tenaciously to their precious positivist picture of Galileo, refuse to allow that he ever engaged in serious metaphysical

as a youth and even became a novice in that order before Vincenzio put a stop to a monastic career for his son.


speculation.\textsuperscript{5} Maurice Clavelin, I think, comes much closer to the truth:

To hold that mathematical reason is capable of embracing reality, to assume that rational necessity is akin to natural necessity, to turn simplicity into a touchstone of scientific explanation is not to introduce so many ostensive definitions based on the evidence of our senses, but rather to choose a metaphysical position.\textsuperscript{6}

He did so consciously, above all in the Dialogue, where the debate between Salviati and Simplicio hinged on the relevance of mathematics to the physical world.\textsuperscript{7} In the ensuing discussion we shall see that Galileo's ideal of a


\textbf{7.} Simplicio maintained, "with Aristotle, that in physical [naturali] matters one need not always require a mathematical demonstration." \textit{Dialogue Concerning the Two Chief World Systems--Ptolemaic & Copernican}, trans. Stillman Drake (Berkeley: University of California Press, 1953), p. 14. Simplicio did not come over to Salviati's position until the First Day of the Discourses, when he admitted that "if I were to begin my studies over again, I should try to follow the advice of Plato and commence from mathematics, which proceeds so carefully, and does not admit as certain anything except what it has conclusively proved." On the Second Day he added, "Truly, I begin to understand that although logic is a very excellent instrument to govern our reasoning, it does not compare with the sharpness of geometry in awakening the mind to
mathematical, a priori science of nature was grounded explicitly on a rationalistic understanding of God's relation to created objects and to created minds.

The Perfect Creation of an Omnipotent God

Philosophy, wrote Galileo in The Assayer,

is written in this grand book— I mean the universe—which stands continually open to our gaze, but it cannot be understood unless one first learns to comprehend the language and interpret the characters in which it is written. It is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures, without which it is humanly impossible to understand a single word of it; without these, one is wandering about in a dark labyrinth. 8

The strong Platonic flavor of this passage and others like it has lent credence to the notion that Galileo can best be understood as a Platonist. 9 To be sure, he styled himself as a champion of Plato's emphasis on mathematics and pure discovery [invenzione]." Two New Sciences, trans. Stillman Drake (Madison: University of Wisconsin Press, 1974), pp. 93 and 133. Hereafter these translations will be referred to as the Dialogue and the Discourses, respectively.


reason, as over and against Aristotle's reliance on dialectic and direct sense experience; in the great Renaissance debate immortalized in Raphael's "School of Athens," Galileo followed Plato's upraised arm rather than Aristotle's earthbound gesture. But Plato's god differed profoundly from Galileo's, and consequently so did his conception of science. Although the Demiurge had wanted to make a perfect world, he had been limited by a recalcitrant matter. Necessity—not natural law but its very antithesis, an indeterminate, unintelligible chaos—had required to be persuaded to cooperate with Reason in producing the world. Alas, Reason had not been wholly successful, so the product was only an imperfect copy of the ideal reality. Physical things, as flawed images in the world of becoming, merely "participated" in number; they did not perfectly embody the mathematical forms of the world of being which alone were fully comprehensible. Physics, the study of physical objects, could therefore be only a "likely story," not a true science capable of giving knowledge.


For Galileo, however, the "great book of nature" was "the creation of the omnipotent Craftsman," not of a mere Demiurge. The world was "most perfect, being the chief work of God." It was therefore "of necessity, most orderly, having its parts disposed in the highest and most perfect order among themselves." This principle being established, said Salviati, it follows that "straight motion cannot be natural for any body," for "whatever moves straight changes place," and "if that were the motion which naturally suited it, then at the beginning it was not in its proper place," which contradicts the assumption of perfect order. Only circular motion and rest were suitable for a perfect world.12 God's perfect creative act was likewise the formal cause of circular motion in the heavens. Twice in the First Day of the Dialogue and once more in the Fourth Day of the Discourses, Galileo speculated on the origin of the solar system.13 Each time conception to himself (under the pseudonym of the "Lincean Academician" or a similar conceit). From this and from the fact that he apparently believed that he had mathematically verified it, we must conclude that Galileo took his "Platonic" cosmogony quite seriously. It is not really Platonic—nothing resembling it can be found in

13. Pages 20-21, 29-30; and 232-234, respectively.
Plato. Nevertheless Galileo believed that he was "illustrating a Platonic concept" whose foundations, which he had discovered by "removing their poetical mask or semblance, show it in the guise of a true story [verace istoria]." According to Sagredo, Plato had said that God, after having created the moveable celestial bodies, in order to assign to them those speeds with which they must be moved perpetually in equable circular motion, made them depart from rest and move through determinate spaces, ... successively accelerating. And he added that these having been made to gain that degree [of speed] which it pleased God that they should maintain forever, He turned their straight motion into circulation, the only kind that is suitable to be conserved equably, turning always without retreat from or approach toward any


15. Dialogue, p. 29; Discourses, p. 233. I cannot resist quoting Cornford's comment about the Timaeus: "Some have regarded the mythical character of the dialogue as a 'veil of allegory,' which can be 'stripped off,' and have imagined that they could state in literal terms the meaning which Plato has chosen to disguise. ... But there remains an irreducible element of poetry, which refuses to be translated into the language of scientific prose. Plato declares that his account, so far from being exact, cannot even be consistent with itself. The inexactness and inconsistency are inherent in the nature of the subject; they cannot be removed by 'stripping off the veil of allegory'." Plato's Cosmology, p. 32.
pre-established goal desired by them.16

More importantly, perfection meant that God's mathematical ideas had been completely realized in the objects he had created. Even the complexities of real bodies were subject to the exacting scrutiny of geometry.17 Simplicio, the plodder who represented Aristotelian philosophy in the Dialogue, argued that while mathematicians may prove their propositions well enough in theory, things happened otherwise in practice. Ideal spheres were not material spheres; the imperfection of matter prevented "things taken concretely from corresponding to those considered in the abstract."

Galileo's spokesman Salviati denied the charge:

SALV. Are you not saying that because of the imperfection of matter, a body which ought to be perfectly spherical and a plane which ought to be perfectly flat do not achieve concretely what one imagines of them in the abstract?

SIMP. That is what I say.

SALV. Then whenever you apply a material sphere to a material plane in the concrete, you apply a sphere which is not perfect to a plane which is not perfect, and you say that these do not touch each other in one point. But I tell you that even in the abstract, an immaterial sphere which is not a perfect sphere can


17. As Crombie has pointed out, Galileo differed with Plato on the matter of essentialism: where Plato maintained that the physical world was a poor copy of mathematical forms, Galileo held that it "actually consisted of the mathematical primary qualities and their laws, and that these laws were discoverable in detail with absolute certainty." Op. cit., p. 135, his italics. William R. Shea, Galileo's Intellectual Revolution (New York: Science History Publications, 1977), agrees. See page xi.
touch an immaterial plane which is not perfectly flat in not one point, but over a part of its surface, so that what happens in the concrete up to this point happens the same way in the abstract. . . . Just as the computer who wants his calculations to deal with sugar, silk, and wool must discount the boxes, bales, and other packings, so the mathematical scientist [filosofo geometra], when he wants to recognize in the concrete the effects which he has proved in the abstract, must deduct the material hindrances, and if he is able to do so, I assure you that things are in no less agreement than arithmetical computations. The errors, then, lie not in the abstractness or concreteness, not in geometry or physics, but in a calculator who does not know how to make a true accounting.18

Although nature might not be simple, it was nevertheless wholly explicable in mathematical terms. As McTighe has put it, for Galileo there was "no intractable surd in the things of nature which defies rationalization."19 Failure to plumb the depths of the created order was due not to the intrinsic recalcitrance of an imperfect matter, but rather to the mathematical incompetence of the human investigator.

Galileo's assumption that, because the Divine geometer had fully carried out His intentions nature was at root mathematical, amounted to the identification of mathematical form as the intelligible essence of bodies. I have said, "of bodies," not "of substances," for Galileo emphatically denied that we could know the true essences of


substances in this temporal world. But the essences of mathematical forms could in fact be known—properties could be deduced from definitions. To learn about a circle, we should begin with one of the simplest properties, and "taking this for the definition of a circle, proceed by reasoning" to other properties. God, who simply apprehends "the circle's essence, knows without time-consuming reasoning all the infinity of its properties." To the degree that we, too, could know the essence of a form, to that same degree we could share in the Divine knowledge.

If one were unable to reduce a thing to intelligible essences—to regular geometric figures—then one could not know its properties. The regular geometric forms—the sphere, the cube, the pyramid, etc.—were "equally eternal

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22. Regular lines, Galileo wrote in The Assayer (p. 197), are "susceptible of definition and of having their qualities and properties demonstrated. Thus the spiral is regular, and its definition originates in two uniform motions, one straight and the other circular; so is the ellipse, which originates from the cutting of a cone or a cylinder; and so on. But irregular lines are those which have no determinacy whatever and are indefinite and casual, and hence indefinite; no property of such lines can be demonstrated, nor in a word can anything be known about them. Hence to say, 'Such events take place by reason of an irregular line' is the same as saying, 'I do not know why they occur.' The introduction of such lines is in no way superior to the sympathy, antipathy, occult properties, influences, and other terms employed by some philosophers as a cloak for the correct reply, which would be: 'I do not know.'"
and prior to the creation of heaven and earth," by which Galileo probably meant that God was the Divine geometer in a literal sense: as constant objects of his intellect, geometrical forms had always existed in his mind, and were thereby "co-eternal with God," to borrow a Neo-Platonic phrase from Johannes Kepler. Galileo therefore equated science, true and necessary knowledge of nature, with mathematics, true and necessary demonstration. Probable arguments were not good enough; conclusions not "proved by necessary demonstrations from their primary and unquestionable foundations" did not belong in science. Natural truths "must follow necessarily, in such a way that it would be impossible for them to take place in any other manner," for "just as there is no middle ground between truth and falsity in physical things, so in rigorous proofs one must either establish his point beyond any doubt or else beg the question inexcusably." "The method that we shall follow," Galileo proclaimed in De motu, "will be always to make what is said depend on what was said before, and, if possible, never to assume as true that which

23. Postil 113 to Orazio Grassi's Ratio ponderum librae et simbellae, quoted by Shea, op. cit., p. 90. Elsewhere Galileo described the circle as "more regular so to say, than any other [form]." Quoted in ibid., p. 107 n32.


requires proof." The contradiction of geometry was "the bald denial of truth."\textsuperscript{27}

In Galileo's opinion, then, scientific conclusions ought to have the force of "necessary and eternal" conclusions.\textsuperscript{28} But this would only be possible if God himself, as Author of the great book of the universe, guaranteed that nature displayed the same characteristics as the mathematical language in which it was written, and further guaranteed that the human mind was capable of reading that language. Galileo claimed nothing less. Since he took "matter to be inalterable--that is, always the same," it was evident that for any "eternal and necessary property, purely mathematical demonstrations can

\begin{quote}

27. The Assayer, p. 164.

\end{quote}
be produced that are no less rigorous than any others." 29
As "the obedient executrix of God's commands," nature was
"inexorable and immutable," never transgressing "the laws
imposed upon her." 30 The human mind could comprehend those
laws specifically because God allowed it "to partake of
divinity" by understanding numbers. Within the limited
range of mathematical demonstration, human "knowledge
equals the Divine in objective certainty, for here it
succeeds in understanding necessity, beyond which there can
be no greater sureness." 31 Indeed this certainty was
inborn—by means of the thought experiment, one discovered
the truth which was already present in his own mind.
Presumably it had been implanted there by God, "who has
endowed us with sense, reason, and intellect... to give
us knowledge." Holy Scripture itself could be interpreted
in more than one way. But necessary demonstration yielded
unique, certain conclusions which could—and should—aid

29. Discourses, p. 13. Galileo's words here are the same
as before: "eterna e necessaria." (Favaro VIII, 51) The
translation of Henry Crew and Alfonsio de Salvio reads as
follows: "Since I assume matter to be unchangeable and
always the same, ... we are no less able to treat this
constant and invariable property in a rigid manner than if
it belonged to simple and pure mathematics." Dialogues
3.

30. Letter to the Grand Duchess Christina, p. 182. Cf. the
Letters on Sunspots, p. 136. In a letter to Diodati of 16
July 1611 (Favaro XI, 149), Galileo referred to nature as
the "inexorable and immutable minister of God." Quoted by
McTighe, op. cit., p. 375.

31. Dialogue, pp. 11 and 103. For Galileo's Platonic
theory of knowledge, see Shea, pp. 150-155.
even "in the true exposition of the Bible and in the
investigation of those meanings which are necessarily
contained therein, for these must be concordant with
demonstrated truths."\(^{32}\) The Book of Nature and the Book of
Scripture had in fact the same Author, but the Divine
geometer had spoken a different language than the Holy
Spirit, and had written with greater clarity and force.

**Divine Transcendence and the Limits of Human Reason**

**Rationalism in theology, according to M.B. Foster, "is**
the doctrine that the activity of God is an activity of
reason. It implies the corollary that the activity of
reason in man, in so far as it is pure, is itself
divine."\(^{33}\) This, the dominant theme of Galileo's theology,
served as the foundation for his ideal of a deductive
science of necessary truths. Yet Galileo never lost sight
of his only limited capacity to participate in God's
unlimited understanding of the creation. He believed that
"the human understanding can be taken in two modes, the

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Galileo's position in this letter and in the controversy
which provoked it was always to maintain, with Bellarmine,
that only an absolutely certain physical demonstration
could be the basis for interpreting scripture contrary to
the consensus opinion of the Church Fathers. A merely
probable demonstration was not enough. Of course Galileo
thought he had a certain demonstration of the earth's
motion in his explanation of the tides. See pp. 163f, 166,
169, 177, 183f, 194f, and 199. Also see Langford, *op.
cit.*, pp. 50-78.

intensive or the extensive." Intensively, with regard to "understanding some proposition perfectly, I say that the human intellect does understand some of them perfectly," and here it "equals the Divine in objective certainty, for here it succeeds in understanding necessity, beyond which there can be no greater certainty." But extensively, with regard to the infinite number of intelligibles, "the human understanding is as nothing even if it understands a thousand propositions; for a thousand in relation to infinity is zero." And God knows all the infinite propositions in a way "exceedingly more excellent than ours. Our method proceeds with reasoning by steps from one conclusion to another, while His is one of simple intuition." While our intellect moves laboriously from one step to the next, the Divine mind moves like light in an instant; which is the same as saying that everything is always present to it.

I conclude from this that our understanding, as well in the manner as in the number of things understood, is infinitely surpassed by the Divine; but I do not thereby abase it so much as to consider it absolutely null. No, ... I recognize and understand only too clearly that the human mind is a work of God's, and one of the most excellent.34

Thus for Galileo, our minds differ from God's both in kind and in degree; his knowledge of things is immediate and complete, ours only discursive and partial.35

34. Dialogue, pp. 103f.

35. Burtt, op. cit., p. 82. In the notes (p. 115) to his edition of the Dialogue, Santillana attributes to Augustine
The discussion about extensive and intensive understanding rounded out the First Day of the Dialogue. Just before this, the three interlocutors were actively debating what the surface of the moon might be like, and whether life could be found there. After some guarded remarks about the severity of lunar conditions, Salviati noted that any creatures living there would have to be unimaginably different from terrestrial species, "for this seems to me to fit with the richness of nature and the omnipotence of the Creator and Ruler." Sagredo nodded assent; those who would "make human abilities the measure of what nature can do" are extremely rash, for not a single effect in nature is fully understood by anyone.36 Indeed Galileo confessed in The Assayer that he was "almost totally blind when it comes to penetrating the secrets of Nature." The more his science partook of perfection, the fewer were the conclusions it could demonstrate.37 Instead of trying to subsume every effect of nature under an all-embracing world system, Galileo contented himself with trying to grasp just a small portion of the cornucopia of created phenomena.38 His cautious, intellectually modest

the view "that God can conceive the infinity of numbers as a whole and see it in action in His own mind, sine cogitationis alternatone." See De Civitate Dei xii, 17.

37. Pages 260 and 189.
rationalism—which constrasts so sharply with Cartesian presumptiveness—revealed his constant consciousness of and deep appreciation for the richness of nature. Nowhere is this clearer than in his parable of the cicada, about a bird lover who studied the causes of musical sounds. He learned that sweet songs could arise from an amazing variety of sources—hollow sticks, taut strings, squeaky hinges, glass goblets, and beating insect wings. Then, when he had come to believe that he had exhausted all the possibilities, he heard a new sound which he could not explain, the song of the cicada. After many false starts he finally succeeded in locating a possible mechanism, the shaking of certain thin, hard ligaments in the chest. But his efforts to determine whether this really was the source were too coarse, and he managed only to kill the little creature. Now he would never know for sure just what the source of the sound had been. From then on, when asked how sounds are generated, he would "reply tolerantly that although he knew some of the ways, he was certain that many more existed which were unknown and unimaginable." Nature was so bounteous that even our senses and experience were not always sufficient to teach us the means by which an effect was produced.

Because God's thoughts were often above ours, nature


was not open to human reason at every point. God was not a Pythagorean; one could not derive the universe from pure number. Indeed one could not even discover a posteriori the precise pattern of the heavens. In a letter to Gallenzone Gallenzoni, Galileo distinguished three classes of proportions: the perfect, between proximate numbers; the less perfect, between "more remote prime numbers"; and the imperfect, between incommensurables, these being inexplicable. If it were up to us to arrange the motions of the celestial bodies, said Galileo,

we should have to rely on proportions of the first type, which are the most rational; God, on the other hand, not bothering about symmetries that man can understand, has ordered these motions with the help of proportions that are not only incommensurable and irrational but totally inaccessible to our intelligence.

Again, if a famous architect were to distribute the fixed stars throughout the vault of heaven, he would employ regular geometric figures and familiar ratios that provide the best proportions. But God, "by apparently scattering them at random, impresses us as having arranged them


41. Letter of 16 July 1611 (Favaro XI, 149-150), quoted by Clavelin, pp. 447f, emphasis mine. Here Galileo was almost certainly following Nicole Oresme, who had argued that the ratios of the celestial motions were likely to be incommensurable, so that no astrological Great Year of the planets could occur. See Edward Grant, ed. and trans., Nicole Oresme, De proportionibus proportionum and Ad paucarrespicientes (Madison: University of Wisconsin Press, 1966), pp. 111-122.
without heeding any rules or any demands of symmetry and elegance."42 The problem of the finiteness or infinity of the world was also beyond human determination. It is one of those questions, Galileo told Liceti, which is "happily inexplicable to human reason, and similar perchance to predestination, free will, and such others in which only Holy Writ and divine revelation can give an answer to our reverent remarks."43 God's reasons were his own, not man's, and we must not presume to know them. When Simplicio objected that Copernican cosmology put a vast, useless space between the orbit of Saturn and the fixed stars, Salviati replied that "it is brash for our feebleness to attempt to judge the reason for God's actions," and to label this space superfluous. How inept, added Sagredo, are those who would have God make the universe "more in proportion to the small capacity of their reason than to His immense, His infinite power."44

* * * * *

Precisely because God's reasons are often inscrutable, Galileo believed it fruitless to speculate on what might happen if God, by his absolute power, were to perform an

42. Loc. cit.

43. Letter of 10 February 1640 (Favaro XVIII, 293ff), quoted by Alexandre Koyré, From the Closed World to the Infinite Universe (Baltimore: Johns Hopkins UP, 1957), p. 98.

act outside the normal course of nature. Unlike his medieval predecessors, Galileo rejected arguments based on supernatural possibilities, neither taking them seriously when introduced by his opponents nor employing them in his own natural philosophy, not even in thought experiments, the traditional vehicle for the consideration of supernatural possibilities. An ideal place to have invoked divine intervention would have been in his treatment of a body dropped into a tunnel through the earth. Twice Galileo suggested this problem, and twice he declined to attribute the construction of the tunnel to the power of God. The first time he wrote, "if the earth were tunneled through the center"; the second time, "if the terrestrial globe were pierced by a hole." Neither time did he suggest an agent.45 Had he accepted the medieval mode of arguing secundum imaginationem, surely he would have employed it here.

Equally he refused to accept supernatural possibilities proposed by others. Several times in the Diaglogue, Simplicio quoted from an anti-Copernican work, Disquisitiones mathematicae de controversiis ac novitatis astronomicis, by Christopher Scheiner's pupil Locher. One of Locher's objections was cast in the form of a supernatural possibility. If, "by Divine power, or by means of some angel, a very large cannon ball were

45. Ibid., pp. 22 and 236.
miraculously transported" to the orbit of the moon and then dropped, it is incredible that the ball should remain always over the same spot on the earth's surface, if the earth is really rotating. At first Salviati took the opportunity to calculate how long such a fall would take, in order to refute Locher's absurd figure of six days. Then the conversation turned to the question of whether an internal or an external principle would be sufficient to keep the ball moving along with the earth. Locher claimed that it could be neither. If an external principle, does God cause it by a continuous miracle? Or an angel? The air? It could be none of these. Before Simplicio could read the arguments, Salviati abruptly cut him off:

Do not bother to read the objection, for I am not one of those who assign such a principle to the surrounding air. As to the miracle or the angel, I rather lean that way, because whatever begins with a Divine miracle or an angelic operation, such as the transportation of a cannon ball to the moon's orbit, is not unlikely to do everything else by means of the same principle.46

They proceeded to a second argument. If the earth were to stop by God's will, would objects on its surface stop, too? Would the seagull be unable to hover over the fish? Salviati's tongue found his cheek at once: if the earth should stop whirling by the will of God, "the birds would

do whatever that same will of God desired." Simplicio tried again at the close of the Fourth Day, taking his argument this time not from Locher but from "a most eminent and learned person," none other than Maffeo Barberini, Pope Urban VIII. Referring to Galileo's "proof" of the earth's motion from the tides, Simplicio asked whether "God in His infinite power and wisdom could have conferred upon the watery element its observed reciprocating motion" by some means other than that proposed by Salviati. Anticipating that his friends would concede that God could have done this in many ways beyond our comprehension, Simplicio concluded that "it would be excessive boldness for anyone to limit and restrict the Divine power and wisdom to some particular boldness of his own," echoing the argument that Salviati had earlier used against him. Salviati's reply is worth quoting in full.

An admirable and angelic doctrine, and well in accord with another one, also Divine, which, while it grants to us the right to argue about the constitution of the universe (perhaps in order that the working of the human mind shall not be curtailed or made lazy) adds that we cannot discover the work of His hands. Let us, then, exercise these activities permitted to us and ordained by God, that we may recognize and thereby so much the more admire His greatness, however much less fit we may find ourselves to penetrate the profound depths of His infinite wisdom.48

47. Page 240.

48. Page 464. The Pope was understandably very offended by the fact that Galileo gave his argument to the foolish Simplicio, thus undermining its force and holding him up to ridicule. A similar passage appears in the preface (p. 6),
I am unable to believe that Galileo meant this sincerely. In the *Letters on Sunspots*, he had rejected just this kind of reasoning. The technical apparatus of Ptolemaic astronomy, he noted, was "merely assumed by mathematical astronomers in order to facilitate their calculations." It was not retained by philosophical astronomers who, going beyond the demand that they somehow save the appearances, seek to investigate the true constitution of the universe—the most important and most admirable problem that there is. For such a constitution exists; it is unique, true, real, and could not possibly be otherwise. 49

Galileo's inclusion of the Pope's argument can be explained only as a conciliatory gesture, so that he could claim (falsely) that he had obeyed the Church's instruction not to teach Copernicanism as the true system of the world. Earlier in the Fourth Day, as the interlocutors were just beginning to discuss the tides, Simplicio had stated that unless someone could show him a more reasonable cause for

where Galileo stated, "It is not from failing to take count of what others have thought that we have yielded to asserting that the earth is motionless, and holding the contrary to be a mere mathematical caprice, but (if for nothing else) for those reasons that are supplied by piety, religion, the knowledge of Divine Omnipotence, and a consciousness of the limitations of the human mind."

49. Page 97. "Galileo had pointed out that there is no sense in looking for many probable reasons if we can find the mathematical one, for that single reason becomes necessity itself. And this is what the pope could in no wise accept." Giorgio de Santillana, "Necessity, Contingency, and Natural Law," in *Mélanges Alexandre Koyré*, ed. I.B. Cohen and Rene Taton (2 Vols.; Paris: Hermann, 1964) II, 458-470, at p. 463.
the ebb and flow of the sea than Salviati's explanation (based on the double motion of the earth), he would conclude that it is a supernatural effect. Then Salviati asked, "do you not believe that the terrestrial globe could be made moveable supernaturally, by God's absolute power?"

Of course, answered Simplicio. All right, said Salviati, since we must introduce a miracle, then "let us make the earth miraculously move with that motion by which the oceans are naturally moved," for this would be far simpler and involve fewer miracles than making an immense bulk of water perform all the intricate movements associated with the tides. Lest we take this seriously, lest we think that Salviati had adorned himself with his opponent's mantle, Galileo added a warning through the mouth of Sagredo: let us not have recourse to miracles unless natural explanations fail. Though indeed, he added piously, "to my mind all works of nature and of God appear miraculous." I feel the same way, said Salviati, with doubtful sincerity: "saying that the natural cause of the tides is the motion of the earth does not exclude this operation from being miraculous."50

The Ideal of a Deductive Science

The major emphasis of Galileo's theology of creation was on the ability of the human mind to participate in

50. Pages 421f.
divinity, to read the mathematical language of the perfectly written Book of Nature. Therefore his concept of science was heavily weighted toward a priori demonstration. This is not to deny that Galileo gave ample room to empirical factors— one must not forget that it was his telescope which first opened the heavens to modern astronomical observation. It is only to assert that his ideal science, the kind of science he advocated from the beginning of his career and brought to full fruition in the Discourses, to wit, the science of mechanics, was given at heart much more to deductive demonstration than to inductive investigation. I am not claiming that Galileo's physics divorced reason from reality, mathematics from experience. There can be no doubt that he experimented; he was not the pure abstractionist of Koyré's Galileo Studies. Clearly experiment was an essential element in the process of discovery. Yet the role he assigned it in his published writings was a very different one. In the context of justification, it took a back seat to necessary mathematical reason.

The well-known inclined plane experiment from the Third Day of the Discourses is a good example of the true function of experimentation in Galileo's ideal science. It is Simplicio--the naive sense empiricist--not Salviati, who calls for an experimental check on the demonstrated

51. Pages 169f.
conclusions; this experiment is therefore introduced for polemical, not strictly methodological, reasons. True enough, Salviati says that experiments are "usual and necessary" when applying mathematics to the physical world and that the Author [Galileo] himself has "not failed to make them." Closer attention shows, however, that Galileo could not have performed some of the experiments he claimed to have performed. This should not be surprising. If, as Galileo repeatedly said, a true science consists only of necessary mathematical demonstrations, it ought to follow that true scientific conclusions require no direct confirmation from experience and might even contradict that experience. In the Dialogue, when the discussion turns to a stone falling from the mast of a ship, Salviati makes the claim that "experiment shows ... that the stone always falls" at the foot of the mast, whether or not the ship is moving. Now Galileo had in fact done this experiment—at least he said as much in his Reply to Ingoli, and there is no reason to doubt it—but Salviati does not argue on that basis. Simplicio rhetorically asks whether Salviati, who freely declares the result to be certain, has made the test even once. "Without experiment," comes the reply, "I

52. For this and the following point, see McTighe.

53. "I have made the experiment—before which, physical reasoning had persuaded me that the effect must turn out as it indeed does." Quoted in Drake, Galileo at Work, p. 294. Note that Galileo's emphasis, even here, is on the demonstration, not the verification.
am sure that the effect will happen as I tell you, because it must happen that way"; and what is more, Simplicio, you know it, too. What follows is not a real experiment, the dropping of a ball from the mast of a moving ship, but a series of thought experiments intended to convince Simplicio that he really does "know" the truth of the matter already. Similarly Galileo needed no experimental confirmation for his conclusions about artillery; "having gained by demonstrative reasoning the certainty that the maximum of all ranges of shots is that of elevation at half a right angle, the Author demonstrates to us something that has perhaps not even been demonstrated through experiment," the fact that two shots fired at complementary angles will travel equally far. Causal knowledge of one effect (maximum range occurs at 45 degrees) leads to "the understanding and certainty of other effects without need of recourse to experiment."54 As he told Pietro Carcavy, even if it is not the case that experience supports the conclusions, "my demonstrations founded on my supposition lose nothing of their force and conclusiveness."55 Or, as he wrote to Baliani, "it would matter little" [poco a me importerebbe] whether demonstrated conclusions correspond well to the "accidents" of nature.56

54. Discourses, pp. 245f.
56. Letter of 17 January 1639 (Favaro XVIII, 12-13);
Little wonder, then, that Galileo plainly contradicted experience on more than one occasion. It is not true, for example, that two pendulums, one with a narrow arc and the other with a wide arc, will swing together for hundreds of oscillations, as Galileo claimed in the Discourses.\textsuperscript{57} Nor is it true that if a wooden ball and a lead ball are dropped together, the former at first moves more swiftly than the latter, and then the latter overtakes and passes the former. Yet Galileo explicitly said, in the essay version of De motu, that he had "often tested" this.\textsuperscript{58} In fairness to Galileo, let me add that he later stated the correct law; nevertheless he did claim experimental verification for this "fact." Perhaps the most glaring contradiction of experience was his "proof" of the earth's motion from the tides. According to his theory, high and low tides ought to be twelve hours apart. Unfortunately, as every sailor in Italy knew all too well, they are only six hours apart. In his first treatise on the subject, an unpublished but widely circulated work from 1616, Galileo flatly rejected this fact, calling it a "fallacy which has led writers to imagine many useless fantasies."\textsuperscript{59} In the Dialogue he admitted the six hour interval for the

\textsuperscript{57} An "experiment gives firm assurance of this." Pages 226f.

\textsuperscript{58} \textit{On Motion and On Mechanics}, p. 107.

\textsuperscript{59} Favaro V, 388f; quoted by Shea, p. 177. Shea's excellent treatment (pp. 172-186) of this topic accents the
Mediterranean, but attributed it to secondary causes; the primary cause (the earth's double motion) was still credited with producing just one full cycle per day.

This is not to deny that observation and experiment had an essential function in Galilean science. Reason can err; a true conclusion can be obtained from false premises. Shea has convinced me that Galileo discovered this for himself in his early work on floating bodies, and that he subsequently paid more attention to what Shea has called "the regulative use of experiment," whereby Galileo would try experimentally to confirm at least one conclusion of a theory. Galileo was concerned that the world he was deducing would not be just a world on paper, but the world of our sense experiences. There was nothing wrong with inventing motions and deriving properties, but he wanted to discover the motion which freely falling bodies actually have in nature. He was confident that he had done so, "chiefly for the very powerful reason that the essentials successively demonstrated by us correspond to, and are seen to be in agreement with, that which physical experiments show forth to the senses." The world could only be mathematical, but which mathematical laws it incorporated was a matter for empirical determination.

