The Scientific Revolution:

Science and Society from the Renaissance to the Early Enlightenment

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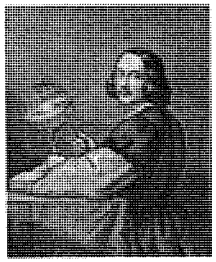
Readings for Tuesday

From Copernicus to Descartes

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(b) Foreword by Andreas Osiander

To the Reader
Concerning the Hypotheses of this Work[1]

There have already been widespread reports about the novel hypotheses of this work, which declares that the earth moves whereas the sun is at rest in the center of the universe. Hence certain scholars, I have no doubt, are deeply offended and believe that the liberal arts, which were established long ago on a sound basis, should not be thrown into confusion. But if these men are willing to examine the matter closely, they will find that the author of this work has done nothing blameworthy. For it is the duty of an astronomer to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain to the true causes, he will adopt whatever suppositions enable the motions to be computed correctly from the principles of geometry for the future as well as for the past. The present author has performed both these duties excellently. For these hypotheses need not be true nor even probable. On the contrary, if they provide a calculus consistent with the observations, that alone is enough. Perhaps there is someone who is so ignorant of geometry and optics that he regards the epicycle of Venus as probable, or thinks that it is the reason why Venus sometimes precedes and sometimes follows the sun by forty degrees and even more. Is there anyone who is not aware that from this assumption it necessarily follows that the diameter of the planet at perigee should appear more than four times, and the body of the planet more than sixteen times, as great as at apogee? Yet this variation is refuted by the experience of every age. In this science there are some other no less important absurdities, which need not be set forth at the moment. For this art, it is quite clear, is completely and absolutely ignorant of the causes of the apparent nonuniform motions. And if any causes are devised by the imagination, as indeed very many are, they are not put forward to convince anyone that they are true, but merely to provide a reliable basis for computation. However, since different hypotheses are sometimes offered for one and the same motion (for example, eccentricity and an epicycle for the sun's motion), the astronomer will take as his first choice that hypothesis which is the easiest to grasp. The philosopher will perhaps rather seek the semblance of the truth. But neither of them will understand or state anything certain, unless it has been divinely revealed to him.

Therefore alongside the ancient hypotheses, which are no more probable, let us permit these new hypotheses also to become known, especially since they are admirable as well as simple and bring with them a huge treasure of very skillful observations. So far as hypotheses are concerned, let no one expect anything certain from astronomy, which cannot furnish it, lest

1 This foreword by Osiander was originally anonymous.

he accept as the truth ideas conceived for another purpose, and depart from this study a greater fool than when he entered it. Farewell.

(c) Letter of Nicholas Schönberg

Nicholas Schönberg, Cardinal of Capua,
to Nicholas Copernicus, Greetings.

Some years ago word reached me concerning your proficiency, of which everybody constantly spoke. At that time I began to have a very high regard for you, and also to congratulate our contemporaries among whom you enjoyed such great prestige. For I had learned that you had not merely mastered the discoveries of the ancient astronomers uncommonly well but had also formulated a new cosmology. In it you maintain that the earth moves; that the sun occupies the lowest, and thus the central, place in the universe; that the eighth heaven remains perpetually motionless and fixed; and that, together with the elements included in its sphere, the moon, situated between the heavens of Mars and Venus, revolves around the sun in the period of a year. I have also learned that you have written an exposition of this whole system of astronomy, and have computed the planetary motions and set them down in tables, to the greatest admiration of all. Therefore with the utmost earnestness I entreat you, most learned sir, unless I inconvenience you, to communicate this discovery of yours to scholars, and at the earliest possible moment to send me your writings on the sphere of the universe together with the tables and whatever else you have that is relevant to this subject. Moreover, I have instructed Theodoric of Reden to have everything copied in your quarters at my expense and dispatched to me. If you gratify my desire in this matter, you will see that you are dealing with a man who is zealous for your reputation and eager to do justice to so fine a talent. Farewell.

Rome, 1 November 1536

(d) Preface to the Pope

TO HIS HOLINESS, POPE PAUL III,
NICHOLAS COPERNICUS' PREFACE
TO HIS BOOKS ON THE REVOLUTIONS

I can readily imagine, Holy Father, that as soon as some people hear that in this volume, which I have written about the revolutions of the spheres of the universe, I ascribe certain motions to the terrestrial globe, they will shout that I must be immediately repudiated together with this belief. For I am not so enamored of my own opinions that I disregard what others may think of them. I am aware that a philosopher's ideas are not subject to the judgement of ordinary persons, because it is his endeavor to seek the truth in all things,

Some think that the earth remains at rest. But Philolaus the Pythagorean believes that, like the sun and moon, it revolves around the fire in an oblique circle. Heraclides of Pontus and Ecphantus the Pythagorean make the earth move, not in a progressive motion, but like a wheel in a rotation from west to east about its own center.

Therefore, having obtained the opportunity from these sources, I too began to consider the mobility of the earth. And even though the idea seemed absurd, nevertheless I knew that others before me had been granted the freedom to imagine any circles whatever for the purpose of explaining the heavenly phenomena. Hence I thought that I too would be readily permitted to ascertain whether explanations sounder than those of my predecessors could be found for the revolution of the celestial spheres on the assumption of some motion of the earth.

Having thus assumed the motions which I ascribe to the earth later on in the volume, by long and intense study I finally found that if the motions of the other planets are correlated with the orbiting of the earth, and are computed for the revolution of each planet, not only do their phenomena follow therefrom but also the order and size of all the planets and spheres, and heaven itself is so linked together that in no portion of it can anything be shifted without disrupting the remaining parts and the universe as a whole. Accordingly in the arrangement of the volume too I have adopted the following order. In the first book I set forth the entire distribution of the spheres together with the motions which I attribute to the earth, so that this book contains, as it were, the general structure of the universe. Then in the remaining books I correlate the motions of the other planets and of all the spheres with the movement of the earth so that I may thereby determine to what extent the motions and appearances of the other planets and spheres can be saved if they are correlated with the earth's motions. I have no doubt that acute and learned astronomers will agree with me if, as this discipline especially requires, they are willing to examine and consider, not superficially but thoroughly, what I adduce in this volume in proof of these matters. However, in order that the educated and uneducated alike may see that I do not run away from the judgement of anybody at all, I have preferred dedicating my studies to Your Holiness rather than to anyone else. For even in this very remote corner of the earth where I live you are considered the highest authority by virtue of the loftiness of your office and your love for all literature and astronomy too. Hence by your prestige and judgement you can easily suppress calumnious attacks although, as the proverb has it, there is no remedy for a backbite.

Perhaps there will be babblers who claim to be judges of astronomy although completely ignorant of the subject and, badly distorting some passage of Scripture to their purpose, will dare to find fault with my undertaking and censure it. I disregard them even to the extent of despising their criticism as unfounded. For it is not unknown that Lactantius, otherwise an

illustrious writer but hardly an astronomer, speaks quite childishly about the earth's shape, when he mocks those who declared that the earth has the form of a globe. Hence scholars need not be surprised if any such persons will likewise ridicule me. Astronomy is written for astronomers. To them my work too will seem, unless I am mistaken, to make some contribution also to the Church, at the head of which Your Holiness now stands. For not so long ago under Leo X the Lateran Council considered the problem of reforming the ecclesiastical calendar. The issue remained undecided then only because the lengths of the year and month and the motions of the sun and moon were regarded as not yet adequately measured. From that time on, at the suggestion of that most distinguished man, Paul, bishop of Fossombrone, who was then in charge of this matter, I have directed my attention to a more precise study of these topics. But what I have accomplished in this regard, I leave to the judgement of Your Holiness in particular and of all other learned astronomers. And lest I appear to Your Holiness to promise more about the usefulness of this volume than I can fulfill, I now turn to the work itself.

(e) Introduction to Book One

Book One

INTRODUCTION

Among the many various literary and artistic pursuits which invigorate men's minds, the strongest affection and utmost zeal should, I think, promote the studies concerned with the most beautiful objects, most deserving to be known. This is the nature of the discipline which deals with the universe's divine revolutions, the asters' motions, sizes, distances, risings and settings, as well as the causes of the other phenomena in the sky, and which, in short, explains its whole appearance. What indeed is more beautiful than heaven, which of course contains all things of beauty? This is proclaimed by its very names [in Latin], *caelum* and *mundus*, the latter denoting purity and ornament, the former a carving. On account of heaven's transcendent perfection most philosophers have called it a visible god. If then the value of the arts is judged by the subject matter which they treat, that art will be by far the foremost which is labeled astronomy by some, astrology by others, but by many of the ancients, the consummation of mathematics. Unquestionably the summit of the liberal arts and most worthy of a free man, it is supported by almost all the branches of mathematics. Arithmetic, geometry, optics, surveying, mechanics and whatever others there are all contribute to it.

Although all the good arts serve to draw man's mind away from vices and lead it toward better things, this function can be more fully performed by this art, which also provides extraordinary intellectual pleasure. For when a

to the extent permitted to human reason by God. Yet I hold that completely erroneous views should be shunned. Those who know that the consensus of many centuries has sanctioned the conception that the earth remains at rest in the middle of the heaven as its center would, I reflected, regard it as an insane pronouncement if I made the opposite assertion that the earth moves. Therefore I debated with myself for a long time whether to publish the volume which I wrote to prove the earth's motion or rather to follow the example of the Pythagoreans and certain others, who used to transmit philosophy's secrets only to kinsmen and friends, not in writing but by word of mouth, as is shown by Lysis' letter to Hipparchus. And they did so, it seems to me, not, as some suppose, because they were in some way jealous about their teachings, which would be spread around; on the contrary, they wanted the very beautiful thoughts attained by great men of deep devotion not to be ridiculed by those who are reluctant to exert themselves vigorously in any literary pursuit unless it is lucrative; or if they are stimulated to the non-acquisitive study of philosophy by the exhortation and example of others, yet because of their dullness of mind they play the same part among philosophers as drones among bees. When I weighed these considerations, the scorn which I had reason to fear on account of the novelty and unconventionality of my opinion almost induced me to abandon completely the work which I had undertaken.

But while I hesitated for a long time and even resisted, my friends drew me back. Foremost among them was the cardinal of Capua, Nicholas Schönberg, renowned in every field of learning. Next to him was a man who loves me dearly, Tiedemann Giese, bishop of Chelmno, a close student of sacred letters as well as of all good literature. For he repeatedly encouraged me and, sometimes adding reproaches, urgently requested me to publish this volume and finally permit it to appear after being buried among my papers and lying concealed not merely until the ninth year but by now the fourth period of nine years. The same conduct was recommended to me by not a few other very eminent scholars. They exhorted me no longer to refuse, on account of the fear which I felt, to make my work available for the general use of students of astronomy. The crazier my doctrine of the earth's motion now appeared to most people, the argument ran, so much the more admiration and thanks would it gain after they saw the publication of my writings dispel the fog of absurdity by most luminous proofs. Influenced therefore by these persuasive men and by this hope, in the end I allowed my friends to bring out an edition of the volume, as they had long besought me to do.

However, Your Holiness will perhaps not be greatly surprised that I have dared to publish my studies after devoting so much effort to working them out that I did not hesitate to put down my thoughts about the earth's motion in written form too. But you are rather waiting to hear from me how it occurred to me to venture to conceive any motion of the earth, against the traditional opinion of astronomers and almost against common sense. I have

accordingly no desire to conceal from Your Holiness that I was impelled to consider a different system of deducing the motions of the universe's spheres for no other reason than the realization that astronomers do not agree among themselves in their investigations of this subject. For, in the first place, they are so uncertain about the motion of the sun and moon that they cannot establish and observe a constant length even for the tropical year. Secondly, in determining the motions not only of these bodies but also of the other five planets, they do not use the same principles, assumptions, and explanations of the apparent revolutions and motions. For while some employ only homocentrics, others utilize eccentrics and epicycles, and yet they do not quite reach their goal. For although those who put their faith in homocentrics showed that some nonuniform motions could be compounded in this way, nevertheless by this means they were unable to obtain any incontrovertible result in absolute agreement with the phenomena. On the other hand, those who devised the eccentrics seem thereby in large measure to have solved the problem of the apparent motions with appropriate calculations. But meanwhile they introduced a good many ideas which apparently contradict the first principles of uniform motion. Nor could they elicit or deduce from the eccentrics the principal consideration, that is, the structure of the universe and the true symmetry of its parts. On the contrary, their experience was just like some one taking from various places hands, feet, a head, and other pieces, very well depicted, it may be, but not for the representation of a single person; since these fragments would not belong to one another at all, a monster rather than a man would be put together from them. Hence in the process of demonstration or 'method', as it is called, those who employed eccentrics are found either to have omitted something essential or to have admitted something extraneous and wholly irrelevant. This would not have happened to them, had they followed sound principles. For if the hypotheses assumed by them were not false, everything which follows from their hypotheses would be confirmed beyond any doubt. Even though what I am now saying may be obscure, it will nevertheless become clearer in the proper place.

For a long time, then, I reflected on this confusion in the astronomical traditions concerning the derivation of the motions of the universe's spheres. I began to be annoyed that the movements of the world machine, created for our sake by the best and most systematic Artisan of all, were not understood with greater certainty by the philosophers, who otherwise examined so precisely the most insignificant trifles of this world. For this reason I undertook the task of rereading the works of all the philosophers which I could obtain to learn whether anyone had ever proposed other motions of the universe's spheres than those expounded by the teachers of astronomy in the schools. And in fact first I found in Cicero that Hicetas supposed the earth to move. Later I also discovered in Plutarch that certain others were of this opinion. I have decided to set his words down here, so that they may be available to everybody:

human skeletons) he frequently and quite wrongly finds fault with the ancient physicians who actually did their training by dissecting human material. For indeed one can find very many instances in Galen where he was wrong even about his apes; not to mention the remarkable fact that, granted the infinite multiplicity of differences between the organs of the human and the simian bodies, he yet noticed none of them except in the digits and the knee joint. Even these he would no doubt have missed if they had not been obvious to him without any need for human dissection.