_**a priori** nature of Galileo's science._

60. See pp. 14-44.

Galileo's God of Pure Reason

I introduced this study of Galileo's thought with the observation that the theology expressed in his scientific works met an apologetic need: the new science of nature required a new metaphysics for its justification. Although it has not been my primary purpose to prove this assertion, I believe it is a correct assessment of the facts. A significant commitment to a mathematical science of ideal bodies is evident very early in Galileo's career, surely in *De motu* if not before. I can find no evidence of a similar commitment to a theology of creation prior to the sixth decade of his life, when he was openly confronting the Aristotelianism that had so thoroughly entrenched itself in the European intellectual establishment. I am aware of nothing which would support the claim that Galileo's philosophy of nature derived in any way from his theology of creation. It appears rather that Galileo's theology was designed specifically to undergird an approach to nature which he had already embraced for other reasons.

My primary purpose has been to examine the elements of that theology, in order ultimately to determine the impact of voluntarism on early modern science. Galileo believed that an omnipotent God had fully thought into the world the very patterns and figures of mathematical forms. Mortals could share in the objective certainty of the divine mind whenever they could think God's thoughts after him through
the deductive rigor of geometry. Some things, such as the
precise order established in the heavens, were forever
beyond the reach of human reason. Other things, aspects of
the richness of creation, limited the scope of our inquiry.
Nevertheless it was possible to attain enough certain
truths to constitute a demonstrative science of nature. A
Platonic "likely story" simply would not suffice. Thus
Galileo's was a cautious rationalism; but rationalism, not
voluntarism, it primarily remained. God's will had no
place in Galilean natural philosophy. And if God's power
was the acknowledged source of nature's bounty, the notion
that that power might inhibit our search for causes was
laughed out of court. The principal function of divine
omnipotence was to insure that God's geometrical thoughts
would be embodied perfectly in the objects of his making,
so that the ideal world of circular motions and regular
generic forms would indeed be directly applicable to the
world of experience. And since the world was mathematical
to the core, our failure completely to know God's works was
due more to the defect of a finite understanding than to
the exercise of divine freedom. Thus it was largely "from
within," as Maurice Clavelin has concluded, "that Galileo's
rationalism was forced to take stock of its own
limitations, that it came to appreciate its true scope and
thus armed itself against an oversimplified interpretation
of reality."62
CHAPTER THREE:

GOD, MAN, AND NATURE: THE PROBLEM OF CREATION

IN THE NATURAL PHILOSOPHY OF RENÉ DESCARTES

The physics of Descartes, therefore, depends in a particular way upon his metaphysics: it provides merely the lower stages in an hierarchical system that definitely reaches back to God. Descartes is prepared to work out a whole system of the universe, starting with matter (or with what the philosophers call extension) on the one hand, and movement, purely local motion, on the other. Everything was to be accounted for mathematically, either by configuration or by number. His universe, granting extension and movement in the first place, was so based on law that no matter how many different universes God had created—no matter how different from one another these might be at the start—they were bound, he said, to become like the universe we live in, through the sheer operation of law upon the primary material. Even if God had created a different universe at the beginning, it would have worked itself round to the system that now exists.

... He tells us in the Discourse on Method that from one or two primary truths that he had established he was able to reason his way by the deductive method to the existence of the heavens, the stars and the earth, as well as water, air, fire, minerals, etc. When it came farther than that—to the more detailed operations of nature—he needed experiment to show him in which of the alternative ways that were possible under his system God actually did produce certain effects; or to discover which of the effects—amongst a host of possible alternatives that his philosophy would have allowed or explained—God had actually chosen to produce.

Descartes' relationship with the Church provides a sharp contrast to that of the feisty Galileo. In an effort to avoid controversy over his Copernican views, Descartes repressed his early treatise _Le Monde_ and cautiously guarded his statements about cosmology in his later _Principia philosophiae_. The quiet Frenchman, whose motto was "bene qui latuit, bene vixit," lived abroad for most of his adult life in order to steer clear of clerical interference. His writings, both public and private, are filled with avowed refusals to touch on questions of revealed theology, which Descartes believed "must not be subjected to human reasoning." Theology, he thought, should be kept as simple as possible; subjecting its truths to critical examination had led to "sects and heresies" and was unnecessary, for even "simple country folk" had as much

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1. The standard edition of Descartes' letters and writings is the _Oeuvres de Descartes_, edited by Charles Adam and Paul Tannery, 12 Vols. (Paris: Leopold Cerf, 1897-1913). I will usually quote from one of the many reliable English translations, which will be cited as they appear; when quoting from Descartes' correspondence, I will give the location of the letter in Adam and Tannery, which will be abbreviated simply as AT, followed by the volume number and the page(s). If no other source is given, then the translation is my own. Adrien Baillet's two volume _La Vie de Des-Cartes_ (Paris: Daniel Horthemels, 1691), which has recently been reprinted in one binding (Geneva: Slatkine Reprints, 1970), was also printed in an abridged form (Paris: LaVeuve Marbre Cromoysi, 1693) which was translated into English by someone identified only as "S.R." (London: R. Simpson, 1693). A good modern biography in English is Jack R. Vrooman, _René Descartes, a Biography_ (New York: Putnam, 1970).
chance of attaining heaven as the most learned scholar. Whatever God had revealed concerning his own person or his actions, Descartes was content to believe, whether or not he could comprehend it. Like his Jesuit teachers at LaFleche, Descartes left his skepticism at the church door, thereby remaining orthodox in his faith if not always in his philosophy.

Nevertheless Descartes made every endeavor to develop a rational theology, if not a revealed theology. His entire system of knowledge, notably including his natural philosophy, was grounded upon the bedrock of God's existence and attributes. God had established certain laws in nature, and had imprinted notions of them in our souls. The natural world was nothing other than "the order and

2. Descartes' Conversation with Burman, trans. and ed. by John Cottingham (Oxford: The Clarendon Press, 1976), pp. 46f. See the similar passage in the first part of the Discourse on Method, as found in Paul J. Olscamp, trans., Discourse on Method, Optics, Geometry, and Meteorology (Indianapolis: Bobbs-Merrill, 1965), p. 8. In the future, Cottingham's translation will be cited as Burman. References to Olscamp's translation will indicate the relevant treatise and section (for example: Meteorology II), followed by the page number(s) in Olscamp.

3. Passages to this effect are not difficult to find. Two of the clearest are found in the Principles of Philosophy, trans. by Valentine Rodger Miller and Reese P. Miller (Boston: Reidel, 1983), propositions I.25 and IV.207 (pp. 13 and 288, respectively). Hereafter this translation will be called Principles. Another good example appears in the Objections and Replies II, trans. by Elizabeth S. Haldane and G.R.T. Ross in the second volume of their two-volume set, The Philosophical Works of Descartes (New York: Dover, 1955), p. 47. Hereafter this set will be abbreviated as HR, with the number of the appropriate volume.
disposition" of things laid down by God in the creation, and human nature was nothing other than a "complexus" of things given by God.4 Thus his philosophy of nature embraced the three elements of the classical Christian doctrine of creation--God, man, and nature--and the relations among them (see Figure 1). With his radical emphasis on the unity of God's will and intellect, Descartes denied the traditional distinction between these two aspects of God's being, yet his thought exhibits all too clearly a tension between them which manifested itself in his methodology as a tension between empirical and a priori elements.5 Descartes believed that, "because God alone is the true cause of all things which are or can be, it is obvious that we shall be following the best method of philosophizing if we strive to deduce the explanation of the things created by him from the knowledge of God Himself {and the notions innate in us}"; so that "from a

4. Method V (Olscamp, p. 34); Meditations VI (HR I, 192). The natural light of reason, for which Descartes is so well known, was "natural" only in the scholastic sense of being a creation of God, completely dependent on him. For Descartes, God was the source of all truth, both metaphysically and epistemologically. See Michael A. Grill, "Descartes: A Re-interpretation of His Metaphysics and Science," doctoral dissertation at the University of Kansas (1975), pp. ii-iv.

Figure 1:

God, Man, and Nature

God

Nature ← → Man

(Created order)  (Created mind)
consideration of his attributes we can investigate the truth of . . . things, since he is their cause." Taking this as my chief clue, I will try to show how Descartes' conception of God's attributes informed both the content and the method of his natural philosophy. Those attributes which were most important for his natural philosophy were God's infinite perfection, his immense power, and his veracity and immutability as manifested in his infallible decrees. As we shall see, it was God's perfection which determined the outcome of the dialogue between his power and his immutability.

The Relation between God and His Creation

Descartes was content to allow God to be God in all of his transcendence. In contrast to all other possible entities, God was the only necessary being; existence was linked inextricably with his nature. Fixed between man and God, creature and Creator, was an awesome gulf, unbridgeable by finite minds. Undoubtedly this emphasis on

6. Principles I.24 and 75 (Miller, 12f and 35); the phrase in brackets appears only in the French edition.

7. Among those things most to our advantage, Descartes told the Princess Elisabeth, "the first and principal is that there exists a God upon whom all things depend, whose perfections are infinite, power immense, decrees infallible . . ." Letter of 15 September 1645 (AT IV, 288); trans. by John J. Blom in his Descartes, His Moral Philosophy and Psychology (New York: UP, 1978), p. 150. In the future this translation will be called "Blom."

8. See Meditations V (HR I, 181f) and Objections and Replies I (HR II, 20).
what Boyce Gibson has called God's "amplitude" derived from Descartes' strong orientation to the Augustinian theology of the Oratorians. From 1626 to 1628, while he was in Paris, Descartes was in close touch with Gibieuf, whose De libertate dei et creaturae (1632) denied that human standards were applicable to God and asserted God's indivisible unity and unrestricted freedom.9 In the same manner Descartes denied to Aquinas and the scholastics the right to reason analogically from man to God, undermining any attempt to make God in man's own image. As an inseparable unity of will and reason, God was radically free, his will not subject to constraint by his intellect.10 Descartes' theology of an infinite, transcendent God interacted with his nascent physical theory in three main places, which I will discuss in turn as follows: the boundless size of the universe; the

9. See A. Boyce Gibson, The Philosophy of Descartes (London: Methuen, 1932), pp. 23f. There are "marked resemblances between the original elements of the two men's [Descartes and Gibieuf] theories of the relation of God to the world." (p. 45)

10. See Norman Kemp Smith, New Studies in the Philosophy of Descartes: Descartes as Pioneer (New York: St. Martin's Press, 1953), pp. 163-168, and Etienne Gilson, La liberte chez Descartes et la theologie (Paris: F. Alcan, 1913), passim. Cf. passages, quoted below, on the eternal truths. Professor Richard Greaves has kindly called to my attention the interesting fact that the English Puritan (and voluntarist) William Ames was teaching at Franeker while Descartes was enrolled there in 1629-30. Whether this is significant or not I am unable to say. See Keith L. Sprunger, The Learned Doctor William Ames: Dutch Backgrounds of English and American Puritanism (Urbana: University of Illinois Press, 1972), p. 80.
impropriety of teleological explanations; and the nature of the eternal truths.\(^{11}\)

It is "the nature of the infinite," Descartes wrote in the third Meditation, "that my nature, which is finite and limited, should not comprehend it . . ."\(^{12}\) When confronted with infinite quantities, conventional mathematics was powerless to avoid falling into paradoxes. Any number that we could comprehend could not be infinite.\(^{13}\) Because God alone could be said positively to have no limits in any respect, Descartes reserved for him the term "infinite." All other things--numbers, stars, parts of a body, the extension of the world--were said negatively to be "indefinite" because they had no **discernible** limits; because this apparent lack of limits resulted from "the

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11. These correspond to Kemp Smith's "three stages in Descartes' conversion to this new theology." Note, however, his admission that "How far they came in actual succession, or how far they may have overlapped, remains a matter of conjecture." (p. 170) My concern is the substance, not the order, of the stages.

12. HR I, 166.

13. See the well known letter to Mersenne, 15 April 1630 (AT I, 146f), quoted by Kemp Smith, *op. cit.*, p. 171. Mersenne had stated that the number of feet [pieds] in an infinite line would be three times greater than the number of yards [toises], so that the latter number could not be infinite. Descartes replied that we have no basis for comparing infinite quantities. What ground, he asked Mersenne, "have you for judging whether one infinite can or can not be greater than another? It would no longer be infinite, were we able to comprehend it." Actual, or completed, infinities have disturbed philosophers and mathematicians from Aristotle to Cantor. The apparent intractability of infinity has often been associated with the inscrutable but omniscient mind of God.
weakness of our own understanding rather than from the nature of these things," they could not be construed as limitless in a positive sense. This position, which reflected real theological and philosophical concerns, was not without practical benefits for Cartesian natural philosophy. If Descartes denied the motion of the earth "more carefully than Copernicus and more truthfully than Tycho," he also denied the infinity of the world more subtly than anyone else:

We shall find no difficulty in the indefinite extension of the World, if only we would consider that, in saying it is indefinite, we are not denying that perhaps in the very truth of the matter it may be finite, but we are only denying that there are any bounds or extremities which can be comprehended by our intellect. The which estimate seems to me much saner and safer than that of those who, in affirming the world to be finite, dare to prescribe limits to the works of God.

As Descartes well knew, this argument for an apparently boundless universe as an expression of God's infinite power had been used by Nicolas of Cusa and others. It was

14. *Principles I.* 26-27 (Miller, p. 13f); see also *Objections and Replies I* (HR II, 17) and *Burman*, p. 33. Alexandre Koyré has covered this in *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins UP, 1957), pp. 100-124.


16. See the letter to Chanut mentioned in the previous note (Blom, 219f). On Cusa, see Alexandre Koyre, *From the
intended partially to answer the serious objection that, in an infinite (or at least indefinitely large) universe, the place of humanity would be too insignificant and might even render God incapable of special providences. Descartes' two prominent female correspondents voiced this argument, which he did not accept. A finite power, he replied, might be exhausted by such a world, but "the more we esteem the works of God to be great, the more we note the infinity of his power; and the more this infinity is better known to us, the more we are more greatly assured it extends to all the particular actions of men." The real problem, as Descartes saw it, was not so much with our inadequate conception of God's power as with our exalted conception of our own place in the creation. Men commonly suppose, he told Burman, that they themselves are the dearest of God's creatures, and that all things are therefore made for their benefit. They think their own dwelling place, the earth, is of supreme importance, that it contains everything that exists, and that for its sake everything was created. But what do we know of what God may have created outside the earth, on the stars and so on?

17. From Descartes' letter to Elisabeth of 6 October 1645 (AT IV, 304ff; Blom, 163). Elisabeth expressed her reservations in a letter of 30 September 1645 (AT IV, 301ff; Blom, 154ff); Queen Christina of Sweden conveyed her opinions through Chanut, the French ambassador to her court, in his letter of 11 May 1647 (AT X, 617ff; Blom, 213-218). Descartes answered Chanut on 6 June 1647 (AT V, 50ff; Blom, 218-224).

18. Page 36. Also see Principles III.2 and the letter to Hyperaspistes from August 1641 (AT III, 422), in Anthony
Apart from the revelation of Scripture, we are not privy to God's eternal counsel: "we ought not to presume so much of ourselves as to think that we are the confidants of his intentions." Therefore "we shall not undertake any reasonings from the end which God or nature set himself in creating these things, {and we shall entirely reject from our Philosophy the search for final causes}."

Even if we could know the purpose of a thing, arguing from ends—which was "Aristotle's greatest fault"—could never lead to a knowledge of the thing itself.

Nowhere is Descartes' confession of God's absolute power more apparent than in his doctrine of the eternal truths, mathematical or logical propositions and statements pertaining to the essences of entities; for example, "the

Kenny, Descartes: Philosophical Letters (Minneapolis: University of Minnesota Press, 1981), p. 117. Hereafter this translation will be abbreviated as K.

19. Principles I.28 (Miller, 14): the bracketed phrase is found only in the French edition. That Scripture can tell us certain of God's purposes is clear from Burman (p. 19) and elsewhere.

20. Burman, loc. cit.: also see Meditations IV (HR I, 173). Gassendi's objections to Descartes' amputation of final causes from physics is found in Objections and Replies V (HR II, 174-176); Descartes' reply is on p. 222: "We cannot pretend that certain of God's purposes rather than others are openly displayed; all seems to be equally hidden in the abyss of his inscrutable wisdom."

21. Several studies have focused on this aspect of Cartesian thought. In addition to Gilson, op. cit., and portions of the general literature, see Emile Brehier, "The Creation of Eternal Truths in Descartes' System," in Descartes: A Collection of Critical Essays, ed. by Willis Doney (New York: Macmillan, 1967), pp. 192-208; T.J. Cronin, "Eternal Truths in the Thought of Descartes and His
whole is greater than its part," "two plus two equals four," "it is impossible for the same thing to be and not to be at the same time," and "he who thinks cannot not exist while he is thinking."\textsuperscript{22} The orthodox position was the scholastic doctrine of created essences as found in Aquinas' \textit{Contra gentiles}: God can know particulars because his essence contains in itself the essences of all possible particulars. Eternally related to God's understanding, these uncreated possible essences could take on actual existence by an act of divine will with the creation of the bodies to which they applied. Hence Aquinas put into the mind of God archetypes which depended upon his essence or

\textsuperscript{22} See Principles I.49 (Miller, 22); Burman, 34; the letter to Mersenne of 17 May 1638 (AT II, 134ff; K, 55); among other places.
nature but not upon his will. Though owing allegiance to nothing outside God's nature, the divine will nevertheless could not endorse things which were inherently impossible and was bound to accept the truths presented to it by the divine intellect. Thus God could not "make a genus not predicable of its species, or bring it about that the radii of a circle are not equal, or that a rectilinear triangle should not have its three angles equal to two right angles." Suarez taught, beyond this, that God knows the eternal truths necessarily, because they are true in themselves: "man is a rational animal" was true because the idea of man itself contains the idea of rationality. In his Disputationes metaphysicae, a work which Descartes cited in his reply to Arnauld's objections, Suarez wrote: "Habent perpetuam veritatem, non solum ut sunt in divino intellectu, sed etiam secundem se ac praescindendo ab illo." 25

Descartes' own views on the eternal truths are found in several letters from the 1630s and 1640s, in his replies


25. Disp. XXXI, sec. 12, no. 40, quoted by Brehier, p. 195. Also see Cronin, "Eternal Truths," pp. 557-559. Descartes' citation of Suarez can be found at AT VII, 235 (HR II, 107).
to the fifth and sixth sets of objections, and in the
Conversation with Burman. Perhaps for prudence' sake,
Descartes did not specify the theologian(s) against whose
position he was reacting. Gilson denies that it was Thomas
or any schoolman; Garin argues that it was Suarez. In
any case his general position was diametrically opposed to
the prevailing Renaissance conception in which both God and
man were bound by inexorable laws. Descartes stated his
views most clearly in his letter to Mersenne of 15 April
1630, from which I quote at length:

{A} The mathematical truths which you call eternal
have been laid down by God and depend on him entirely
no less than the rest of his creatures. Indeed to
say that these truths are independent of God is to
talk of him as if he were Jupiter or Saturn and to
subject him to the Styx and the Fates. {B} Please do
not hesitate to assert and proclaim everywhere that
it is God who has laid down these laws in nature just
as a king lays down laws in his kingdom. There is no
single one that we cannot understand if our mind
turns to consider it. They are all inborn in our
minds just as a king would imprint his laws on the

26. The letters to Mersenne of 15 April, 6 May, and 27 May
1630 (AT I, 145-6, 149-50, 151-3), and 17 May 1638 (AT II,
138); to Mesland on 2 May 1644 (AT IV, 118f); to Arnauld on
29 July 1648 (AT V, 223f); and to More on 5 February 1649
(AT V, 272f); all of these have been translated by Kenny.
The other locations are HR II, 226 and 248f, and Burman, 22.

27. Gilson, op. cit., pp. 34-75; P. Garin, Theses Car­
tesiennes et Theses Thomistes (Paris: Desclee de Brouwer,
no date), pp. 130-138. For useful summaries of the
considerable literature on this subject, see the appendix
to Cronin, Objective Being in Descartes and Suarez, and
Wells, "Descartes and the Scholastics Briefly Revisited,"

28. See James D. Collins, Descartes' Philosophy of Nature
(American Philosophical Society Quarterly Monograph Series,
hearts of all his subjects if he had enough power to do so. . . .

{C} It will be said that if God had established these truths he could change them as a king changes his laws. To this the answer is: "Yes he can, if his will can change." "But I understand them to be eternal and unchangeable." "I make the same judgement about God." "But his will is free." "Yes, but his power is incomprehensible." {D} In general we can assert that God can do anything that we can comprehend but not that he cannot do what we cannot comprehend. It would be rash to think that our imagination reaches as far as his power.29

To aid in discussing this passage, I have divided it into four sections (A through D).

{A} and {D}: God's Absolute Power Over the Eternal Truths

Descartes refused to allow that anything could be independent of God. He could not accept any view which subordinated God's will to his reason or failed adequately to distinguish between our finite minds and God's infinite mind. The eternal verities did not exist in any sense apart from God and were true only because God had willed them to be so, for "the existence of God is the first and most eternal of all possible truths and the one from which alone all others derive."30 As the efficient and total cause of all things, as author of both the essence and the existence of every creature, God had created the eternal truths freely. Just as


30. Letter to Mersenne, 6 May 1630 (K, 14).
he was free not to create the world, so he was no less free to make it untrue that all the lines drawn from the centre of a circle to its circumference are equal. And it is certain that these truths are no more necessarily attached to his essence than other creatures are.31

God's creative acts had been radically free, undetermined by any considerations whatsoever.

God did not will to create the world in time because he saw that it would be better thus than if he created it from all eternity; nor did he will the three angles of a triangle to be equal to two right angles because he knew that they could not be otherwise. On the contrary, because he worked to create the world in time it is for that reason better than if he had created it from all eternity; and it is because he willed the three angles of a triangle to be necessarily equal to two right angles that this is true and cannot be otherwise; and so in other cases. . . .

For if any reason for what is good had preceded his preordination, it would have determined him toward that which it was best to bring about; but on the contrary because he determined himself towards those things which ought to be accomplished, for that reason, as it stands in Genesis, they are very good; that is to say, the reason for their goodness is the fact that he wished to create them so. . . . Hence neither should we think that eternal truths depend upon the human understanding or on other existing things; they must depend on God alone, who, as the supreme legislator, ordained them from all eternity.32

Here, as in {B} from the letter to Mersenne quoted above, Descartes employed the voluntarist metaphor of God as the ruler of creation who sovereignly imposed on his kingdom laws of his own choosing, the products of his free will and

32. Objections and Replies VI (HR II, 248-251).
not of a rational necessity external to himself. Nothing could be farther from the Greek conception of creation as found, for example, in Galen,\(^3^3\) or in the (post-Cartesian) Protestant rationalist David Derodon, who held that God's wisdom and goodness necessitated the creation of the world and that his creative act was limited to the actualization of possible entities whose essences were intrinsic to themselves.\(^3^4\) Thomas Aquinas and John Calvin had argued that divine goodness was the reason for creation, although they had denied that there had been any necessity in this--while God of necessity willed his own being, he did not of necessity will other beings--rather he had had freedom of indifference.\(^3^5\)

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\(^3^3\) With regard to omnipotence, said Galen, "the doctrine of Moses differed from that of Plato and of all the Greeks who have correctly approached the study of Nature. For Moses, God has only to will to bring matter into order, and matter is ordered immediately. We do not think in that way; we say that certain things are impossible by nature and these God does not even attempt; he only chooses the best among the things that come about." On the Uses of the Parts IX, 14, quoted by Francis Macdonald Cornford, Plato's Cosmology (London: Kegan Paul, 1937), p. 36.

\(^3^4\) Disputatio de libertate (Geneva, 1662); see Michael Heyd, Between Orthodoxy and the Enlightenment, p. 60. For Derodon, possible essences were co-eternal with God: "Non est autem absurdum ut sint actu duo entia aeterna, quorum unum sit actu aeternum ens simpliciter, absolute et perfecte, scilicet Deus. Alterum vero sit actu aeternum ens secundum quid, conditionale et imperfecte, scilicet res possibilis." Quoted by Heyd, "From a Rationalist Theology," p. 534.

\(^3^5\) Summa theologica I, 19, ii-iii; Summa contra gentiles I, 74-82; Institutus of the Christian Religion I.V.6. See Heyd, "From Rationalist Theology," p. 531. Descartes' insistence on the unity of God's will and God's intellect led him into deep water in several places, among them the
For Descartes, God's omnipotence required him to be able to perform even what we understand to be logically impossible. The limits of human reason were only that—the limits of human reason, not of possible truths. The eternal verities were "inherently as contingent as any other propositions" which God could have freely willed to create.36 God could have made it untrue that twice four is eight or that one and two make three, though if he had done so, the minds he in fact gave us would be incapable of comprehending it, for God has so created our minds "as to be able to conceive as possible things which God has wished to be in fact possible," but not those things "which God could have made possible, but which he has in fact wished to make impossible." So we perceive as necessary those truths which God has willed to be necessary, but this did

question of necessity and indifference as applied to God. Thus he told Burman (pp. 32f) that, "although God is completely indifferent with respect to all things, he necessarily made the decrees he did, since he necessarily willed what was best, even though it was of his own will that he did what was best. We should not make a separation here between the necessity and the indifference that apply to God's decrees: although his actions were completely indifferent, they were also completely necessary. . . . In reality the decrees could not have been separated from God: he is not prior to them or distinct from them, nor could he have existed without them. It is clear enough[?] how God accomplishes all things in a single act." This amazing passage might be explained away by attributing to Burman an incorrect transcription or to Descartes a change of opinion, but I prefer to interpret it as simple confusion, the outcome of Descartes' position that an act of free divine will ("his actions were completely indifferent") was simultaneously an act of rational intellection ("they were also completely necessary").

not mean "that he willed them necessarily: for it is one
ting to will that they be necessary, and quite another to
will them necessarily, or to be necessitated to will
them."37 It would be rash indeed to think that our
imagination reaches as far as his power.

But there was still one thing which even God could not
do. He could not act against his own perfect nature, for
then he would not be God. Although he could, by his
absolute power, have made it untrue that two plus two is
four, he could not make it untrue that "God exists"--he
could not deprive himself of existence, for that would be
an imperfection.38 Hence there were two kinds of eternal
truths in Cartesian philosophy. Uncreated eternal truths,
which could not be otherwise, flowed necessarily from God's
essence. Created eternal truths, free products of the
divine will, appeared to the human mind to be necessary but
could have been otherwise if God had so willed.39

37. Letter to Mesland, 2 May 1644 (K, 151); Objections and
Replies VI (HR II, 251). Cf. the letters to Beeckman on 17
October 1630 (AT I, 156ff) and to Arnauld on 29 July 1648
(AT V, 223f), in which Descartes refused to maintain that
God could not perform certain things, such as logical
 contradictions (K, 17 and 236f). Descartes' position here
appears to be identical to that of those medievals who
taught that there was a theological logic superior to
ordinary logic. Professor Edward Grant kindly pointed this
out to me.

38. Letter to ***, March 1642 (AT V, 544).

39. See Wells, "Descartes' Uncreated Eternal Truths." J.D.
Collins further divides the uncreated eternal truths into a
single "most eternal" truth--that God exists--and several
"more eternal" truths of the divine being and nature. See
the uncreated eternal truths were not subject to change--they were in fact "eternal." But what of the created truths? If they were wholly dependent on God's unfettered will and not upon any external standard of reason, how could they be eternally valid, and how could they possibly be discovered by the human mind? These are separate questions, and the answer to each lies buried in Descartes' understanding of God's attributes, especially his perfection.

{C}: Divine Unity and Perfection

The eternal validity of the created truths obviously hinged upon the immutability of God's will, for if he were able to change his will, he would be able to change the eternal truths. In a definite break with scholastic tradition but fully in keeping with his emphasis on divine transcendence, Descartes refused to accept any distinction between God's will and his reason--a distinction, he thought, which told nothing of God but reflected a purely human limitation. In reality, he said, God's nature was an indivisible unity of will and reason.40 Therefore a change in God's will would entail a change in his understanding, but a change in his understanding would be an imperfection, since at some time his understanding would have been


40. Principles I.23 (Miller, 12); letter to Mesland of 2 May 1644 (K, 151); Burman, 31f.
mistaken or incomplete; therefore God's will could not change. "Concerning the decrees of God which have already been enacted," Descartes told Burman, "it is clear that God is unalterable with regard to these, and, from the metaphysical point of view, it is impossible to conceive the matter otherwise." Thus, although Descartes did not think that "the essence of things, and those mathematical truths which may be known about them," were independent of God, he nevertheless affirmed "that because God so wished it and brought it to pass, they are immutable and eternal." In the opinion of Boyce Gibson, Descartes established a division, irreconcilable with his doctrine of God's unity, at the moment of God's decision to create a specific eternal verity. Prior to that moment, his will was supreme over his intellect, in that no proposition necessarily required his assent; but once he had determined which propositions would be true eternally, his intellect gained

41. This is M.J. Osler's interpretation, which I find very convincing. See "Eternal Truths and the Laws of Nature."

42. Page 32. In the same place Descartes discussed the efficacy of prayer in light of God's immutable decrees, concluding that "God is indeed quite unalterable, and that he has decreed from eternity either to grant me a particular request or not to grant it." Cf. the similar passage in Descartes' letter to Elisabeth of 6 October 1645 (AT IV, 304ff; Blom, 163f) and the resignation of his letter to Huygens upon the death of Huygens' wife (20 May 1637, AT I, 371).

43. Objections and Replies V (HR II, 226), emphasis his.
the upper hand, for he could not change his mind. It is not clear to me that Descartes believed what Boyce Gibson assumes he did—to wit, that God created the eternal truths in time and not from eternity—although he did believe that the world had been created in time. It remains true that Descartes' God could have done things differently, even outlandishly so, but what he had done could not be undone. When Burman asked if God could have commanded a creature even to hate him, Descartes could see no reason to deny it. "We simply do not know what he could have done," he said, but "God could not now do this."

Descartes heavily stressed God's immutable nature as one of his perfections. It was another divine perfection to be

immutable and completely constant in the way he acts. Thus, with the exception of those changes which either manifest experience or divine revelation renders certain, and which we perceive or believe to occur without any change on the part of the Creator; we must not suppose that there are any others in his works, for fear of accusing him of inconstancy. From this it follows that it is completely consistent with reason for us to think that, solely because God moved

44. The Philosophy of Descartes, p. 277.

45. The key passage would appear to be Objections and Replies VI (HR II, 248), part of which was quoted above at note 32.

46. Page 22, emphasis mine. A related proposition, "that God might have made creatures independent of him," is considered in Descartes' letter to Mesland of 2 May 1644 (AT IV, 110). Descartes called this an "evident contradiction," yet refused to say that God was bound by it (K, 151).
the parts of matter in diverse ways when he first created them, and still maintains all this matter exactly as it was at its creation, and subject to the same law as at that time; he also always maintains in it an equal quantity of motion.47

This understanding of divine immutability was a curious one indeed: "that God is immutable and that, acting always in the same way, he always produces the same effect."48 To hold that God's nature and will did not change was entirely orthodox, but to hold in addition that God always acts in the same way was not the usual interpretation. Even John Calvin, who staunchly defended the constancy of God's will, readily admitted that God's actions could change.49 For Descartes, however, divine immutability meant the constancy

47. *Principles II.36* (Miller, 58).


49. Speaking of divine repentance, Calvin said that "we ought not to understand anything else under the word 'repentance' than change of action, because men are wont by changing their action to testify that they are displeased with themselves. Therefore, since every change among men is a correction of what displeases them, but that correction arises out of repentance, then by the word 'repentance' is meant the fact that God changes with respect to his actions. Meanwhile neither God's plan nor his will is reversed, nor his volition altered; but what he had from eternity foreseen, approved, and decreed, he pursues in uninterrupted tenor, however sudden the variation may appear in men's eyes." *Institutes of the Christian Religion I.17.13*, trans. by Ford Lewis Battles and ed. by John T. McNeill (2 Vols.; London: SCM Press, 1960) I, 227. Descartes' view of prayer (see note 42 above) was not very different from this, but Calvin seems to have been unperturbed by the notion of God acting in different ways at different times—always, of course, in harmony with his immutable decrees.
of his action in the world as manifested in the
conservation of quantity of motion, whereby God maintained
every motion precisely as it was at that moment, and not as
it had been an instant before. Apart from external
causes—collisions with other bodies were the only possible
agents—bodies at rest would remain at rest and those in
motion would continue in motion. Rectilinear motion could
be apprehended in a single instant, and so was the most
fundamental of all.50 God was therefore the active
efficient cause of motion, just as he was "the cause of
created things, not only in respect of their coming into
existence, but also in respect of their continuing to
exist," for "in order to be conserved in each moment in
which it endures, a substance has need of the same power
and action as would be necessary to produce and create it
anew, supposing it did not yet exist"; the distinction
between creation and conservation was "solely a distinction
of the reason."51 For Descartes, then, the laws of nature
were not simply decrees, they were enactments whereby God
immutably and universally sustained what he had fully

50. Principles II.36-39 (Miller, 58-61); Le Monde, chap. 7
(Mahoney, 71-73). As Peter Machamer has pointed out,
Descartes was following the traditional Neoplatonic and
Christian-Aristotelian practice of connecting a phenomenon
directly to one of God's attributes. See "Causality and
Explanation in Descartes' Natural Philosophy," in P.K.
Machamer and R.G. Turnbull, eds., Motion and Time, Space
and Matter: Interrelations in the History and Philosophy of

51. Objections and Replies V (HR II, 219); Meditations III
(HR I, 168); also see Method V (Olscamp, 37).
Yet decrees they no less remained, immutable and universal in their efficacy. In spite of his voluntaristic conception of freely ordained, direct divine action in nature, Descartes placed over nature not the providential miracle worker of the Bible, but the constant preserver of the coming Enlightenment. A God who performed miracles could stand in the way of the universal demonstrative science that Descartes so earnestly desired to create. Apart from those actions which "divine revelation renders certain" and these did not include the Eucharist -- Descartes displayed a skeptical attitude towards miracles. He also mitigated God's sovereignty with his belief that, while the regular laws of nature were the direct result of divine superintendence of motion, the actual, highly irregular paths of particles were produced

52. J.D. Collins, op. cit., pp. 48f. "Laws of nature are quite pregnantly laws for nature, in the sense of being dependent and instrumental expressions of the manner in which the divine power conveys movement to the whole field of material particles." (p. 27)

53. Le Monde, chap. 7 (Mahoney, 77).

54. Principles II.36 (Miller, 58); I take this to refer implicitly to miracles.

55. See his natural explanation in Objections and Replies IV (HR II, 116ff) and in his letter to Mesland of 9 February 1645 (AT IV, 161ff; K, 154-159).

56. See the letters to Mersenne of 19 June 1639 (AT II, 557-568) and 28 October 1640 (AT III, 205-221), and Method V (Olscamp, 37).
by "the diverse disposition of matter," for which God was apparently not responsible. Indeed at one point Descartes was willing to entertain the thought that God might have created the world in a state of chaos from which he brought order by his laws, but he later abandoned this as unbecoming to the character of God.

{B} God and Human Knowledge: Certainty and Innate Ideas

If it is one thing to assert that God made certain propositions true for all eternity, it is quite another to assert that the human mind is capable of discovering them and of recognizing them as truths. Descartes raised this question in the Third Meditation:

But when I took anything very simple and easy in the sphere of arithmetic or geometry into consideration, e.g. that two and three together made five, and other things of the sort, were not these present to my mind so clearly as to enable me to affirm that they were true? Certainly if I judged that since such matters could be doubted, this would not have been so for any other reason than that it came into my mind that perhaps a God might have endowed me with such a nature that I may have been deceived even concerning things which seemed to me most manifest. But every time that this preconceived opinion of the sovereign power of a God presents itself to my thought, I am constrained to confess that it is easy to him, if he wishes it, to cause me to err, even in matters in

57. Le Monde, chap. 7 (Mahoney, 75).

58. Le Monde, chap. 6 (Mahoney, 55); Cf. Method V (Olscamp, 35). This reminds one of Genesis 1:1-3.

which I believe myself to have the best evidence.\(^60\)

The God who created us could do all things, and "we do not know whether he chose to make us in such a way that we are always mistaken, even about those things which appear to us to be the best known of all."\(^61\) But the God who created us was yet perfect, and Descartes recognized "it to be impossible that he should ever deceive me; for in all fraud and deception some imperfection is to be found, and ... the desire to deceive without doubt testifies to malice or feebleness, and accordingly cannot be found in God."\(^62\) This proposition, "that God cannot lie," was "the foundation of faith and all our belief"; those theologians who denied it, in opposition to Augustine and Aquinas, would "have to abandon all certainty." Precisely because God "is veracious in the highest degree," Descartes believed that it followed "that all things which we clearly perceive are true," beyond any possibility of doubt, or else God would be a deceiver. Thus our conceptions of the eternal truths of mathematics and other propositions perceived clearly and distinctly were in fact true.\(^63\) As

\(^{60}\) HR I, 158.

\(^{61}\) Principles I.5 (Miller, 4).

\(^{62}\) Meditations IV (HR I, 172); cf. Principles I.29 (Miller, 15).

\(^{63}\) See the letter to Mersenne of 21 April 1641 (AT III, 358ff; K, 99) and Principles I.29-30 (Miller, 15); cf. Method IV (Olscamp, 32).
the ruler of creation, God had implanted in the human mind certain "innate" ideas, "such as the idea of God, mind [or soul], body, triangle, and in general all those which represent true immutable and eternal essences," that is, the eternal truths.64

The process whereby Descartes established the eternal truths as eternal truths closely paralleled the methodic doubt for which he is well known. Having denied that God was subject to any rational constraint whatsoever, Descartes was nevertheless faced with the hard fact that a perfect God could not act against his own nature by changing his mind, and therefore whatever he had freely chosen to make true would remain true for all eternity. The human investigator might doubt the truth of any proposition except the proposition that the ability to doubt implied the existence of the doubter; the clarity and distinctness of this indubitable truth became the cornerstone for the edifice of certain knowledge. The evil genius who haunted the sleep of reason was God shorn of His veracity, the creator of arbitrary and continually changing

64. Letter to Mersenne of 16 June 1641 (AT III, 383; K, 104); cf. Method IV (Olscamp, 33). The idea of God was "the mark of the workman imprinted on his work," the very imago dei. (Meditations III; HR I, 170) In the early Regulae, Descartes had spoken of "certain primary germs of truth implanted by nature" rather than implanted directly by God. (HR I, 12) His mature works are more explicitly theistic.
essences. Doubt was transformed into the means for arriving at eternal truths, "an acid for etching away what does not belong to a thing's essence." In the absence of prejudices--to wit, by sticking to the Cartesian method of doubt--all men would clearly perceive the same set of eternal truths, the very essences ordained by God. What is more, if we were unable to conceive of something, if we "found a contradiction in attempting to conceive it clearly," we could then conclude that it did not exist at all, which is just what Descartes did with regard to atoms and the void. He could not conceive of matter apart from extension, nor extension apart from matter; the idea of body was contained in the idea of space no less than the idea of a mountain was contained in the idea of a valley. To imagine "that God removes all the air in a room without putting any other body in its place," he wrote to Mersenne, "you will have to suppose eo ipso that the walls of the room will touch each other; otherwise you will be thinking


66. Jonathan Ree, Descartes (London: Allen Lane, 1974), p. 71. Ree stresses the "reductive ideal" of Cartesian thought rather than the "deductive ideal" found by many other scholars and upon which I will build the rest of my argument.

67. Principles I.50 (Miller, 22).

68. Meditations VI (HR I, 185): "For there is no doubt that God possesses the power to produce everything that I am capable of perceiving with distinctness, and I have never deemed that anything was impossible for him, unless I found a contradiction in attempting to conceive it clearly."
a self-contradictory thought." Hence a vacuum was impossible.69 Again, because matter and extension were inseparable, an atom was necessarily an extended body which was clearly and distinctly divisible, and anything clearly and distinctly conceived to be divisible had in fact to be divisible, at least by God if not by human agents. So atoms could not exist either.70 The same issue came up again in Descartes' letter to Arnauld of 29 July 1648 and in his letter to More of 5 February 1649.71 In both places Descartes tempered his earlier position (in the Principles), conceding that he could not place limits on God's absolute power to perform a contradiction. But the thrust of each passage was to affirm anew that Descartes could not comprehend such an act, so that as far as he was concerned, it could not be considered a live possibility. As he said in his reply to the authors of the Sixth Objections, "it is useless to inquire how God could from all eternity bring it about that it should be untrue that twice four is eight"; "it would be irrational to doubt concerning that which we correctly understand, because of that which we do not understand and perceive no need to


70. Principles II.20 (Miller, 48f).

understand."72 Metaphysical doubt gave way to practical certainty. In the last resort, as Reijer Hooykaas has noted, "human reason became the measuring-rod for the truth of existence!"73

The Relation between Created Minds and Created Objects

Descartes recognized that the possibility of certain knowledge depended solely on the knowledge of God. Once God was known in all of his veracity and constancy, Descartes had "the means of acquiring a perfect knowledge of an infinitude of things, not only of those which relate to God himself and other intellectual matters, but also of those which pertain to corporeal nature in so far as it is the object of pure mathematics."74 First of all, he "tried to discover the general principles, or first causes, of all that is or can be in the world, without for this purpose considering anything but God alone, its Creator, and without deriving these principles from anything but certain seeds of truth which are naturally in our souls."75 In

72. HR II, 251.
73. Religion and the Rise of Modern Science (Grand Rapids: Eerdmans, 1972), p. 42. His analysis rings true: "There cannot be a void, not because God could not have made it, but because He does not will it to be, and I know this because my reason cannot conceive how a void could possibly exist."
74. Meditations V (HR I, 185); cf. Principles III.43 (Miller, 104f).
75. Method VI (Olscamp, 52). One's view of the Cartesian method in natural philosophy is in large part determined by
spite of appearances, Descartes did not see himself as an ivory tower philosopher who built a world on paper according to his personal whims. The actually existing world is what he wanted to explain, and this could not be done with imaginary principles "established through the caprice of several armchair thinkers."76 It was nevertheless true that, as G.A.J. Rogers has said, "a large part of [Cartesian] physics could be done in an armchair."77 With the infinite perfections of God as his sole starting point, Descartes "tried to demonstrate all those laws about which we might have any doubt, and to show that they are such that even if God had created many worlds, there would have been none of them where these laws failed to be observed."78 The knowledge of those laws--the three laws of motion and the eternal truths of mathematics--was

which passages one chooses to take as normative. Some scholars rely heavily on the second part of the Discourse on Method, but I agree with the bulk of Cartesian scholarship in taking the sixth part of the Discourse as the most definitive statement. The rest of this passage will be quoted below.

76. From a lost letter to Villebressieu, indirectly recorded by Baillet and quoted by Collins, op. cit., p. 29. Even the most a priori thinker of all, Plato, fully acknowledged the role of the senses at the most fundamental level; the very sight of the heavens, said Timaeus (47A), "has caused the invention of number" and motivated science. Cornford, Plato's Cosmology, p. 157.


78. Method V (Olscamp, 35f).
so natural to our souls that we cannot but judge them infallible when we conceive them distinctly, nor doubt that, if God had created many worlds, the laws would be as true in all of them as in this one. Thus, those who can examine sufficiently the consequences of these truths and of our rules will be able to know effects by their causes and (to explain myself in the language of the schools) will be able to have demonstrations a priori of everything that can be produced in that new world.79

For Descartes, then, it was not enough merely to know a set of laws that described or explained selected phenomena. The laws of physics had to be necessary truths, valid in all possible worlds and capable of yielding certain knowledge through a priori demonstration. If God did indeed create many worlds, each with its own sun, there was only one kind of world, one which the human mind could penetrate completely because God had established certain truths both in the world and in the minds of men. Only the certainty of mathematics, which he deeply wished his physics should resemble, was acceptable to him. Unless it could be deduced from indubitable common notions with the force of a mathematical demonstration, a proposition could not be accepted as true. Even this was not enough. If he could only say how things could be, without showing that they could not be otherwise, Descartes would think he knew nothing.80

79. Le Monde, chap. 7 (Mahoney, 75-77).

80. Objections and Replies II (HR II, 131); Principles II,64 (Miller, 76f); letter to Mersenne of December 1640 (AT III, 258).
This is not to say that Cartesian physics was mathematical—its sparse use of mathematics was perhaps its greatest flaw—but rather that mathematics was, for Descartes, the paradigm of science, the model of certain knowledge. He admired mathematics not so much for its content as for its method of moving from one proposition to another, by which the certainty of the antecedent flowed undiminished down to the consequent. Perceived clearly and distinctly by the light of reason alone, the innate ideas functioned as seeds of truth from which, by deduction, the tree of knowledge grew. Now for Descartes, deduction was not limited to syllogistic reasoning, but included any sequence of propositions in which could be perceived a clear and distinct relation between the premises and the conclusion. At least in part, deduction was an ampliative process whereby intuition moved to extend itself to embrace previously uncertain notions. It was the natural light of reason, not the form of the argument, which established the validity of a proposition.\footnote{81. See Desmond Clerke, "Physics and Metaphysics in Descartes' Principles," SHPS 10 (1979), 89-112, esp. p. 100f, and "Descartes' Use of 'Demonstration' and 'Deduction'," The Modern Schoolman 54 (1977), 333-344; Charles Larmore, "Descartes' Empirical Epistemology," in Stephen Gaukroger, ed., Descartes: Philosophy, Mathematics and Physics (New York: Barnes & Noble, 1980), pp. 6-22; N. Kemp Smith, New Studies, pp. 67-71; and A. Boyce Gibson, The Philosophy of Descartes, p. 155. Descartes expounded his view of deduction at length in parts two through seven of the Regulae (HR I, 4-21).}
material objects, derived not from the prejudices of our senses but from the light of reason, so that their truth is indubitable," Descartes went on to consider "whether we are able to explain all the phenomena of nature by these principles alone; and we must begin with those phenomena which are the most universal and on which the rest depend, namely, the general structure of this whole visible world."82 Proceeding to reconstruct the world, Descartes examined what were the first and most ordinary effects that we could infer from these causes. And it seems to me that I thereby discovered the skies, the stars, an earth, and even, on the earth, water, air, fire, minerals, and certain other such things, which are the commonest and simplest of all, and thus the easiest to understand.83

The first and most ordinary effects mentioned here were the basic parts of the heavens and the earth (the subject of Le Monde), though later (in the Principles) Descartes seems to have limited them to celestial phenomena alone.84 Whatever they were, he claimed to have "discovered" them, by which he could only have meant that he had successfully derived them from first principles, so that their causes had been found. That he believed he had found such causes for the

82. Principles III.1. Here I have quoted from two different translations, first from Elizabeth Anscombe and Peter Geach, Descartes: Philosophical Writings (New York: Scribner's, 1954), p. 222, and then from Miller, p. 84.

83. I have returned to the passage in Method VI (Olscamp, 52).

84. See the introductory letter and principle III.42 (Miller, xxiv-xxv and 104).
general effects cannot be questioned. Assuredly, he said, if the principles I use are very obvious, if I deduce nothing from them except by means of a Mathematical sequence, and if what I thus deduce is in exact agreement with all natural phenomena; it seems {to me} that it would be an injustice to God to believe that the causes of the effects which are in nature and which we have thus discovered are false. For we would then be accusing him of having made us so imperfect as to be liable to make mistakes, even when correctly using our reason {which he has given us}.85

For Descartes, then, science was rooted in metaphysics, the first part of true philosophy, and achieved a sure and certain knowledge of nature by holding to what I will call the deductive ideal: from indubitable first principles derived from the divine perfection and immutability, one could deduce the world and all that is therein.86 But God was more than perfect and changeless;

85. Principles III.43 (Miller, 104f); bracketed portions are found only in the French edition.

86. See the introduction to the French edition of the Principles. Most commentators have agreed that the primary thrust of Descartes' method was deduction from first principles, however much he may have allowed for empirical factors. A few scholars, most notably Olscamp and Clerke, have pushed the opposite view to the point where they would make of Descartes a modern, hypothetico-deductivist. The view I am defending here gives ample consideration to empirical elements without losing sight of the overall structure of Cartesian thought. Errors result from giving too much weight either to Descartes' pressing philosophical goals or to his work in natural science, as if he were either a philosopher or a scientist but not both. See the introduction to Olscamp's translation of the Discourse on Method, Optics, Geometry, and Meteorology and the following works by Desmond Clerke: "The Ambiguous Role of Experience in Cartesian Science," PSA 1976 ed. Frederick Suppe and Peter D. Asquith (East Lansing: Philosophy of Science Association, 1976), Vol. 1, pp. 151-164; "Physics and Metaphysics in Descartes' Principles," SHPS 10 (1979),
he was also omnipotent, and his unlimited power could and
did produce an unlimited variety of effects. To be sure,
there could be only one universe--only one general fabric
of the world--but within this framework were an infinity of
possible particulars. Thus when Descartes wanted to
descend to those effects that were more particular,
so many diverse ones presented themselves to me that
I did not believe it possible for the human mind to
distinguish between the forms or species of objects
that are on the earth, and an infinity of other ones
which could have been, if it had been the will of God
to put them there. Nor, as a result, did I believe
it possible to direct them to our use, unless it be
by arriving at their causes through their effects and
by using many particular experiments.87

If the particular effects could not be predicted from
metaphysical truths--rather, if far too many particulars
followed therefrom--then how was Descartes to know what the
effects actually were? Simple observation would tell him.
Clearly he already knew what phenomena he wished to
explain; his problem was to "discover" them by showing that
they followed from first principles and the general

87. Method, loc. cit. On 5 April 1632 Descartes wrote to
Mersenne that, "in the treatise which I now have in hand
[Le Monde], after the general description of the stars, the
heavens and the earth, I did not originally intend to give
an account of particular bodies on the earth but only to
treat of their various qualities. In fact, I am now
discussing in addition some of their substantial forms, and
trying to show the way to discover them all in time by a
combination of experiment and reasoning." (AT I, 242;
K, 22)
effects. Once he had "reflected upon all the objects that [had] ever presented themselves" to his senses, that is, once he had determined what the actual effects were, Descartes ventured to say

that I never noticed a single thing about them which I could not explain quite conveniently through the principles I had discovered. But I must also confess that the power of nature is so ample and so vast, and these principles so simple and so general, that I almost never notice any particular effect such that I do not see right away that it can be derived from these principles many different ways; and my greatest difficulty is usually to discover in which of these ways the effect is derived. And to do that I know no other expedient than again to search for certain experiments which are such that their result is not the same when we explain the effect by one hypothesis, as when we explain it by another.88

Descartes saw the impossibility of a purely a priori physics all the way down to the last detail. If the general effects could be deduced from first principles alone, the particulars could not. In a letter to Mersenne, Descartes revealed his dream of an a priori physics while confessing his inability to create it:

For the last two or three months I have been rapt in the heavens. I have discovered their nature and the nature of the stars we see there and many other things which a few years ago I would not even have dared to hope; and now [I have] become so rash as to seek the cause of the position of each fixed star. For although they seem very irregularly distributed in various places in the heavens, I do not doubt that there is a natural order among them which is regular and determinate. The discovery of this order is the key and foundation of the highest and most perfect science of material things which men can ever attain.

88. Ibid.
For if we possessed it we could discover a priori all the different forms and essences of terrestrial bodies, whereas without it we have to content ourselves with guessing them a posteriori from their effects. . . . I think that the science I describe is beyond the reach of the human mind; and yet I am so foolish that I cannot help dreaming of it though I know that this will only make me waste my time as it has already done for the last two months.89

Why did such a physics come to naught? Early on, in the Regulae, Descartes conceded that some things were beyond the reach of human knowledge, but not because of a defect in intelligence. Rather because "the nature of the problem itself," or the fact that the investigator is human, could prevent one from learning what he wanted to know; success might depend "upon a certain experiment which he is unable to perform" or it might be "that the knowledge desired wholly exceeds the limits of the human intelligence."90 In his later works, starting with the sixth part of the Discourse on Method (quoted above), Descartes developed this theme at greater length, stressing interchangeably now the fecundity of his principles, now the complexity of nature, and now the creative power of God. The principles we have discovered, he said, "are so vast and so fertile that their consequences are far more numerous than the observable contents of the visible universe"; they were "so simple and so general" and the power of nature was "so ample and so vast" that a given

89. Letter of 10 May 1632 (AT I, 250-252; K, 23f).
phenomenon could be explained in any number of ways. Of course this was only to say that his principles were so vague and so imprecise that they appeared to possess great fecundity—from virtually any initial arrangement of particles and motions, he thought, he could deduce the present form of the world. The objects of physics were "composite," that is, they were characterized by a multiplicity of detail, which contrasted with the simplicity of mathematics. The indeterminate nature of the particulars was attributed also to the inscrutability of God's will; reason alone was insufficient to determine which of the possible objects God had chosen to create. Similarly, although we could be certain that the universe consisted of one and the same matter, that this matter was divisible into parts with essentially cyclical motions, and that the quantity of motion in the world was always conserved; nevertheless the unaided human reason was unable to determine the exact sizes, shapes, speeds, and trajectories of these particles, for God could have

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91. Principles III.4, quoting from Anscombe and Geach, op. cit., p. 223; Method, loc. cit.

92. Principles III.47 (Miller, 107f). Cf. passages in note 58 above. That the initial state of the world should be almost irrelevant to its present state was a curious claim for a determinist—indeed it shows how undeterministic (in a mathematical sense, at least) Cartesian physics really was. See Bernard Williams, Descartes: The Project of Pure Enquiry (Hassocks, Sussex: Harvester, 1978), pp. 270-275.

arranged them "in an infinity of ways; experience alone should teach us which of all these ways he chose."94 As Descartes cautioned his readers in the opening paragraphs of the third part of the Principles, "we must pay attention to two things"; God's infinite power and our limited reason.95

* * * * *

Experiment was thus an essential part of Cartesian science, since many questions could not be answered without it.96 Although the law of refraction could not be determined from experience, the index of refraction of a substance could be found only by an appeal to the phenomenon.97 In order to deduce the motion of the blood, the disposition of the organs of the heart and of the parts of the body had to be known.98 Since he lacked "the

94. Method, loc. cit.; Principles III.46 (Miller, 106).
95. III.1-2 (Miller, 84). The chief purpose of these two principles, of course, was to lay the foundation for a universe of indefinite dimensions.
97. Regulae VIII (HR I, 23f) and Dioptrics II (Olscamp, 81), respectively.
98. Method V (Olscamp, 41): letter to Elisabeth of May 1646
required experimental evidence," he would not dare to undertake an explanation of human embryology.\textsuperscript{99} So many experiments were needed for the progress of human knowledge that Descartes despaired of ever having the time and the resources to complete them. In order to do all the experiments of use to him, he told Mersenne, he would have to be wealthier than the King of China.\textsuperscript{100}

The need for experiment in Cartesian physics was critical, yet its place was subordinate to the dictates of reason. Experience was unambiguous "only when dealing with the wholly simple and absolute." Ingenious experiments were called for only at the latter stages of investigation; if performed too early, they were likely to mislead us. In the beginning, it was better to rely on ordinary sense experience.\textsuperscript{101} Indeed, when Mersenne asked Descartes to tell him how to make useful experiments, the latter replied that, without devoting excessive attention to minor details, one ought to make general surveys of the most common things, for these were certain and could be known

(\textit{AT IV}, 406, Blom, 180).

\textsuperscript{99} Letter to the Princess Elisabeth of 31 January 1648 (\textit{AT V}, 112). Descartes nevertheless did undertake this explanation.

\textsuperscript{100} Letter of 20 October 1642 (\textit{AT III}, 590). On the need for experiments, see \textit{Method VI} (Olscamp, 52f), the preface and article IV.188 of the \textit{Principles} (Miller, xxvi and 275f), and the letter to Huygens of 4 December 1637 (\textit{AT I}, 506f).

\textsuperscript{101} \textit{Regulae VIII} (HR I, 23f): \textit{Method VI} (Olscamp, 51). See Desmond Clerke, "The Ambiguous Role of Experience."
without expense--has Descartes had Bacon for breakfast? But with regard to the more particular experiments, it was impossible not to make many that were superfluous, or even false, if one did not know the truth of things before making them.\textsuperscript{102} Quite so--as Gilson has observed, Descartes was concerned principally with explanations, not with facts.\textsuperscript{103} Nowhere is this clearer than in his opinion of Galileo:

It seems to me that he lacks a great deal in that he is continually digressing and never stops to explain one topic completely, which demonstrates that he has not examined them in an orderly fashion and that, without having considered nature's first causes, he has sought only the reasons for a few particular effects, and thus he has built without a sure foundation.\textsuperscript{104}

If Descartes could not place an experiment into the context of his own system of nature, he disregarded it. Experiments performed by others, he wrote in the Discourse on Method, were too clouded with extraneous ingredients to yield a clear truth; beyond this, "because those who performed these experiments have forced themselves to make

\begin{itemize}
\item \textsuperscript{102} Letter of 23 December 1630 (AT I, 195f).
\item \textsuperscript{103} Etudes sur le rôle de la pensée médiévale dans la formation du système cartésien (Paris: J. Vrin, 1930), p. 137.
\item \textsuperscript{104} From the letter to Mersenne of 11 October 1638 (AT II, 379), quoted by Vrooman, Descartes, p. 115. Predictably enough, Descartes rejected Galileo's conclusions about the fall of bodies in vacuo as "without foundation"--if Galileo had truly understood the nature of gravity, he would have known that bodies could have no weight in a vacuum (if a vacuum could even exist)."
\end{itemize}
them appear to conform to their principles," almost all of them were "badly explained, or even false."105 Though Harvey's hypothesis of the contraction of the heart appeared to be confirmed by a convincing experiment [par une experience fort apparente], for Descartes this proved only that experiments could deceive us when we had insufficient knowledge of all the causes which could be involved. The same effect might have a different cause than the one Harvey had proposed--a good mechanistic cause, of course, not an "occult" contraction--only further experimentation could render a definitive verdict.106 When Beeckman and Mersenne measured the acceleration of a pendulum bob and their results differed from Descartes' theoretical value, he ignored their work, for it could not be explained by reason.107 Experiment had validity only in the context of a priori argument: induction completed deduction, which could not pass beyond a certain level of particularization. It served to close lines of inquiry, not to originate them. In order to learn the nature of the


107. I am following Sakellariadis' analysis of Descartes' correspondence with Mersenne from the latter part of 1629. See "Descartes's Use of Empirical Data."
magnet, the Cartesian physicist, who has reflected "that there can be nothing to know in the magnet which does not consist of certain simple natures evident in themselves" --that is, who shares Descartes' confident knowledge of the essences of things--"will have no doubt how to proceed." After collecting all possible observational data, "he will next try to deduce the character of that inter-mixture of simple natures" which explains the data. But in the event that the magnet should contain "any sort of nature the like of which our mind had never yet known"--such as action at a distance, I am compelled to suggest--it would be "hopeless to expect that reasoning will ever make us grasp it"; it would be enough to "discern with all possible distinctness that mixture of entities or natures already known which produces just those effects which we notice in the magnet." 108

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As we have seen, the first principles of Cartesian physics were separated from the particulars of everyday experience by God's omnipotence and freedom. Just as there might be two clocks made by the same craftsman, equally good time-keepers and with exactly the same faces, yet constructed internally with completely different combinations of wheels; so the supreme Craftsman

108. Regulae X and XII (HR I, 47 and 55), emphasis mine.
undoubtedly could have produced all that we see in many diverse ways.109 The deductive ideal had broken down. There was no necessary connection between first principles and particular phenomena: one could not determine by reason alone which of the possible explanations was the actual explanation of a given effect. This logical gap could be bridged only by hypotheses. Since God could have arranged the shapes, sizes, and motions of particles in countless ways, we were free to make any assumptions we pleased about them, provided that the consequences agreed with experience.110

Descartes spoke of hypotheses in two different senses. Pragmatically, he presented as hypotheses propositions which he believed he could deduce from first principles but preferred not to do so, whether for fear of censorship or for sheer convenience. At the same time, he urged his readers to accept hypotheses for true explanations in themselves, as demonstrated by their heuristic value in accounting for a wealth of phenomena. With regard to light, he wrote to Vatier,

if you look at the third page of the Dioptrics, you will see that I said there expressly that I was going to speak about it only hypothetically. Indeed, since the treatise which contains the whole body of my physical theory is named On Light [this refers to Le Monde], and since in it I explain light with greater

109. *Principles* IV.204 (Miller, 286).
detail and at greater length than anything else, I
did not wish to write again what I had written there,
but only to convey some idea of it by comparisons and
hints, so far as seemed necessary for the subject
matter of the Dioptrics.

... I cannot prove a priori the hypotheses I
proposed at the beginning of the Meteors without
expounding my whole physical theory; but the
phenomena which I have deduced necessarily from them,
and which cannot be deduced in the same way from
other principles, seem to me to prove them
sufficiently a posteriori. ... I chose this manner
of expounding my thoughts for two reasons. First,
believing that I could deduce them in order from the
first principles of my Metaphysics, I wanted to pay
no attention to other kinds of proofs; secondly, I
wanted to try whether the simple exposition of truth
would be sufficient to carry conviction without any
disputations or refutations of contrary opinions.
... And indeed it is not always necessary to have a
priori reasons to convince people of a truth.111

The assumptions he had made about light, although in reality
"conclusions" derived solely from "the axioms on which
geometers base their demonstrations," to wit, the eternal
truths, were nonetheless "proved by everything that comes
after."112 What he had written about refraction was thus a
demonstration, to the extent that one could be given
"without a previous demonstration of the principles of
physics by metaphysics," which was not forthcoming until
the Principia philosophiae of 1644.113 In the absence of
this demonstration, however, Descartes was content to deal

111. Letter of 22 February 1638 (AT I, 562f; K, 47f); cf.
the very similar passage in Method VI (Olscamp, 60f).

112. Letter to Plempius, 20 December 1637 (AT I, 476; K,
43f).

The date in AT (27 May) is incorrect.
in probabilities rather than certainties. To ask for geometrical demonstrations in physics was "to ask the impossible." Archimedes in mechanics, Witello in optics, and Ptolemy in astronomy had demonstrated nothing geometrically, but no one criticized them for this. It was enough in such matters that their hypotheses were not manifestly contrary to experience and that their arguments were logically sound, even though their hypotheses might not have been strictly true.114 Having concluded willingly that God was free to arrange things as he wished and not necessarily as we might have, Descartes claimed that he had done enough if those things which he had written corresponded accurately with all natural phenomena, whether or not he had found the true causes. For practical purposes, no more was required.115 Such things were "held to be morally certain, that is, to a degree which suffices for the needs of everyday life; although if compared to the absolute power of God, they are uncertain." Suppose, for example, that one were trying to read a ciphered message. If by substituting B for A, C for B, and so on, one were

114. Ibid. "I say that there are only two ways to refute what I have written. One is to prove by experience or reason that the hypotheses I have made are false; the other is to show that what I have deduced from them cannot be deduced from them. . . . But if people simply say that they do not believe what I have written, because I deduce it from certain hypotheses which I have not proved, then they do not know what they are asking or what they ought to ask." (K, 56).