At this point, however, I have no intention whatever of criticizing the false teachings of Galen, who is easily first among the professors of dissection, for I certainly do not wish to start off by gaining a reputation for impiety toward him, the author of all good things, or by seeming insubordinate to his authority. For I am well aware how upset the practitioners (unlike the followers of Aristotle) invariably become nowadays, when they discover in the course of a single dissection that Galen has departed on two hundred or more occasions from the true description of the harmony, function, and action of the human parts, and how grimly they examine the dissected portions as they strive with all the zeal at their command to defend him. Yet even they, drawn by their love of truth, are gradually calming down and placing more faith in their own not ineffective eyes and reason than in Galen's writings; they are making careful notes of the contradictions, which they have not simply begged from other authors and which are supported by something better than a mere heap of authorities, and are sending the notes to their friends in various places with a firm but friendly exhortation to carry out their own investigation and so gain knowledge of the real anatomy. As a result there is hope that this last will soon be cultivated in all universities as it was once practiced in Alexandria long ago in the days of . . . famous experts in dissection.

I have done my best to bring the assistance of the Muses to this process by setting out afresh our knowledge of the parts of the human body in seven books; this is over and above my other publications on this subject, which certain plagiarists, thinking me well away from Germany, have passed off as their own. The order of these books is that in which I normally treat the subject in the congregation of eminent men in this city and in Bologna. This means that those who were present at my dissections will have notes of what I demonstrated and will be able with greater ease to demonstrate anatomy to others. But the books will be particularly useful also for those who cannot see the real thing, since they consider at sufficient length the number of each part of the body, its position, shape, size, substance, connection with other parts, use, function and many similar matters; all of these are aspects of the nature of the parts into which we normally inquire when dissecting. The method of dissecting the dead and the living is also described, and pictures of all the parts are incorporated into the text of the discourse, so as virtually to set a dissected body before the eyes of students of the works of Nature. [. . .]

I am not unmindful of the opinion of certain people, who strongly deny that even the most exquisite delineations of plants and of parts of the human body should be set before students of the natural world; they take the view that these things should be learned, not from pictures but from careful dissection and examination of the actual objects. In adding to the context of my discourse such detailed diagrams of the parts (and God grant that the printers will not ruin them!) it was never my intention that students should rely on these without ever dissecting cadavers; rather I would, as Galen did, urge students of medicine by every means at my command to undertake dissections with their own hands. If the custom of the ancients, who trained their lads at home in carrying out dissections as much as in writing the alphabet and in reading, had been brought down to the present time, I would be very happy that we, like the ancients, should dispense not only with pictures but with commentaries as well; for the ancients only began to write about anatomical procedures when they decided it was permissible to communicate the art, not only to one's children but also to grown men from other families who were taken on because of their good qualities. As soon as the custom of training lads in dissection was discontinued, forthwith it came about of necessity that they learned anatomy less well, lacking the training that they used to begin in childhood. And so when the art dropped away altogether from the sons of Asclepius and went downhill for many centuries, there was a need of books to preserve its theory untouched.

In fact, illustrations greatly assist the understanding, for they place more clearly before the eyes what the text, no matter how explicitly, describes. This fact is well known in respect of geometry and other branches of mathematics. But in addition our pictures of the parts of the body will give particular pleasure to those people who do not always have the opportunity of dissecting a human body or who, if they do have the opportunity, are by nature so squeamish (a very inappropriate quality in a physician) that, although they are fascinated and delighted by the study of man (which attests, if anything does, to the wisdom of the infinite Creator of the world), yet they cannot bring themselves to the point of ever actually attending a dissection. But in any case I have throughout the work pursued single-mindedly the one aim of giving assistance to as many people as possible in a matter that is extremely recondite and no less arduous, by detailing as accurately and completely as I can the investigation of the fabric of the human body, which is formed, not from ten or twelve different parts (as might appear at a casual glance) but from something like a thousand. I aim also to do something not without value for students of medicine by interpreting those books of Galen which have been preserved to posterity and which, like all the monuments of his divine genius, now need the work of an expositor.

I am not unaware that, because of my age (I am not yet twenty-eight years old), my undertaking will wield little authority and, because I have frequently demonstrated the inaccuracy of Galen's teachings, will not be

architect. We, therefore, while we devoutly acknowledge and adore the inscrutable wisdom of the triune Godhead, having with all diligence investigated and discerned the wondrous work of his hands in the magnetic movements, do hold it to be entirely probable, on the ground of experiments and philosophical reasons not few, that the earth while it rests on its centre as its basis and foundation, hath a spherical motion nevertheless.

But, apart from these matters (touching which no one, I do believe, ever gave more certain demonstrations), no doubt your discussion of the causes of variation and of the dip of the needle beneath the horizon (to say nothing of sundry other points which 'twould take too long to mention) will find the heartiest approval among all intelligent men and 'children, of magnetic science' (to use the language of the chemists). Nor have I any doubt that, by publishing these your books on the Loadstone, you will stimulate all wide-awake navigators to give not less study to observation of dip than of variation. For it is highly probable, if not certain, that latitude, or rather the effect of latitude, can be determined much more accurately (even when the sky is darkest) from the dip alone, than longitude or the effect of longitude can be found from the variation even in the full light of day or while all the stars are shining, and with the help of the most skilfully and ingeniously contrived instrument. Nor is there any doubt that those most learned men, Petrus Plantius (a most diligent student not so much of geography as of magnetic observations) and Simon Stevinius, a most eminent mathematician, will be not a little rejoiced when first they set eyes on these your books and therein see their own λιμενευρετικήν or method of finding ports so greatly and unexpectedly enlarged and developed; and of course they will, as far as they may be able, induce all navigators among their own countrymen to note the dip no less than the variation of the needle.

Let your magnetic Philosophy, most learned Mr. Gilbert, go forth then under the best auspices – that work held back not for nine years only, according to Horace's Counsel, but for almost other nine; that Philosophy which by your multitudinous labors, studies, vigils, and by your skill and at your no inconsiderable expense has been after long years at last, by means of countless ingenious experiments, taken bodily out of the darkness and dense murkiness with which it was surrounded by the speculations of incompetent and shallow philosophizers; nor did you in the mean time overlook, but did diligently read and digest whatever had been published in the writings whether of the ancients or the moderns. [...]

3.3 Tycho Brahe, *De disciplinis mathematicis oratio*, 1574, trans. and ed. P. Maxwell-Stuart in *The Occult in Early Modern Europe* (Basingstoke: Macmillan, 1999), pp. 84–5

To deny the power and influence of the stars is to detract from divine wisdom and influence. What more prejudiced or what sillier thought could one have about God than that He had made the most enormous and extra-

ordinary of all heavens and a theatre of so many shining stars in vain and to no useful purpose, when no human being does even the most worthless task except for a particular purpose? ... We see a great diversity of natures in individual human beings. Some who have been shaped under the fortunate influence of Saturn, the highest star, investigate in solitude matters which are exalted and far beyond the understanding of common people. There are those who have a greater interest in judicial and political affairs, and upon them the brilliance of Jupiter has looked with favour. There are several – those who are stirred up by the hot passion of Mars – who do not breathe at all unless it be for wars, slaughters, disorders and altercations. Others, under the ambitious influence of the Sun, strive after honours and dignities, and seek to control things; and there are those under the spell of Venus, the seductive star, who spend their lives in love-affairs, giving and receiving pleasure, music, and other delicious delights. Others, aroused by Mercury, devote themselves completely to the exercise of other remarkable talents, or even to commerce. Some, allocated the influence of a lunar nature, spend the whole of their lives doing ordinary things, foreign travel, sea-voyages, fishing and stuff like that. In this way one can see that the great variety of dispositions mirrors the influences of the seven planets. However, most people are affected by various combinations of these planets and they pursue different types of activity at different stages of their lives, now occupied with one kind of business, now with another, according to the way they are subjected to a greater or lesser extent at one time or another to the rays of a planet by means of hidden progressions. These differences may be seen in brothers born to the same parents in the same place and brought up in similar fashion, to such an extent that brothers very often differ in nature and character more than any other people. The reasons for these and similar diversities can be sought nowhere better than in astrology, although I do not deny that people can also be changed by lesser causes such as upbringing, education, conversation, foreign travel and things like that. ... Philosophers maintain that astrology should not be included among the other arts because it lacks reliable, clear principles. It is impossible, they say, to know the exact moment of birth and hence astrologers vainly fall back on the moment of conception, since this is a lot less uncertain. They adduce further arguments hostile (as they see it) to the art – that many people are born at the same time and yet have different fates and different things happen to them during their lives. Twins born of the same parents at almost the same time are very often allotted completely different fortunes; very many die at one and the same time, in war, in time of plague, during other general catastrophes, and yet their horoscope could not have signified the same type of death at all. ... Theologians agree with these arguments and add others, proclaiming that this art has been forbidden by the word of God and that it impiously leads people away from the knowledge of God and acts against good morals. ... But those who say that people born at the same time have different fortunes know that astrologers do not claim that

the sky acts in precisely the same way upon all those born at one and the same time, but that they are subject to diversity and are altered in different ways by heavenly influences. Very often the influence of the stars is shifted about in different ways for different reasons, such as upbringing, schooling, conversation and similar changing circumstances in life. Nor is man's free will in any way made subordinate to the stars but through it, under the guidance of reason, he can do very many things beyond the influence of the stars, if that is what he wishes. Astrologers do not require everyone to receive the influences of the stars in the same way, but some more and some less, according to their aptitude for receiving them or their immunity to them.... Theologians do not take into consideration that astrologers do not bind people's will to the stars, but agree that there is something in humanity which has been raised above all the stars and whose beneficial effect is that if people wish to live as true and supra-mundane human beings, they can conquer whatever malevolent inclinations they may have from the stars. But if they choose to live a brutish life, to be carried along by blind emotions, and prefer to fornicate with the beasts, they must not think God is the author of this mistake; for God created human beings in such a way that they can, if they wish, overcome all malevolent inclinations they get from the stars.

3.4 J. Kepler, *Astronomia Nova*, Heidelberg, 1609, trans. C. A. Russell, in D. C. Goodman (ed.), *Science and Religious Belief, 1600–1900: A Selection of Primary Sources* (John Wright and Open University Press, 1973), pp. 22–3

See Chapter 10 of my *Astronomy: the Optical Section* where you will find reasons why the sun in this way seems to all men to be moving, but not the earth: namely, because the sun seems small, but the earth truly appears to be large. Nor is the motion of the sun to be grasped by sight (since it gives the appearance of being slow) but by reason alone on account of the changed relationship to the mountains after some time. It is therefore impossible that reason not previously instructed should imagine anything other than that the earth is a kind of vast house with the vault of the sky placed on top of it; it is motionless and within it the sun being so small passes from one region to another, like a bird wandering through the air.

This universal image has produced the first line in the sacred page. *In the beginning*, said Moses, *God created the heaven and the earth*; this is a natural expression because these two aspects of the universe are those that chiefly meet the eye. It is as if Moses were saying to man 'all this architecture of the universe that you see, the brightness above, by which you are covered, the widespreading darkness below, upon which you stand – all this had been created by God'.

In other places man is questioned whether he has learned how to penetrate the height of the sky above or the depth of the earth beneath. This is natural because to the mass of men each of these appears equally to project

into infinite space. Nevertheless, there never was a man who, listening rationally, would use these words to circumscribe the diligence of the astronomers, whether in demonstrating the most contemptible weakness of the earth by comparison with the sky, or through investigations of astronomical distance. These words do not speak about intellectualised dimensions, but about the dimension of reality – which, for a human body fixed on the earth and drinking in the free air, is totally impossible. Read the whole of Job Ch. 38 and compare with it the matters that are disputed in astronomy and physics.

If anyone alleges on the basis of Psalm 24 *The earth is founded upon the seas* (in order to establish some new philosophical dictum, however absurd to hear) that the earth is floating on the waters, may it not be rightly said to him that he ought to set free the Holy Spirit and should not drag Him in to the schools of physics to make a fool of Him. For in that place the Psalmist wishes to suggest nothing other than what men know beforehand and experience each day: the lands, uplifted after separation of the waters, have great rivers flowing through them and the seas around them on all sides. Doubtless the same is spoken of elsewhere, when the Israelites sing *By the waters of Babylon there we sat down*, i.e., by the side of the rivers, or on the banks of the Euphrates and Tigris.

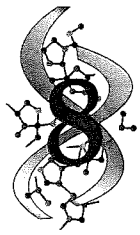
If anyone receives the one freely, why not the other, so that in other places which are often quoted against the motion of the earth we should, in the same way, turn our eyes from physics to the tradition of scripture?

One generation passes away, says Ecclesiastes, *and another generation is born*, but the earth abides for ever. Is Solomon here, as it were, disputing with the astronomers? No, he is rather warning men of their changeableness whereas the earth, the home of the human race, always remains the same; the movement of the sun keeps returning it to its starting-point; the wind is driven in a circle, and returns to the same plan; rivers flow from their sources to the sea, and thence return to their sources. Finally, while some men perish others are born, and always the drama of life is the same; there is nothing new under the sun.

You are listening to no new principle of physics. It is a question of ethical instruction in a matter which is clear on its own, observed universally but receives scant consideration. That is why Solomon insists on the matter. Who does not know the earth to be always the same? Who does not see that the sun rising daily in the East, that the rivers run perpetually down to the sea, that the pattern of changes of the wind is fixed and recurring and that one generation succeeds another? Who in fact considers that the drama of life is being perpetually performed, with only a change of cast and that there is nothing new in human affairs? And so, by rehearsing things which everyone sees, Solomon warns of that which the majority wrongly neglect.

But some men think Psalm 104 to be wholly concerned with physics, since it is wholly concerned with physical matters. And there God is said to have

From Brian Baigrie, Scientific Revolutions (Pearson)



A Guide to the Interpretation of Nature

Francis Bacon (1561–1626)

The first quarter of the seventeenth century witnessed the appearance of new technical instruments (e.g., the telescope, barometer, thermometer) and the increasing variety of experiments made possible by the flourishing of this new experimental technology. Francis Bacon marks the first systematic attempt to give formal shape to this rapidly emerging experimental science. Indeed, the central feature of his enormously influential philosophy of science is its commitment to the role of observation and experiment as prerequisites for the construction of scientific theory. Where his predecessors regarded experiment as a litmus test of theory that had been derived by a process of deductive reasoning, Bacon took experiment to be the very foundation of science and its generalized methodology. Bacon's work left an indelible imprint on all subsequent philosophical discussions of scientific method.

The title of Bacon's work, Novum Organum, *or* The New Organon *(1620), from which this reading is taken, is based on Aristotle's work on logic, the "Organon" or "Instrument for Rational Thinking." Bacon proposes a new style of reasoning to supplant Aristotle's—one tailored for the pursuit of knowledge in an age of science dominated by the appearance of new instruments and associated experiments. Where Aristotelian science was based on a set of rules that governed the consistency between conclusion and a set of premises accepted unquestioningly as true, Bacon's new experimental style was designed to investigate the soundness of the very foundations of scientific theory—that is, to put nature itself to the test.*

It is part of our plan to set everything out as openly and clearly as possible. For a naked mind is the companion of innocence and simplicity, as once upon a time the naked body was. And therefore we must first lay out the order and plan of our work. It consists of six parts.

Source: Francis Bacon. 2000. *The New Organon.* Eds. Lisa Jardine and Michael Silverthorne. Cambridge: Cambridge University Press, 14–24.

The first part gives a summary or general description of the science or learning which the human race currently possesses. It seemed good to us to spend some time on what is presently accepted, thinking that this would help the perfection of the old and the approach to the new. We are almost equally eager to develop the old and acquire the new. This also gives us credibility, according to the saying that "an ignorant man will not believe words of knowledge until you have told him what he has in his heart." There-

fore, we shall not neglect to sail along the shores of the accepted sciences and arts, importing some useful items into them, in our passage.

However, the divisions of the sciences which we employ include not only things which have been noticed and discovered but also things that until now have been missed but should be there. For in the intellectual as in the physical world, there are deserts as well as cultivated places. And so it is not surprising if we sometimes depart from the customary divisions. An addition not only changes the whole, but necessarily also alters the parts and sections; and the accepted divisions merely reflect the currently accepted outline of the sciences.

In matters which we shall note as missing, we shall be sure to do more than simply suggest a bare title and an outline account of what is needed. For if we report among things missing anything (of some value) whose method seems so obscure that we are justified in suspecting that men will not easily understand what we mean, or what is the task which we imagine and conceive in our mind, we will always take the trouble either to add instructions for carrying out the task or a report of our own performance of a part of it, as an example of the whole; so that we may give some help in each case either by advice or in practice. We feel that our own reputation, as well as the interest of others, requires that no one should suppose that some superficial notions on these matters have simply entered in our heads, and that the things we desiderate and try to grasp are mere wishes. They are such that they are clearly within men's power (unless men fail themselves), and I do have a firm and explicit conception of them. I have undertaken not merely to survey these regions in my mind, like an auger taking the auspices, but to enter them like a general, with a strong will to claim possession. *And this is the first part of the work.*

After coasting by the ancient arts, we will next equip the human understanding to set out on the ocean. We plan therefore, for our second part, an account of a better and more perfect use of reason in the investigation of things and of the true aids of the intellect, so that (despite our humanity and subjection to death) the understanding may be raised and enlarged in its ability to overcome the difficult and dark things of nature. And the art which we apply (which we have chosen to call *Interpretation of Nature*) is an art of logic, though with a great difference, indeed a vast difference. It is true that ordinary logic also claims to devise and prepare assistants and supports for the intellect; in this they are the same. But it differs altogether from ordinary logic in three particular ways: viz., in its end, in its order of demonstration, and in the starting points of its inquiry.

For the end we propose for our science is the discovery of arts, not of arguments, of principles and not of inferences from principles, or signs and indications or works and not probable reasonings. Different results follow from our different design. They defeat and conquer their adversary by disputation; we conquer nature[1] by work.

The nature and order of our demonstration agree with such an end. For in ordinary logic almost all effort is concentrated on the syllogism. The logicians seem scarcely to have thought about induction. They pass it by with barely a mention, and hurry on their formulae for disputation. But we reject proof by syllogism, because it operates in confusion and lets nature slip out of our hands. For, although no one could doubt that things which agree in a middle term, agree also with each other (which has a kind of mathematical certainty), nevertheless, there is a kind of underlying fraud here, in that a syllogism consists of propositions, and propositions consist of words, and words are counters and signs of notions. And therefore if the very notions of the mind (which are like the soul of words, and the basis of every such structure and fabric) are badly or carelessly abstracted from things, and are vague and not defined with sufficiently clear outlines, and thus deficient in many ways, everything falls to pieces. And therefore we

reject the syllogism; and not only so far as principles are concerned (they do not use it for that either) but also for intermediate propositions, which the syllogism admittedly deduces and generates in a certain fashion, but without effects, quite divorced from practice and completely irrelevant to the active part of the sciences. For even if we leave to the syllogism and similar celebrated but notorious kinds of demonstration jurisdiction over the popular arts which are based on opinion (for we have no ambitions in this area), still for the nature of things we use induction throughout, and as much for the minor propositions as for the major ones. For we regard *induction* as the form of demonstration which respects the senses, stays close to nature, fosters results and is almost involved in them itself.

And so the order of demonstration also is completely reversed. For the way the thing has normally been done until now is to leap immediately from sense and particulars to the most general propositions, as to fixed poles around which disputations may revolve; then to derive everything else from them by means of intermediate propositions; which is certainly a short route, but dangerously steep, inaccessible to nature and inherently prone to disputations. By contrast, by our method, axioms are gradually elicited step by step, so that we reach the most general axioms only at the very end; and the most general axioms come out not as notional, but as well defined, and such as nature acknowledges as truly known to her, and which live in the heart of things.

By far the biggest question we raise is as to the actual form of induction, and of the judgment made on the basis of induction. For the form of induction which the logicians speak of, which proceeds by simple enumeration, is a childish thing, which jumps to conclusions, is exposed to the danger of instant contradiction, observes only familiar things and reaches no result.

What the sciences need is a form of induction which takes experience apart and analyzes it, and forms necessary conclusions on the basis of appropriate exclusions and rejections. And if the logicians' usual form of judgment has been so difficult and required so much intellectual exertion, how much more effort should we expend on this other judgment, which is drawn not only from the depths of the mind but from the bowels of nature?

And this is not all. For we place the foundations of the sciences deeper and lay them lower, and set our starting points further back than men have ever done before, subjecting them to examination, while ordinary logic accepts them on the basis of others' belief. For logicians borrow (if I may put it this way) the principles of the sciences from the particular sciences themselves; then they pay respect to the first notions of the mind; finally they are happy with the immediate perceptions of healthy senses. But our position is that true logic should enter the provinces of the individual sciences with greater authority than is in our own principles, and compel those supposed principles themselves to give an account as to what extent they are firmly established. As for the first notions of the intellect: not one of the things which the intellect has accumulated by itself escapes our suspicion, and we do not confirm them without submitting them to a new trial and verdict given in accordance with it. Furthermore, we have many ways of scrutinizing the information of the senses themselves. For the senses often deceive, but they also give evidence of their own errors; however the errors are to hand, the evidence is far to seek.

The senses are defective in two ways: They may fail us altogether or they may deceive. First, there are many things which escape the senses even when they are healthy and quite unimpeded; either because of the rarity of the whole body or by the extremely small size of its parts, or by distance, or by its slowness or speed, or because the object is too familiar, or for other reasons. And even when the senses do grasp an object, their apprehensions of it are not always reliable. For the evidence and information given by the senses is always

PLATE 7 Portrait of Francis Bacon.

based on the analogy of man not of the universe; it is a very great error to assert that the senses are the measure of things.

So to meet these defects, we have sought and gathered from every side with great and faithful devotion, assistants to the senses, so as to provide substitutes in the case of total failure and correction in the case of distortion. We do this not so much with instruments as with experiments. For the subtlety

of experiments is far greater than that of the senses themselves even when assisted by carefully designed instruments; we speak of experiments which have been devised and applied specifically for the question under investigation with skill and good technique. And therefore we do not rely very much upon the immediate and proper perception of the senses, but we bring the matter to the point that the senses judge only of the experiment, the experiment judges of the thing. Hence we believe that we have made the senses (from which, if we prefer not to be insane we must derive everything in natural things) sacred high priests of nature and skilled interpreters of its oracles; while others merely seem to respect and humor the senses, we do so in actual fact. Such are the preparations which we make for the light of nature and its kindling and application; and they would be sufficient in themselves if men's understanding were unbiased, a blank slate. But as men's minds have been occupied in so many strange ways that they have no even, polished surface available to receive the true ray of things, it is essential for us to realize that we need to find a remedy for this, too.

The *Idols*[2] by which the mind is occupied are either artificial or innate. The artificial *idols* have entered men's minds either from the doctrines and sects of philosophers or from perverse rules of proof. The innate idols are inherent in the nature of the intellect itself, which is found to be much more prone to error than the senses. For however much men may flatter themselves and run into admiration and almost veneration of the human mind, it is quite certain that, just as an uneven mirror alters the rays of things from their proper shape and figure, so also the mind, when it is affected by things through the senses, does not faithfully preserve them, but inserts and mingles its own nature of things as it forms and devises its own notions.

The first two kinds of *idols* can be eliminated, with some difficulty, but the last in no way. The only strategy remaining is, on the one hand, to indict them, and to expose and condemn the mind's insidious force, in case after the destruction of the old, new shoots of error should grow and multiply from the poor structure of the mind itself, and the result would be that errors would not be squashed but simply altered; and on the other hand, to fix and establish forever the truth that the intellect can make no judgment except by induction in its legitimate form. Hence the teaching which cleanses the mind to make it receptive to truth consists of three refutations: a refutation of philosophies; a refutation of proofs; and a refutation of natural human reason. When we have dealt with these, and clarified the part played by the nature of things and the part played by the nature of the furnished and adorned the bedchamber for the marriage of the mind and the universe. In the wedding hymn we should pray that men may see born from this union the assistants that they need and a lineage of discoveries which may in some part conquer and subdue the misery and poverty of man. *And this is the second part of the work.*

But we plan not only to show the way and build the roads, but also to enter upon them. And therefore the third part of our work deals with the *Phenomena of the Universe*, that is, every kind of experience, and the sort of natural history which can establish the foundations of philosophy. A superior method of proof or form of interpreting nature may defend and protect the mind from error and mistake, but it cannot supply or provide material for knowledge. But those who are determined not to guess and take omens but to discover and know, and not to make up fairytales and stories about worlds, but to inspect and analyze the nature of this real world, must seek everything from things themselves. No substitute or alternative in the way of intelligence, thought or argument can take the place of hard work and investigation and the visitation of the world, not even if all the genius of all the world worked together. This then we must unfailingly do or abandon the business for-

ever. But to this very day men have acted so foolishly that it is no wonder that nature does not give them access to her.

For in the first place, the information of the senses themselves is defective and deceiving; observation is lazy, uneven and casual; teaching is empty and based on hearsay; practice is slovenly bent on results; experimental initiative is blind, unintelligent, hasty, and erratic; and natural history is shallow and superficial. Between them they have accumulated very poor material for the intellect to construct philosophy and the sciences.

And the tendency to introduce subtle and intricate disputation prematurely comes too late to remedy a situation which is utterly desperate, and does nothing to move on the enterprise or remove error. Thus there is no hope of major development or progress except in a renewal of the sciences.

Its beginnings must come from a natural history, and a natural history of a new kind with a new organization. It would be pointless to polish the mirror if there were no images; and clearly we must get suitable material for the intellect, as well as making reliable instruments. And our history (like our logic) differs from that now in use in many ways: in its purpose or task, in its actual extent and composition, in its subtlety, and also in the selection and arrangement of it in relation to the next stage.

First we propose a natural history which does not so much amuse by the variety of its contents or give immediate profit a first breast to feed philosophy. For although our ultimate aim is works and the active part of science, still we wait for harvest time and do not try to reap moss and the crop while it is still green. We know very well that axioms properly discovered bring whole companies of works with them, revealing them not singly but in quantity. But we utterly condemn and reject the childish desire to take some pledges prematurely, in the form of new works, like an apple of Atalanta which shows the race.[3] Such is the task of our natural history.

And as for its composition, we are making a history not only for nature free and unconstrained (when nature goes its own way and does its own work), such as a history of the bodies of heaven and the sky, of land and sea, or minerals, plants and animals; but much more of nature confined and harassed, when it is forced from its own condition by art and human agency, and pressured and molded. And therefore we give a full description of all the experiments of the mechanical arts, all the experiments of the applied part of the liberal arts, and all the experiments of several practical arts which we have not yet formed a specific art of their own (so far as we have had an opportunity to investigate and they are relevant to our purpose). Moreover (to be plain) we put much more effort and many more resources into this part than into the other, and pay no attention to men's disgust or what they find attractive, since nature reveals herself more through the harassment of art than in her own proper freedom.

And we do not give a history of bodies only; we felt that we should also take the trouble to make a separate history of the powers themselves (which plainly constitute the originals of nature, since they are the material for the first passions and desires, viz., *Dense, Rare, Hot, Cold, Solid, Liquid, Heavy, Light* and many others).