115. Principles IV.204 (Miller, 286).
able to obtain a sensible message, then he would conclude that he had guessed the true pattern of the cipher, even though it is possible that the writer had actually written a different message in another cipher. Possible? perhaps; but probable? It would "be so difficult for this to happen, {especially if the message contains many words}, that it does not seem credible." Moreover there were some things

which we judge to be absolutely, and more than morally, certain, of which we judge that it is impossible that the thing should be other than as we think it. This certainty is 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. Of this nature are mathematical demonstrations, the knowledge that material things exist, and the evidence of all clear reasoning that is carried on about them. Amongst these truths it seems to me that there should be counted those conclusions which have been arrived at in this treatise, {at least the principal and more general [au moins les principales & plus generales]}, if it be considered that they are derived in a continual series from the first and most simple principles of human knowledge. ... for these facts being admitted, all the others, at least the more general [au moins les plus generales] doctrines which I have advanced about the world and the earth, appear

116. Principles IV.205 (Miller, 287); the bracketed phrase is only in the French edition. On moral certainty, see John Morris, "Descartes and Probable Knowledge," Journal of the History of Philosophy 8 (1970), 303-312. Descartes believed in something akin to Whewell's "consilience of inductions": if a single cause, however hypothetical, could be assigned to several diverse effects, one could assume that the true cause had been found. See the letters to Morin of 13 July 1638 (AT II, 197-200; K, 57-59), to Plempius (for Fromondus) of 30 October 1637 (AT I, 406; K, 40), and to Huygens of June 1645 (AT IV, 224f); also see Burman, p. 38.
to be the only possible explanations of the phenomena they present.\footnote{Principles IV.206, quoting from HR I, 301f instead of from Miller (p. 287f). The French and Latin versions of this article are substantially different. For some reason, the Miller translation has not considered these differences to be important. I have added the braketed phrase to the text in HR. See AT IX, 324f. On 28 October 1640, Descartes wrote to Mersenne that, although one could explain a given particular effect in many different ways, things in general had only one explanation, which was the true one. (AT III, 212)}

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The Cartesian universe consisted of two storeys (see Figure 2). The general effects, the world of Le Monde, resided in the upper storey, the realm of absolute certainty and \textit{a priori} demonstration. Here the very structure of the world lay exposed for all to see. The lower storey, the realm of practical certainty, yielded its secrets more reluctantly. The appeal to experience was required to augment the power of reason; the deductive ideal had broken down. The filter of experiment was called upon to separate reality from possibility, actuality from contingency.\footnote{The role of experimentation was "to answer the questions set by reason at the outset of the deduction during the preliminary survey of the ground, and at each stage of the deduction when a logical bifurcation is possible." Beck, \textit{The Method of Descartes}, p. 251.} Yet even though experimentation was an integral part of the pursuit of truth, it remained subordinate to rational necessity, implemented only after one had discovered the general causes of things by pure
Figure 2:
The Relation between Created Minds and Created Objects

UPPER STOREY

Divinely given intuition

First principles of physics:
Laws of motion
Eternal truths
Matter=Extension

General effects

LOWER STOREY

Which possible particulars actually exist?

How can they be explained?

Sense data

"Crucial" experiments
intuition. To be sure, nature might not be completely predictable—it might dictate which effects really exist and which combinations of entities suffice to explain them—but it could never surprise us with something wholly new. For those who followed the Cartesian method, the universe was like a second-rate opera: the basic plot was known even before the curtain was raised; only the incidentals remained to be found.\textsuperscript{119}

Voluntarism, Rationalism, and Demonstrative Science: A Consideration of the Foster Thesis

It is now time to consider the validity of the Foster thesis when applied to Rene Descartes: was there in fact a connection between his theology of creation and his

understanding of scientific method? I will begin by noting that Foster's own view of Descartes betrays an inadequate grasp of his scientific method and an unfamiliarity with his conception of the eternal truths. Cartesian natural philosophy, he stated, can not demonstrate the existence of the material world by pure reason; sense perception is required here. But once the world is known to exist, argued Foster, "no further element of contingency is held to belong to the nature of particular material things, and consequently the science of them can rely upon the method of demonstration alone." 120 This is not correct. As we have seen, Descartes was unable to determine, without an appeal to the phenomena, which particular effects God chose to create and which mechanisms he used to produce them. In determining which of his ideas to embody, God exercised his arbitrary will. Apparently Foster did not see this, for he described "this further element of voluntarism," which he found in Leibniz's theology, as "over and above that which Descartes had recognized." 121 He likewise missed seeing the voluntarism manifest in Descartes' belief that God was utterly free to choose the eternal truths in any manner he wished. Hence his mistaken analysis of the Cartesian position:

121. Ibid., p. 20.
His Rationalist doctrine of nature corresponds with his Rationalist doctrine of God: as he cannot conceive of a voluntary activity in God, so he cannot conceive the reality of a contingent element in nature, and his identification of matter with extension is the inevitable consequence of his identification of the divine activity with thought.122

Why was Foster so wide of the mark in his characterization of Descartes as wholly rationalist in both theology and science? Two considerations are relevant here. First of all, Foster was writing at a time when Cartesian natural philosophy was almost universally equated with intellection alone, an opinion derived from an over attention to the Regulae, the Meditations, the second part of the Discourse on Method, and the first half of the Principles, to the relative neglect of the sixth part of the Discourse, the Dioptrics, and the latter half of the Principles. Secondly, Foster probably read little, if any, of Descartes' extensive correspondence, only a tiny fraction of which was then available in English. Unfortunately it was primarily in letters that Descartes outlined his highly voluntaristic views on the eternal truths.

Granted that Foster's conclusions about Descartes are erroneous, is there still any merit to his basic thesis? Is there in fact a clear relationship between Descartes' theology and his natural philosophy, if both are properly

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understood? I believe that there is, if we look closely enough at the individual elements of Cartesian thought, keeping in mind the dialectic nature of Christian theology. The essence of the Christian doctrine of creation is that God, of his own free will, gave existence to an ordered world which continues to exist at his pleasure. It would therefore be heretical to hold either that the world is God or that it is not God to the extent that it exists independently of God. The logical space between these two assertions is the maneuvering room for Christian theologians. In a like manner, Descartes found himself between the rock of asserting that God's creative acts are entirely conformable to human reason and the hard place of asserting that they are wholly beyond our comprehension. On the ground between these propositions he erected his system of thought; that this system contains elements of both rationalism and voluntarism only reflects tensions inherent to the Christian doctrine of creation.123

Starting from God's utter transcendence, Descartes denied that any limits could be placed on God's power to create a boundless universe or eternal truths.

123. In an excellent (unpublished) article on "Eternal Truths and the Laws of Nature," M.J. Osler correctly states that "since both intellectualists and voluntarists ascribed both will and intellect to God, the difference between them is largely one of emphasis." Osler's argument is very similar to mine, but less detailed and more limited in scope. We differ somewhat in our evaluations of the suitability of applying Foster's criteria to Descartes.
incomprehensibly different from those actually perceived by the human mind (see Figure 3). However because God was perfect and his will and intellect were one, he could not change his mind once he had chosen which truths to create. If we could gain knowledge of these truths, that knowledge would be permanent and necessary, not contingent. Without question, here Descartes took a step away from the radical voluntarism from which he began. Yet in and of itself this did not lead to scientific rationalism. A stable set of truths is surely a necessary condition for an a priori science of nature—if God can change his mind, then we can never be sure of our knowledge—but a sufficient condition it is not, for it provides no guarantee that we can know those truths. The key question for Descartes was not whether God could have created a different set of eternal truths or even whether He could now change those truths; rather the key question was whether we could in fact know the eternal truths for what they were: did the truths in our minds correspond to those in the created order? And at this point his answer was a resounding, rationalistic 'Yes!' A perfect God could not deceive us by implanting in our souls seeds of error rather than seeds of truth. It was on this bedrock of certainty that Descartes erected a demonstrative science.

But if God's freedom to employ his absolute power was confined to the period prior to the creation, it was not
Figure 3:
The Relation between God and His Creation

- God's Perfection
  - God's understanding is always correct
  - God's will is immutable
  - Eternal truths are immutable
  - God is not a deceiver
  - Our intuitive notions of eternal truths are reliable
  - Our idea of how God made the world is correct and will always be correct
  - A rationalistic science of nature

- God's Absolute Power
  - Unity of God's Being (Will & Reason)
  - Radical Contingency of Eternal Truths

A change in God's will =
A change in God's understanding
altogether denied. Initially to determine which propositions to make true and which mechanisms to place in nature remained the privilege of the divine will, not the human mind. Results of that determination were shared only partially—the eternal truths were revealed to mankind by the light of reason, but the actual mechanisms only by experience. In spite of this unmistakable element of voluntarism, however, Descartes' ideal of science remained essentially rationalistic; the God who reigned sovereignly over the eternal truths and the laws of nature, the God who functioned as efficient cause of motion, was ultimately out of step with the scientific enterprise as Descartes conceived it. For a demonstrative science to be possible, God's absolute power had to be constrained by God's ordained power. The sovereign God of truth could not be allowed to change his decrees; the Lord of nature must not disobey his own laws by performing miraculous acts; the Sustainer of the world had always to act in the same way.

It is therefore apparent that theological voluntarism, in itself, need not lead to an empirical science of nature. It depends on where that voluntarism asserts itself. By deliberately mitigating the strong voluntarism of his initial position, above all by his strident announcement that God gave us minds which could not but think aright when properly employed, Descartes established the theological basis for his a priori science of nature.
To find a well-balanced position, to evade the Scylla of an arrogant and scientifically sterile rationalism, without falling into the Charybdis of a pseudo-religious blind faith, meant also to find a solid basis for empirical and experimental science. This problem occupied the Christian thinkers who tried to solve it in different ways since the twelfth century.

--R. Hooykaas, "Science and Theology in the Middle Ages," Free University Quarterly 3 (1954), p. 85

It is difficult to overestimate the significance of Boyle's keen sense of God's "arbitrary" freedom vis-a-vis even the laws of nature. Like Newton, he felt no compulsion to construct a completely detailed natural philosophy tied to divine attributes. At the same time, both men expressed man's responsibility to observe the regularities of phenomena according to experience and experiment.

--Eugene Klaaren, Religious Origins of Modern Science, p. 169
"I am not a Christian, because it is the religion of my country, and my friends," wrote Robert Boyle; "when I choose to travel in the beaten road, it is not, because I find it is the road, but because I judge it is the way." His was an intelligent, informed decision not made in ignorance of contemporary philosophical currents. Aware of the new science and difficulties in biblical interpretation, Boyle was no naive literalist, though his traditional stance on miracles and doctrine might suggest otherwise. Careful to distinguish between "what the

1. The Works of the Honourable Robert Boyle, ed. Thomas Birch, is available in a five volume folio (London, 1744) and a six volume quarto (London, 1772). All of my references will be to the latter, which has recently been reprinted with an introduction by Douglas McKie (Hildesheim: Georg Olms, 1965). I have quoted here from Some Considerations about the Reconcileableness of Reason and Religion (Works IV, 155), a tract published in 1675 by "T.E. a layman," usually assumed to have been Rober[T] Boyl[E]. See Samuel Halkett and John Laing, ed., Dictionary of Anonymous and Pseudonymous English Literature (9 Vols.; London: Oliver and Boyd, 1926-1962) V, 305; their reference to the DNB is incorrect, however. The earliest (and most reliable) identification of Boyle as the author of Reason and Religion that I can find is in Edward Jones, A Catalogue of the Philosophical Books and Tracts Written by the Hon. Robert Boyle, esq.: together with the order of time, wherein each of them hath been publish'd respectively. To which is added a catalogue of the theological books, written by the same author (London, 1689). The catalogue was apparently prepared by an unnamed French physician, almost certainly Denis Papin, who collaborated with Boyle for several years on many experiments. The catalogue includes Reason and Religion as a work considered to be Boyle's. The title page of Boyle's The Excellency of Theology, published (in 1674) just one year before Reason and Religion, transparently disguised the author as "T.H.R.B.E." (The Honourable Robert Boyle, Esq.). Perhaps Boyle simply used the first and last letters of this pseudonym in his next theological book.
scripture itself says, and what is only said in the scripture," he recognized that biblical passages on nature spoke "rather in a popular than accurate manner." Holy Writ, he claimed, was "designed to teach us rather divinity than philosophy," echoing the Augustinian notion of accommodation which had been adopted by Calvin and had proved so convenient for Galileo and Kepler. If he remained ever conscious of doing science willingly within the bounds of Christian theism, he never attempted, as van Helmont did, to derive the content of his science from the Bible.

Boyle's views on ecclesiastical polity reveal the same reasoned consideration. Like many other Restoration intellectuals, Boyle found himself attracted to the moderate wing of the Anglican Church, the so-called Latitudinarians who sought to steer a middle course between Romanists, on the one hand, and radical Protestants, on the other. His compulsion for moral living, his focus on essential doctrines rather than trivialities, his toleration and compassion for dissenters, and his abiding

interest in the rational underpinnings of the Christian faith all reflected Latitudinarian concerns, as several scholars have noted. My interest in this chapter, however, will be not the social relations of science and religion—nor, as the Jacobs would have it, the social and political roots of science—but their intellectual relations as seen in the thought of one Latitudinarian, Robert Boyle. The question I propose to answer is this: specifically how did Boyle's understanding of God's relation to the world influence his conception of natural philosophy?

Piety and Sovereignty: Boyle's Voluntarism

Boyle's piety is a matter of historical record. While still a very young man, he wrote an autobiography, "An

Account of Philaretus in his Minority," an essentially religious work in which God, ever mindful of the care of his own, brings Boyle safely into manhood and personally into the fold of the righteous. It is clear from his deeds, if not also from his words, that Boyle never lost the deep sense of gratitude to divine providence that so permeates his own record of his early years. He gave ungrudgingly of his substance, in life for the propagation of the gospel in Ireland, America, and elsewhere, in death for the establishment of annual lectures to prove the truth of the Christian religion "against notorious infidels."

Even if he did not write the Free Discourse against Customary Swearing, he certainly could have (and probably did), for his opposition to oaths and his veneration of God

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4. In "Robert Boyle's Anonymous Writings," Isis 68 (1977), 284-87, Joseph Agassi opposes Boyle's authorship of the Discourse on the grounds that "the vulgarity of some of its anecdotes (especially the one about two friends accidentally meeting in a whorehouse) makes it beyond dispute that the author is not the gentle and pious Boyle." Has Agassi forgotten that, in the "Account of Philaretus," Boyle tells of visiting a Continental brothel (from which he nevertheless emerged innocent) and expresses his disgust with two mendicants who tried to bugger him? J.P. Fulton accepts the Discourse as authentic, but has reservations about the aforementioned Reason and Religion, which most scholars accept. See A Bibliography of the Honourable Robert Boyle, 2nd ed. (Oxford: Clarendon Press, 1961). "An Account of Philaretus" can be found (abridged) in Birch's The Life of the Honourable Robert Boyle, which is bound with the first volume of the Works and is still the basic biography, and (complete) in R.E.W. Maddison, The Life of the Honourable Robert Boyle, F.R.S. (London: Taylor & Francis, 1969), a disappointing book. Flora Masson, Robert Boyle, A Biography (London: Constable, 1914), and Roger Pilkington, Robert Boyle, Father of Chemistry (London: John Murray, 1959), are less scholarly but better written.
were well known in his day. He is said to have paused routinely before uttering the name of God;\textsuperscript{5} if so, then he wrote as he spoke. Before discoursing \textit{Of the High Veneration Man's Intellect Owes to God}, Boyle paused to consider his subject:

Upon this occasion I shall take leave to declare, that it is not without some indignation, as well as wonder, that I see some men, and some of them divines too, who little considering what God is, and what themselves are, presume to talk of him and his attributes as freely and as unpremeditatedly, as if they were talking of a geometrical figure, or a mechanical engine: so that even the less presumptuous discourse, as if the nature and perfections of that unparalleled Being were objects, that their intellects can grasp: and scruple not to dogmatize about those abstruse subjects, as freely as about other things, that are confessedly within the reach of human reason, or perhaps are to be found among the more familiar objects of sense.

It is probable, he continued, "that God may have diverse attributes, and consequently perfections, that are, as yet, unknown to us . . ." Neither "the contemplation of his works" nor "the study of his word . . . will suffice to acquaint us with all his perfections." Not even "the idea of a Being supremely or infinitely perfect" sufficed to show us all of his attributes. God had probably made other worlds and "displayed in some of the creatures, that

\textsuperscript{5}. Birch tells us that Boyle "had so profound a veneration for the Deity that the very name of God was never mentioned by him without a pause and a visible stop in his discourse; in which Sir Peter Pett, who knew him for almost forty years, affirms that he was so exact, that he did not remember to have observed him once to fail in it." \textit{Works I}, cxxxviii.
compose them, diverse attributes, that we have not
discovered by the help of those works of his, that we are
acquainted with." And scripture, which discloses to us the
whole counsel of God insofar as it is necessary for
salvation, yet affirms our inability to know perfectly the
nature, attributes, and providence of God.6

What Boyle did know is that God is wise, powerful,
and, above all, free. The outstanding feature of Boyle's
theology is in fact not his Latitudinarianism, but his
voluntarism. Perhaps Boyle's piety produced in him a
voluntaristic conception of God; perhaps it was the other
way around. Deep personal piety often indicates a profound
sense of divine transcendence. In any case, all of Boyle's
theological works and, to a lesser extent, many of his
scientific works display a strong voluntaristic
orientation.7 The central theme of voluntarist theology is
God's unrestricted freedom to do as he pleases. For Boyle
this meant that God "needs not the services of men," and
was not obliged to create us. From "the same lump of
tearly matter, of which he formed the body of the first

6. Works V, 130-32. Boyle's lack of confidence in the
ontological argument, vis-a-vis Descartes, displays his
fundamentally different theological orientation.

7. The only studies of Boyle's voluntarism of which I am
aware are Eugene Klaaren, Religious Origins of Modern
Science (Grand Rapids: Eerdmans, 1977); Mary E.C. Bowen,
"'This great automaton, the world': The Mechanical
Philosophy of Robert Boyle, F.R.S.," doctoral dissertation
at Columbia University (1976); and J.E. McGuire, "Boyle's
man, he might, if he had pleased, as easily have formed a
dog, or an ape." His love for us was just as free and
unmerited. It did not even follow from God's power and
wisdom that he was bound to make the best possible world.

When

he made the world, and established the laws of
motion, [he] gave them to matter, not to himself: and
so being obliged to none, as his superior or
benefactor, he was not bound to make, or administer,
corporeal things after the best manner, that he
could, for the good of the things themselves . . .

Boyle therefore based his theodicy on the voluntaristic
premise that God is entitled to dispose of his works "as he
thinks best for his own glory; . . . he may have designs
. . . which we men are too short sighted to discern . . ."9
Indeed the Christian religion embraced diverse truths "that
reason, left to itself, would never have been able to find
out, nor perhaps to have so much as dreamed of," because
they "depend upon the free will and ordination of God," and
"consequently are not to be explicitly known but by his
revelation; which he has not, that appears, vouchsafed to
us in any other book than the scripture." The creation of
the world in six days, the incarnation, the virgin birth,
the resurrection of the dead, the last judgment—all these
were free decrees of God, beyond the determination of

8. The Christian Virtuoso (VI, 767) and Seraphick Love
(I, 266).

9. A Free Inquiry into the Vulgarly Received Notion of
Nature (V, 195-97).
The point here is not that Boyle admitted that certain doctrines depended on the will of God—any Christian would have admitted this—the point is that, as a voluntarist, he repeatedly emphasized it. Once these truths had been revealed to us, however, reason could readily embrace them. While above reason in that they were unknowable apart from revelation, they were not contrary or repugnant to reason. For examples of this distinction, Boyle turned to Galileo's telescopic observations of the Jovian moons and the phases of Venus, neither of which could have been anticipated by unaided reason; yet both made sense once discovered. Thus for Boyle both the word and the works of God reflected the voluntarist dialectic between God's will and intellect. Neither could be determined by the human mind alone, yet neither, once made known, mocked the human mind with truths against its nature.

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If God revealed some of his decrees in scripture, he revealed his matchless power and unequaled wisdom in the

10. Christian Virtuoso (V, 542f) and Style of the Scriptures (II, 284). Also see A Discourse of Things Above Reason (IV, 406f and 450). In Seraphick Love (I, 267) and The Excellency of Theology (IV, 15f), Boyle declined to delve into such mysteries as whether or not God could have redeemed mankind without the passion of Christ.

11. Christian Virtuoso (V, 546); cf. Excellency of Theology (IV, 9).
creation. The "immense quantity of corporeal substance, that the divine power provided for the framing of the universe; and the great force of the local motion, that was imparted to it, and is regulated in it," spoke volumes of God's omnipotence. Within such a vast and beautiful world, our proper response was awe and wonder at the richness of the creation, a richness which only mirrored the fecundity of the Creator.

Thus heaven goes under one name, but contains so many fixed stars and planets, and they, by their diversity of motions, exhibit so many phaenomena, that though they have employed the curiosity of astronomers for many ages, yet our times have, in the celestial part of the world, made discoveries as considerable, if not as numerous, as all those of the antients; and as our optick glasses have detected many fixed stars, and divers planets, that were unknown to former times, so our navigators, by their voyages beyond the line, have discovered divers whole constellations in the southern hemisphere: so that though heaven be an object, that has been perpetually and conspicuously exposed to men's view and curiosity for some thousands of years, yet it still affords new subjects for their wonder; and I scarce doubt, but by the farther improvements of telescopes posterity will have its curiosity gratified by the discovery both of new constellations, and of new stars in those that are known to us already. We need not therefore fear our admiration of God should expire, for want of objects to keep it up. That boundless ocean contains a variety of excellent objects, that is as little to be exhausted, as the creatures, that live in our sublunary ocean, or lie on the shores, that limit it, can be numbered.12

The telescope, the microscope, the anatomical knife, and the chemical furnace were but instruments of God's glory.

12. High Veneration (IV, 132 and 153). One is immediately reminded of Newton's famous remark about pebbles on the shore.
When Boyle studied the book of nature and consulted "the glosses of Aristotle, Epicurus, Paracelsus, Harvey, Helmont, and other learned expositors of that instructive volume," he found himself "reduced to exclaim with the Psalmist, How manifold are thy works, O Lord? in wisdom hast thou made them all!" All of nature's engines, animate and inanimate, great and small, pointed to the most excellent craftsman; but the exquisite construction, symmetry, variety, and economy of the organic world did so with the greatest force. Though it be true, said Boyle, "that the greater works of God do as well declare his great wisdom as his power," yet no less did his wisdom appear in lesser creatures. God, "in these little creatures, oftentimes draws traces of omniscience, too delicate to be liable to be ascribed to any other cause." The mole was no less wonderful than the elephant; nature's clocks were no more wonderful than her watches.

Almost all natural philosophers of the scientific revolution expressed awe and amazement when confronted with the majestic and intricate works of nature. Even Robert Hooke, not a particularly pious man, described the effects of nature as "wonderful because every natural production may be truly said to be a wonder or miracle if duly

14. High Veneration (IV, 136f) and Usefulness (II, 22); cf. A Disquisition about the Final Causes of Natural Things (V, 403).
considered.\textsuperscript{15} For Boyle, however, the religious dimension of scientific investigation was almost overwhelming. He considered himself a priest in the temple of God's works, an interpreter of the book of creation.\textsuperscript{16} Far from divorcing design from science, Boyle insisted that it was "injurious to God, as well as unwarrantable in itself, to banish from natural philosophy the consideration of final causes . . ." In abandoning the argument from design, he thought, the Cartesians had thrown away an argument "which the experience of all ages shews to have been the most successful (and in some cases the only prevalent one) to establish, among philosophers, the belief and veneration of God." The innate idea of God might suffice to show his

\begin{itemize}
\item \textsuperscript{15} From "A Discourse of Earthquakes," in The Posthumous Works of Robert Hooke, ed. Richard Waller (London, 1705), pp. 423f. John Calvin, who never denied the reality of secondary causes, once said that "there are as many miracles of divine power, as many tokens of goodness, and as many proofs of wisdom, as there are kinds of things in the universe, indeed, as there are things either great or small." Institutes of the Christian Religion, ed. John T. McNeill and trans. Ford Lewis Battles (2 Vols.; London: SCM Press, 1960), I.14.21 (Vol. I, p. 181).
\item \textsuperscript{16} Final Causes (V,401) and Usefulness (II, 31f). See Harold Fisch, "The Scientist as Priest: A Note on Robert Boyle's Natural Theology," Isis 44 (1953), 252-65. Boyle attributed the metaphor of the world as a temple to classical antiquity. Calvin used a similar expression, calling the world "this most beautiful theater"; see Institutes I.5.8., I.6.2, I.14.20, and II.6.1. I do not find in Boyle the lack of spirituality for which R.S. Westfall generally condemns the virtuosi in Science and Religion in Seventeenth-Century England (New Haven: Yale UP, 1958). What I find is a lack of emphasis on redemption within a creation orientation. The same could be said of Calvin, for whom redemption was not as much salvation from damnation as it was a restoration of the created state.
\end{itemize}
power, but not his wisdom and goodness. 17 Thus Boyle turned Cartesianism on its head, arguing for God teleologically rather than ontologically. Boyle also inverted Descartes' inference from an omnipotent God to a universe of seemingly boundless size; instead of arguing that an infinite God demanded an immense universe, Boyle took the fact of an immense universe as evidence of God's infinite power. 18

This is not to say that Boyle equated the practice of science with the pursuit of final causes. No good voluntarist--no good Christian--could presume to know all of God's purposes. But there were two very different ways wherein a man may pretend to know the ends of God in his visible works: for, he may either pretend to know only some of God's ends, in some of his works; or he may pretend to know all his ends. He, that arrogates to himself to discover God's ends in this latter sense, will scarce be excused from a high presumption, and no less a folly, from the reason lately intimated in the Cartesian objection. But to pretend to know God's ends in the former sense, is not a presumption, but rather to take notice of them is a duty. For there are some things in nature so curiously contrived, and so exquisitely fitted for certain operations and uses, that it seems little less than blindness in him, that acknowledges, with the Cartesians, a most wise Author of things, not to conclude, that, though they may have been designed for other (and perhaps higher) uses, yet they were designed for this use. 19


18. Usefulness (II, 20).

19. Final Causes (V, 397).
A modest search for final causes was entirely appropriate, indeed a duty. If it was erroneous to say "that everything in the visible world was made for the use of man," it was "more erroneous to deny, that any thing was made for ends investigable by man."20 Some purposes were very clear: the manifestation of God's glory, the general welfare of the creation, the welfare of individual creatures, and the suitability of certain things for human needs.21 Final causes and efficient causes were complementary and harmonious. Both were required for a complete understanding. A man might "give a mechanical reason of the structure of every wheel and other part of a watch," all the while supposing "that the artificer designed it to shew the hours of the day."22

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Design for Boyle was more than just a manifest feature of the world which pointed unambiguously to a Designer. It was a necessary principle of natural philosophy; without it, the origin of the world was inexplicable. Mechanical principles alone were insufficient to account for the

20. Ibid., p. 396.


22. Ibid., p. 399; also see p. 443 and Free Inquiry (V, 245).
formation of the universe. We needed in addition

an architectonick principle or power; by which I mean
those various determinations, and that skilfull
guidance of the motions of the small parts of the
universal matter by the most wise Author of things,
which were necessary at the beginning to turn that
confused chaos into this orderly and beautiful world;
and especially, to contrive the bodies of animals and
plants, and the seeds of those things whose kinds
were to be propagated. For I confess I cannot well
conceive, how from matter, barely put into motion,
and then left to itself, there could emerge such
curious fabricks as the bodies of men and perfect
animals, and such yet more admirably contrived
parcels of matter, as the seeds of living
creatures.23

Boyle rejected Descartes' cosmogony in which God set matter
into motion according to laws he established and then
ceased to interpose. Although Boyle saw "some probability"
that, once God had properly set matter into motion,
vortices might be produced by "numberless occursions" of
the parts of the world without further divine action, he
deemed it "utterly impossible that brute and unguided,
though moving, matter should ever convene into such
admirable structures as the bodies of perfect animals."24
But once God had framed the world and established the
course of nature,

the naturalist (except in some few cases where God or
incorporeal agents interpose) has recourse to the
first cause but for its general and ordinary support

23. The Sceptical Chymist (I, 571).
24. Origin of Forms and Qualities (III, 30f), emphasis his;
cf. p. 15 and The Relation betwixt Flame and Air
(III, 597f).
and influence, whereby it preserves matter and motion from annihilation or desition; and in explicating particular phenomena considers only the size, shape, motion (or want of it), texture, and the resulting qualities and attributes, of the small particles of matter. And thus in this great automaton, the world (as in a watch or clock), the materials it consists of being left to themselves could never at the first convene into so curious an engine: and yet, when the skilful artist has once made and set it a-going, the phenomena it exhibits are to be accounted for by the number, bigness, proportion, shape, motion (or endeavor), rest, coaptation, and other mechanical affections, of the spring, wheels, pillars, and other parts it is made up of; and those effects of such a watch that cannot this way be explicated must, for aught I know, be confessed not to be sufficiently understood.25

By this Boyle meant only that scientific explanations of the world as it now is (ever since God finished his creative work) had to be mechanical in character. He most emphatically did not mean that divine superintendence had ended with the creation of the world. The transcendent Clockmaker was also an immanent Mechanic. The most potent Author and Officer of the world, wrote Boyle,

hath not abandoned a master piece so worthy of Him, but does still maintain and preserve it, so regulating the stupendiously swift motions of the great globes, and other vast masses of the mundane matter, that they do not, by any notable irregularity, disorder the grand system of the universe, and reduce it to a kind of chaos, or confused state of shuffled and depraved things.26

No single metaphor is sufficient to convey the full

25. Ibid., p. 31; cf. Sceptical Chymist (I, 571), quoted above.

Judeo-Christian concept of God. The Father Almighty is also the Maker of heaven and earth: the God of Abraham, Isaac, and Jacob is also the Ancient of Days. In precisely the same way, no single metaphor can fully capture the nature of God's relationship to the world. The clock metaphor, one of the most widely used images of the world throughout the scientific revolution, beautifully harmonized the mechanical philosophy with the notion of intelligent design, but simultaneously suggested the dangerous, deistic thought that the craftsman might leave his clock to run on its own after making it. This occurred to Boyle, as it had others before him. 27 Thus he stressed

27. The Puritan divine John Robinson (1576?-1625) had said that "it addes to the honour of the skilfull Artificer, so at the first to frame his Clocke or other worke of like curious devise, as that the severall parts should constantly move, and order each other in infinite varietie, hee, as the Maker, and first Mover moving, and ordering all. Where yet this difference must alwayes be minded, that the Artisan leaves his worke being once framed to it selfe; but God by continuall influx preserves, and orders both the being, and motions of all Creatures. Here also we except both unnaturall accidents; and specially, supernaturall, and miraculous events; which are, as it were, so many particular creations, by the immediate hand of God." See his Essays: or, Observations Divine and Morall. Collected out of Holy Scriptures, ancient and moderne writers, both divine and humane. As also, out of the great volume of mens manners (2nd ed.; London, 1638), pp. 31f. This passage is mentioned by John Dillenberger, Protestant Thought and Natural Science (Garden City, NY: Doubleday, 1960), p. 116. On Robinson see the DNB, XVII, 18-22. Cf. Calvin's comment that "to make God a momentary Creator, who once for all finished his work, would be cold and barren, and we must differ from profane men especially in that we see the presence of divine power shining as much in the continuing state of the universe as in its inception." Institutes I.16.1 (Vol. I, p. 197). S.L. Macey, Clocks and the Cosmos: Time in Western Life and Thought (Hamden, Connecticut: Archon Books, 1980), traces
repeatedly the necessity of what he often called God's "general" or "ordinary concourse"—that is, his ordained power—for the orderly running of the universe and even for its moment by moment existence. God was "the continual preserver and upholder of [the universe]."\textsuperscript{28} Just "as the world could not have had a beginning, without having been provided by God, so for the continuance of the being it enjoys, it depends altogether, and every moment, upon the will and pleasure of its first author," to the extent that "if God should at any time withdraw his preserving influence, the world would presently relapse, or vanish into its first nothing..."\textsuperscript{29} All of God's creatures were likewise preserved in being "by that supporting influence of God, which keeps them from relapsing into their first nothing..."\textsuperscript{30}

In no sense, then, can Boyle's world be said to have run on its own, without the constant, direct supervision of its maker. God had not appointed a vice-gerent, "nature," to oversee his handiwork in his stead. The "vulgar notion of nature," by which Boyle signified the peripatetic

\textsuperscript{28} \textit{Free Inquiry} (V, 163).