As for subtlety, we are certainly looking for a kind of experience which is far more subtle and simple than those which simply happen. For we bring and draw many things out of obscurity which no one would ever have thought to investigate if he were not following the sure and steady path to the discovery of causes. For in themselves they are of no great use, so that it is quite clear that they have not been sought for themselves. Rather they are to things and works exactly like the letters of the alphabet to speech and words: though useless in themselves, they are still the elements of all discourse.

And in the choice of narratives and experiences we think that we have served men

DESCRIPTION OF A NEW WORLD; AND THE QUALITIES OF THE MATTER OF WHICH IT IS COMPOSED

For a while, then, allow your thought to wander beyond this world to view another world—a wholly new one which I shall bring into being before your mind in imaginary spaces. The philosophers tell us that such spaces are infinite, and they should certainly be believed, since it is they themselves who invented them. But in order to keep this infinity from hampering and confusing us, let us not try to go right to the end: Let us enter it only far enough to lose sight of all the creatures that God made five or six thousand years ago; and after stopping in some definite place, let us suppose that God creates anew so much matter all around us that in whatever direction our imagination may extend, it no longer perceives any place which is empty.

Even though the sea is not infinite, people on some vessel in the middle of it may stretch their view seemingly to infinity; and yet there is more water beyond what they see. Likewise, although our imagination seems able to stretch to infinity, and this new matter is not supposed to be infinite, yet we can suppose that it fills spaces much greater than all those we have imagined. And just to ensure that this supposition contains nothing you might find objectionable, let us not allow our imagination to extend as far as it could; let us intentionally confine it to a determinate space which is no greater, say, than the distance between the Earth and the principal stars in the heavens, and let us suppose that the matter which God has created extends indefinitely far beyond in all directions. For it is much more reasonable to prescribe limits to the action of our mind than to the works of God, and we are much better able to do so.

Now since we are taking the liberty of fashioning this matter as we fancy, let us attribute to it, if we may, a nature in which there is absolutely nothing that everyone cannot know as perfectly as possible. To this end, let us expressly suppose that it does not have the form of earth, fire, or air, or any other more specific form, like that of wood, stone, or metal. Let us also suppose that it lacks the qualities of being hot or cold, dry or moist, light or heavy, and of having any taste, smell, sound, color, light, or other such quality in the nature of which there might be said to be something which is not known clearly by everyone.

On the other hand, let us not also think that this matter is the "prime matter" of the philosophers, which they have stripped so thoroughly of all its forms and qualities that nothing remains in it which can be clearly understood. Let us rather conceive it as a real, perfectly solid body which uniformly fills the entire length, breadth and depth of this huge space in the midst of which we have brought our mind to rest. Thus, each of its parts always occupies a part of that space which it fits so exactly that it could neither fill a larger one nor squeeze into a smaller; nor could it, while remaining there, allow another body to find a place there.

Let us add that this matter may be divided into as many parts having as many shapes as we can imagine, and that each of its parts is capable of taking on as many motions as we can conceive. Let us suppose, moreover, that God really divides it into many such parts, some larger and some smaller, some of one shape and some of another, however we care to imagine them. It is not that God separates these parts from one another so that there is some void between them: Rather, let us regard the differences he creates within this matter as consisting wholly in the diversity of the motions he gives to its parts. From the first instant of their creation, he causes some to start moving in one direction and others in another, some faster and others slower (or even, if you wish, not at all); and he causes them to continue moving, thereafter, in accordance with the ordinary laws of nature. For God has established these laws in such a marvelous way that even if we suppose he creates nothing beyond what I have mentioned,

PLATE 10 Nineteenth century engraving of René Descartes.

and sets up no order or proportion within it but composes from it a chaos as confused and muddled as any the poets could describe, the laws of nature are sufficient to cause the parts of this chaos to disentangle themselves, and arrange themselves in such good order that they will have the form of a quite perfect world; a world in which we shall be able to see not only light but also all the other things, general as well as particular, which appear in the real world.

But before I explain this at greater length, pause again for a bit to consider this chaos, and observe that it contains nothing which you do not know so perfectly that you could not even pretend to be ignorant of it. For, as regards the qualities I have put into it, you may have noticed that I supposed them to be only of such a kind that you could imagine them. And, as regards the matter from which I have composed it, there is nothing simpler or easier to know in inanimate creatures. The idea of this matter is included to such an extent in all the ideas that our imagination can form that you must necessarily conceive it or else you can never imagine anything at all.

Nevertheless, the philosophers are so subtle that they can find difficulties in things which seem extremely clear to other men, and the memory of their "prime matter," which they know to be rather hard to conceive, may divert them from knowledge of the matter of which I am speaking. Thus, I must tell them at this point that, unless I am mistaken, the whole difficulty they face with their matter arises simply from their wanting to distinguish it from its own quantity, and from its external extension, that is, from the property it has of occupying space. In this, however, I am quite willing for them to think they are right, for I have no intention of stopping to contradict them. But they should also not find it strange if I suppose that the quantity of the matter I have described does not differ from its substance any more than number differs from the things numbered. Nor should they find it strange if I conceive its extension, or the property it has of occupying space, not as an accident, but as its true form and essence. For they cannot deny that it can be conceived quite easily in this way. And my purpose is not to explain, as they do, the things which are in fact in the real world, but only to make up, as I please, a world in which there is nothing that the dullest minds are incapable of conceiving, and which nevertheless, could be created exactly as I have imagined it.

Were I to put into this new world the least thing that is obscure, this obscurity might well conceal some hidden contradiction. I had not perceived, and hence, without thinking, I might be supposing something impossible. Instead, since everything I propose here can be distinctly imagined, it is certain that even if there were nothing of this sort in the old world, God can nevertheless create it in a new one. For it is certain that he can create everything we can imagine.

THE LAWS OF NATURE OF THIS NEW WORLD

But I do not want to delay any longer telling you by what means nature alone can untangle the confusion of the chaos of which I have spoken, and what the laws are that God has imposed on it.

Note, in the first place, that by "nature" here I do not mean some goddess or any other sort of imaginary power. Rather, I am using this word to signify matter itself, in so far as I am considering it taken together with all the qualities I have attributed to it, and under the condition that God continues to preserve it in the same way that he created it. For it follows of necessity, from the mere fact that he continues thus to preserve it, that there must be many changes in its parts which cannot, it seems to me, properly be attributed to the action of God (because that action never changes), and which therefore I attribute to nature. The rules by which these changes take place I call the "laws of nature."

In order to understand this better, recall that among the qualities of matter, we have

supposed that its parts have had various different motions from the moment they were created, and furthermore that they are all in contact with each other on all sides without there being any void between any two of them. From this it follows necessarily that from the time they began to move, they also began to change and diversify their motions by colliding with one another. So if God subsequently preserves them in the same way that he created them, he does not preserve them in the same state. That is to say, with God always acting in the same way and consequently always producing substantially the same effect, there are, as if by accident, many differences in this effect. And it is easy to accept that God, who is, as everyone must know, immutable, always acts in the same way. But without involving myself any further in these metaphysical considerations, I shall set out two or three of the principal rules according to which it must be thought that God causes the nature of this new world to operate. These, I believe, will suffice to acquaint you with all the others.

The first is that each individual part of matter continues always to be in the same state so long as collision with others does not force it to change that state. That is to say, if the part has some size, it will never become smaller unless others divide it; if it is round or square, it will never change that shape unless others force it to; if it is brought to rest in some place, it will never leave that place unless others drive it out; and if it has once begun to move, it will always continue with an equal force until others stop or retard it.[a]

There is no one who does not believe that this same rule holds in the old world with respect to size, shape, rest and numerous other such things. But the philosophers have excluded motion from the rule which is just the thing I most definitely wish to include in it. Do not think, however, that I intend to contradict them: The motion they speak of is so very different from the one I conceive that it may very easily happen that what is true of the one is not true of the other.

They admit themselves that the nature of their motion is very little understood. To render it in some way intelligible they have not yet been able to explain it more clearly than in these terms: *Motus est actus entis in potentia, prout in potentia est.*[b] For me these words are so obscure that I am compelled to leave them in Latin because I cannot interpret them. (And in fact the sentence "Motion is the actuality of a potential being in so far as it is potential" is no clearer for being translated.) By contrast, the nature of the motion I mean to speak of here is so easy to know that the geometers themselves, who among all men are the most concerned to conceive very distinctly the things they study, have judged it simpler and more intelligible than the nature of their surfaces and lines—as is shown by the fact that they have explained "line" as the motion of a point and "surface" as the motion of a line.

The philosophers also posit many motions which they think can take place without any bodies changing place, like those they call *motus ad formam, motus ad calorem, motus ad quantitatem* ("motion with respect to form," "motion with respect to heat," "motion with respect to quantity") and numerous others. For my part, I am not acquainted with any motion except that which is easier to conceive than the lines of the geometers; the motion which makes bodies pass from one place to another and successively occupy all the spaces which exist in between.

In addition, the philosophers attribute to the least of these motions a being much more solid and real than they attribute to rest, which they say is nothing but the privation of motion. For my part, I conceive of rest as a quality too, which should be

[a]This ontological equivalence of rest and motion is the very heart of the new idea of motion fashioned by Descartes. Motion and rest are similarly positive states of bodies that are conserved in the absence of external actions. [B.]

[b]This definition is advanced by Aristotle in his *Physics*, III, 201[a]10. [B.]


I Think, Therefore
I am paid.
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cause, the cause of all things. And incomprehensibly difficult as it is for man to conceive what a first cause is, he arrives at the belief of it from the tenfold greater difficulty of disbelieving it. It is difficult beyond description to conceive that space can have no end; but it is more difficult to conceive an end. It is difficult beyond the power of man to conceive an eternal duration of what we call time; but it is more impossible to conceive a time when there shall be no time. In like manner of reasoning, everything we behold carries in itself the internal evidence that it did not make itself. Every man is an evidence to himself that he did not make himself; neither could his father make himself, nor his grandfather, nor any of his race; neither could any tree, plant, or animal make itself; and it is the conviction arising from this evidence that carries us on, as it were, by necessity, to the belief of a first cause eternally existing, of a nature totally different to any material existence we know of, and by the power of which all things exist; and this first cause, man calls God.

It is only by the exercise of reason that man can discover God. Take away that reason and he would be incapable of understanding anything; and, in this case, it would be just as consistent to read even the book called the Bible to a horse as to a man. How then is it that those people pretend to reject reason?

Isaac Kramnick, The Portable Enlightenment Reader

PART IV

REASON AND HUMANITY

THE MIND AND IDEAS

"I THINK, THEREFORE I AM . . ."

RENÉ DESCARTES

The French mathematician and philosopher Descartes (1596–1650) was one of the great precursors of the Enlightenment—indeed, one of the founders of modern rationalism. This famous selection is from his Discourse on Method, *published in Latin in 1637.*

Like a man who walks alone and in darkness, I resolved to go so slowly, and to use so much circumspection in everything, that if I did not advance speedily, at least I should keep from falling. I would not even have desired to begin by entirely rejecting any of the opinions which had formerly been able to slip into my belief without being introduced there by reason, had I not first spent much time in projecting the work which I was to undertake, and in seeking the true method of arriving at a knowledge of everything of which my understanding should be capable.

When I was younger, I had devoted a little study to logic, among philosophical matters, and to geometrical analysis and to algebra, among mathematical matters—three arts or sciences which, it seemed, ought to be able to contribute something to my design. But on examining them I noticed that the syllogisms of logic and the greater part of the rest of its teachings serve rather for explaining to other people the things we already know, or even, like the art of Lully, for speaking without judgment of things we know not, than for instructing us of them. And although they indeed contain many very true and very good precepts,

there are always so many others mingled therewith that it is almost as difficult to separate them as to extract a Diana or a Minerva from a block of marble not yet rough hewn. Then, as to the analysis of the ancients and the algebra of the moderns, besides that they extend only to extremely abstract matters and appear to have no other use, the first is always so restricted to the consideration of figures that it cannot exercise the understanding without greatly fatiguing the imagination, and in the other one is so bound down to certain rules and ciphers that it has been made a confused and obscure art which embarrasses the mind, instead of a science which cultivates it. This made me think that some other method must be sought, which, while combining the advantages of these three, should be free from their defects. And as a multitude of laws often furnishes excuses for vice, so that a state is much better governed when it has but few, and those few strictly observed, so in place of the great number of precepts of which logic is composed, I believed that I should find the following four sufficient, provided that I made a firm and constant resolve not once to omit to observe them.

The first was, never to accept anything as true when I did not recognize it clearly to be so, that is to say, to carefully avoid precipitation and prejudice, and to include in my opinions nothing beyond that which should present itself so clearly and so distinctly to my mind that I might have no occasion to doubt it.

The second was, to divide each of the difficulties which I should examine into as many portions as were possible, and as should be required for its better solution.

The third was, to conduct my thoughts in order, by beginning with the simplest objects, and those most easy to know, so as to mount little by little, as if by steps, to the most complex knowledge, and even assuming an order among those which do not naturally precede one another.

And the last was, to make everywhere enumerations so complete, and surveys so wide, that I should be sure of omitting nothing.