\textsuperscript{30} \textit{Usefulness} (II, 25), again commenting on Nehemiah 9:6; cf. his comments on Psalm 104:29-30 in \textit{Occasional Reflections}, loc. cit. Commenting on Hebrews 1:3, Calvin said that "all things would instantly come to nothing, were they not sustained by his power."
conception, was "both injurious to the glory of God, and a
great impediment to the solid and useful discovery of his
works."31 By endowing the world with understanding or a
rational soul called "nature," philosophers had been led to
worship the creature rather than the Creator, an error
which even Christians had not escaped. To say that "nature
does such and such a thing" explained nothing, for it did
not explicate how the thing was done, which could only be
by mechanical and not incorporeal causes, "according to the
laws of motion settled by the omniscient Author of things."
As a "clear and eminent example" of the damage done by
adhering to the received notion of nature, Boyle pointed to

the ascension of water in pumps, and in other
phenomena of that kind, whose true physical causes
had never been found out, if the moderns had
acquiesced, as their predecessors did, in that
imaginary one, that the world was governed by a
watchful being, called nature, and that she abhors a
vacuum, and consequently is still in a readiness to
do irresistibly whatever is necessary to prevent it;
nor must we expect any great progress in the
discovery of the true causes of natural effects,
whilst we are content to sit down with other, than
the particular and immediate ones.32

It was unbecoming to the naturalist "to attribute to the

31. Free Inquiry (V, 162). Mary E.C. Bowen has properly
said, "Indeed, just as the new science was an intellectual
revolt against Aristotelian science, so also theologically
it was an assertion of theism against Aristotelian

32. Free Inquiry (V, 183f, 172, 176, and 165). Cudworth,
Glanvill, and More were three of the Christian philosophers
Boyle must have had in mind. See Steneck, "Greatrakes the
Stroker," pp. 174f.
senseless and inanimate body of water an aim at the good of the universe, . . . as if it were a free agent" capable of acting contrary to its nature by ascending to prevent a vacuum, "like a noble patriot, that sacrifices his private interests to the publick ones of his country." For Boyle, matter was correctly understood, both scientifically and theologically, as wholly inert and mindless, incapable of acting according to any intelligent principle—incapable, therefore, even of obeying laws. Properly speaking, he said,

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\text{a law being but a notional rule of acting according to the declared will of a superior, it is plain, that nothing but an intellectual Being can be properly capable of receiving and acting by a law. For if it does not understand, it cannot know what the will of the legislator is; nor can it have any intention to accomplish it, nor can it act with regard to it, or know when it does, in acting, either conform to it or deviate from it: and it is intelligible to me, that God should at the beginning impress determinate motions upon the parts of matter, and guide them, as he thought requisite, for the primordial constitution of things; and that ever since he should, by his ordinary and general concourse, maintain those powers, which he gave the parts of matter, to transmit their motion thus and thus to one another. But I cannot conceive, how a body devoid of understanding and sense, truly so called, can moderate and determinate its own motions, especially so, as to make them conformable to laws, that it has no knowledge or apprehension of . . .}^{34}
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The laws of motion "did not necessarily spring from the nature of matter, but depended on the will of the divine

33. *Experimental History of Cold* (II, 500) and *Usefulness* (II, 38).

34. *Free Inquiry* (V, 170), italics Boyle's.
author of things . . . " Boyle therefore looked upon a law

as a moral, not a physical cause, as being indeed but
a notional thing, according to which, an intelligent
and free agent is bound to regulate its actions. But
inanimate bodies are utterly incapable of
understanding what a law is, or what it enjoins, or
when they act conformably or unconformably to it; and
therefore the actions of inanimate bodies, which
cannot incite or moderate their own actions, are
produced by real power, not by laws; though the
agents, if intelligent, may regulate the exertions of
their power by settled rules.35

Manifestly, Boyle's conception of natural law was
voluntaristic. God operated directly on matter, governing
his actions by rules which were products of his own will.
In commenting on these passages, J.E. McGuire has
attributed to Boyle a view of causality akin to that of
David Hume, concluding that "Boyle implicitly expressed the
view that causation is something imposed upon observed
regularity by the conceptualizing power of the human
mind."36 I am unconvinced that Boyle would have put it
quite so strongly. It is clear, however, that he denied
any immanency and necessity to natural laws. Because they
were imposed by the will of a transcendent God, we could
presumably know them in a manner analogous to that in which
we could learn of his decrees in theology--to wit, by
revelation and not by unaided reason. Just as the book of

35. Christian Virtuoso (V, 521).
36. "Boyle's Conception of Nature," p. 536. For a
dissenting opinion, see Mary E.C. Bowen, op. cit., pp.
69-71.
scripture revealed certain truths above reason, so the book of nature revealed certain patterns by which its author exercised his sovereign will.

If the world was therefore not intelligent in that it possessed no mind of its own, it was yet intelligible because the Lord of nature continually imposed his will on his subjects. Instead of finding mind in nature, Boyle found it over and behind nature. Though in themselves mindless, inanimate bodies conformed to the intentions of human and divine agents, thus giving the appearance of innate intelligence where none was actually present. An arrow shot at a mark had no design to strike it, but moved as if it did because a man had aimed it. In declaring the hour, the wheels of a timepiece had no thoughts of their own, but only accomplished the intentions of the designer. As God's own masterpiece perfectly embodying his ends, the universe itself was "like a rare clock, such as may be that at Strasburgh, where all things are so skilfully contrived, that the engine being once set a moving, all things proceed, according to the artificer's first design . . .." The all-knowing Lord was more than

37. Final Causes (V, 413), Free Inquiry (V, 171), and Usefulness (II, 40).

38. Free Inquiry (V, 163). Cf. this passage from Usefulness (II, 39), which could easily be mistaken for a selection from Query 31 of Newton's Opticks: God in the beginning divided matter "into an innumerable multitude of very variously figured corpuscles, and both connected those particles into such textures or particular bodies, and
merely a divine mathematician who established initial conditions based on their calculated outcomes—indeed he was not a mathematician at all. His knowledge was not "a progressive or discursive thing, like that assigned by our ratiocinaton, but an intuitive knowledge" obtained, as it were, by looking into himself "as in a divine and universal looking-glass."39 He was the unsearchably wise DEMIURGOS, "whose piercing eyes were able to look, at once, quite through the universe, and take into his prospect both the beginning and end of time" with perfect knowledge not only of the mechanical parts of the world, but also of the secret thoughts and intentions of men and the contingent actions of free agents.40 God was indeed more than a watchmaker, and his creation more than a watch. Instead of dividing divine operations "into two sorts only, natural and supernatural," Boyle added a third category, "supra-mechanical," for those operations which were "natural in a larger sense." Whereas

placed them in such situations, and put them into such motions, that by the assistance of his ordinary preserving concourse, the phaenomena, which he intended should appear in the universe, must as orderly follow, and be exhibited by the bodies necessarily acting according to those impressions or laws, though they understand them not at all, as if each of those creatures had a design of self-preservation, and were furnished with knowledge and industry to prosecute it . . . "

39. High Veneration (IV, 150). This recalls Galileo's view.

40. Free Inquiry (V, 190) and High Veneration, loc. cit. This image is strikingly similar to Newton's PANTOCRATOR.
all the phaenomena of the world, as it is an aggregate, or system of mere bodies, are performed by matter, and local motion, according to mechanical laws; the operations of the human mind, and its organical body upon one another, are not to be accounted for by mere matter, and its mechanical powers ... So that these operations, that belong to a man as he is so, though in some sense they are not supernatural, because the order of things being once established by the most wise and powerful author of them, they are produced according to the course of nature; yet they may be stiled supra-mechanical, because they cannot be mechanically explicated or produced, nor can they be proved to flow from natural causes, if these are considered, as but corporeal ones.41

In its proper context, then, the clockwork metaphor was intended to convey the lawlike, mechanical regularity of the created universe under the absolute sovereignty of an omnipotent, wise, and free creator. Some measure of Boyle's appreciation of divine sovereignty and freedom can be obtained from an examination of his position on the plurality of worlds, a topic of frequent discussion in the scientific revolution.42 If God has made other worlds, wrote Boyle, he "may have given peculiar and admirable instances of his inexhausted wisdom in the contrivance and government of systems, that, for aught we know, may be

41. Christian Virtuoso (VI, 754). In an unpublished manuscript listing remarks "About Atheism," Boyle said that "no mechanical account can be given of Paine and Griefe felt from the Body." Royal Society, Boyle Papers, vol. 6, folio 61, quoted by Bowen, op. cit., p. 86.

42. See Steven J. Dick, Plurality of Worlds: The Extraterrestrial Life Debate from Democritus to Kant (Cambridge: UP, 1982). Dick's statement (p. 200 n18) that Boyle "did not specifically address himself to the question of other worlds" is incorrect.
framed and managed in a manner quite differing from what is observed in that part of the universe, that is known to us." The kind of matter, the laws of motion, and the living creatures might be highly unlike those in our own world. In contrast to the Cartesian God, Boyle's God apparently saw no necessity to create a given type of matter or a given set of laws. These things could not be prescribed a priori. God could just as easily have made other kinds of worlds as other worlds of the same kind. Boyle thought that in the new heaven and new earth which God would someday substitute for the present one, "the primordial frame of things, and the laws of motion, and consequently, the nature of things corporeal, may be very differing from those that obtain in the present world."

Boyle extended God's sovereignty yet further. Just as God could, at his pleasure, create other worlds or recreate the present one, so he could alter the established course of nature to suit his own purposes. It is not so much that Boyle admitted miracles, for any Christian would have, but that he dwelt on them as an integral part of his natural philosophy. Where Galileo and Descartes had relegated miracles forever to the realm of theology, Boyle considered them worthy of inclusion within the pale of philosophical discourse as something to be accounted for by the Christian

43. High Veneration (V, 138-147).
44. Christian Virtuoso (VI, 788f).
virtuoso. To be sure, this was not without its difficulties for the committed mechanist that Boyle was, but to say with R.S. Westfall that Boyle's reconciliation of miracles and mechanisms was "artificial and arbitrary" is to ignore the nuances and resources of the voluntarist tradition.45

The paradigm miracle for Boyle was the creation of the world, an act of pure omnipotence accomplished by fiat without toil or pre-existent matter. But God was no less sovereign now as then. The world was to God as a shadow to a man: both could be changed at will, "in the twinkling of an eye." When God had a mind to work those miracles, we most admire, as when at Joshua's prayer he stopped the course of the sun, and at Hezekiah's, made him go back; we men are apt to imagine, that these prodigious effects must needs cost their author much, and that he must strain his power, and be necessitated to a troublesome exertion of his omnipotence, to be able to produce them: whereas to that divine agent, those things, that would be to all others impossible, are so far from being difficult, and the creatures have so absolute and continual a dependance on him, that it is as easy for him to effect the greatest alterations in them, as to resolve to do so. And even those miraculous changes of the course of nature, that do the most astonish us, do so naturally and necessarily flow from the motions of his own will, that to decree, and to execute, (whether or no they require powers otherwise than notionally differing) are alike easy to him: and that irresistible agent finds as

45. Science and Religion, p. 89. Otherwise keenly aware of seventeenth century theological currents, Westfall failed to appreciate the signifigance of voluntarist orientations. In this of course he was not alone—it is only recently that historians have begun to see the importance of such orientations.
little more difficulty to produce the greatest changes among the creatures, than to produce the least, as I find it harder to move the whole arm of my shadow, than to move the little finger.

By diverse ways, "some of them imaginable by us, and others inconceivable to us," the grand Author of nature could "bring such things to pass, as the ordinary course of nature would never produce, and surpassing those which her unassisted power could ever reach to." The laws of nature were not necessary truths binding on God, but were "arbitrarily instituted by God" and, in reference to him, were "but arbitrary still." It is a rule in natural philosophy, said Boyle,

that causae necessariae semper agunt quantum possunt; but it will not follow from thence, that the fire must necessarily burn Daniel's three companions, or their clothes, that were cast by the Babylonian king's command into the midst of a burning fiery furnace, when the author of nature was pleased to withdraw his concourse to the operations of the flames, or supernaturally to defend them against the bodies, that were exposed to them. That men once truly dead cannot be brought to life again, hath been in all ages the doctrine of mere philosophers; but though this be true, according to the course of nature, yet it will not follow, but that the contrary may be true, if God interpose either to recall the departed soul, and re-conjoin it to the body, if the organization of this be not too much vitiated, or by so altering the fabric of the matter, whereof the carcass consists, as to restore it to a fitness for the exercise of the functions of life. Agreeably to this, let me observe to you, that, though it be unreasonable to believe a miraculous effect, when attributed only to a mere physical agent: yet the same thing may reasonably be believed, when ascribed to God, or to agents assisted with his absolute or

46. Occasional Reflections (II, 402f) and Christian Virtuoso (VI, 678-80); cf. Final Causes (V, 414).
supernatural power.

Physical laws were just "collected or emergent" truths inductively obtained by comparing many particulars regarding "the settled phaenomena of nature," not "axioms metaphysical, or universal, that hold in all cases without reservation." Thus Boyle rejected as "a great error" the idea of the double truth—"that this or that thing is true in philosophy, but false in divinity"—for it was "not repugnant to reason" that God might interpose his power to make iron float or a virgin conceive.47

God had indeed performed miracles, always for a religious purpose, especially to authenticate the divine origin of Christianity. An argument grounded on miracles, Boyle thought, was "little less than absolutely necessary, to evince, that any religion, that men believe to be supernatually revealed, . . . does really proceed from God." The miracles of Christ and his disciples certified the truth of their message. Although we ourselves have not seen them, Boyle argued, we have experienced them vicariously through the biblical histories, which were penned by men who "cheerfully suffered to attest the truth" of their witness. Knowledge of the true limits of mechanical powers would qualify the Christian virtuoso "to

47. Christian Virtuoso (V, 714), Reason and Religion (IV, 161f), Things above Reason (IV, 463), and Reason and Religion (IV, 163).
distinguish between things, that are only strange and surprising, and those that are only miraculous; so that he will not mistake the effects of natural magic, for those of a divine power." The mechanical notion of nature was thus superior to the vulgar because it enabled its proponents more readily to recognize true miracles. Among the many biblical miracles which Boyle mentioned, the two already cited were perhaps his favorite examples of divine sovereignty over nature. One of these, the deliverance of Daniel's friends from the fiery furnace, was a standard theme of voluntarist theologians after Ockham. The resurrection of the dead, the other example, drew from Boyle an explanation of its possibility in light of the mechanical philosophy. By "recollecting a sufficient quantity of the scattered matter of a dead human body" and re-uniting it with a soul, God could "effect that wonder we call the resurrection." Putting aside considerations of


49. See Reason and Religion (IV, 162), Usefulness (II, 17), The Martyrdom of Theodora, and of Didymus (V, 268), and The Possibility of the Resurrection (IV, 201f). Francis Oakley, "Christian Theology and the Newtonian Science of Nature," in Creation: The Impact of an Idea, ed. Oakley and Daniel O'Connor (New York: Scribners, 1969), pp. 54-83, has found the fiery furnace as an example of divine freedom in the works of Luther, Melanchthon, Suarez, Perkins, Preston, Ames, Shepard, Norton, Increase Mather, and Willard. Klaaren (op. cit., p. 221 n22) has called it a "stock voluntarist example."

50. Reason and Religion (IV, 159); cf. Usefulness (II, 48f). Boyle's short treatise on The Possibility of the Resurrection was appended to Reason and Religion.
how God might have accomplished it, Boyle clearly believed that we too, like Christ, would be raised from the dead. On the occasion of his only known visit to a nonconformist religious service, Boyle disputed the meaning of Daniel 12:2 ("And many that sleep in the dust of the earth shall awake, some to everlasting life, and some to everlasting shame and contempt.") with Sir Henry Vane, who gave it an allegorical interpretation in terms of the revival of long dead religious doctrines. According to Birch (who followed Sir Peter Pett's account), Boyle "thought himself obliged for the honour of God's truth to say, that this place in Daniel being the clearest one in all the Old Testament for the proof of the resurrection, we ought not to suffer the meaning of it to evaporate into allegory..."51 A third miracle, that at Pentecost, illustrates the apologetic function of miracles in Boyle's thought. In an unpublished essay on the circumstances of and inferences deducible from the Pentecost miracle, Boyle argued that the biblical account satisfied the basic criteria of historical veracity and then concluded that it confirmed such fundamental articles of the faith as the existence of God, the immortality of the soul, the reality of providence, the triune nature of God, the messiahship of Christ, and the

51. Life of Boyle (I, cxl). Whether Boyle's objection was motivated, at least in part, by political goals as J.R. Jacob claims, I will not venture to consider. My point stands that Boyle believed in the importance of a literal resurrection of the dead.
That Boyle accepted biblical miracles is one thing. Did he also believe that God continued to perform miracles in the present age or did he hold with many other Protestants that they ceased with the apostolic era? To the best of my knowledge, Boyle addressed this question in only two contexts, when discussing either the origin of the soul or medical miracles. From the immateriality of the soul, Boyle inferred that the divine providence extends to every particular man; since whenever an embryo, or little human body formed in the womb, is, by being duly organized, fitted to receive a rational mind, God is pleased to create one, and unite it with that body. In which transaction, there seems to me a necessity of a direct and particular intervention of the divine power; since I understand not, by what physical charm or spell an immaterial substance can be allured into this or that particular embryo, of many that are at the same time fitted to receive a human soul; nor by what merely mechanical tie, or band, an immaterial substance can be so durably (perhaps for 80 or 100 years) joined and united with a corporeal, in which it finds no parts, that it has organs to take hold of, and to which it can furnish no parts to be fastened upon by them.

In this sense at least Boyle believed that God had

52. I am following Mary E.C. Bowen's account of this document on pp. 122-23 of her dissertation. The manuscript is in the Royal Society, Boyle Papers, vol. 7, folios 5 and 95.

53. *Christian Virtuoso* (V, 520). Boyle affirmed the miraculous origin of each soul in *A Defense of the Doctrine touching the Spring and Weight of Air* (I, 146) and in *Free Inquiry* (V, 241); in the latter place, he assigned this union of body and soul to the sixth or seventh week after conception.
performed miracles throughout human history. But these miracles involved no observable or unpredictable disturbance of the ordinary course of nature—indeed they happened normally, if not naturally, in the process of embryological growth. They were not miracles in the usual sense, nor did Boyle call them "miracles." In the affair of Greatecakes the Stroker, however, the occurrence of true miracles was certainly the issue.54 While visiting London in 1665–66 (the height of the plague and the year of the great fire), the Irish healer performed before reliable witnesses (including Boyle) numerous apparent cures of the king's evil and other ailments. Henry Stubbe, a Stratford physician who had seen some of the cures, published an account of his observations, accompanied by an explanation, in the form of a letter to Robert Boyle.55 Stubbe interpreted Greatecakes' deeds as the effects of a sanative temperament which was God's special gift to him. They were miracles equal to those of Christ and the apostles, yet the result of a natural power and not the direct hand of God. Boyle's reply, which was not published before Birch's 1744 edition of his works, took exception to Stubbe's careless conflation of the natural and the supernatural. In the


first part of his letter, said Boyle, Stubbe had argued for the miraculous character of Greatrakes' cures, but in the latter part he had offered a natural explanation. With regard to biblical miracles, in contrast, Boyle was "far from believing, that any mechanical or physical hypothesis will make out those supernatural phaenomena, without having recourse to the miraculous interposition of God." But if Boyle readily dismissed Stubbe's explanation, he did not so readily dismiss the possibility that Greatrakes might in fact have been the doer of miracles. For his part, he said,

though I be very backward to believe any strange thing in particular, though but purely natural, unless the testimonies that recommend it be proportionable to the extraordinariness of the thing proposed; yet I remember not, that I have hitherto met with (no more than you have done) any, at least any cogent proof, that miracles were to cease with the age of the apostles; and not only the excellent Grotius, but Tertullian, Justin Martyr, Cyprian, and other ancients tell us, that the power of ejecting devils out of possessed persons lasted long after that, and was not infrequent in the Christian church. And therefore if those relations of Mr. Greatraks's cures, that I have not yet seen, shall convince me, I shall not scruple, since his belief and life give me no just suspicions to acknowledge my conviction, and to rejoice in the appearing of a protestant, that is enabled and forward to do good in such a way, especially in an age where so many do take upon them to deride all that is supernatural; and, whilst they loudly cry up reason, make no better use of it than to employ it, first to depose faith, and then to serve their passions and interests. But by what hitherto appears to me of Mr. Greatraks's cures, I must take leave to think, that either they are not real miracles; or, if they have any thing in them of a supernatural gift, it is so far short of the gifts of our Saviour Christ and his apostles, that I presume your friends will think, that if it were not the effect of your haste, it was rather to shew your
wit than declare your opinion, that you seem to make a parity between them. And for my part I should in that case, reflecting upon the passage you cite [1 Cor 12:5], that there are different administrations, but the same Lord, think it more fit to look upon this gift of Mr. Greatraks, as a distinct and inferior kind, than degrade the unquestionable miraculous gifts of the apostles, to depress them to the same level with his.

Boyle's position here was an ambiguous one. While unwilling to affirm that miracles had ceased with the apostolic age, he nevertheless remained "not fully convinced" that Greatrakes' cures contained "any thing that is purely supernatural." Though open to the possibility of miracles in his own day, he did not see in the Greatrakes controversy an opportunity convincingly to settle the issue.

Boyle brought to his study of miracles the same critical attitude that guided his study of Holy Writ. His Copernican leanings required adherence to the principle of accommodation, and his endorsement of the mechanical philosophy tempered his conviction that God could act as he pleased in the natural world. This is particularly clear in his views on the origin of plagues. The sacred writings expressly teach, said Boyle with his customary prolixity,

that some plagues, and particularly that, which in David's time swept away in three days 70,000 persons, have been in an extraordinary manner inflicted by God. And to me it appears either scarce possible, or

56. Birch, Life of Boyle (I, lxxix, lxxvi-lxxvii, and lxxx).
far more difficult, than those that have not attentively enough considered the matter, are wont to think it, to deduce the astruse origin, strange symptoms, and other odd phaenomena of some plagues, that are recorded in history, from merely corporeal causes.

On the other side it seems unphilosophical . . . to recur, without an absolute necessity, to supernatural causes, for such effects as do not manifestly exceed the power of natural ones; though the particular manner of their being produced is perchance more than we are yet able to explicate. . . .

Upon these and the like reasons I have sometimes suspected, that in the controversy about the origin of the plague; namely, whether it be natural or supernatural, neither of the contending parties is altogether in the right: since it is very possible, that some pestilences may not break forth, without an extraordinary, though perhaps not immediate, interposition of almighty God, provoked by the sins of men; and yet other plagues may be produced by a tragical concourse of merely natural causes.

But though the difficulties, that incumber each of the opposite opinions, keep me both from dogmatically asserting, that all plagues have a supernatural origin, and from denying, that they have it; yet, to say something on such an occasion, though I can speak but very hesitantly, I shall venture to add, that, whether or no the true plague be said to descend to the earth from a higher sphere, than that of nature; yet its propagating and effects are (at least for the most part) carried on mainly by a malignant disposition in the air . . . 57

Miracles did happen, but only rarely. And some events we were wont to call miracles were not really the effects of supernatural causes, but rather of rational minds above the level of the purely mechanical. At diverse times—"perhaps oftener than mere philosophers imagine"—God, by the "intervention of rational minds," whether human or angelic, gave to the parts of human bodies motions which they would

57. An Experimental Discourse of some Unheeded Causes of the Insalubrity and Salubrity of the Air (V, 56).
not have had "by laws merely mechanical" in order to produce things "conducive to the welfare or detriment of men." It was becoming to the Christian philosopher to admit "that God doth sometimes, in a peculiar though hidden way, interpose in the ordinary phaenomena and events of [medical] crises"; but this happened so seldom "that we are not hastily to have recourse to an extraordinary providence, . . . if it may probably be accounted for by mechanical laws, and the ordinary course of things."58 We must be careful not to make too much of Boyle's insistence on the rarity of miracles. One scholar has said that because Boyle was "unable to deny biblical miracles, he forced himself to make miracles an exception to the general rule."59 What else was anyone to make of miracles? Without the ordinary course of nature, the extraordinary acts of God could not be recognized for what they are; there is no supernatural without the natural.

* * * * *

Boyle believed that miracles were events whose causes wholly exceeded the bounds of natural processes. Although miracles could be understood theologically and were a legitimate subject of rational discourse, supernatural explanation had no place in natural philosophy. It was

God's ordained power, not his absolute power, which the virtuoso ought to employ. Appeals to angels and astral influences were equally improper. Ockham's razor forbade any other approach.60 Those "schoolmen and philosophers [who] have derived forms immediately from God," Boyle protested in the Origin of Forms and Qualities, have "put omnipotence upon working I know not how many thousand miracles every hour, to perform that . . . in a supernatural way which seems the most familiar effect of nature in her ordinary course."61 

"'Tis the part of a philosopher," wrote John Wilkins in 1640, "not to fly unto the absolute power of God and tell us what He can do, but what according to the usual way of providence is most likely to be done, to find out such causes of things as may seem most easy and probable to our reason."62 Boyle himself never said it any better. In 1661 the Jesuit Franciscus Linus proposed his funicular hypothesis to explain Boyle's experiments with the vacuum pump. In order to account for the existence of a space between the top of a column of mercury and the top of a closed glass  

60. An Hydrostatical Discourse (III, 608f) and Suspicions about Some Hidden Qualities of the Air (IV, 95).  

61. Works III, 40.  

62. Discourse concerning a New World & Another Planet, Book 2, p. 193. This was said with reference to the exceedingly great velocity of the celestial sphere which geocentric cosmology required. Although it was possible for God to perform such a motion, Wilkins argued, it was repugnant to the nature of things.
tube, Linus suggested that Nature formed an invisible elastic membrane of air or subtle matter between the mercury and the tube. As the mercury dropped, this funiculus resisted distention, suspending the liquid in the tube. Reluctant to admit that the apparently empty space left behind by the funiculus was a true vacuum, Linus called it "virtual extension," adding that such a thing was at least possible by divine fiat—to which Boyle replied, "our controversy is not what God can do, but about what can be done by natural agents, not elevated above the sphere of nature." In my hypothesis, Boyle said, "things are explicated by the ordinary course of nature, whereas in the other [Linus'] recourse must be had to miracles."63 Boyle reacted in a similar way when Hobbes introduced God's power into a discussion of infinite divisibility: "when Mr. Hobbes has recourse to what God can do (whose omnipotence we have both great reason to acknowledge) it imports not to the controversy about fluidity to determine what the almighty Creator can do, but what he actually has done."64

Boyle's determination to limit scientific explanation to the sphere of God's ordinary activity—to what God


64. An Examen of Mr. T. Hobbes's "Dialogus Physicus de Natura Aeris" (I, 236).
actually did, not to what he had the power to do--betrays both a fundamental distrust of human speculation and a healthy respect for the facts as God saw fit to establish them. It is to the theological roots of that attitude that we will now turn our attention.

God's Creative Power, the Limits of Human Knowledge, the Eternal Truths, and Empirical Science

Some of the greatest minds of the seventeenth century yielded to the temptation to impose the bounds of their own reason on God's absolute power, enclosing his creative acts in a box of their own making. For Boyle, however, the rationalist enterprise amounted to sheer, unwarranted presumption. As "purblind mortals, that are not of the highest order of God's creatures," we could not but be "incompetent judges" of God's power, which could "justly be supposed to reach farther than our limited intellects can comprehend; or, ... without a saucy rashness, can presume to bound."65 We men, he wrote in the *Christian Virtuoso*,

have too good a conceit of ourselves, when we think that no such thing can have an existence or at least have a nature or being, as we are not able to comprehend. For if we believe God to be the author of things, it is rational to conceive that he may have made them commensurate, rather to his own designs in them, than to the notions we men may best be able to frame of them.

The world was made before man, who was not consulted in its

65. *Christian Virtuoso* (VI, 676f).
construction. The author of nature "made things in such manner as he was pleased to think fit, and afterwards left human understandings to speculate as well as they could upon those corporeal, as well as other things." Therefore Boyle saw "no necessity, that intelligibility to a human understanding should be necessary to the truth or existence of a thing . . ." God was under no obligation to conform to human notions in anything he did. Boyle rejected as "not very cogent, and somewhat irreverant," Van Helmont's argument that divine providence was compelled to provide a cure for every disease; God was "not obliged any more to continue life or health to sinful man, than to beasts, that never offended him . . ." Neither the stars nor the passages of scripture had been "nicely or methodically placed," for "it became not the majesty of God to suffer himself to be fettered to human laws of method," which were far below his own conception of things. Fully to comprehend God's infinite nature required no less than an infinite understanding. Even for the corporeal works of God our knowledge was

66. Works VI, 694. Things above Reason (IV, 450) contains a passage parallel to the last quotation. In an unpublished paper on the causes and remedies of atheism, Boyle denied that "the intellect of man is the genuine standard of truth, so that whatever surpasses his comprehension must not be admitted to be." Royal Society, Boyle Papers, vol. 6, folio 330, quoted by R.S. Westfall, Science and Religion, p. 168.

67. Usefuless (II, 101) and Style of the Scriptures (II, 270).
incomparably inferior to his: for though some modern philosophers have made ingenious attempts to explain the nature of things corporeal, yet their explications generally suppose the present fabric of the world, and the laws of motion that are settled in it; but God knows particularly, both why and how the universal matter was first contrived into this admirable universe, rather than a world of any other of the numberless constructions he could have given it; and both why those laws of motion, rather than others, were established; and how senseless matter, to whose nature motion does not at all belong, comes to be both put into motion, and qualified to transfer it according to determinate rules, which itself cannot understand. 

Boyle considered it improper for the Cartesians to argue a priori that divine immutability implied the conservation of the quantity of motion. To do so was to presume too much knowledge of God's intentions. Nor did he see how that law could be demonstrated a posteriori, since its agreement with terrestrial motions was questionable, and no one had directly experienced the propogation of celestial bodies. The "truth of the Cartesian rules [of impact] being evinced neither a priori, nor a posteriori," he concluded, it would not be unreasonable to think that God might have done things otherwise. Similarly, Descartes' identification of body and extension suffered from the "inconvenience" that God could not "annihilate the least particle of matter" without creating another "at the same instant and place"--which, as Boyle perceptively commented, agreed

68. High Veneration (V, 149f).

69. Ibid., p. 140. Cf. Final Causes (V, 396f), where Boyle challenged the logic of arguing from divine immutability to uniformity in nature.
"very ill with that necessary and continual dependence, which he [Descartes] asserts matter itself to have on God for its very being."70 Reason concluded many other things which, if not directly repugnant to God's freedom, were clearly contradicted by his works. Experience showed, for example, that "bodies of very unequal weight, let fall together, will reach the ground at the same time": that "weaker sounds are ... transmitted through the air as swiftly as stronger ones"; and that water expands rather than contracts upon freezing.71 Experience had likewise disproved "diverse very plausible and radicated opinions, such as that of the uninhabitableness of the torrid zone, of the solidity of the celestial part of the world, of the blood's being conveyed from the heart by the veins (not the arteries) to the outward parts of the body," all of which had to be abandoned upon the discovery of phenomena with which they were inconsistent.72

Boyle's suspicion of pure reason was intimately connected with his theological voluntarism. Revelation had already answered the larger questions of life; further speculation on God's purposes and decrees was pointless,

70. Excellency of Theology (IV, 43). Professor Edward Grant has suggested that Boyle chose the word "inconvenience" because of its Latin root inconveniens, "unsuitable."

71. Christian Virtuoso (V, 527f).

72. Certain Physiological Essays (I, 312).
even dangerous, for it could lead us into error. Science could progress without knowledge of ultimate realities, without encroaching on theological ground. Unlike Descartes, Boyle did not consider himself "obliged to treat of the cause of gravity in general" in order to use it in his explanations. The elasticity of air could be explained in two different ways, one atomist and the other Cartesian. To determine whether "the parts of a body are put into motion by the bending of the spring, or from the endeavor of some subtle ambient body" was a difficult business with which Boyle declined to meddle. His purpose was "only to manifest, that the air hath a spring, and to relate some of its effects," a position he maintained when attacked by Hobbes, who was contemptuous of "experimentarian philosophers" and criticized Boyle for refusing to specify the causes of the elasticity of air and of gravity. The nature of the continuum--whether or not matter was infinitely divisible--was probably insoluble, but "natural philosophy may be daily advanced without the decision of it, because there is a multitude of considerable things to be discovered and performed in

73. For a similar interpretation, see the books by Fisher and Hunt.

74. An Hydrostatical Discourse (III, 601).

75. Spring of the Air (I, 12).

nature, without so much as dreaming of this controversy . . . "77

Thus Boyle eschewed the kind of rationalistic science pursued by Descartes and others. It was better to know a little with certainty from experiment than to construct speculative systems of the universe.78 Although he saw the advantage of knowing "in general, how the qualities of things are deducible from the primitive affections of the smallest parts of matter," he affirmed that knowing merely how one body affects another was sufficient. We might, "without ascending to the top in the series of causes, perform things of great moment; and such, as without the diligent examination of particular bodies, would, I fear, never have been found out a priori, even by the most profound contemplators."79 Arguments a posteriori were just as valid, and more useful, than those a priori.80

77. Excellency of Theology (IV, 43).
79. Certain Experimental Physiological Essays (I, 310). Cf. the Short Memoirs for the Natural History of Mineral Waters (IV, 796), where Boyle stated that the ingredients and proportions of mineral waters "may be numberless, and the qualities resulting from these commixtures may be very differing from those of the separate ingredients; I am apt to look upon the difficulty of securely determining the effects of mineral waters a priori, as little, if at all less than insuperable to human understandings."
80. See the continuation of Spring and Weight of the Air (III, 279). Cf. Of the Strange Subtilty of Effluviums (III, 661) and Experiments and Considerations touching Colours (I, 663) for two of many similar statements.
Boyle devoted a short essay, "Of Unsucceeding Experiments," to the defense of experimentally derived knowledge in the face of contingencies. His heavy emphasis on Baconian natural histories is wholly consistent with this. Properties, not essences, were the aspects of nature he sought to determine. It is no accident that among Boyle's chief contributions to science are his discoveries of new chemical indicators and the establishment of almost all the properties of phosphorus known for the next two hundred years.

* * * * *

To say that God's thoughts are higher than ours, even to stress this point as fundamental to human knowledge, is not to say that God is unfettered by any considerations whatsoever. Boyle could not deny "that some things, that men may call bounds, may be assigned to the divine power," but only those boundaries which prevented one from holding "what is manifestly repugnant to the nature either of things, or of God." To turn a sphere of silver into a sphere of gold, though difficult, was not absolutely impossible, but to make a cylindrical sphere of gold was impossible, for "to give gold the necessary properties of a cylinder, the matter to be transformed must necessarily lose those of a sphere"; and one could no more "make an odd number that may be divided into two even whole numbers" than one could "make a square triangle, the ideas of the
subject and the attribute being manifestly inconsistent.\textsuperscript{81} Boyle therefore distinguished between probationary truths and absolute or eternal truths. By absolute truths, he said,

I understand in the first place those theoretical principles and axioms, which are the foundations of our reasonings, such as are, two contradictories cannot both be true, every thing is, or is not, every line is either strait or crooked, every number (whole and finite) is either even or odd. Two quantities, that are each of them equal to a third, are themselves equal, and from truth nothing but truth can be legitimately deduced. And to this sort of primary truths may be referred the definitions of our more simple mental ideas, such as the clear conceptions we have of a triangle, a square, a circle, a cube, a cylinder, &c. And because there neither has [been], nor will be any time, wherein these principles of knowledge and ratiocinations may not be safely assented to, without any relation to contingent circumstances, these self-evident principles may be called eternal truths: whereas for . . . [probationary truths], though a man may rationally look upon them as truths, as long as he sees just cause to believe them, or no sufficient cause to question them, yet he cannot safely judge them to be more than truths upon supposition, or to express it shorter, conditional. . . . For there are many doctrines and assertions, that for a long time (amounting perhaps to many ages) were generally received by philosophers themselves for true, which yet, by the happy discoveries of latter times, appear to unprejudiced judges to be errors.

. . . I conceive, then, that there are two kinds or orders of principles and dictates of reason: the one comprises those primary and universal notices and axioms, that are applicable to all kinds of subjects; . . . [which] hold on all occasions; and therefore may be distinguished from other rules or dictates of philosophy, which, though they will hold in most

\textsuperscript{81} \textit{Christian Virtuoso} (VI, 677f). "Thinkers in the voluntarist tradition do not usually deny that God is bound by the laws of logic; rather they are concerned to emphasize the power of God--PANTOKRATOR--and the inscrutability of Divine Will." J.E. McGuire, "Boyle's Conception of Nature," p. 527 n10.
cases, do not hold in all cases, and are, on that account, subordinate, or at least of an inferior nature, to the primary and catholic principles lately mentioned.

... I look upon the metaphysical and mathematical principles, we have been speaking of, to be truths of a transcendental kind, that do not properly, and exclusively to the other, belong either to philosophy or theology; but are universal foundations and instruments of all the knowledge we mortals can acquire.82

Thus Boyle agreed with Descartes in identifying the basic principles of logic and mathematics as eternal truths which functioned as the foundation of all knowledge. He also agreed that God, as "the author of our reason, cannot be supposed to oblige us to believe contradictions"; God's veracity and boundless knowledge prevented him from deceiving us.83 But here Boyle's similarity to Descartes ended. Where the Frenchman moved on to embrace the proposition that all things perceived clearly and distinctly are true, the Englishman reminded us that we "mistake and flatter human nature too much, when we think our faculties of understanding so unlimited, ... as many philosophers seem to suppose." Created and finite beings came we into the world, "as it pleased the almighty and most free author of our nature to make us." It followed from this that our mental abilities were "proportionable to

82. These quotations have been taken from three separate speeches by the character Eleutherius, who speaks for Boyle in the dialogue appended to the first part of the Christian Virtuoso (VI, 709-711).

83. Ibid., p. 712, and V, 529.
God's designs in creating us, and therefore may probably be supposed not to be capable of reaching to all kinds . . . of truths, many of which may be unnecessary for us to know here . . . ." Thus it was not unreasonable to think that "in our present mortal condition there should be some objects beyond the comprehension of our intellects," so that "we cannot attain to a clear and full knowledge of them."84 Therefore Boyle distinguished three degrees of demonstration and certainty. In metaphysical demonstration, built on the eternal truths, the conclusion was true and could not be otherwise. Physical demonstration, which presupposed physical principles (such as \textit{ex nihilo nihil fit}), was less certain because subject to God's absolute power. Moral demonstration relied on the concurrence of probabilities, as in the agreement of testimony from two different witnesses in a murder trial.85 Articles of religion Boyle assigned to the level of moral certainty, where he also placed most reasoning in physics: "in many things, that are looked upon as physical demonstrations, there is really but a moral certainty." For example, when astronomers discussed the paths and nature of comets, some did so without ever having seen a comet in their lives, but relied on their predecessors for information. Though the inferences they drew might "have a

84. Things above Reason (IV, 410).

85. Reason and Religion (IV, 182).
demonstrable certainty; yet the premises they are drawn from having but an historical one, the presumed physico-mathematical demonstration can produce in a wary mind but a moral certainty," and not even the greatest degree of that. It was no easy task to make the exacting observations required for constructing "an undoubted theory upon them." Boyle knew not "how many things in physics, that men presume they believe upon physical and cogent arguments, wherein they really have but a moral assurance . . ." 86

In adopting this view of knowledge, Boyle rejected both Cartesian and Baconian views. If Descartes had admitted into natural philosophy knowledge which was not more than morally certain, the basic propositions of his physics were derived, in his opinion, from reason alone and partook of absolute certainty. Bacon, though differing from Descartes on the means of obtaining scientific knowledge, also believed it to be demonstrable and absolutely certain. For both men, philosophers could learn the true structure or essence of the macroscopic and the microscopic. For Boyle, only God could have such a science; finite and fallen men could expect no more than moral certainty. 87 As Henry Van Leeuwen has shown, the

86. Excellency of Theology (IV, 42).

87. Boyle put it more forcefully in Excellency of Theology (IV, 50): "our knowledge is not very deep, not reaching with any certainty to the bottom of things, nor penetrating
theory of certainty that had been worked out by liberal Anglican divines in defense of Protestantism—the certainty of reasonable men—was later adopted by the most influential members of the Royal Society. That this theory appealed to the voluntarist (and liberal Anglican) that Boyle was, is not at all surprising.  

* * * *

If Boyle rejected Baconian and Cartesian notions of scientific certainty, he also drew from each tradition elements which harmonized more readily with his understanding of God's creative power: from Bacon, the conviction that experiments were the source of science; from Descartes, a hypothetical corpuscularism in explaining natural phenomena. Many atomists, Boyle observed, confidently

\[ \text{presume to know the true and genuine causes of the things they explicate; yet very often the utmost they can attain to, in their explications, is, that the explicated phaenomena may be produced after such a manner, as they deliver, but not that they really are so. For as an artificer can set all the wheels of a clock a going, as well with springs as with weights; and may with violence discharge a bullet out of the barrel of a gun, not only by means of gunpowder, but} \]

to their innate or inmost natures . . ." For Boyle's belief that the fall had affected our minds, see Reason and Religion (IV, 165f).

of compressed air, and even of a spring: so the same effects may be produced by diverse causes different from one another; and it will oftentimes be very difficult, if not impossible, for our dim reasons to discern surely, which of these several ways, whereby it is possible for nature to produce the same phaenomena, she has really made use of to exhibit them. ... [It] is a very easy mistake for men to conclude, that because an effect may be produced by such determinate causes, it must be so, or actually is so. ... For it is one thing to be able to shew it possible, for such and such effects to proceed from the various magnitudes, shapes, motions, and concretions of atoms; and another thing to be able to declare what precise, and determinate figures, sizes, and motions of atoms, will suffice to make out the proposed phaenomena, without incongruity to any others to be met with in nature ... Atomists were wont to assume "that either the proposed explication must be allowed, or men can give none at all, that is intelligible," an attitude which Boyle found wanting. No one, he thought, had shown "that men must be able to explicate all nature's phaenomena"; how could it be proved that the omniscient God could not exhibit phenomena in ways other than those "explicable by the dim reason of man?" If we admit that God is the author of the universe, he argued, how could it be "that he, whose knowledge infinitely transcends ours, and who may be supposed 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 human understandings" rather than to any other?89 God had made a very complex world indeed.

89. Usefulness (II, 45f). On Boyle's use of the Cartesian clock metaphor and the methodology it implies, see Laurens Laudan, "The Clock Metaphor and Probabilism: The Impact of Descartes on English Methodological Thought, 1650–65,"

There were often "so many subordinate causes between particular effects and the most general causes of things, that there is left a large field, wherein to exercise men's industry and reason" in the framing of causal schemes for various illnesses. Since we knew "very little a priori," it was without question "a great advantage" to have learned "by a variety of experiments" the "differing ways, whereby nature produces the same effects."  

Boyle had met with

Annals of Science 22 (1966), 73-104. Cf. this passage from Joseph Glanvill's *Scepsis scientifica* (London, 1665): "And though the Grand Secretary of Nature, the miraculous Des-Cartes, hath here infinitely out-done all the Philosophers that went before him, in giving a particular and Analytical account of the Universal Fabric: yet he intends his principles but for Hypotheses, and never pretends that things are really or necessarily, as he hath supposed them: but that they may be admitted pertinately to solve the Phaenomena, and are convenient supposals for the use of life. Nor can any further account be expected from humanity, but how things possibly may have been made consonantly to sensible nature: but infallibly to determine how they truly were effected, is proper to him only that saw them in the Chaos, and fashion'd them out of that confused mass. For to say the principles of Nature must needs be such as our Philosophy makes them is to set bounds to Omnipotence, and to confine infinite power and wisdom to our shallow models." I am quoting here from pp. 182ff of the 1885 reprint, ed. John Owen (London: Kegan Paul, Trench & Co.), italics Glanvill's.

90. Certain Physiological Essays (I, 309) and Usefulness (II, 76). Cf. Experimental History of Colours (I, 692): "though by making the experiments and reflections deliver'd in this paper, I have endeavoured somewhat to lessen my ignorance in this matter, and think it far more desirable to discover a little, than to discover nothing, yet I pretend but to make it probable by the experiments I mention, that some colours may be plausibly enough explicated in general by the doctrine here proposed; for whenever I would descend to the minute and accurate explication of particulars, I find my self very sensible of the great obscurity of things . . ." Boyle's "descent" to the particulars recalls the sixth part of Descartes' *Discourse on Method*. 
many things which could not be assigned a single, probable cause and some things which could be assigned several causes of widely differing character. He had often encountered "such difficulties in searching into the causes and manner of things," and was so aware of his "own disability to surmount those difficulties," that he dared to speak "confidently and positively of very few things, except matters of fact." No theory could be expected to endure all experimental tests. Boyle had seen many doctrines "confuted by the discovery of some new phaenomena in nature, which was either unknown . . ., or not sufficiently considered," a fate which any theory could suffer if proposed too hastily.91

The contingency of all hypotheses was deeply ingrained in Boyle's thought. Among "The Requisites of a Good Hypothesis" was the requirement "That it be, at least consistent, with the rest of the Phaenomena it particularly relate to; and do not contradict any other known Phaenomena of Nature; or manifest Physical Truth."92 But he who established a theory and expected it to last long enough to make him famous "must not only have a care, that none of the phaenomena of nature, that are already taken notice of,


do contradict his hypothesis at the present, but that no phaenomena, that may be hereafter discovered, shall do it for the future." Boyle seriously questioned whether philosophers realized how incomplete the history of nature was, and how difficult it was "to build an accurate hypothesis upon an incompleat history of the phaenomena" it had to explain. The future might bring new discoveries which "may yet overthrow doctrines speciously enough accommodated to the observations, that have been hitherto made." The uninhabitability of the torrid zone, the solidity of the celestial orbs, and the received number of planets had all been overturned by recent observations. 93 I know not, he said, "but that future discoveries by improved telescopes and other philosophical instruments may reduce us to make changes in the grand system of the universe itself, and in . . . the terraquaeous globe we live on."94 Thus Boyle preferred to finish his Experimental History of Cold before asserting a particular hypothesis concerning the cause of cold.95 Although he nevertheless ventured an hypothesis in the preface, Boyle emphasized, not the hypothesis, but the phenomena he had studied. Even the most well established laws of his time,

93. Excellency of Theology (IV, 59f). He had noted earlier (p. 50) that the extent of our knowledge was "not very large," for experience had acquainted us with only the "crust or scurf" of our own planet.

94. Cosmical Suspicions (III, 318).

95. Works II, 478.
about the motions of the planets, he was unwilling to place beyond doubt. "There may be less of accurateness, and of constant regularity, than we have been taught to believe, in the structure of the universe," he suspected. It could be the case that some things taken "for deviations and exorbitancies from the settled course of nature," if observed for a sufficiently long time, would "be found to be but periodical phaenomena, that have very long intervals between them," as was the case with the "strangely varying appearances of Saturn" due to the changing inclinations of the ring system.96

Voluntarism and Empiricism: A Manifest Connection

The ultimate goal of Boyle's scientific work, as Mrs. Hall has so eloquently shown, was the advancement of what he was the first to call the "mechanical philosophy" of nature.97 Boyle believed that matter and motion alone could explain almost everything, except the free actions of rational agents. This was the focus of his brief essay, "About the Excellency and Grounds of the Mechanical Hypothesis."98 No other philosophy of nature, he argued, rivals the mechanical in clarity, simplicity, and

98. Works IV, 67-78.
versatility; more than this, no other is even intelligible. For Boyle, then, the mechanical hypothesis represented the true system of the world, the correct picture of reality—at least in so far as man could discover it.

Nevertheless a hypothesis it remained, however much he may have believed in its veracity. When contrasted with the absolutely certain axioms of metaphysics, its provisional character stands out. Absolute proof is something which Boyle never claimed for the mechanical view of nature. "That which I need to prove," he wrote in The Mechanical Origin of Qualities, "is not that mechanical principles are the necessary and only things, whereby qualities may be explained, but that probably they will be found sufficient for their explication." To be sure, Boyle believed that mechanical principles were in fact the only things whereby qualities could be explained. It is however wholly in keeping with his conception of science that he chose to demonstrate this from the phenomena, not from any innate truths implanted in his soul.

In his astute critique of the "revisionist" thesis of M.B. Foster and others, Rolf Gruner concludes that modern science did not grow out of Christianity "as an oak tree grows out of an acorn." He is certainly correct. There is no necessity in the process of history—"nothing natural,

predestined, [or] logical about historical development."¹⁰⁰ It is not the case, as Reijer Hooykaas would have it, that "things happened thus and therefore, thus they must have happened."¹⁰¹ If the preceding study of Robert Boyle has shown anything, however, it is this: within the thought of a given individual, setting aside all questions of the flow of ideas from one person to another, a strong connection can be found between theological voluntarism and an empirical science of nature. Without a doubt, Boyle understood God's relation to the world in unabashedly voluntaristic terms. Transcendent and omniscient, God was known only as he chose partially to reveal himself in nature and scripture. Revelation, not ontology, was the road to religion: worship, not contemplation, was the way to God. Omnipotent and free, God the creator was not bound to make the best possible world or to employ, in the world he did make, notions wholly comprehensible to merely human minds. As the product of uninterrupted and direct divine action, the universe reflected the laws by which its Author freely governed the brute matter he had made. Not necessary truths binding on God, the laws of nature were only collected or emergent truths arising from the phenomena rather than from unaided reason. Even with much


aid from experience and observation, reason could easily go awry. Influenced perhaps by his Calvinist tutor Marcombes or by the moderate Anglicans of seventeenth century England, Boyle brought to his natural philosophy a healthy scepticism about the scope and autonomy of human reason. All hypotheses, without which there can be no science, were to a greater or lesser degree contingent on the phenomena of nature.

It is therefore clear that the voluntarist elements in Boyle's theology of creation impinged directly on corresponding aspects of his natural philosophy. Because the creator had worked and continued to work in accordance with his free will and not out of necessity, the order of nature was contingent and could not be known a priori. Because the creator had made us but purblind mortals of limited capacity, we could not presume to share his infinite understanding of the inner constitution of things. The best that could be achieved was a hypothetical modelling of empirically determined properties, an a posteriori science of phenomena. It is not always necessary, said Boyle,

that he, that propounds an hypothesis in astronomy, chemistry, anatomy, or other part of physicks, be able a priori, to prove his hypothesis to be true, or demonstratively to show, that the other hypotheses proposed about the same subject must be false. For . . . in the physical explications of the parts and system of the world, methinks, there is somewhat like what happens when men conjecturally frame some several keys to enable us to understand a letter
written in cyphers. For though one man by his sagacity have found out the right key, it will be very difficult for him, either to prove otherwise than by trial, that this or that word is not such, as it is guessed to be by others, according to their keys: or to evince, a priori, that theirs are to be rejected, and his to be preferred; yet, if due trial being made, the key that he proposes, shall be found so agreeable to the characters of the letter, as to enable one to understand them, and make a coherent sense of them, its suitableness... is sufficient to make it be accepted as the right key of that cypher. And so, in physical hypotheses, there are some, that, without noise, or falling foul upon others, peaceably obtain discerning men's approbation only by their fitness to solve the phaenomena, for which they were devised, without crossing any known observation or law of nature. And therefore, if the mechanical hypothesis go on to explicate things corporeal at the rate it has of late years proceeded at, it is scarce to be doubted, but that, in time, unprejudiced persons will think it sufficiently recommended by its consistency with itself, and its appreciableness to so many phaenomena of nature.102

Such an attitude could hardly go unnoticed in the vigorous debate from which the modern philosophy of nature emerged.

Gottfried Leibniz, that great rationalist, complained to Christiaan Huygens that

Mr. Boyle spends too much time, to be truthful, drawing from an infinity of splendid experiments no other conclusions than those which he could have taken for principles of nature... which one can certify to be true from reason alone, whereas experiments, no matter how numerous, cannot prove them.103

102. Of the Excellency and Grounds of the Mechanical Hypothesis (IV, 77). Boyle employed the Cartesian cypher metaphor (from Book IV of the Principles) in other ways at other times too numerous to explore here.

103. Letter of 8 January 1692, Oeuvres completes des Christiaan Huygens (22 vols.; The Hague, 1882-1944) X,
By the time Huygens read these words, Boyle was dead. But ideas, like states and institutions, do not die with the individuals who shape them. Empiricism, that attitude toward nature which Boyle so strongly endorsed, and voluntarism, the theological orientation in which it thrived, both lived on in the person of Isaac Newton.

228f, quoted by M.B. Hall, Robert Boyle on Natural Philosophy, p. 43.
CHAPTER FIVE:
ISAAC NEWTON, DIVINE FREEDOM, AND THE REJECTION
OF RATIONALISTIC NATURAL PHILOSOPHY

In distinguishing matter from extension, and in transferring the intelligibility of extension to the neuter realm of space, Newton denied the program and method of Cartesian science. Man faces an arbitrary universe created by omnipotent will and comprehensible only to omniscient wisdom. In such a universe we can never achieve necessary demonstrations. Our information is limited to sensations; our knowledge is confined to phenomena.

--R.S. Westfall, "Newton and Absolute Space," Arch. int. hist. sci. 17 (1964), pp. 129f

"Metaphysical hypotheses," so Newton told us, "have no place in experimental philosophy." Yet it seems quite clear that metaphysical convictions play, or at least have played, an important part in the philosophy of Sir Isaac Newton. It is his acceptance of two absolutes--space and time--that enabled him to formulate his fundamental three laws of motion, as it was his belief in an omnipotent and omniactive God that enabled him to transcend both the shallow empiricism of Boyle and Hooke and the narrow rationalism of Descartes, to renounce mechanical explanations, and, in spite of his own rejection of all action at a distance, to build up his world as an interplay of forces, the mathematical laws of which natural philosophy had to establish. By induction, not by pure speculation. This because our world was created by the pure will of God: we have not, therefore, to prescribe his action for him; we have only to find out what he has done.

The belief in creation as the background of empirico-mathematical science--that seems strange. Yet the ways of thought, human thought, in its search for truth are, indeed, very strange.

--Alexandre Koyré, Newtonian Studies, pp. 113f

It is noticeable that Newton, in common with the whole voluntaristic British tradition in medieval and modern philosophy, tended to subordinate in God the intellect to the will; above the Creator's wisdom and knowledge is to be stressed his power and dominion. In some passages this emphasis is not present, but usually the proportions are unmistakable.

--E.A. Burtt, The Metaphysical Foundations of Modern Physical Science, p. 294
Without question, Isaac Newton was a deeply religious man. His private theological writings contain over a million words devoted primarily to prophecy, sacred history, and doctrine. Though far less extensive, his public utterances leave no doubt that natural theology also received its fair share of attention. Yet in spite of substantial recent study, the relationship between Newton's public scientific life and his private religious life remains, like almost all facets of this complex man, enigmatic. I do not propose here completely to clarify


that relationship. Rather it is my intention to focus on one aspect of Newton's theological thought, his voluntarism, in an attempt to show how his concept of God influenced the content and the character of his natural philosophy.³


"In dealing with Philosophy, one must abstain from religion," Newton wrote in a private manuscript. If he meant this absolutely, or practiced it faithfully, there would be no point to this investigation. Fortunately he qualified himself elsewhere: "religion and Philosophy are to be preserved distinct. We are not to introduce divine revelations into Philosophy nor philosophical opinions into religion." What Newton intended to proclaim was not the divorce of science and religion--this would have been anathema to a man who believed he had rediscovered the *prisca theologia* of true religion hand in hand with the true system of the world--but their relative autonomy within the bounds of holy matrimony. Like Bacon and Boyle before him, Newton refused to use the Bible as an authority on matters scientific. If he went beyond his illustrious predecessors in seeking also to purge Christianity of what he perceived to be dangerous metaphysical errors, this was done for the fear of God and the love of true, biblical religion. The fact that the first editions of the *Principia* and the *Opticks* do not contain the theological material found in later editions must not be misinterpreted. To be sure, Newton wrote the General


5. Keynes MS. 6, folio 1r, printed by McLachlan, p. 58.

Scholium only in reply to critics like Berkeley and Leibniz, who charged him with atheism and impiety. But his reluctance to mingle religion with science stemmed more from discretion than from principle. Always one to dodge disputes in an age much given to them, Newton knew that a full disclosure of his theological views would cost him his position and destroy his reputation. Publicly, he was content to leave theology to others, Bentley and Clarke among them. But privately—and we must remember that Newton's natural philosophy grew to fruition in solitude—he gave himself wholeheartedly to the God of Abraham, Isaac, and Jacob, and he took no pains to keep his God out of his natural philosophy.

Newtonian Voluntarism Versus Cartesian Materialism and Leibnizian Rationalism: The Primacy of Divine Will

The divine being has always been associated with perfection, but this has not always meant the same thing. For Galileo, a perfect God had perfect knowledge, a portion of which the human mind could share; for Descartes, perfection meant that God could not be a deceiver and had to be immutable in his actions. For Newton, perfection entailed the constant activity of the divine will. The highest idea of a perfect entity was

that it should be one substance, simple, indivisible, living and life-giving, always everywhere of necessity existing, in the highest degree understanding all things, freely willing good things; by his will effecting things possible; communicating as far as is possible his own similitude to the more noble effects; containing all things in himself as their principle and location; decreeing and ruling all things by means of his substantial presence (as the thinking part of a man perceives the appearances of things brought into the brain and thence rules its own body); and constantly co-operating with all things according to accurate laws, as being the foundation and cause of the whole of nature, except where it is good to act otherwise.\footnote{7}

Newton's conception of worship was equally voluntaristic. In a manuscript commentary on 2 Kings 17:15-16, after acknowledging the piety of celebrating God "for his eternity, immensity, omnisciency, and omnipotence," Newton added that these attributes spring "not from the freedom of God's will but the necessity of his nature ..." The wisest of beings, he continued, "required of us to be celebrated not so much for his essence as for his actions, the creating, preserving, and governing of all things according to his good will and pleasure."\footnote{8} The word God referred "not to the metaphysical nature of God but to his


\footnote{8}{Yahuda MS. 21, folio 1r, quoted by Manuel, *Religion*, pp. 21ff. The circumstances surrounding the composition of this manuscript are set forth in *Never at Rest*, p. 355. 2 Kings 17:15f condemns idolatry.}
dominion," relating us to him as servants. 9 Whoever could demonstrate that there is a perfect being without at the same time demonstrating that he is Lord of the Universe would not have shown that God exists, for "A Being eternal, infinite, all-wise and most perfect without dominion is not God but only Nature." 10 So great was Newton's emphasis on God's will that even God's power, upon which voluntarists traditionally placed much weight, was relegated to a secondary role. "If God be called PANTOKRATOR the omnipotent," he wrote in a fragment on true religion, "they take it in a metaphysical sense for God's power of creating all things out of nothing whereas it is meant principally of his universal irresistible monarchical power to teach us obedience." 11

The salient features of Newton's religion--his

9. Yahuda MS. 15.7, folio 154r, quoted by Manuel, loc. cit. This idea worked its way into the General Scholium. See the Mathematical Principles of Natural Philosophy, trans. Andrew Motte and revised by Florian Cajori (Berkeley: University of California Press, 1934), p. 544. Hereafter this edition will be called "Cajori."

10. From a draft of the General Scholium, translated and printed by A. Rupert Hall and Marie Boas Hall in Unpublished Papers of Isaac Newton (Cambridge: UP, 1962), p. 363. This volume will be referred to simply as "Halls."

11. "Of the faith which was once delivered to the Saints," Yahuda MS. 15.5, folios 96v, 97r, and 98r, quoted by Manuel, loc. cit. Yahuda MS. 9.2, folio 140r, which Manuel cites on pp. 101f, shows that Newton had no small view of God's power, in spite of his placing it under God's will: "He that shall well consider the strange and wonderful nature of life and the frame of Animals, will think nothing beyond the possibility of nature, nothing too hard for the omnipotent power of God."
Arianism, his desire to avoid metaphysical formulations, his abiding interest in prophecy, his insistence on the importance of natural theology--are all consistent with his concept of God exercising his dominion by absolute will. As the sole Lord of the Universe, God the Father could have no equals, not even God the Son. Christ did not deserve our worship because of who he was--a better man than us--he earned it by his perfect obedience unto death. And this was the Christ of unadorned scripture, the Christ whom God had revealed to men, not the Christ of idolatrous reason. It was not enough to say that an article of faith could be deduced from scripture. "It must be exprest in the very form of sound words in which it was delivered by the Apostles," for men were apt to "run into partings about deductions. All the old Heresies lay in deductions; the true faith was in the text." This was the meaning of Newton's remark about keeping philosophical opinions out of theology. Although he thought that true religion was indeed reasonable, rationalism in religion is something Newton never sought. His Sovereign Ruler was no constitutional monarch, no petty prince bound by the wishes and understanding of his subjects. It was "contrary to God's purposes that the truth of his religion should be as obvious and perspicuous to all men as a mathematical

12. Commenting on 2 Timothy 1:13, "Hold fast to the form of sound words, which thou hast heard of me..." Yahuda MS. 15.1, folio 11r, quoted by Manuel, Religion, pp. 54f.
demonstration." God moved the assent of those whom he had chosen to save, allowing the rest to "dy in their sins." Men erred when they pretended to foreknow events by interpreting prophecy according to their fancies, for "the design of God was much otherwise." Prophecy was intended "not to gratify men's curiosities by enabling them to foreknow things, but that after they were fulfilled they might be interpreted by the event," thereby manifesting divine Providence to the world. Newton's argument for the existence of God was equally a posteriori. "The dominion or Deity of God," he wrote in a draft of the General Scholium, "is best demonstrated not from abstract ideas but from phenomena, by their final causes."