The long chains of perfectly simple and easy reasons, which geometers are accustomed to employ in order to arrive at their most difficult demonstrations, had given me reason to believe that all things which can fall under the knowledge of man succeed each other in the same way, and that provided only we abstain from receiving as true any opinions which are not true, and always observe the necessary order in deducing one from the other, there can be none so remote that they

may not be reached, or so hidden that they may not be discovered. And I was not put to much trouble to find out which it was necessary to begin with, for I knew already that it was with the simplest and most easily known; and considering that of all those who have heretofore sought truth in the sciences it is the mathematicians alone who have been able to find demonstrations, that is to say, clear and certain reasons, I did not doubt that I must start with the same things that they have considered, although I hoped for no other profit from them than that they would accustom my mind to feed on truths and not to content itself with false reasons. But I did not therefore design to try to learn all those particular sciences which bear the general name of mathematics: and seeing that although their objects were different they nevertheless all agree, in that they consider only the various relations or proportions found therein, I thought it would be better worth while if I merely examined these proportions in general, supposing them only in subjects which would serve to render the knowledge of them more easy to me, and even, also, without in any wise restricting them thereto, in order to be the better able to apply them subsequently to every other subject to which they should be suitable. Then, having remarked that in order to know them I should sometimes need to consider each separately, I had to suppose them in lines, because I found nothing more simple, or which I could more distinctly represent to my imagination and to my senses; but to retain them, or to comprehend many of them together, it was necessary that I should express them by certain ciphers as short as possible, and in this way I should borrow all the best in geometrical analysis, and in algebra, and correct all the faults of the one by means of the other.

I do not know whether I ought to discuss with you the earlier of my meditations, for they are so metaphysical and so out of the common that perhaps they would not be to everyone's taste; and yet, in order that it may be judged whether the bases I have taken are sufficiently firm, I am in some measure constrained to speak of them. I had remarked for long that, in conduct, it is sometimes necessary to follow opinions known to be very uncertain, just as if they were indubitable, as has been said above; but then, because I desired to devote myself only to the research of truth, I thought it necessary to do exactly the contrary, and reject as absolutely false all in which I could conceive the least doubt, in order to see if afterwards there did not remain in my belief something which

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totally independent sources argues well for the essential reliability of these data. The correlation in rank order is very high, virtually perfect. The one instance where there is some variation represents but a slight difference in percentage. Moreover, a competent observer of scientific development during this period ranks the sciences in approximately the same order. " The greatest progress was evinced in physics, astronomy, medicine and mathematics...; considerable progress was shown in botany, zoölogy, and chemistry; least in geology and paleontology." (25)

To be sure the DARMSTÄDTER data, since they include so few cases, cannot be used to verify the *trends* obtained from the *Transactions* compilation. But with the establishment of the reliability of the rank order of the sciences, it seems a reasonable assumption that the trend data are not misleading. These trends are ascertainable only through such indirect means as have been here employed and in view of the substantiation afforded by a variety of sources it seems justifiable to conclude that the indices are approximately accurate.

It is misleading to assume that these foci of scientific interest are exclusively due to the intrinsic developments within the various sciences. It was RICKERT and MAX WEBER who most forcefully indicated the phenomenon of *Wertbeziehung* in scientific activity, the fact that scientists commonly select for treatment problems which are vitally linked with the dominant values and interests of the day (26). Much of our study will, in fact, be devoted to the isolation of some of the extra-scientific elements which strongly influenced, if they did not determine, the centering of scientific attention upon certain fields of investigation.

(25) MARTHA ORNSTEIN, *The Rôle of Scientific Societies*, p. 19.

(26) *Cf.* the discussion by ALEXANDER VON SCHELTING, *Max Webers Wissenschaftslehre* (Tübingen : J. C. B. Mohr, 1934), esp. pp. 235 ff.

CHAPTER IV

PURITANISM AND CULTURAL VALUES

From the middle of the seventeenth century, science and technology claimed an increasing meed of attention. No longer an errant movement finding faltering expression in occasional discoveries, science had become accredited and organized. To this, the establishment of the Royal Society bears some witness. But all this was no spontaneous generation. It had its antecedents rooted deep in the culture which fathered it and assured its further growth; it was the child of a long period of cultural incubation. And if we are to find the specific sources of this newly expressed vitality of science, of this new-won prestige, they must be sought among these cultural values. If it be true that science, just as any other activity, attracts followers to its ranks to the extent that it is regarded with favor by society, then the marked increase in the number of scientists which occurred during the seventeenth century is a symptom of the changing temper of the time.

The Sociological Approach

Religion is one expression of cultural values—and in the seventeenth century a clearly dominating expression. In view of this, the commonly accepted and even more widely discussed thesis that science and religion have always been at odds is not unrelated to our inquiry. In the nineteenth century, bold intellectuals berated religious opposition and saw in the outcome of this conflict the triumph of reason over superstition, whereas pacific mediators sought to establish an essential harmony between science and religion. Neither of these was a properly sociological point of view. The sociologist is not a Defender of the Faith, religious or scientific. When he has uncovered the sentiments

crystallized in religious values and the cultural orientation which governs their expression, when he has determined the extent to which this led men toward or away from scientific pursuits or perhaps influenced them not at all, then his task is, in its initial outlines, complete.

Puritanism, evoking and shaping the sentiments which pervaded every phase of human action in this period, was the religious movement which notably incorporated dominant cultural values. As such, it provided a measuring rod for the worth of various social activities. What, then, were its relations to science? Did Puritanism, as so often we are told, involve that sort of fervid fanaticism which brooks nothing but its own religious goals? And, if so, what of the cultural implications of such an attitude? What were the consequences for the new science of the powerful motivations which derived from Puritanism? In short, we are concerned with the complex modes of interaction between a religious ethic and science, not as these appear to apologists of the two camps, but as they occurred in the course of actual social development.

To this end, we must probe under the surface of theological contentions to the sentiments which give them meaning. The religious component of thought, belief and action becomes effective only when it is reinforced by strong sentiments which lend meaning to certain forms of conduct. These sentiments find expression in word and deed alike. Words are full of equivocation and doubtless we shall find many pious utterances which are more significant for what they leave unsaid than for what they say. We are concerned with verbal responses, religious exhortations and appeals, in so far as they enable us to arrive at the motivating sentiments which give rise to these ideas and the behavior associated with them. And, as we shall see, behavior in its turn reacts upon the sentiments, re-enforcing, moulding, at times altering them so that the whole process is one of incessant interaction.

The Protestant Ethic

Though the diversity of theological doctrines among the Protestant groups of seventeenth century England is evident

—in 1650, THOMAS EDWARDS enumerated 180 sects—there was a core of common values which was accepted by all (1). Sectarian differences were largely confined to matters of church ceremony and ecclesiastical organization as well as to esoteric theology (2); but all this did not materially influence the religious ethos. Anglicans, Calvinists, Presbyterians, Independents, Anabaptists, Quakers, and Millenarians—bickering and quarreling amongst themselves as they did—nevertheless subscribed to a substantially identical nucleus of religious and ethical convictions. This common attitude of mind and mode of life may be denominated by that " word of many shades," Puritanism. Nor need we be alarmed because this usage does not coincide with the original sense of the term as referring to the reform of the Church of England in a Presbyterian manner since our interest is primarily directed toward the social and not the ecclesiastic implications of Protestantism.

Calvinism spread its roots in all the Protestant sects of the time. Though Mr. TAWNEY notes that " Calvinist theology was accepted where Calvinist discipline was repudiated," (3) the converse may likewise be maintained. It is precisely Calvinism which constitutes the " ideal type " of that Puritanism which was confined to no single sect and which was represented in the Anglican Church almost as fully as in those groups which later broke away from it. (4) Differences in theological minutiae were brought to convergence in the actual social ethic. If later Presbyterianism differed from Calvinist Precisianism by declaring that man is justified by good works as well as by faith, it none the less led to a sanction of persistent, hard labor as a means of salvation, while the latter exacted the same sort of behavior as establishing the *conviction* of a state of grace.

(1) G. N. CLARK, *The Seventeenth Century*, p. 317.

(2) JOHN TULLOCH, *English Puritanism and Its Leaders* (Edinburgh and London : WILLIAM BLACKWOOD, 1861), pp. 4 ff. This had been long since noted by GEORGE BERKELEY in his brochure, *Historical Applications and Occasional Meditations upon Several Subjects* (London, 1670, 2d ed.), pp. 101-2.

(3) R. H. TAWNEY, *Religion and the Rise of Capitalism* (New York : HARCOURT, BRACE & Co., 1926), p. 112.

(4) *Ibid.*, p. 198. *Cf.* H.H. HENSON, *Studies in English Religion in the Seventeenth Century* (London : J. MURRAY, 1903), p. 188. " It is very noteworthy that there is no essential divergence either of principle or method between Puritans and Anglicans on the subject of *moral* theology." [italics present writer's.]

The conception of " meritory works " was of course also current in the Middle Ages, but—especially in the early part of that epoch—its meaning was radically different from that of the Protestant precept (5). Monastic limitations and an other-worldly orientation (in a quite different sense from that of the Calvinists) were insuperable barriers to the utilization of the concept in active, worldly service. For both medieval Catholicism and Calvinism, this world was evil, but, whereas the prescribed solution for the one was retirement from the world into the spiritual calm of the monastery, it was incumbent on the other to conquer the temptations of this world by *remaking it* through ceaseless, unflinching toil. The sentiments with which the various Puritan sects were imbued, despite different rationalizations and theological views, led to approximately identical implications for social conduct.

Perhaps the one major Protestant variation from the Puritan ethos is afforded by Lutheranism, with its precepts of justification by faith only and its emphasis on penitent grief, but since this sect had no appreciable influence on English life, this divergence is of no importance. Again, there must be no confusion between CALVIN's own teachings and those of the subsequent Calvinist-Puritan movement (6), particularly in England, for the latter

(5) The importance of primarily considering the social meaning (*i.e.* definition) and correlated sentiments rather than the rationalized version of religious precepts is deftly summarized by FRIEDELL. " Protestantism denies justification by works and puts repentance in the heart, in mere faith, and yet at the same time it demands a practical, active Christianity and thus again comes back to a sort of sanctity of works, ... it sanctifies even *profane* works, thus achieving the last degree of sanctimoniousness. Catholicism accepts justification by works, but means by the latter only performances of a minor sort, and thus it arrives at apotheosizing the unworldly and other-worldly life, which is concentrated on inner penitence and meditation, and which knows nothing of profane works in the ordinary sense. Thus, starting from opposite standpoints, each ends in the contrary view from that with which it began : Protestantism, opposed to works, ends in a glorification of the most worldly tasks, the state, the magistrates, the family, manual work, *science*, even war; the more worldly Catholicism rises to complete contempt for all these things..." EGON FRIEDELL, *A Cultural History of the Modern Age* (New York : A. A. KNOPF, 1930-31), Vol. I, p. 259.

(6) One of the basic results of this study is the fact that the most significant influence of Puritanism upon science was largely *unintended* by the Puritan leaders. That CALVIN himself deprecated science only enhances the paradox that from him stemmed a vigorous movement which furthered interest in this very field.

represents a marked development of the Great Reformer's conceptions, rather than a rigid maintenance of them. As we shall see, the mode of life which bore the imprint of Calvinism was not so much adherence to the logical implications of a system of theology as domination by a particular group of sentiments. The values implicit in these doctrines which struck the deepest roots in English life were those congenial to tendencies developing independently in other compartments of culture, and, in this way, Puritanism was integrated with many cultural trends which were in their incipiency. A number of studies have shown that the Protestant ethos exerted a stimulative effect upon capitalism (7). Since science and technology play such dominant rôles in modern capitalistic culture, it is possible that tangible relationship likewise exist between the development of science and Puritanism (8). Indeed MAX WEBER incidentally notes the possibility of such a connection (9).

The dominant Puritan teachings of the time may best be culled, not from esoteric theological treatises which had no direct

(7) MAX WEBER, *The Protestant Ethic and the Spirit of Capitalism*, trans. by T. PARSONS, (New York : CHARLES SCRIBNER's Sons, 1930); ERNST TROELTSCH, *The Social Teachings of the Christian Churches*, trans. by OLIVE WYON (New York : MACMILLAN, 1931), 2 volumes; W. CUNNINGHAM, *Christianity and Economic Science* (London : J. MURRAY, 1911); TAWNEY, *op. cit.;* H. LEVY, *Die Grundlagen des ökonomischen Liberalismus in der Geschichte der englischen Volkwirtschaft* (Jena, 1912). A striking adumbration of the theories presented in these works appears in a book by JOHN WILKINS, one of the virtuosi of the seventeenth century, who was also a leading spirit in the group which formed the Royal Society. In his work, *On the Principles and Duties of Natural Religion*, interrupted by his death in 1672, he asserts that " Religion is a *natural* Cause of Riches," and proceeds to demonstrate this fact by isolating those Protestant teachings which sanction behavior inevitably conducing to the accumulation of capital. It should be noted that his explanation is a " naturalistic " one and not the familiar argument that the hand of Providence aids the virtuous, simply because of their religiosity.

(8) Since the completion of this study have appeared several papers and books by DEAN DOROTHY STIMSON, OLIVE GRIFFITHS and R. F. JONES which trace, with varying degrees of detail, a positive connection between Puritanism and science. These materials will be considered in a later chapter. See also ROBERT K. MERTON, " Puritanism, Pietism and Science," *The Sociological Review*. Vol. XXVIII (1936), pp. 1-30.

(9) *Op. cit.*, p. 249. But WEBER goes onto say : " Auf die Bedeutung [des Puritanismus] für die Entwicklung der Technik und der empirischen Wissenschaften kommen wir nicht zu sprechen." *Cf.* his *Religionssoziologie* (Tübingen : J. C. B. MOHR, 1920), Vol. I, p. 188 n.

influence upon the social life of the period, but from the compilations of *casus conscientiae*, sermons, and similar exhortations directed primarily toward the actual behavior of individuals. This procedure is based upon the assumption that these are expressions of the sentiments and values which permeated the thought and action of believers. Moreover, it is probable that sermons not only reflected but also reinforced the dominant sentiments of the day (10). If, as has been repeatedly noted, "RICHARD BAXTER is the most representative Puritan in history,"(11) we may expect to find in his *Christian Directory* (12), that popular " Body of Practical Divinity and Cases of Conscience," a typical presentation of the leading elements in the Puritan ethos. In this way it is possible to arrive at an understanding of the values and sentiments which lent meaning to certain of the activities, among them science and technology, of seventeenth century man. Recourse to the writings of other spiritual leaders of that day will help us to determine the extent to which this compendium of Protestant ethics and convictions is typical.

" *Glorification of God* "

One formula which, largely meaningless though it be to the emancipated individual of today, became the focus of strong sentiments among Puritans is " the glorification of God " as the end and all of existence (13). Familiar to Christian ears

(10) Analogous assumptions are involved in the works of such anthropologists as RADCLIFFE-BROWN and MALINOWSKI and the sociological writings of DURKHEIM and PARETO, among others.

(11) JOHN S. FLYNN, *The Influence of Puritanism on the Political and Religious Thought of the English* (New York : DUTTON, 1920), p. 138. *Cf.* TULLOCH, *op. cit.*, p. 377, who writes : " Certainly, of all the men who express and represent the spiritual thought of the Puritan age, none does so more completely... than RICHARD BAXTER." *Cf.* also WEBER, *op. cit.*, p. 156.

(12) The edition used here was published in five volumes, London, 1825. The compendium was written in 1664-65. This work will be cited as *C. D.*

(13) " God must be the ultimate end of your religion : it must be intended to please and glorify him. God must be the continual motive and reason of your religion; and of all you do..." *C. D.*, Vol. I, pp. 165-6; *cf.* also, Vol. II, pp. 181, 239 ff. *Cf.* commentary of TROELTSCH, *op. cit.*, Vol. II, p. 588. Foremost in the Westminster Catechism (1648) was the query : " What is the chief and

as this was—medieval Catholicism knew the phrase well—it was now clothed with new meanings and a new emphasis. God must be glorified but institutional controls canalized this glorification in particular directions, with a variety of social effects. Since a wide variety of behavior, all of which is not equally desirable, may presumably be oriented toward the attainment of this goal, BAXTER proceeds upon a further definition of the most appropriate means. It is in the definition of these and other leading tenets of Protestantism rather than in the sheer phraseology (which resembles Catholicism in many respects) that the real significance of these teachings is found.

One of these directions was eminently practical. For those whom the new faith provided strong motivations was urged the subordinate, though highly important, aim of usefulness to one's fellow-men, of utility to society; for " Though God need none of our good works, yet that which is good materially pleaseth Him, as it tendeth to His glory, and to our own and others' benefit, which He delighteth in." (14) Nor need we halt here. The idea is carried to its extreme and we are told that " public service is God's greatest service." (15) Thus, a social utilitarianism, having been established as one of the leading criteria of acceptable, even praiseworthy, behavior inasmuch as it is a most effective means of glorifying God—the basic and ultimate end—is imbued with a power of its own. Various activities were built up around this and other tenets of a religious system which, at the time, carried with it all the force of deep-rooted, hardly questioned convictions. In fact, since the utilitarian principle lent itself to a ready concrete application, it came to be the guiding tenet in actual practice. It is this *definition* (16) of the precept

highest end of man?—To glorify God, and fully to enjoy him for ever." This is a concrete example of the exhortation of what WEBER has called " wertrational " action, i.e., " durch bewussten Glauben an den—ethischen, ästhetischen, religiösen oder wie immer zu deutenden—unbedingten Eigenwert eines bestimmten Sichverhaltens rein als solchen und unabhängig von Erfolg." *Wirtschaft und Gesellschaft* (Tübingen : MOHR, 1922), pp. 12 ff.

(14) *C. D.*, Vol. I, p. 322.

(15) *C. D.*, Vol. I, p. 456.

(16) The motivation for this " definition " will become more apparent as other features of this religious system are considered.

in basically *utilitarian* terms which allied Protestantism with the rest of the associated culture.

A further fundamental doctrine, peculiar, however, to the Calvinist sects, is that of predestination : God grants salvation to some purely of His own free will, irrespective of the faults or virtues of the elect. We need only realize the Puritan's profound anxiety concerning his spiritual grace to appreciate the desperate insistence with which he propounded the immediate question : how am I to know that I am among the elect? The Church could provide no assurance. Yet an answer was psychologically imperative; to continue the routine of daily life in the face of such uncertainty was simply unthinkable. An answer was demanded and soon came forth. Since the time of BEZA, it held that election is proved by " good works " which are outward signs of an inward state of grace (17). Here again, the essential difference between Catholicism and Puritanism is in the definition of a nominally similar conception. " Good works " in the Protestantism of this time is basically a term to refer to achievements which are useful and profitable in a worldly sense; at first blush, it would appear to be sheer utilitarianism. Good works now demanded participation in mundane affairs, not withdrawal from them through flight to the monastery.

Thus, by satisfying the drive for the conviction of one's election, *certitudo salutis*, the Calvinist doctrine of predestination escapes any drift toward an apathetic pessimism (18). Those sects which did not accept the notion of predestination, arrived at a conclusion which in its practical consequences is identical with those of the Calvinists, since for them " good works," still understood in

(17) TROELTSCH, *op. cit.*, Vol. II, p. 590.

(18) ROLAND G. USHER, in his generally excellent study, *The Reconstruction of the English Church* (New York and London : APPLETON, 1910), 2 volumes, provides a careful summary of Puritan theology, but errs in his analysis of the *practical consequences* of Puritan beliefs, as is evidenced by the following " ... for his future bliss, the Puritan needed but faith in Christ : he could by his human ' works ' accomplish nothing : and he felt that such attempts were an insult to God and to His eternal grace." " Such a theology made man despondent morbid, morose, introspective." Vol. I, 78-79. As a matter of fact, as we shall have occasion to see, the doctrine of predestination with its Puritan corrollary of conviction of grace through successful labor obviated the feeling of individual helplessness and afforded a sense of transcendent power to the individual who felt that he was one of the elect.

the sense of worldly accomplishment, are equally necessary, but in this instance to *reach* a state of grace. Thus, we find abundant confirmation of MAX WEBER's dictum that " similar ethical maxims may be correlated with very different dogmatic foundations." (19) This likewise corroborates the contention that there is substantial uniformity in the *social* implications of the various Protestant dogmas.

Diligence and Industry

On these diverse theological bases—predestination and justification through good works—is erected the structure of an additional doctrine governing behavior : diligence in one's calling becomes a necessity (20). This principle merges into its consequences, for since systematic, methodic, and constant labor enables the attainment of success in one's profession—which is the hallmark of salvation—such achievement itself becomes a worthwhile goal.

The demand for constancy in labor is justified by all the fundamental Puritan doctrines which carry with them the absolute character of a closed system of integrated sentiments and beliefs. In the first place, it is a means of glorifying God (21), for " it is God that calleth thee to labour." Again, it is a means of aiding the public weal (22). Thirdly, diligence in our labors necessarily entails less leisure and liberty for succumbing to the multifarious temptations, odious to the sight of God, which beset us. Time must be spent solely in the way of duty and not an hour must

(19) *Protestant Ethic*, p. 97.

(20) " Be diligent in your callings, and spend no time in idleness, and perform your labours with holy minds, to the glory of God..." *C. D.*, Vol. II, pp. 196-97.

(21) *C. D.*, Vol. II, pp. 122-24. *Cf.* TAWNEY, *op. cit.*, p. 240.

(22) " The public welfare, or the good of the many, is to be valued above your own. Every man therefore is bound to do all the good he can to others, especially for the church and commonwealth. And this is not done by idleness, but by labour ! As the bees labour to replenish their hive, so man being a sociable creature, must labour for the good of the society which he belongs to, in which his own is contained as a part." *C. D.*, Vol. II, p. 580. Here is to be noted again the shift from a dominant emphasis on the glorification of God to a stress on utilitarianism.

be misspent (23), in excess of sleep or of play, for this is the sign of the fleshpleaser. Not stinting variations in the bases of appeal, the Puritan emphasis upon reason as a praiseworthy faculty is called into play. Labour is necessary for the preservation of the faculties of the mind (24).

These attitudes obviously do not at all imply monastic asceticism, *ausserweltliche Askese*, " far from the madding crowd's ignoble strife," but rather an intramundane asceticism, *innerweltliche Askese* (25). The Puritan ethic, couched in vivid, insistent terms which brooked no dispute, demanded participation in the affairs of this world. Thus, BAXTER raises the hypothetical question : " Must every man do his best to cast off all worldly and external labours, and to retire himself to a contemplative life as the most excellent? " His answer is categorical :

> No : no man should do so without a special necessity or call : for there are general precepts on all that are able, that we live to the benefit of others, and prefer the common good, and as we have opportunity do good to all men... (26)

Once again there is the tendency to have the utilitarian criterion supersede that of the glorification of God, a transition which is even more marked in subsequent passages from BAXTER (27).

(23) *C. D.*, Vol. I, p. 334; Vol. II, Chap. IV.

(24) *C. D.*, Vol. II, p. 581. This rationalization possibly reflects the increasing esteem in which certain intellectual pursuits were coming to be held.

(25) The most lucid exposition of this point is by MAX WEBER, *op. cit.*, especially chapter IV. *Cf.* also TROELTSCH, *op. cit.*, Vol. II, p. 604 ff; TAWNEY, *op. cit.*, p. 240 *et passim;* MARGARET JAMES, *Social Problems and Social Policy during the Puritan Revolution* (London : ROUTLEDGE & SONS, 1930), p. 17, which is an excellently detailed study. *Cf.* CHRISTOPHER LOVE, *The Combat between Flesh and Spirit* (London, 1654), p. 52. " God never did so order Religion that it should be a disadvantage to our particular callings in the world."

(26) *C. D.*, Vol. II, p. 212. The extreme statement of this Puritan rationalization of secular and utilitarian activity is found in SPRAT's *Sermons*. He states . " ... so far is the True Religion from obliging all its Professors, either to withdraw wholly out of the World, or in Conscience to avoid all the usual Observances, and Manners, or even the innocent Delights of it, whilst they are in the World; that perhaps none are more capable of bringing more *Benefit to Mankind*, so of doing more Service to God, or exercising more Evangelical Graces, than those Men, that are of the most practical Lives, and engag'd in most secular Business." THOMAS SPRAT, *Sermons on Several Occasions*, pp. 18-19.

(27) *E. g.*, *C. D.*, Vol. II, pp. 244-5. " The work of a magistrate, a lawyer, a physician, and such like, is principally in doing good in their several callings which must not be neglected for contemplation. Some persons in the same calling, whose callings are not so urgent upon them, by any necessities of themselves or others, and who may have more vacant time, must gladly take it for the good of their souls, in the use of contemplation and other holy duties. And others that under greater necessities, urgencies, obligations, cannot be spared from the service of others, (as physicians, lawyers, etc.) must be less in contemplation and prefer the greatest good." This dictum quite clearly illustrates the transition; utilitarianism is not to be sacrificed to religious contemplation in any concrete case. The significance of this for the contemporary evaluation of science will be indicated later.

Choice of Vocation

Since the necessity for zeal in a calling has been admirably justified by reference to unquestionable fundamental Puritan dogmas, BAXTER goes on to rank the occupations in order of desirability. They are not equally efficient means of attaining the prescribed goals nor is every individual capable of pursuing those vocations which are most desirable. The general principles to be followed in the selection of a calling of course revert to the original premises : choose that employment in which you may be most serviceable to God (28) and that which most contributes to the common weal (29); " and, (' *caeteris paribus* ') that calling which most conduceth to the public good is to be preferred." (30) The callings, in order of desirability, are the learned professions —though only those who have had a " special call " should enter the ministry—agriculture, trade and the crafts (31). The pre-eminence of the learned vocation is congruent with the high esteem in which education is held by the Puritan.

These, then, constitute the fundamental elements of the Puritan ethos which together defined the acceptable " way of life." It is vital to an understanding of this world-view that we do not under-estimate the tremendous control that was then exercised

(28) *C. D.*, Vol. I, p. 332.

(29) *C. D.*, Vol. III, p. 186.

(30) *C. D.*, Vol. II, p. 584. This virtually completes the shift to a dominant emphasis on utilitarianism.

(31) *C. D.*, Vol. II, p. 584. This conception provides a definite basis for individuals to turn to the learned professions, other than the ministry, even though this latter is the most desirable calling. That this precept exercised some influence will be seen very definitely in at least two outstanding instances, those of ROBERT BOYLE and of Sir SAMUEL MORLAND. It is doctrines of this sort which much later emerge as definitely subversive of formal religion and which make for secularization.

by religion over the Puritan mind. We would certainly be led to profound error were we to assume that religious beliefs played the perfunctory rôle which is generally their lot today. No doubt, then as now, particular individuals had broken away from the strong hold of religious authority, but in the main, Puritanism was a powerful social force which was not readily gainsaid.

Blessed Reason

Closely related to the foregoing doctrines was another class of beliefs which pertains more directly to the social evaluation of science and technology. First among these is the tendency to laud the faculty of reason (32). The nominal basis for this attitude is manifold. Reason is praiseworthy because man, chosen of God, alone possesses it; it serves to differentiate him from the beasts of the field (33). Further, it is an admirable function since it serves to curb and restrain the appetite which provokes the " master sin," sensuality, fleshpleasing or voluptuousness (34); it limits any pernicious tendency toward idolatry.

The rôle of reason as a device for controlling idolatry of the flesh is sufficient to endear it to the Puritan heart, but it possesses still another exemplary characteristic; it enables man more fully to glorify God by aiding him to appreciate His works (35). Through the previously noted tendency toward relating the various elements of this religious system by a series of judgments and endowing each of these elements with the sentiments centered about the system as a whole, Reason takes on an exacting authority. Hence

(32) Thus, even ROBERT BARCLAY, the leading apologist of the Quakers, the most mystical of the major seventeenth century Protestant sects, exclaims : " [I do not] at all despise reason, that noble and excellent faculty of the mind, because wicked men have abused the name of [it] ..." *An Apology for the True Christian Divinity* (Philadelphia, 1805), p. 76; also p. 159. [This work was originally written in 1675.] The preponderant place of rationalism in the more orthodox Puritan sects has been established by WEBER, *Protestant Ethic*, p. 224, *et passim*.