Being the voluntarist that he was, Newton rejected the ontological argument in favor of the teleological. God had to exist not by the necessity of his being or the force of innate ideas, but by the clear evidence of his willful actions in nature, evidence to which Newton believed he had

13. Fragments from a treatise on Revelation, Yahuda MS. 1, folio 19r, printed as an appendix to Manuel, Religion, p. 124.

14. Observations upon the Prophecies of Daniel and the Apocalypse of St. John, in Isaac Newton opera quae existant omnia, ed. Samuel Horsley (5 Vols.; London, 1779-85) V, 449, emphasis mine. "It is not for us to know the times & seasons which God has put in his own breast." Yahuda MS. 7.3g, folio 13, quoted in Never at Rest, p. 816.

15. Halls, p. 363. The final version of the Scholium put it like this: "We know him only by his most wise and excellent contrivances of things, and final causes . . ." (Cajori, p. 546)
contributed in no small measure. "When I wrote my treatise about our Systeme," he told the Rev. Mr. Richard Bentley, "I had an eye upon such Principles as might work with considering men for the beliefe of a Deity & nothing can rejoice me more than to find it usefull for that purpose."\(^{16}\) Bentley had asked the great man to comment on the first set of Boyle lectures, which he had been appointed to deliver. There is reason to believe that Newton may have had a hand in the selection of Bentley as the inaugural lecturer.\(^{17}\) Certainly he was receptive and more than a bit helpful. In the correspondence which followed, and in the General Scholium which was added to the 1713 edition of the *Principia*, Newton answered Bentley's every inquiry, including these: Could the system of the world have been produced by purely natural causes from an initial uniform distribution of matter in space? Could the planetary motions have resulted from gravitation alone, unassisted by God? The answer to both was in the negative. The only possible cause of the frame of the world and the diversity of creatures was the will of a sovereign God. The six planets, Newton observed in the General Scholium, all revolve about the sun in concentric

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circles in the same direction and almost in the same plane; the ten moons show a similar regularity. Though their orbits might continue "by the mere laws of gravity, yet they could by no means have at first derived the regular position of the orbits themselves from those laws." It was inconceivable that "mere mechanical causes could give birth to so many regular motions . . ." Such a beautiful system "could only proceed from the counsel and dominion of an intelligent and powerful Being." From the direct hand of that Being, Newton could have added. Gravity alone might have sufficed to give the planets their orbital speeds, but the divine arm had been required to bend them into their proper orbits around the sun. The astronomical bodies required divine agency also for their formation, in order to separate the opaque matter of the planets from the lucid matter of the stars. Newton summarized his general position in a letter to Thomas Burnet: "Where natural


20. Ibid., p. 234.
causes are at hand God uses them as instruments in his works, but I do not think them alone sufficient for ye creation."21

Divine counsel and contrivance were no less apparent in the animal kingdom. It could be no accident that birds, beasts, and men had a perfect symmetry of parts on both sides of their bodies, a matched pair of limbs, wings, eyes, and ears. The specialized organs of sense and motion—above all the eye—had to have been made by one who understood the nature of light, sound, and the rest of the world in which creatures had been placed. "In ye frame of animals," as Newton told William Briggs, God "has done nothing without reason."22

If regularity pointed to choice rather than chance, variety pointed to will rather than necessity. "Blind metaphysical necessity," argued Newton in the General Scholium, "could produce no variety of things. All that diversity of natural things which we find suited to different times and places could arise from nothing but the will of a Being necessarily existing."23 Because it became


23. Cajori, p. 546. This passage was added in the third
him who created all material things to set them in order, Newton found it "unphilosophical to seek for any other Origin of the World, or to pretend that it might arise out of a Chaos by the mere laws of Nature . . ." To discourse of God from the appearances of things, he proclaimed in the General Scholium, "does certainly belong to Natural Philosophy."24 Far from excluding teleology from natural philosophy as Descartes had done, Newton made divine purpose the ultimate explanation within natural philosophy. Indeed the "main Business of natural Philosophy" was

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to \text{argue from Phaenomena without feigning Hypotheses, and to deduce Causes from Effects, till we come to the very first Cause, which certainly is not mechanical; and not only to unfold the Mechanism of the World, but chiefly to resolve . . . [ultimate] Questions}.25
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Thus Newton proposed a hierarchy of causes, each inferred from effects. Embracing both mechanisms and minds, his was truly a natural philosophy: all of created nature, together with the Creator, fell within its domain. The frame of the world spoke volumes of the counsel and dominion of God.


Natural causes alone were insufficient to explain its regularity and variety. There was only one ultimate cause of phenomena, and all true science sought that cause. True science and true religion literally went hand in hand; heliocentrism and monotheism were partners. The ancients had known the true system of the world and had possessed the *prisca theologia* which Newton thought he had rediscovered in his chronological and prophetical studies. Noah and his sons took the heavens for "ye true & real temple of God," so they framed their own Temple "in the fittest manner to represent the whole system of the heavens," placing fire in the center to represent the sun. Geocentrism, a corruption of true philosophy, resulted from the corruption of true religion when the vestal fire was erroneously taken for a fire in the center of the earth.  

This is just what Newton had in mind when he concluded Query 31 with the following observation:

> And if natural Philosophy in all its Parts, by pursuing this Method [of analysis and synthesis], shall at length be perfected, the Bounds of Moral Philosophy will also be enlarged. For so far as we can know by natural Philosophy what is the first Cause, what Power he has over us, and what Benefits we receive from him, so far our Duty towards him, as well as that towards one another, will appear to us by the Light of Nature. And no doubt, if the Worship

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of false Gods had not blinded the Heathen, their moral Philosophy would have gone farther than to the four Cardinal Virtues; and instead of teaching the Transmigration of Souls, and to worship the Sun and Moon, and dead Heroes, they would have taught us to worship our true Author and Benefactor, as their Ancestors did under the Government of Noah and his Sons before they corrupted themselves.27

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Of all the competing natural philosophies which rushed into the vacuum left behind by the disintegration of Aristotelianism, two stand out as prime examples of an approach to nature which Newton particularly loathed: the materialism of René Descartes and the rationalism of Gottfried Leibniz. Neither one, as Newton saw it, allowed God to exercise dominion over the creation he had made. Already in the early treatise De gravitatione et equipondo fluidorum, written around 1670, a strong aversion to Cartesianism was clearly well advanced. It was Descartes' relativistic definition of motion which, in the words of one scholar, "first aroused Newton's opposition to Cartesian physics."28 According to Descartes, as Newton pointed out, place was only a relative notion. But since "there are no bodies in the world whose relative positions remain unchanged with the passage of time," there are no fixed points of reference which enable us to locate the

27. _Opticks_, pp. 405f.

28. Alexandre Koyré, _Newtonian Studies_, p. 82. The Latin text of De gravitatione is printed with an English translation in Halls, pp. 89-156.
past positions of bodies. From this Newton inferred that "not even God himself could define the past position of any moving body accurately . . . , since in fact, due to the changed positions of [all] the bodies, the place does not exist in nature any longer." Such a conception of motion was absurd to Newton, for a body could not meaningfully be said to have moved from place to place. Following the same definition of motion, he said, "God himself could not generate motion in some bodies even though he impelled them with the greatest force." If, for example, God were to apply a very great force to the starry heaven, causing it to revolve about the earth, Descartes would maintain that "the Earth alone and not the sky would be truly said to move," as if there were no difference between moving the heavens in one direction with a tremendous force and moving the earth in the opposite direction with a small force. Again, "if God should cause any Planet to stand still and make it continually keep the same position with respect to the fixed stars," Descartes would say that the planet moves because it is no longer at rest relative to the solar vortex.29 Though unstated, the clear implication of Newton's argument was that Descartes' definition of motion placed unacceptable limits on God's ability to know and to control his universe. The same could be said of Descartes' description of the world as being of "indefinite"

dimensions. Recall that Descartes reserved the term "infinite" for God alone, because only he could be known positively to have no limits. Other entities might have no perceivable limits and might appear to be boundless, but since we could not know positively that they were infinite, we should call them "indefinite." Newton disagreed. The world was "indefinite" in size, he said, only before God had decreed anything about its creation—if there ever was such a time. After that time, however, the quantity of matter and the number of stars were very definitely defined. And though we were ignorant beings incapable of grasping infinity, "God at least understands that there are no limits [to space] not merely indefinitely but certainly and positively . . ." 30 The scope of the imaginable could not be presumed to be the same as that of God's creative act.

Newton's most vociferous—and most voluntaristic—objection to Cartesian physics was directed at Descartes' conception of matter, which Newton took for a path to atheism. Body "does not exist necessarily but by divine will," Newton began. Our notion of it was therefore uncertain.

30. Ibid., p. 135. Cf. Certain Philosophical Questions, p. 453: "To say that extension is but indefinite . . . because we cannot perceive its limits, is as much as to say, God is but indefinitely perfect because we cannot apprehend his whole perfection." Henry More also attacked Descartes on this point. See Koyré, Newtonian Studies, p. 89.
because it is hardly given to us to know the limits of the divine power, that is to say whether matter could be created in one way only, or whether there are several ways by which different beings similar to bodies could be produced.

Newton went on to "describe a certain kind of being similar in every way to bodies, and whose creation we cannot deny to be within the power of God, so that we can hardly say that is is not body." The analogy upon which he relied was the human ability to move the body at will, by thought alone. The same "free power of moving bodies at will can by no means be denied to God, whose faculty of thought is infinitely greater and more swift." By "the sole action of thinking and willing," God could "prevent a body from penetrating any space defined by certain limits." If by his power God should cause some part of space to be impenetrable, to reflect light, and to resonate when struck, it would be impossible to distinguish that space from true body.

Thus we may imagine that there are empty spaces scattered through the world, one of which, defined by certain limits, happens by divine power to be impervious to bodies, and ex hypothesi it is manifest that this would resist the motions of bodies and perhaps reflect them, and assume all the properties of a corporeal particle, except that it will be motionless. If we may further imagine that that impenetrability is not always maintained in the same part of space but can be transferred hither and thither according to certain laws, yet so that the amount and shape of that impenetrable space are not changed, there will be no property of body which this does not possess. It would have shape, be tangible and mobile, and be capable of reflecting and being reflected, and no less constitute a part of the structure of things than any other corpuscle, and I
do not see that it would not equally operate on our minds and in turn be operated upon, because it is nothing more than the product of the divine mind realized in a definite quantity of space. For it is certain that God can stimulate our perception by his own will, and thence apply such power to the effects of his will. 31

If the whole world were constituted of only such spaces, "it would seem hardly different." Thus "we can define bodies as determined quantities of extension which omnipresent God endows with certain conditions." 32 "I have deduced a description of this corporeal nature from our faculty of moving our bodies," Newton added, "so that God may appear ... to have created the world solely by the act of will, just as we move our bodies by an act of will alone ..." Newton allowed the possibility of the Cambridge Platonist belief in a world soul created by God with the power to do this, but he did not see "why God himself does not directly inform space with bodies ..." The point of this voluntarist conception of matter, as Newton was not reluctant to say, was that "we cannot postulate bodies of this kind without at the same time supposing that God exists, and has created bodies in empty space out of nothing ..." The Cartesian identification of matter and extension, on the other hand, was manifestly "a path to Atheism, both because extension is not created

31. Ibid., pp. 138f. If Berkeley had known of this passage, I doubt that his criticism of Newton would have been quite so acerbic.

32. Ibid., pp. 139f, emphasis his.
but has existed eternally, and because we have an absolute idea of it without any relationship to God," which would make it "possible for us to conceive of extension while imagining the non-existence of God."\textsuperscript{33}

Now Descartes had never imagined that matter could exist, even for a moment, without the ordinary concourse of God, which he understood as the continuous divine re-creation of the world. As I have argued in an earlier chapter, however, divine sovereignty and freedom were not unambiguously on the cutting edge of Cartesian natural philosophy, so Newton can readily be excused for failing to find them here. Less warranted was his implicit attribution to Descartes of his own view that extension is uncreated.\textsuperscript{34} When coupled with Descartes' assumption that matter and extension are the same thing, the eternity of extension yields the eternity of matter, a conclusion which Descartes not only never drew but surely never believed. The source of Newton's idea of an uncreated, infinite extension was probably the Neoplatonic philosophy of Henry

\textsuperscript{33} Ibid., pp. 141-43. Cf. pp. 132 and 145. This entire argument recalls Boyle's simile, which compared God's ability to move the bodies in his world to a man's ability to move his own shadow by an act of pure volition. See Occasional Reflections and The Christian Virtuoso, in The Works of the Honourable Robert Boyle, ed. Thomas Birch (2nd edn., 6 Vols.; London, 1772), II, 402, and VI, 678-80, respectively.

More, Newton's colleague at Cambridge. Space, Newton proclaimed in *De gravitatione*, is fundamental to the existence of every being.

God is everywhere, created minds are somewhere, and body is in the space that it occupies; and whatever is neither everywhere nor anywhere does not exist. And hence it follows that space is an effect arising from the first existence of being, because when any being is postulated, space is postulated. And the same may be asserted of duration: for certainly both are dispositions of being or attributes according to which we denominate quantitatively the presence and duration of any existing individual thing.

Thus space and time were coeval with God--to assert God's existence was to assert his duration in time and his presence in space--and logically prior to God's existence, though not to his being, of which they were emanent effects. God's relation to the frame of time and space


36. Halls, p. 136. In the early notebook *Certain Philosophical Questions*, Newton had interpreted Genesis 1, Colossians 1:16, and Hebrews 1:2 to mean that God created time (see p. 449). Obviously he changed his mind in the few years before *De gravitatione* was written.

was indeed an intimate one. As the eternal and infinite
PANTOKRATOR,

he governs all things, and knows all things that are
or can be done. He is not eternity and infinity, but
eternal and infinite; he is not duration or space,
but he endures and is present. He endures forever,
and is everywhere present; and, by existing always
and everywhere, he constitutes duration and space.
Since every particle of space is always, and every
indivisible moment of duration is everywhere,
certainly the Maker and Lord of all things cannot be
never and nowhere. ... He is omnipresent not
virtually only, but also substantially; for virtue
cannot subsist without substance. In him are all
things contained and moved; yet neither affects the
other: God suffers nothing from the motion of bodies;
bodies find no resistance from the omnipresence of
God. It is allowed by all that the Supreme God
exists necessarily; and by the same necessity he
exists always and everywhere.38

Because God had "a propensity to action," it concerned his
glory and majesty "that he should never and nowhere be
idle."39 The omnipresent, eternal God "is more able by his
Will to move the Bodies within his boundless uniform
Sensorium, and thereby to form and reform the Parts of the
Universe, than we are by our Will to move the Parts of our
own Bodies."40

p. 481.

38. From the General Scholium to the second (1713) edition
of the Principia (Cajori, p. 545), italics Newton's. The
third (1726) edition contains three additional sentences
which I have replaced with an ellipsis. Cf. the draft
version in Halls, pp. 359f.

39. ULC Add. MS. 3965.13, folio 541v, quoted by McGuire,
"FAN," p. 201.

Newton's belief in space as the literal sensorium of God, a
position which he later tried to hide, see Koyré and Cohen,
Activity was for Newton "the province of divinity," as Mrs. Dobbs has put it. Influenced by More's Christian Neoplatonism and his own extensive alchemical investigations, Newton rejected the brute mechanisms of traditional mechanical philosophies, infusing the inert world of matter with the activity of the divine will, either directly through the hand of God or indirectly through active principles, which gave the world a structure and order that evinced providential choice rather than blind mechanical necessity. In the end, if Dobbs is correct, Newton assigned to Christ control over the short range forces of alchemical, electrical, and vital phenomena, leaving the cosmic force of gravitation to God himself.

42 A number of Newton's contemporaries certainly understood the latter to have been the case. According to "The Case of the Missing Tanguam: Leibniz, Newton & Clarke," Isis 52 (1961), 555-66, and Never at Rest, pp. 646-48.


42. Ibid., pp. 527ff.

43. This would include Locke, Wren, Gregory, and Whiston. See Never at Rest, pp. 510 and 647, and Westfall, Force in Newton's Physics (New York: American Elsevier, 1971), pp. 395-400. Leibniz, another who understood this, will be discussed below. Newton's return to an aether in his old age, as seen in Queries 17-24, must not be mistaken for a return to traditional mechanical explanation. See Never at Rest, p. 794. For an account of Newton's changing views on the cause of gravitation and other forces, see McGuire,
to Gregory's memorandum from May 1694, Newton also gave God the responsibility of preventing the stars from collapsing together under the very attraction which he caused: "[Newton says] that a continual miracle is needed to prevent the Sun and the fixed stars from rushing together through gravity . . ."\(^44\) This is probably what Newton had in mind fifteen months before when he agreed with Bentley that if "all ye matter were at first divided into several systems & every system by a divine power [were] constructed like ours: yet would the outward systemes descend towards the middlemost so yt this frame of things could not always subsist without a divine power to conserve it."\(^45\) Thus in Query 31 Newton described Nature as

> very conformable to her self and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles. The Vis *inertiae* is a passive Principle by which Bodies persist in their Motion or Rest, receive Motion in proportion to the Force impressing it, and resist as much as they are resisted. By this Principle alone

"FAN."

\(^{44}\) *Corres* III, 336.

\(^{45}\) Letter of 25 February 1693 (ibid., 255). In Query 28 (Opticks, p. 369), published first in 1706, Newton implied that God was "what hinders the fix'd stars from falling upon one another?" In the General Scholium, however, we find only the following phrase, added to the third (1726) edition: "and lest the systems of the fixed stars should, by their gravity, fall on each other, he [God] hath placed those systems at immense distances from one another." (Cajori, p. 544) Apparently the continuous action of God was no longer thought to be required for the stability of the universe.
there never could have been any Motion in the World. Some other Principle was necessary for putting Bodies into Motion; and now they are in Motion, some other Principle is necessary for conserving the Motion. 46

On the following pages, Newton elaborated on the inadequacies of a purely mechanical world. Without active principles, he argued, the quantity of motion in the world would decrease. What he had in mind here—that collisions are rarely elastic and that rotating vortices quickly slow down—fails to distinguish between what we now call momentum and energy. But it would not be misleading to suggest that his insight, despite serious difficulties, captured the essential thrust of the law of entropy: the universe is running down. "Seeing therefore the variety of Motion which we find in the World is always decreasing," he concluded,

there is a necessity of conserving and recruiting it by active Principles, such as are the cause of Gravity, by which Planets and Comets keep their Motions in their Orbs, and Bodies acquire great Motion in falling; and the cause of Fermentation, by which the Heart and Blood of Animals are kept in perpetual Motion and Heat; the inward Parts of the Earth are constantly warm'd, and in some Places grow very hot; Bodies burn and shine, Mountains take fire, the Caverns of the Earth are blown up, and the Sun continues violently hot and lucid, and warms all things by his Light. For we meet with very little Motion in the World, besides what is owing {either} to these active Principles {or to the Dictates of a Will}. And if it were not for these Principles the Bodies of the Earth, Planets, Comets, Sun, and all things in them would grow cold and freeze, and become inactive Masses; and all Putrefaction, Generation, Vegetation, and Life would cease, and the Planets and

46. Opticks, p. 397.
Comets would not remain in their Orbs.47

The end of this passage, which was added in the 1717 edition, suggests a further, more cosmic, sense in which Newton believed the universe was running down. By virtue of their great masses, Jupiter and Saturn noticeably perturb one another's orbits and those of passing comets, which in turn perturb the rest of the planets. Eventually these perturbations would accumulate "till this System wants a Reformation."48 A few years before his death, Newton confided to John Conduitt what may have been the full meaning of this cryptic remark. It was Newton's conjecture, Conduitt recorded, "that there was a sort of revolution in the heavenly bodies." Vapors and light from the sun "had gathered themselves by degrees into a body and then attracted more matter from the planets," at length forming a new planet and then a comet, which eventually fell into the sun and replenished its matter. The comet of 1680, Newton thought, would someday meet the same fate, at which time "this earth would be burnt" and all animals would perish. Apparently he believed that something like this had happened previously, for the earth bore "visible marks of ruin upon it which could not be effected by a flood only." When Conduitt asked how the earth could have

47. Pages 399f. The words in brackets were deleted from the 1717 edition, in which the last sentence was added.
been repeopled if this had ever happened, Newton replied that "the power of a creator" was required.49 We have come a long way from the Cartesian universe of matter and necessity.

* * * * *

In 1714 Queen Anne died without surviving heirs. Under terms of the Act of Settlement the crown passed to the Elector of Hanover, who became King George I. When Caroline, the Princess of Wales, joined her father-in-law at court in London, she left behind her philosophical mentor, Gottfried Wilhelm Leibniz, with whom she continued a personal and intellectual correspondence. Her efforts to find a translator for Leibniz's *Theodicy* (1710) led her to Dr. Samuel Clarke, a theologian and disciple of Newton. Although Clarke declined to undertake the translation, he became a regular courtier and, in time, an advisor to the Princess. When in late 1715, in answer to an inquiry about Clarke's theological position, Leibniz sent a letter to Caroline charging Newton with theological errors, it was Clarke who took it upon himself to reply. Before their

49. King's College, Conduitt Papers, Keynes MS. 130.11, quoted by Castillejo, The Expanding Force, pp. 95-97. According to Gregory's memorandum of May 1694 (Corres III, 336), Newton believed that "The Satellites of Jupiter and Saturn can take the places of the Earth, Venus, Mars if they are destroyed, and be held in reserve for a new Creation." Cf. Newton's letter to Bentley of 25 February 1693 (ibid., 253). Whether Newton believed in pre-Adamite men, I do not know and do not care to speculate.
correspondence ended just a year later with the death of Leibniz, the two men had laid bare the fundamental theological and philosophical differences which separated Newton from his German rival.50

It is not immediately apparent that Clarke can be taken for Newton's spokesman. He was, after all, an accomplished theologian capable of debating Leibniz in his own right—remember that he had been recommended as a translator for the *Theodicy.*51 The weight of the evidence, however, favors the conclusion that Newton worked closely with him, at least to the extent that Clarke spoke with Newton's approval. That Newton preferred to deal with Leibniz—and Hooke, and others—through intermediaries is well known. As a voluntarist52 and fellow Arian—for which he lost his position as chaplain to Queen Anne—Clarke was worthy of his trust, but it is hard to believe that Newton, even in his seventies, would have allowed

50. Clarke himself published Leibniz's five papers together with his own replies in 1717. I have used the excellent edition prepared by H.G. Alexander, *The Leibniz-Clarke Correspondence* (Manchester: UP, 1956), which will be cited as "Alexander."


52. Clarke's voluntarism is discussed in John H. Gay, "Matter and Freedom in the Thought of Samuel Clarke," *JHI* 24 (1963), 85-105. In Gay's opinion, "the reconciliation of freedom with Newtonian science" was an impossible task. I am afraid that Gay does not understand Newtonian science.
anyone to work unsupervised on a project of such importance as that of refuting charges of impiety. The documents do in fact confirm Caroline's report that Clarke consulted with Newton. First of all, Clarke's replies reveal an intimate understanding of Newton's views on absolute space, the non-mechanical nature of gravitation, and the need for miracles in the cosmos. Secondly, surviving drafts of Newton's letter to Conti, composed before Clarke sent his third reply to Leibniz, contain the same views on the nature of miracles that Clarke defended in his later replies. Finally, Des Maizaeux's compilation of the debate papers prompted Newton in 1720 to draft a letter, purporting to have been written by Clarke, in which he explained the significance of principal concepts from the controversy. I shall therefore assume that though Clarke very likely contributed some of his own arguments to the defense of Newton's ideas, the bulk of the correspondence was written in consultation with Newton and bore his seal of approval.

Certainly Newton approved of Clarke's vigorous defense of theological voluntarism, which reflected the same basic concerns that Newton himself had expressed forty five years

earlier in De gravitatione. The central issue of the entire debate was the nature of divine freedom: is God's will wholly conformable to his reason? or, to put it another way, are all of God's actions subject to certain rational constraints? Consistently Leibniz answered in the affirmative; just as consistently, Clarke did not. The position against which Clarke reacted was summarized by Leibniz in the letter to Princess Caroline which accompanied his fourth paper. Clarke "and his like," he wrote,

\textit{do not properly understand that great principle that nothing happens without a sufficient reason for it and, what follows, that even God cannot choose without having a reason for his choice. This is the error of vague indiiference or the absolutely absolute decree, which I have refuted in the Theodicy. This error is also the source of the}

vacuum and atoms.\textsuperscript{55} Leibniz distinguished between the factual truths of physics (\emph{verités de fait}) and the eternal truths of mathematics (\emph{verités éternelles}). The principle of sufficient reason derived its importance from its ability to bridge the gap between these two realms, transforming contingent truths into necessary truths, subsuming all of nature under the power of pure reason. The principle of contradiction, he explained in his second paper, "is sufficient to demonstrate every point of arithmetic and geometry, that is, all mathematical principles. But in order to proceed from mathematics to natural philosophy, another principle is requisite," namely the principle of sufficient reason, "that nothing happens without a reason why it should be so, and not otherwise." By that principle one could "demonstrate the being of a God, and all the other parts of metaphysics or natural theology; and even, in some measure, ... the dynamical principles, or the principles of force."\textsuperscript{56} Thus for Leibniz, the goal of science was to reduce all of nature to rational necessity, a goal which could be attained because the creative power of God was bound by the principle of sufficient reason. As he had told Varignon at the turn of the century, "the real never ceases to be governed perfectly by the ideal and the

\textsuperscript{55} Alexander, p. 195.

\textsuperscript{56} Ibid., pp. 15f. Cassirer gives a clear analysis of Leibniz's view of knowledge in "Newton and Leibniz."
This is because everything is governed by reason; otherwise there could be no science and no rule, and this would not at all conform with the nature of the sovereign principle.  

The principle of sufficient reason had two major consequences for Leibniz's natural philosophy. There could be no void (and therefore no atoms), and there could be no absolute space. "When I was a young man, I also gave into the notion of a vacuum and atoms," he condescended to confess to Clarke, "but reason brought me into the right way." To admit a vacuum in nature "is ascribing to God a very imperfect work: 'tis violating the grand principle of the necessity of a sufficient reason . . ." Leibniz took it for granted that "every perfection, which God could impart to things without derogating from their other perfections, has actually been imparted to them"—God is bound to make the best of all possible worlds. But God could have placed some matter in a space wholly empty "without derogating in any respect from all other things: therefore he has actually placed some matter in that space: therefore, there is no space wholly empty: therefore all is full." Leibniz based this argument explicitly on the principle of plenitude. To this he added "another

argument, grounded upon the necessity of a sufficient reason." There could be no principle--no sufficient reason--"to determine what proportion of matter [to space] there ought to be, out of all the possible degrees from a plenum to a vacuum, or from a vacuum to a plenum." As for atoms, "what reason can one assign for confining nature in the progress of subdivision?" Unwilling to leave such matters to the unencumbered will of God, Leibniz flatly asserted that atoms and the void were "fictions merely arbitrary, and unworthy of true philosophy."58

He was no less convinced of the imaginary quality of absolute space. In his second reply, Clarke agreed "that nothing is, without a sufficient reason why it is, and why it is thus rather than otherwise." But he immediately qualified himself: frequently this sufficient reason was none other than the pure will of God. For example,

why this particular system of matter, should be created in one particular place, and that in another particular place; when, (all place being absolutely indifferent to all matter,) it would have been exactly the same thing vice versa, supposing the two systems (or the particles) of matter to be alike; there can be no other reason, but the mere will of God.59


59. Alexander, pp. 20f. Later Clarke put it thusly (p. 119): "the question is, whether, in some cases, when it may be highly reasonable to act, yet different ways of acting may not possibly be equally reasonable; and whether,
This was something which Leibniz could in no way allow. To say that the mere will of God is a sufficient reason was to deny the principle entirely, to fall back "into the loose indifference, which I have confuted at large, and showed to be absolutely chimerical even in creatures, and contrary to the wisdom of God, as if he could operate without acting by reason." If space were absolutely uniform, then there could be no reason why God should have placed bodies in space in one particular manner rather than in another. Clarke, a shrewd thinker, then caught his opponent in a dilemma. Supposing with Leibniz that space "were nothing real, but only the mere order of bodies," the situation would be no different. There could still be "no other reason but mere will, why three equal bodies should be placed or ranged in the order a, b, c rather than in the contrary order." In reply, Leibniz resorted once again to the denial of divine freedom. To place three identical bodies in any order whatsoever would be "a thing indifferent"; and "consequently they will never be placed in any order, by him who does nothing without wisdom. But then he being the author of things, no such things will be produced by him at all . . ." Therefore there was "no such thing as two indivisibles indiscernible from each in such cases, the bare will of God be not itself a sufficient reason for acting in this or the other particular manner . . ." Cf. pp. 30 and 35.

60. Leibniz's third paper (Alexander, pp. 26f).

61. Clarke's third reply (p. 30).
other"—another good reason to deny atoms. The argument continued, but the basic disagreement remained. Leibniz insisted that God required a sufficient reason for each creative act; indifference would paralyze his infinite wisdom. Against this, Clarke maintained that God is not a balance which cannot move itself when the weights on both sides are equal. He is a free agent, capable of acting according to his own will, apart from external considerations.

Divine freedom was also fundamental to the debate over the nature of God's ongoing relation to the world. Leibniz spelled out his differences with Newton in a letter to Johann Bernoulli, dated just a month after his first paper for Clarke. What Newton thinks, the German complained, "seems plainly absurd to me, namely that the motion of the world-machine will come to cease unless from time to time restored by God. Thus miracles are necessary to him, and he will prove unable to explain his attraction without perpetual miracles." Leibniz believed that vis viva was conserved in all natural events, so that the world needed no divine renewal for its continued operation. In his opinion, Newton's concept of divine maintenance reflected poorly on God's wisdom. If God had "to wind up his watch

64. Corres VI, 261.
from time to time," then he lacked "sufficient foresight to make it a perpetual motion." According to the Newtonians, Leibniz claimed, God had made a machine so imperfect that he was "obliged to clean it now and then by an extraordinary concourse, and even to mend it, as a clockmaker mends his work ..." Against this, Leibniz held that God worked miracles not "in order to supply the wants of nature, but those of grace." To think otherwise was to "have a very mean notion of the wisdom and power of God." Clarke did not agree. God was not a watchmaker; nor was the world a watch. The skill of a human artificer lay in combining certain motions which he himself could not produce, but only adjust. However God was "himself the author and continual preserver" of the forces in the world. Consequently it was not a diminution, but the true glory of his workmanship, that nothing is done without his continual government and inspection. The notion of the world's being a great machine, going on without the interposition of God, as a clock continues to go without the assistance of a clockmaker; is the notion of materialism and fate, and tends, (under pretence of making God a supra-mundane intelligence,) to exclude providence and God's government in reality out of the world. And by the same reason that a philosopher can represent all things going on from the

65. The first paper for Clarke (Alexander, pp. 11f). Cf. his letter to Conti from late 1715: "I am astonished that Mr. Newton and his followers believe that God has made his machine so badly that unless he affects it by some extraordinary means, the watch will very soon cease to go. This is to have very narrow ideas of the wisdom and power of God. I call extraordinary every operation of God demanding something other than the conservation of the natures of created things." (Ibid., p. 185.)
beginning of the creation, without any government or interposition of providence; a sceptic will easily argue still farther backwards, and suppose that things have from eternity gone on (as they now do) without any true creation or original author at all, but only what such arguers call all-wise and eternal nature.