(33) *C. D.*, Vol. II, p. 109. It is significant that this idea was specifically used as a basis for the justification of scientific study. *Viz. infra.*

(34) *C. D.*, Vol. II, p. 95 ff.

(35) For a detailed discussion of this point, *viz. infra.*

it becomes imperative for them who would rationalize these doctrines to " prove " that *reason* and *faith*—two such highly exalted virtues of the Puritan—are not inconsistent. It is in this vein that BAXTER maintains :

> Though some deluded men may tell you, that faith and reason are such enemies, that they exclude each other as to the same object, and that the less reason you have to prove the truth of the things believed, the stronger and more laudable is your faith; yet, when it cometh to the trial, you will find, that faith is no unreasonable thing; and that God requireth you to believe no more, than is your perception of the reasons why you should believe : that God doth suppose reason, when he infused faith, and useth reason in the use of faith. They that believe, and know not why, or know no sufficient reason to warrant their faith, do take a fancy, or opinion, or a dream for faith (36).

This exaltation of reason and derogation of " enthusiasm " —in the original etymological sense of the term—is characteristic of the rationalistic aspect of the Puritan teachings (37). The Scriptures were not intended instead of reason or any of the sciences (38), since these latter may be independent, efficacious means for glorifying God. Anticipating, we may say that the elevation of an empirico-rationalism to such a lofty plane that it is admitted—at times by theologians themselves !—to be a

(36) *C. D.*, Vol. I, p. 171.

(37) Rationalism is here not used in its customary philosophical sense as the theory that reason is a source of knowledge in itself, superior to and independent of sense perceptions, *i.e.*, as opposed to empiricism; nor entirely in the theological sense as the doctrine which holds that religious opinions should be based on reason rather than on revelation, though it does include this latter meaning as a specific case. (Thus, BAXTER holds : " The Holy Spirit, by immediate inspiration, revealed to the apostles the doctrines of Christ, and caused them infallibly to indite the Scriptures. *But this is not the way of ordinary illumination now.*" *C. D.*, Vol. I, p. 104. And again : " Though your religion must not be taken upon trust, there are many controverted smaller opinions that you must take on trust, until you are capable of discerning them in their proper evidence." *C. D.*, Vol. I, p. 100). It means rather reasonableness, conformity to *reason and experience;* it is a combination of rationalism and empiricism, as is quite evident from Puritan writings. This attitude of empirico-rationalism is of moment, as shall be indicated, for the relation between Protestantism and science.

(38) *C. D.*, Vol. I, p. 11. Reason is accorded a carefully circumscribed place. God is " irrational " in the sense that He cannot be measured by human reason. Rather, reason is one of the tools to be used in our tasks in this world. The intellect is to be used to aid action, the ultimate purpose of which is beyond our grasp. *Cf.* TROELTSCH, *Social Teachings*, Vol. I, p. 585.

justifiable criterion of the validity of various religious beliefs introduced the opening wedge for later processes of secularization (39). It may also be suggested that the emphasis upon reason—in the sense in which the term is used here—is no less related to the beginnings of biblical criticism (40) than to rationalization in industry and in science. Had the seventeenth century Puritan foreseen some of the consequences of his espousal of reason, he would have punctuated his repudiation of it with pious shudders.

Profitable Education

Allied with this emphasis on rationalism is the widely recognized interest of the Puritan in education. " Education and converse [conversation] have so great a power on the mind that they come next to grace, and are often the means of it." (41) But this education must be directed in specific channels; certainly not in literature or art or other similar " unprofitable studies " which are simply time-wasting self-indulgences (42).

(39) HENRY MORE, in his *Brief Discourse of the True Grounds of the Certainty of Faith in Point of Religion* (London, 1688), pp. 578-80, reflects this tendency. " ... to take away all the certainty of sense rightly circumstantiated, is to take away all the certainty of belief in the main points of our religion." " ... no revelation is from God that is repugnant to sense rightly circumstantiated."

(40) Cf. ÉMILE BRÉHIER, " The Formation of our History of Philosophy," pp. 159 ff. in *Philosophy and History*, ed. by R. KLIBANSKY and J. H. PATON, (Oxford : Clarendon Press, 1936).

(41) *C. D.*, Vol. I, p. 86. The attitude of the Quakers is quite the same as remarked by J. S. FLYNN, *op. cit.*, p. 159. " ... the whole Society [of Friends] placed the cultivation of the intellect next to the knowledge of God." See also BARCLAY, *op. cit.*, p. 323. BAXTER amiably announces that " it is a very good work to set up free-schools in populous and in ignorant places, especially in Wales [!]; that all may be taught to read, and some may be prepared for the Universities." *C. D.*, Vol. V, p. 481.

(42) *C. D.*, Vol. I, p. 150 ff; Vol. II, p. 167; Vol. III, p. 202; Vol. IV, p. 484. *Cf.* BAXTER's *Book of Self-Denial, passim.* This hostile attitude toward certain types of literature did actually result in Puritans largely eschewing this field save as it was related to expressions of Puritan sentiments. *Cf.* FRANS DIRK DE SOET, *Puritan and Royalist Literature in the Seventeenth Century* (Delft : J. WALTMAN, 1933), Introduction. HERBERT SCHÖFFLER remarks, in connection with this antipathy, that there was not a single Quaker poet of significance until late in the Enlightenment. *Cf.* his *Protestantismus und Literatur.*

Flights of fancy could scarcely be condoned unless they carried moral implications. The cleric ALEXANDER HOME warned youth against the reading of " profane sonnets and vain ballads of love, the fabulous feats of PALMERINE and such like reveries." This attitude is correlated with the decline of interest in certain of the arts which was noted in Chapter II.

Nor is the pursuit of the scholastic philosophy approvable, for it is full of false teachings which seem to lead away from God rather than toward Him (43). Especially pernicious is this pseudo-Aristotelian philosophy because it induces error and confusion which is verisimilar by virtue of the rigorous syllogistic reasoning employed. But starting frequently from false premises it must needs come to false conclusions. Hence, in outlining a course of study for one who intends the ministry, BAXTER deliberately refrains from including any such philosophy (44). This careful direction of intellectual interests into definite fields and away from others is of moment when one considers the contemporary power of such religiously-founded attitudes. Having eliminated certain studies as inappropriate, BAXTER continues by designating those which are to be preferred.

The primary emphasis in education should be, of course, religious; but since all who seek instruction are not equally suited for the clergy one can best serve the public good by following one's individual inclination in the choice of other lawful, desirable callings (45). As already indicated, the other learned professions are next in point of desirability. In the educational curriculum, Mathematics, a part of " organical knowledge " since its uses are so fundamental and diverse, takes a prominent place. Physics, understood always as the study of God in his works, is the favorite Puritan scientific discipline (46). This selection illustrates the correlated aspects of Puritan thought : mathematics representing the rationalistic aspect and physics the empirical (47). The

(43) *Cf.* observation of MAX WEBER, *Protestant Ethic*, p. 249.

(44) *C. D.*, Vol. IV, pp. 577-8. *Cf.* WEBER, *Religionssoziologie*, Vol. I, p. 564. " Nicht selten betrachtete daher die Religiosität die rein empirische, auch naturwissenschaftliche Forschung als besser mit ihren Interessen vereinbar als die Philosophie. So vor allem der asketische Protestantismus."

(45) *C. D.*, Vol. II, p. 212 ff.

(46) *C. D.*, Vol. IV, p. 577.

(47) It is this same convergence which characterizes the growth of modern

emphasis upon these studies is significant when one remembers that the advance in these fields was more pronounced than in any other.

A knowledge of many languages is also desirable since it facilitates the acquisition of further learning—it is esteemed not as an attainment desirable in itself, but as a means for attaining a further knowledge of *things*. The pure linguist, who did not apply his faculties to increasing man's knowledge, was too close to the inadmissible status of the contemplative monk. This attitude was also repeatedly maintained by the scientists of the period.

In his " directions for young Students, for the most profitable ordering of their studying Thoughts," the Reverend Mr. BAXTER skillfully steers a safe course, twixt the Scylla of utter conformity to intellectual tradition and the Charybdis of radical divergence from antecedent scientific conceptions (48). The test for the acceptance or rejection of theories is to be empirical : submission of the theses to the relevant sensory experience, " for it is not science, but human belief, else, whoever you take it from." (49) BAXTER would not dismiss rationalism beyond recall, but he would subordinate it; it is not to be preferable, but rather ancillary, to the study of irreducible and stubborn facts. Here is evidenced the revolt against scholasticism, against rationalism (in the philosophical sense) which is so characteristic of two of the major movements of the century : the Protestant-Reformist and the scientific.

science. The unrelieved rationalism of the Scholastics was insufficient; the unimaginative and incomplete empiricism of FRANCIS BACON could prove no better. But the interaction of abstract reasoning with experiment and observation, typified by the conjunction of mathematics and physics, was the fruitful key to the problem. Now while this development may have been largely an intra-scientific one, it was not wholly unrelated to the society in which it occurred. The coincidence of these converging movements in the realms of both religion and science was not fortuitous, as we shall see.

(48) The following quotation differs significantly from the rigidity of traditionalism manifest in the writings of medieval theologians and, in great part of CALVIN himself. " Avoid both extremes, of them that study no more, but to know what others have written and held before them; and of them that little regard the discoveries of others : learn all of your teachers and authors that they can teach you; but make all your own, and see things in their proper evidence..." *C. D.*, Vol. II, p. 246-7. The context emphasizes the empiricist bent.

(49) *C. D.*, Vol. IV, p. 579.

At this point a distinction must be drawn between medieval and seventeenth century rationalism. The impress of rationalism was marked throughout the latter Middle Ages; it was an essential of scholasticism. As Professor WHITEHEAD has shown (50), this engendered a habit of orderly thought which remained long after the scholastic philosophy had been repudiated. HOOKER, in his *Ecclesiastical Polity*, however, criticised the Puritans for their failure to subordinate themselves completely to such rationalism. With the Puritans, who so fully exemplify a mercantile and scientific age, the term reason takes on a new connotation : the rational consideration of empirical data. Logic is reduced to a subsidiary rôle. It is occasionally a useful element in thought, but the test of reality comes not from scholastic logic, which adds nothing to knowledge and may perpetuate falsehood, but from the observation of facts. It was this accent, coupled with an " irrational " faith in the efficacy and utility of science, which characterizes both Puritanism and modern science (51).

Physics : God in His Works

Education in general having been deemed a good work, the logically-minded BAXTER goes on to provide a rationale for the emphasis on scientific and empirical studies. Again, there is the reversion to the fundamental aim of all life as the basis for sanction : the study of natural phenomena is an effective means for promoting the glory of God (52). The study of Nature in a

(50) A. N. WHITEHEAD, *Science and the Modern World* (New York : MACMILLAN Co., 1931), pp. 17 ff.

(51) *Cf.* WALTER PAGEL, " Religious Motives in the Medical Biology of the XVIIth Century," *Bulletin of the Institute of the History of Medicine*, Vol. III (1935), pp. 97-128, who contrasts the preponderance of rationalism in medieval science with the " empirical implications " of seventeenth century science and religion.

(52) " The great means of promoting love to God is duly to behold Him in His appearances to man, in the ways of Nature, Grace and Glory. First, therefore, learn to understand and improve his appearances in Nature, and to see the Creator in all His works, and by the knowledge and love of them to be raised to the knowledge and love of Him." *C. D.*, Vol. I, p. 375. This argument for the justification of science is characteristic of all the Protestant sects. Thus GILBERT, Lord Bishop of Sarum [GILBERT BURNET] in *A Sermon Preached at*

" convincing, scientifical way " furthers a full appreciation of the Creator's power, so that the natural scientist must needs be better equipped than the casual observer to glorify Him. In this direct fashion, religion sanctioned science and raised the social estimation of those who pursued scientific investigation, with the associated intensification and spread of interest in such pursuits.

A further basis for the sanctification of science was found in the second major tenet of the Puritan ethos : *the utilitarian principle*. The linkage is apparent. " Knowledge is to be valued according to its usefulness," (53) since anything which tends " to sweeten the lives of mortals," to facilitate their material well-being, is good in the sight of God (54). The religiously-assigned value of science is hence immeasurably increased in view of the fact that the scientific study of nature tends to enlarge

the Funeral of the Honorable ROBERT BOYLE (London : 1692), p. 14, repeats : " ... the viewing of the works of God even in a general survey, gives insensibly a greatness to the Soul. But the more extended and exact, the more minute and severe, the Enquiry be, the Soul grows to be thereby the more inlarged by the variety of Observation that is made, either on the great Orbs and Wheels that have their first motion, as well as their Law of Moving, from the Author of all; or on the Composition of Bodies, ..." It is of course true that this same view—that the study of natural phenomena discovers the glory of God revealed in His handiwork—became fairly common toward the latter part of the Middle Ages. In Islam, the same notion was also widespread. AVERRÖES held that the noblest worship which can be paid to God lies in the knowledge of His works. But the experimental method, while faintly present, was not sufficiently cultivated to make for what is called modern science. In medieval Europe this neo-Platonic conception of God revealed in Nature was coupled with the doctrine of the complete subservience of these studies to the infallible teachings of the Bible (which were not interpreted by the individual in the light of his reason and experience but by the Church). Moreover, since this idea was then not allied with a similarly sanctioned emphasis on observation and experiment, it could at best lead to fruitless rationalistic discussions, largely divorced from empirical study. Seldom did religious leaders carry this point further and suggest that the scientist was better able to glorify God than were others; and hence the complete sanction of scientific work was in no wise comparable to that of the later Puritan teachings. It was the conjunction of these prerequisite factors, empiricism, rationalism and positive evaluation of science, in the post-Reformist teachings which was associated with the spread, and indirectly, with the advance of science.