Just as Newton had objected to the Cartesian notion of matter because it did not require a creator, so Clarke objected to the Leibnizean notion of the world machine, which likewise made the creator a dispensible appendage. Casting away the clockwork metaphor, Clarke turned to the much more Newtonian image of the world as the dominion of a sovereign ruler:

If a king had a kingdom, wherein all things would continually go on (as they now do) without his government or interposition, or without his attending to and ordering what is done therein; it would be to him, merely a nominal kingdom; nor would he in reality deserve at all the title of king or governor. And as those men, who pretend that in an earthly government things may go on perfectly well without the king himself ordering or disposing of any thing, may reasonably be suspected that they would like very well to set the king aside: so whosoever contends, that the course of the world can go on without the continual direction of God, the Supreme Governor: his doctrine does in effect tend to exclude God out of the world.66

Clarke had gone straight to the heart of the matter: what is the nature of God's relation to the world? Is he an absentee landlord, a perfect watchmaker who has built into his machine every event which he has foreordained? Or is he an omnipotent governor who rules his kingdom directly

and continually as active cause of all that comes to pass?

Leibniz opted for the former. Although he denied that the world is a machine "that goes without God's interposition," he affirmed it "to be a watch, that goes without wanting to be mended by him," for "God has foreseen every thing" and "has provided a remedy for every thing before-hand; there is in his works a harmony, a beauty, already pre-established." This opinion, he argued, did not exclude divine providence or government, but made it perfect. True providence required perfect foresight and advance provision of adequate remedies. As he told Wolff, Clarke "does not realize that the divine governance of natural things consists in sustention, and must not be taken in an anthropological sense."68

For his part, Clarke continued his attack on the purely mechanical universe, upholding in its stead the picture of the world painted by Newton in the Queries and the General Scholium. Contrary to what Leibniz had argued, neither the motions of heavenly bodies, nor the formation and motions of plants and animals were merely mechanical in nature. Whoever thought so was

obliged in reason to be able to explain particularly, by what laws of mechanism the planets and comets can

67. Leibniz's second paper (pp. 18f).

68. Letter of 23 December 1715, in Alexander, p. 188. The original Latin letter is printed in Corres VI, 257ff.
continue to move in the orbs they do, thro' unresisting spaces: and by what mechanical laws, both plants and animals are formed: and how the infinitely various spontaneous motions of animals and men, are performed. Which, I am fully persuaded, is as impossible to make out, as it would be to show how a house or a city could be built, or the world itself have been at first formed by mere mechanism, without any intelligent and active cause. That things could not be at first produced by mechanism, is expressly allowed: and, when this is once granted: why, after that, so great concern should be shown, to exclude God's actual government of the world, and to allow his providence to act no further than barely in concurring (as the phrase is) to let all things do only what they would do of themselves by mere mechanism; and why it should be thought that God is under any obligation or confinement either in nature or wisdom, never to bring about any thing in the universe, but what is possible for a corporeal machine to accomplish by mere mechanical laws, after it is once set a going: I can in no way conceive.69

For Clarke, divine wisdom entailed not the making of a world capable of operating independently of God, but rather "the perfect and complete idea of a work, which began and continues, according to that original perfect idea, by the continued uninterrupted exercise of his power and government." Nothing prevented that perfect idea from involving disorder and divine renovation, or even miracles. The wisdom of God did not consist in making the present frame of the world eternal, but only in making it "to last as long as he thought fit." Nor did it consist in providing remedies for natural disorders, for "with regard to God, there are no disorders, and consequently no remedies, and indeed no powers of nature at all, that can

do anything of themselves . . ." From God's point of view, the world never needed correction or amendment; it always followed his original perfect design, which could certainly include the reformation of what he had made. Where Leibniz insisted upon limiting God's actions by the ordinary course of nature and the principle of sufficient reason, Clarke allowed God to act in any way he pleased for reasons known only to him. Leibniz was operating with a rationalistic definition of perfection--God's design must not involve "corrections"--but Clarke conceived of perfection in a voluntaristic sense--perfection was whatever God had intended to do, for God is perfect:

For why was not God at liberty to make a world, that should continue in its present form as long or as short a time as he thought fit, and should then be altered (by such changes as may be very wise and fit, and yet impossible perhaps to be performed by mechanism,) into whatever other form he himself pleased?71

Thus for Clarke, as for Newton, divine wisdom and foresight were identified with dominion, with God's activity "in continuing at once, what his power and government is continually putting in actual execution." God's ordinary concourse meant "his actual operation and government, in preserving and continuing the beings, powers, orders, dispositions and motions of all things";

70. Clarke's second reply (pp. 22f).
71. Clarke's fifth reply (p. 113).
anything less would make him "a governor only nominal."

This conception of divine governance implies that the distinction between natural and supernatural is an artificial one, of merely human convenience. This was indeed the next step in Clarke's argument:

To cause the sun (or earth) to move regularly, is a thing we call natural: to stop its motion for a day, we call supernatural: but the one is the effect of no greater power, than the other; nor is the one, with respect to God, more or less natural or supernatural than the other. . . . God is present to the world, not as a part, but as a governor: acting upon all things, himself acted upon by nothing. He is not far from every one of us, for in him we (and all things) live and move and have our beings.72

With regard to God, no one possible thing was more miraculous than another. Miracles were simply unusual acts of God, but no more or less acts of God than ordinary events of nature. The raising of a dead human body and the sudden stopping of the earth's motion were called miracles; the ordinary generation of a human body and the continual motion of the earth were called natural, "for no other reason, but because the power of God effects one usually, the other unusually."73 This was precisely the same view of miracles which Newton himself expressed. In an undated

72. Clarke's second reply (pp. 23f). For a provocative treatment of the breakdown of the natural/supernatural distinction in theological and scientific literature of the Middle Ages and the Renaissance, see Keith Hutchinson, "Supernaturalism and the Mechanical Philosophy," History of Science 21 (1983), 297-333.

manuscript now in the library of Lehigh University, he wrote:

For Miracles are so called not because they are the works of God but because they happen seldom & for that reason create wonder. If they should happen constantly according to certaine laws impressed upon the nature of things, they would no longer be wonders or miracles, but might be considered in Philosophy as part of the Phenomena of Nature {notwithstanding their being the effects of the laws impressed upon Nature by the powers of God} notwithstanding that the cause of their causes might be unknown to us.  

The identical opinion is found in several drafts of Newton's February 1716 letter to Conti, certainly written before Clarke wrote his third reply and perhaps before the second reply had been completed. The drafts also contain Newton's views on Leibniz's perfect watch, which are similar to those of Clarke.  

74. Quoted by Guerlac and Jacob, "Bentley, Newton, and Providence," p. 309 n8, and McLachlan, pp. 17f. The passage in brackets was crossed out.

75. The drafts are printed in Koyré and Cohen, "Newton and the Leibniz-Clarke Correspondence," pp. 72-75 and 108-115. The dating of the drafts is discussed on p. 115, where it is stated that the letter from Caroline which accompanied Clarke's second reply is dated 20/30 December 1715. Following Onno Klopp, the editor of Leibniz's correspondence with the Princess, Alexander gives the date as 10 December. Probably someone has erred in moving between Continental dates and English dates. The following are representative of Newton's opinions in the drafts (as printed by Koyré and Cohen): "Miracles are so called not because they are the actions of God but because they happen seldom & by happening seldom create wonder. If they happened constantly they would not be wonders." (p. 74) "[Leibniz] calls the world Gods Watch, & insinuates that it is the fault of the workman & not of the materials if a Watch will at length cease to go, & in like manner that it would be Gods fault if his Watch should ever decay & want an amendment. And by the same way of arguing a man may say
influenced Newton on these points, but I think it was more likely the other way around. In any case it is clear that Clarke and Newton both held the highly voluntaristic interpretation of miracles which Clarke defended in his correspondence with Leibniz.

Of course Leibniz wanted no part of this voluntarism. There is a vast difference between the natural and the supernatural, he maintained, for the latter "exceeds all the powers of creatures." He offered an example, deliberately chosen to arouse the ire of any good Newtonian: the free motion of a body in the aether around "a certain fixed centre, without any other creature acting upon it," was something which "could not be done without a miracle; since it cannot be explained by the nature of bodies." Since a free body would naturally recede from a curved path along the tangent, Leibniz concluded that "the attraction of bodies, properly so called, is a miraculous thing, since it cannot be explained by the nature of bodies." 76 It was not a new complaint. Leibniz had first aired it in a February 1711 letter to Hartsoeker which was published in the 5 May 1712 issue of the weekly paper Memoirs of Literature, where Cotes saw it and called it to that it would be Gods fault if matter doth not think." (p. 73)

76. Leibniz's third paper (pp. 29f). Cf. pp. 42f and 90-95; his letter to Johann Bernoulli of 27 May 1716, printed with a translation in Corres VI, 353-56; and his letter to Conti in Alexander, pp. 184-86.
Newton's attention. In an undated reply to the editor of the Memoirs, Newton argued that gravitation had been "proved by mathematical demonstrations grounded upon experiments & the phaenomena of nature: & Mr Leibnitz himself cannot deny [this]." Gravity should not be called a miracle just because no mechanical hypothesis has been offered to explain its operation, Newton said. Hardness, inertia, and extension were the natural real reasonable manifest qualities of all bodies seated in them by the will of God from the beginning of creation & perfectly incapable of being explained mechanically . . . And therefore if any man should say that bodies attract one another by a power whose cause is unknown to us or by a power seated in the frame of nature by the will of God, . . . I know not why he should be said to introduce miracles & occult qualities & fictions into ye world. For Mr Leibnitz himself will scarce say that thinking is mechanical as it must be if to explain it otherwise be to make it a miracle an occult quality and a fiction.

But he goes on & tells us that God could not create Planets that should move round of themselves without any cause that should prevent their removing through the tangent. For a Miracle at least must keep the Planet in. But certainly God could create Planets that should move round of themselves without any other cause then gravity that should prevent their removing through ye tangent. For gravity without a Miracle may keep the Planets in.77

Newton had spelled out precisely the fundamental disagreement with his archrival: mechanical explanation did not wholly exhaust the range of natural phenomena; the

77. Corres VI, 299f. Here Newton seems to allow that gravity might be innate to bodies, a position he explicitly denied elsewhere. See the appropriate comments of A.R. Hall and Laura Tilling on p. 301 n6.
process of thought was neither mechanical nor miraculous, and the same was true of gravitation. The ontology which Newton employed recognized categories which Leibniz could only label "occult" and wish to go away. In a set of notes on Leibniz's "Tentamen," Newton took exception to the hypothesis that the centrifugal tendency of a body describing a curved line in a fluid "is only overcome by a contiguous moving [body]." "Then a body is only moved by a corporeal agent," Newton observed, and "not by the human mind (unless it be corporeal) nor by God (unless he be corporeal)." If so, then "God does not govern the world and so he is not the Lord God." 78 The first cause was certainly not mechanical; if only mechanical causes could keep bodies in curved paths, then the first cause was certainly not the Lord God, either.

I wish further to clarify an important point. Like Leibniz, Newton called non-mechanical causes "occult." Unlike Leibniz, he asserted that they were no less real and natural. This is apparent from a draft of his letter to Conti:

[Leibniz] gives the name of Miracles or Wonders to the laws impressed by God upon Nature tho by reason of their constant working they create no Wonder; & that of occult qualities to qualities which are not occult but whose causes are occult tho the qualities

Provided that a quality itself was not occult—that is, provided that an effect was manifest and not hidden—Newton did not hesitate to accept its reality, whether or not the cause was equally demonstrable. God was free to impress on nature whatever laws he pleased. If he chose to produce gravitation mechanically, then let a mechanical cause be sought; if not, the phenomenon was no less lawlike and subject to philosophical understanding. "Gravity must be caused by an agent acting constantly according to certain laws," Newton explained to Bentley, "but whether this agent be material or immaterial is a question I have left to ye consideration of my readers."80 One reader who had considered this, Gottfried Wilhelm Leibniz, was unwilling to allow an immaterial agent. Those who avow that gravity is an occult quality are correct, if they mean "that there is a certain mechanism unknown to them" by which bodies fall to earth, he told Hartsoeker in the letter later.


80. Letter of 25 February 1693 (Corres III, 254). In the same paragraph Newton showed his hand: "Tis inconceiveable that inanimate brute matter should (without ye mediation of something else wch is not material) operate upon & affect other matter without mutual contact . . ." Cf. his earlier letter to Bentley in ibid., 240.
published in the Memoirs. But if they mean "that this transpires without any mechanism, by a simple primitive property, or by a law of God which brings about this effect without using any intelligible means, then it is a senseless occult quality . . ."81

Newton could not abide such an attitude. It was bad science and bad theology, perhaps even more the latter than the former. "It must be allowed that these two Gentlemen differ very much in Philosophy," he smugly addressed the readers of the Philosophical Transactions in his anonymous "Account of the Book Commercium epistolicum."82 For want of decisive experiments, he wrote, the one

doth not affirm whether the Cause of Gravity be Mechanical or not Mechanical: the other that it is a perpetual Miracle if it be not Mechanical. The one (by way of Enquiry) attributes it to the Power of the Creator that the least Particles of Matter are hard: the other attributes the Hardness of Matter to conspiring Motions, and calls it a perpetual Miracle if the Cause of this Hardness be other than Mechanical. The one doth not affirm that animal Motion in Man is purely mechanical: the other teaches that it is purely mechanical, the Soul or Mind (according to the Hypothesis of an Harmonia Praestablitia) never acting upon the Body so as to alter or influence its Motions. The one teaches that God (the God in whom we live and move and have our Being) is Omnipresent; but not as a Soul of the

81. Quoted by Cajori, pp. 668f.

82. Found in volume 29 (1714). The Commercium, a collection of documents pertaining to the calculus priority dispute, was compiled by Newton and published by the Royal Society during Newton's presidency. Not exactly intended to please Leibniz and his retinue, it poured oil on the flames of controversy. Newton's review added insult to injury by casting aspersion on Leibniz's theology.
World: the other that he is not the Soul of the World, but INTELLIGENTIA SUPRAMUNDANA, an Intelligence above the Bounds of the World; whence it seems to follow that he cannot do any Miracle. The one teaches that Philosophers are to argue from Phaenomena and Experiments to the Causes thereof, and thence to the Causes of those Causes, and so on till we come to the first Cause: the other that all the Actions of the first Cause are Miracles, and all the Laws imprest on Nature by the Will of God are perpetual Miracles and occult Qualities, and therefore not to be considered in Philosophy. But must the constant and universal Laws of Nature, if derived from the Power of God or the Action of a Cause not yet known to us, be called Miracles and occult Qualities, that is to say, Wonders and Absurdities? Must all the Arguments for a God taken from the Phaenomena of Nature be exploded by new hard Names?83

"Certainly these things deserve to be better considered," Newton concluded. In the following pages I will consider more closely the relationship between Newton's voluntarist God and his conception of natural philosophy.

Newtonian Voluntarism and a Science of Phenomena

"Hitherto I have not been able to discover the cause of those properties of gravity from phenomena," Newton declared in the General Scholium. Although as we have seen he did not lack ideas about the ultimate cause of gravity—he knew that it was not mechanical—he preferred here to feign no hypotheses, "for whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of

83. Ibid., p. 224, italics his. Clarke raised the same issues in his debate with Leibniz. See Alexander, pp. 114-119.
occult qualities or mechanical, have no place in natural philosophy." It is enough, he said, "that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea." Newton captured in this passage the essence of his conception of natural philosophy: that natural phenomena could be understood adequately as phenomena, apart from any knowledge of their causes. As he wrote in Query 31, "we must learn from the Phaenomena of Nature what Bodies attract one another, and what are the Laws and Properties of the Attraction, before we enquire the Cause by which the Attraction is perform'd." Fully aware of alternatives, Newton intended his approach to be seen as the deliberate rejection of the kind of science advocated by his Continental rivals, who sought to derive all of nature from a few principles arising from their own fertile imaginations. He summarized his position in a draft of a letter to Roger Cotes, the gifted mathematician who was supervising the publication of the second edition of the *Principia*:

Experimental philosophy reduces Phaenomena to general Rules & looks upon the Rules to be general when they hold generally in Phaenomena. It is not enough to object that a contrary phaenomenon may happen but to make a legitimate objection a contrary phaenomenon

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84. Cajori, p. 547. Cf. the draft in Halls, pp. 352f.

must be actually produced. Hypothetical Philosophy consists in imaginary explications of things & imaginary arguments for or against such explications, or against the arguments of Experimental Philosophers founded upon Induction. The first sort of Philosophy [i.e., experimental philosophy] is followed by me, the latter too much by Cartes, Leibnitz & some others."86

The letter which Cotes actually received made no mention of those two gentlemen or their philosophies, but Cotes did not need to be told what he could see for himself. Natural philosophers may be reduced to three classes, he advised readers in his preface to the new edition. Some follow Aristotle and reduce the effects of bodies to natures and qualities, which is to tell us nothing. Others assume hypotheses as first principles of their speculations, forming an "ingenious romance" with little resemblance to reality. The third class pursue experimental philosophy, assuming as a principle nothing not proved by phenomena.87

86. ULC Add. MS. 3984.14, folio 1, printed in Corres V, 398f.

87. Cajori, p. xx. Cotes probably borrowed the term "romance" from Newton, who used it in a draft on methodology which McGuire has dated to around 1700: "But if without deriving the properties of things from Phaenomena you feign Hypotheses & think by them to explain all nature you may make a plausible systeme of Philosophy for getting your self a name, but your systeme will be little better than a Romance. To explain all nature is too difficult a task for any one man or any one age. Tis much better to do a little with certainty & leave the rest for others that come after you then to explain all things by conjectures without making sure of any thing." ULC Add. MS. 3970.3, folio 480v, printed in McGuire, "Newton's 'Principles of Philosophy': An Intended Preface for the 1704 Opticks and a Related Draft Fragment," BJHS 5 (1970), p. 183. Cf. the drafts of his letter to Conti (see note 74), where he also
Later in his preface Cotes revealed the religious foundation of this third kind of philosophy:

Without all doubt this world, so diversified with that variety of forms and motions we find in it, could arise from nothing but the perfectly free will of God directing and presiding over all.

From this fountain it is that those laws, which we call the laws of Nature, have flowed, in which there appear many traces indeed of the most wise contrivance, but not the least shadow of necessity. These therefore we must not seek from uncertain conjectures, but learn them from observations and experiments. He who is presumptuous enough to think that he can find the true principles of physics and the laws of natural things by the force alone of his own mind, and the internal light of his reason, must either suppose that the world exists by necessity, and by the same necessity follows the laws proposed; or if the order of Nature was established by the will of God, that himself, a miserable reptile, can tell what was fittest to be done. All sound and true philosophy is founded on the appearances of things; and if these phenomena inevitably draw us, against our wills, to such principles as most clearly manifest to us the most excellent counsel and supreme dominion of the All-wise and Almighty Being, they are not therefore to be laid aside because some men may perhaps dislike them. These men may call them miracles or occult qualities, but names maliciously given ought not to be a disadvantage to the things themselves, unless these men will say at last that all philosophy ought to be founded in atheism. Philosophy must not be corrupted in compliance with these men, for the order of things will not be changed.88

To be sure, Newton himself did not write this; nor did he read what Cotes had written before it went to press.89

But Cotes said nothing which Newton had not already said in

spoke of a "Romance."


89. Samuel Clarke did, however. See Never at Rest, p. 749.
the course of his long and distinguished career. It was by divine will that matter existed and possessed the properties that it did; the same will had ordered the universe and would re-order it again some day. Natural laws were actively imposed by that will and, it seems, could be changed by that will: "it may be allow'd that God is able to create Particles of Matter of Sizes and Figures and in several Proportions to Space, and perhaps of different Densities and Forces, and thereby to vary the Laws of Nature, and make Worlds of several sorts in several Parts of the Universe."\textsuperscript{90}

I can find no necessity either in Newton's theology or in his natural philosophy, no trace of Leibniz's God of sufficient reason or Descartes' God of immutable decrees. Newton's God, as Koyré has noted, was not merely a philosopher's God, an uninterested, impersonal first cause. He was rather the God of the Bible, "the effective Master and Ruler of the world created by him."\textsuperscript{91} Created--it is an important word, conveying the irreducible fact that the world was not made by men. Therefore it might not be made as men would have made it. Therefore an \textit{a priori} science

\textsuperscript{90} Query 31 (Opticks, pp. 403f. The contrast with Descartes' \textit{Le Monde} is instructive. Also cf. Leibniz's use of the principle of sufficient reason to deny that God could create particles of matter in varying proportions to space--he could create only one continuous matter (see note 58 above).

\textsuperscript{91} From the Closed World to the Infinite Universe, p. 225.
could not be a science of nature at all, but only a romance. To Newton the public scientist we owe so much of the modern understanding of nature, but to Newton the private theologian we owe no less: the attitude that what God has freely done can be learned not by inventing it, but by discovering it.
CONCLUSION:

THE IMPACT OF VOLUNTARISTIC THEOLOGY ON SEVENTEENTH CENTURY NATURAL PHILOSOPHY

Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God: Sit down before fact as a little child, be prepared to give up every preconceived notion, follow humbly and to whatever abysses nature leads, or you shall learn nothing.

--T.H. Huxley, letter to Charles Kingsley, 23 September 1860

As we see, empiricism and metaphysics, and even a very definite kind of metaphysics, the creationist, are closely linked together. What other means, indeed, but observation and experience can we possibly use for the study of a world freely created by an Infinite God?

--A. Koyré, From the Closed World to the Infinite Universe, p. 205
I began this dissertation by posing a general question: What was the relation of religion to science in the seventeenth century? Drawing on the insights of M.B. Foster and his followers, I narrowed the scope of my inquiry to the following, very specific question in intellectual history: Was there in the seventeenth century a connection between theological voluntarism and empirical science? The four case studies which comprise the bulk of this dissertation were intended to answer this question as definitively as possible within the obvious limits of my research.

My conclusion is that Foster was correct, at least for the individuals I have studied. Theology impinged on natural philosophy through the doctrine of creation, in terms of which the four subjects of this essay approached the problem of scientific knowledge. How God had made the world, how he continued to uphold it, and how the human mind was related to the divine all had implications for natural philosophy. Ultimately it was a question of which divine attributes received the most attention—perfection, power, reason (and wisdom), or will. An emphasis on the divine will went hand in hand with a belief in the primacy of phenomena; a lack of emphasis on the divine will was accompanied by an a priori attitude toward nature.

For Galileo, divine reason and power were uppermost.
An omnipotent God had perfectly imposed mathematical forms on nature, the obedient executrix of his commands. Made in the image of the divine mind, our own minds could participate in God's absolute knowledge of his creation through the deductive certainty of geometry, to which physics was essentially reduced. Our failure completely to know nature was due, not to the exercise of an inscrutable divine will, but to our finite capabilities.

Descartes began with the unfettered freedom of God's will, but then mitigated that freedom almost totally by stressing divine perfection. Because perfection entailed immutability, God always acted in the same way. A perfect God could not change his mind and could not deceive us by allowing us clearly and distinctly to perceive false propositions. Thus the human mind became the touchstone for created reality: what it could not comprehend God obviously had chosen not to create. If God was free to produce the particulars of nature in a variety of ways, he could have made only one kind of world in general, a world which conformed absolutely to the innate truths he implanted in our souls. Grounded upon such a theology of creation, Cartesian natural philosophy was largely a priori: the appeal to experience was required to augment pure reason only where the vestiges of divine will remained.

Boyle never claimed, as Descartes did, that God could
have made a different set of eternal truths. He never exempted God's creative activity from the law of contradiction. Yet in every other respect, his theology of creation was more voluntaristic than Descartes'. God, when he made the world, had been under no obligation to conform to human thoughts or wishes. Rules by which God freely regulated his own actions, the laws of nature were not necessary truths and could have been otherwise. Therefore they had to be inferred from the phenomena and treated as hypotheses, contingent truths subject to change in light of future discoveries. As purblind mortals, we could know neither God nor nature from essences and innate ideas; truths about both had to be gathered from his two revelations, nature and scripture.

Divine will was also primary for Newton, who upheld God's freedom to do as he pleased both in creating the world and in sustaining it. Nothing limited God to mechanical causes alone or prohibited him from acting miraculously in the cosmos. The sovereign Lord governed matter and motion directly by his will, in accordance with laws of his own choosing. Knowledge of nature, like knowledge of God, was attained by induction from the phenomena, not by vain speculation from supposed necessary truths.

Am I claiming that their voluntarism "caused" Boyle and Newton to advocate empiricism instead of conceptualism,
to use McMullin's terms? That depends on the sense in which the word "cause" is employed. Even in natural science causation is an elusive concept which some would prefer to avoid. Causation in history is considerably less clear, yet historians frequently claim to be explaining the events they have recorded and almost always use language that implies causality—conjunctions like "because" and "since," and adverbs like "thus" and "therefore." I have certainly made similar claims in the present essay.

Webster's Seventh New Collegiate Dictionary states that the term cause "applies to any event, circumstance, or condition or any combination of these that brings about or helps bring about a result." Thus I claim that voluntarism "caused" Boyle and Newton to advocate empiricism in that it helped bring about their rejection of conceptualism and their acceptance of an alternative science of nature.

There is no sense, however, in which I wish to claim that voluntarism "caused" early modern science. I can find no significant references to divine freedom by Copernicus, Vesalius, or Galileo, without whom the scientific revolution as I understand it would never have happened. Voluntarism impinged on a scientific revolution which was already under way. If many natural philosophers were

convinced that the Aristotelian world view had to be replaced, they were not yet willing to abandon the notion that science contains necessary truths. The adoption of a more modest conception of science was left to the voluntarists, for whom a necessary knowledge of nature was incompatible with divine freedom.

It has been a fundamental assumption of this essay that religion and science were inextricably intermingled during the crucial, formative years of the modern scientific world view. For too long historians have taken Galileo's encounter with the Holy See as normative of that relationship. The analysis presented in the preceding pages suggests that this view is much too shallow to stand scrutiny. At a much deeper level than the superficial disputes over the interpretation of scripture, religion exerted a subtle but significant influence on seventeenth century science. In subsequent years the source of that influence—the voluntarist notion of a God who does whatever he pleases—was set aside by deists and

freethinkers. But the result of that influence—an empirical attitude toward nature—was retained.

Divine freedom as a significant influence on early modern science? To the modern mind, accustomed to a radical separation of religion from almost every aspect of intellectual life, that sounds like a contradiction. But the modern world was not erected overnight by modern minds; it has emerged slowly from an older world shaped by minds not quite so modern. That it still bears the marks of its history should not be surprising.
BIBLIOGRAPHY

PRIMARY SOURCES: BOYLE


Reasons Why a Protestant Should not Turn Papist: or, Protestant prejudices against the Roman religion: propos'd, in a letter to a Romish priest. By a person of quality. London, 1687. [anonymous work not included in Birch]

PRIMARY SOURCES: DESCARTES


TRANSLATIONS: DESCARTES


PRIMARY SOURCES: GALILEO


TRANSLATIONS: GALILEO


PRIMARY SOURCES: NEWTON


The Chronology of Ancient Kingdoms Amended. To which is Prefix'd, A Short Chronicle from the First Memory of Things in Europe, to the Conquest of Alexander the Great. London, 1728.


PRIMARY SOURCES: MISCELLANEOUS


Waller, Richard, ed. The Posthumous Works of Robert Hooke... containing his Cutlerian lectures, and other discourses... Illustrated with sculptures. To these discourses is prefixt the author's life, giving an account of his studies and employments... London, 1705.

SECONDARY SOURCES


———. "The Role of Experience in Descartes' Theory of Method." In *Theories of Scientific Method*, pp. 75-103.

Bowen, Mary E.C. "'This great automaton, the world': The Mechanical Philosophy of Robert Boyle, F.R.S." Doctoral dissertation at Columbia University, 1976.


_____. "Descartes' Use of 'Demonstration' and 'Deduction'." The Modern Schoolman 54 (1977), 333-44.

_____. "Physics and Metaphysics in Descartes' Principles." SHPS 10 (1979), 89-112.


Cronin, T.J. "Eternal Truths in the Thought of Descartes and his Adversary." JHI 21 (1960), 553-59.


Garin, P. *Theses Cartesiennes et Theses Thomistes*. Paris: Desclee de Brouwer, no date.


Grant, Edward. "The Condemnation of 1277, God's Absolute Power, and Physical Thought in the Late Middle Ages." *Viator* 10 (1979), 211-244.

________. "Hypotheses in Late Medieval and Early Modern Science." *Daedalus* 91 (1962), 599-616.

________. "Late Medieval Thought, Copernicus, and the Scientific Revolution." *JHI* 23 (1962), 197-220.


Hatfield, Gary C. "Force (God) in Descartes' Physics." SHPS 10 (1979), 113-40.


——. "From a Rationalist Theology to Cartesian Voluntarism: David Derodon and Jean-Robert Chouet." JHI 40 (1979), 527-42.


Holtrop, Philip C. "In Hoc Pulcherrimo Theatro: Calvin's View of Scripture and Natural Science." Unpublished paper.


——. "Science and Theology in the Middle Ages." Free University Quarterly 3 (1954), 77-163.


Jones, Edward. *A Catalogue of the Philosophical Books and Tracts Written by the Hon. Robert Boyle, Esq.: together with the order or time, wherein each of them hath been publish'd respectively. To which is added a catalogue of the theological books, written by the same author*. London, 1689.


_____. "Newton, Barrow and the Hypothetical Physics." Centaurus 11 (1965), 46-56.


_____. "La Vide et l'Espace Infini au XVIe Siecle." Archives d'histoire doctrinale et litteraire du Moyen Age 24 (1947), 45-91.

"Newton and the Leibniz-Clarke Correspondence with Notes on Newton, Conti, and Des Maizeaux." Archives internationales d'histoire des sciences 15 (1962), 63-126.


Mandonnet, P. Siger of Brabant et l'averroisme latin au XIIIme siecle. 2nd ed. Louvain, 1908.


---"Jacobean Political Theology: The Absolute and Ordinary Powers of the King." JHI 29 (1968), 323-46.


Sakellariadis, Spyros. "Descartes' Use of Empirical Data to Test Hypotheses." Isis 73 (1982), 68-76.

_____. "The Role of Evidence in Descartes' Scientific Method." Doctoral dissertation at the University of Pittsburgh, 1980.


________. "Newton and Absolute Space." Archives internationales d'histoire des sciences 17 (1964), 121-32.


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