(53) *C. D.*, Vol. I, p. 13.

(54) GILBERT BURNET, *op. cit.*, pp. 15-18.

man's dominion over it. Science is thought of as a powerful technologic tool and as such deserves to be highly esteemed.

Now, as has been indicated, there was a constant tendency for the to-the-greater-glory-of-God principle to recede as a guiding tenet of actual behavior and for utilitarian considerations to become ever more prominent. Or, to put it in another way, activity which was clearly useful in a practical sense was increasingly held to glorify God most effectively. In view of this process, it may readily be seen that the social utility of both science and technology proved to be one of the most effective arguments for the positive estimation of such pursuits, an argument which was irrelevant to the medieval religious leaders who felt the futility of worldly interests of this sort. Indeed, considerations of mundane utility were simply foreign to medieval teachings. In contrast, Puritanism tends ever more and more to emphasize the value of reshaping this world. Consequently, science, as at least in part the handmaid of socio-economic utility, is positively sanctioned (55).

The Medieval Contrast

The monastic asceticism and the feeling of the impermanence and relative worthlessness of matter which was characteristic of the Middle Ages could obviously not lead to an interest in disciplines which were primarily concerned with this world of sense. The early Church Fathers, such as EUSEBIOS, ST. AMBROSE and LACTANTIUS, consistently proposed the chiliastic doctrine of the New Testament that this earth was soon to be destroyed, that there were to be new heavens and a new earth, and treated the physical sciences with contumely and contempt (56). The

(55) *Cf.* A. C. MCGIFFERT, *The Rise of Modern Religious Ideas* (New York : The MACMILLAN Company, 1922), Chapter 3.

(56) A. D. WHITE, *A History of the Warfare of Science with Theology*, 2 volumes (New York : APPLETON, 1901), Vol. I, pp. 375 ff. This attitude exemplifies what H. O. TAYLOR called the basic principle of patristic faith : that the will of God is the one cause of all things and *that this will is unsearchable*, is " secret." *Cf. The Medieval Mind*, Vol. I, p. 74. See also F. W. BUSSELL, *Religious Thought and Heresy in the Middle Ages* (London : ROBERT SCOTT, 1918), pp. 715-17. CALVIN's point of view, which closely resembled this, was submerged by the implications of his other tenets, which led to directly opposed developments.

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investigation of natural phenomena seemed purposeless. As AMBROSE held in his *Hexaëmeron* [Vol. I, p. 6], " To discuss the nature and position of the earth does not help us in our hope of life to come. It is enough to know what Scripture says, that ' He hung up the earth upon nothing.' "

When this belief had lost something of its force, when the conviction of the imminent end of the earth was not so intense, science came to be regarded with dread since it was " black magic," representing an unlawful alliance with Satan (57). Writing in the late twelfth century, RICHARD OF ST. VICTOR asks rhetorically : " What is all science but a picture without life, a phantom without movement or feeling ? " And BONAVENTURA in the following century warns that " the tree of science cheats many of the tree of life or exposes them to the severest pains of purgatory." It is quite true that some of the great Reformers, in particular LUTHER, were similarly antagonistic to natural science and humanist art, but the religious movements which stemmed from these charismatic leaders grew away from this antagonism and vigorously espoused a favorable attitude (58).

One essential difference between the medieval and post-Reformation type of personality, in which religion was the focal element, is clearly brought out by SPRANGER's ideal-types of the " transcendental mystic " and the " immanent mystic." The first finds rest only in a super-sensuous world. For such a being science is without value since it does not answer the ultimate questions; all his energies are concentrated on preparing his soul for inner vision. The immanent mystic, on the other hand, applies his religious beliefs in a totally different fashion. Life and action become positively valued precisely because they are indications of God. This type of individual possesses a sort of cosmic enthusiasm, for since God is present in every

(57) WHITE, *op. cit.*, Vol. I, p. 383.

(58) For this reason, it is necessary to insist upon the distinction between the teachings of the Reformers themselves and their subsequent *development* in the Puritan and similar movements. Of course, this does not deny that occasionally principles were adopted without any pronounced change. *Cf.* F. VON BEZOLD, " Staat und Gesellschaft des Reformations-Zeitalters " in *Staat und Gesellschaft der neueren Zeit* (Berlin : B. G. TEUBNER, 1908), p. 81, *et passim.*

aspect of life, none should be slighted. Science as the study of His works thus becomes highly regarded (59).

This type of attitude so characteristic of Post-Reformation religious leaders during a period when religion was still a singularly powerful social force may well have been congenial to the development of science. This is not to imply that the discoveries of NEWTON, BOYLE or other scientists can be directly attributed to the sanction of science by religion. Specific discoveries and inventions belong to the internal history of science and are largely independent of factors other than the purely scientific. But the fact that science became socially acceptable, in short, that it became a laudable rather than an unsavory occupation, could not but help direct talents into scientific pursuits which at other times would have found expression in other fields.

Nor is there any implication that religion was the primary factor, the independent variable, so to speak, and science the dependent. Religious conceptions were, as we shall see more clearly, definitely integrated with sentiments basic to the contemporary science and philosophy : there was throughout a reciprocal interaction. But the fact is that religion still constituted a most effective social force and as such it exerted a considerable influence upon contemporary action and the allocation of contemporary interests. In the values of that society, the ideals and goals of religion loomed large and science was regarded as an efficient means for the attainment of these aims.

As SPRANGER has indicated, values from other zones—in this instance, the realm of science—become religious when they are related to the final meaning of life, and consequently they embody a religious emphasis over and above their original value accent (60). This statement, however, should not be generalized for it applies only when religion is clearly a preëminent social value. The realization of the fact provides definite limits on the generalizability of the processes noted in this study, for obviously the influence of religion upon science necessarily varies with the degree of social control which religion manifests in a

(59) EDUARD SPRANGER, *Types of Men*, trans. by P. J. W. PIGORS, (Halle : M. NIEMEYER, 1928), pp. 213-16.

(60) *Ibid.*, p. 285.

given society. The picture which our study has thus far afforded is characteristic of an historical epoch; it cannot be extended, without appropriate modifications, to a period such as the present where religious ideals are in a sense subordinated to others, particularly those of science and the industrial world. But all these are considerations which may best be dealt with in other connections.

Science : Handmaid of Utility

Social utility, an aim prescribed by religion, has been used to sanction science, viewed, in this case, as a handmaid of technology (61). BAXTER points out, further, that scientific and technologic discoveries and inventions increase man's felicity signally, for they enable their originators to arrive at an abundant conviction of their state of grace.

> Grace will become more notable and discernible [if you persevere and succeed in your labours] ... For the very exercise of love to God and man, and of a heavenly mind and holy life, hath a sensible pleasure in itself, and delighteth the person who is so employed : as if a man were to take the comfort of his learning and wisdom, one way is by the discerning his learning and wisdom which he hath, in reading and meditating on some excellent books, and making discoveries of some mysterious excellencies in arts and sciences, which delight him more by the very acting, than a bare conclusion of his own learning in the general, would do. What delight had the inventors of the sea-chart and magnetic attraction, and of printing, and of guns, in their inventions ! What pleasure had GALILEO in his telescopes, in finding out the inequalities and shady parts of the moon, the Medicean planets, the 62 adjuncts of Saturn, the changes of Venus, the stars of the Milky Way, etc...

The sentiments basic to these views would have been simply unthinkable in the medieval period, save as referring, at best, to the intellectual amalgam of science and theology presented by an AQUINAS. To regard with high esteem scientific discoveries attained empirically and without reference to Scriptural or other

(61) We do not wish to confuse the development of science and of technology —they are not identical though they coincided at many points. But the fact is that the religious evaluations were generally concerned with both, and in much the same fashion. At this point, then, they may be considered jointly.

(62) *C. D.*, Vol. V, p. 535.

sacred authority would have been almost as heretical as making the discoveries themselves (63). As Professor HASKINS has observed, the scientific spirit of Christian Europe in the Middle Ages was not liberated from the respect for authority which was characteristic of that epoch (64), whereas Puritan authority was enunciating the very doctrines which furthered interest in science and, ultimately, lack of concern with religion itself.

The contrast between BAXTER's statement and, say, that of PETER DAMIAN, the noted chancellor of POPE GREGORY VII, who declared that all worldly sciences are absurdities and fooleries is perhaps sufficient to account significantly for the social interest in science in the seventeenth century and, relatively speaking, its almost complete absence in the eleventh. This does not imply a complete cessation of interest in science during the eleventh or any other century of the period so popularly and erroneously called the Dark Ages.

The continuity of scientific development was unbroken, but it was a most tenuous thread in Western Europe until at least the twelfth century. Thereafter, science, as a phase of social activity, became increasingly significant, but it could not bloom and prosper for two reasons : the first, intrinsic to the nature of science, and the other, social in character. To a certain degree, a fixed order must prevail in the appearance of scientific discoveries; each discovery must await certain prerequisite developments (65).

(63) Contrast the attitude of Pope ALEXANDER III, who in 1163, in connection with the Council of Tours, forbade the study of physics to all ecclesiastics, which in that age meant the prohibition of scientific studies to the only persons who were even moderately equipped to pursue them. " What the Pope expressly forbade was, in the words of the papal bull, ' the study of physics or the laws of the world ' ..." WHITE, *op. cit.*, Vol. I, p. 386. The condemnation of ROGER BACON who dared suggest a scientific explanation of natural phenomena may have been simply an application of Franciscan discipline, but it seems also to have been animated by a dislike of his originality of theory. In 1278, the Franciscans condemned BACON's teachings as containing " suspected novelties." Likewise, the Dominicans interdicted the study of medicine, natural philosophy and chemistry. Such attitudes of religious authorities could scarce have provided a fruitful social soil for the development of science. *Cf.* LECKY, *History of... Rationalism*, Vol. I, p. 301.

(64) CHARLES H. HASKINS, *The Renaissance of the Twelfth Century* (Cambridge : Harvard University Press, 1928), pp. 336-37.

(65) *Cf.* W. F. OGBURN, *Social Change* (New York : Viking Press, 1932), S. C. GILFILLAN, *Sociology of Invention* (Chicago : FOLLETT Pub. Co., 1935).

(The converse of this does not follow with the ineluctability which some cultural sociologists would have us believe—a discovery does not necessarily follow upon the existence of its " constituent elements " as is well attested by the history of science.) In this sense, we may talk of the time not being ripe for a far-reaching, swift-moving, wide-sweeping development until the seventeenth century (66).

The other factor was the absence of the requisite cultural animus of regarding scientific activity as highly desirable. Occasional " great intellectual sky-rockets " there were to light the world of science, but little in the way of concerted scientific effort viewed with favor by the chief agents of social control; the tendency was, rather, to look benevolently at theological activity and to turn one's back to scientific endeavors. Of course, this statement is but approximate. The tenets of medieval Europe were never as consistently applied and unchallenged as one is at times prone to believe. There were divergences from the dominant tendencies, but those few of the intellectual élite who ran counter to the trend were too much the exception to direct social attention into scientific channels.

The seventeenth century brought the prerequisite factors to convergence : an adequate accumulation of scientific knowledge to cope with the initial problems at hand, the maturation of the experimental method, a consistent provision of " intellectual genius adequate for the greatness of its occasions " and a complex of social attitudes which, for varying reasons, religious, economically utilitarian and idealistic, was favorable to scientific interests.

The specific developments, it should again be emphasized, were not directly dependent upon this social evaluation of science as a focus of social interest, but it is manifest that any field of activity which is regarded with favor will, particularly if like science, it possesses an ongoing dynamic of its own, advance more rapidly than when derogated (67). These social attitudes, positive or negative, are a function of a complex of social trends, which are more or less interdependent : economic, political,

(66) ALFRED VIERKANDT, *Die Stetigkeit im Kulturwandel* (Leipzig : DUNCKER & HUMBLOT, 1908), pp. 123-4 *et passim.*

(67) As BACON observed, " it is nothing strange if a thing [science] not held in honour does not prosper." *Novum Organum*, Vol. I, Aph. XCI.

religious, philosophic, scientific and the like. At various times, the dominant ideals and sentiments of a society are chiefly expressed in one or another of these fields, and it is they which largely determine the social attitudes toward other spheres (68). When, as was apparently the case during the seventeenth century, utilitarian norms are dominant, other activities are evaluated in respect of their apparent accordance with these ideals and, in this sense, may be said to be dependent upon them. Generalizations concerning these social processes are, then, relative to the specific social context; they are not timeless, universal, irrespective of social values and social structure.

The social values inherent in the Puritan ethos were such as to lead to an approbation of science because of a basically utilitarian orientation, couched in religious terms and furthered by religious authority. Scientific investigation, viewed from the rationalized Puritan system of ethics, seemed to possess those qualities characteristic of activities which are effective means for the attainment of the accepted goals. The possibility that science, as a means toward a religious end, would later break away from such religious supports and in a measure tend to delimit the realm of theologic control, was seemingly unrealized (69). The apparent conflicts between theology and science which arose when scientific findings seemed to disprove various contentions of orthodox theologians occurred later with each extension of scientific inquiry to realms which were hitherto regarded as " sacred." But this is simply another example of the frequently observed fact that the Reformers did not anticipate the full actual consequences of their teachings, consequences which did not coincide with their expectations (70).

(68) *Cf.* MAX SCHELER, *Versuche zu einer Soziologie des Wissens* (München und Leipzig : UNCKER & HUMBLOT, 1924), pp. 31 ff.

(69) There were a few far-sighted exceptions, foremost among whom was JOSEPH GLANVILL.

(70) *Cf.* R. K. MERTON, " The Unanticipated Consequences of Purposive Social Action," *American Sociological Review*, Vol. I (1936), 894-904.