Science in Context 3, 1 (1989), pp. 29–65

STEVEN J. HARRIS

Transposing the Merton Thesis: Apostolic Spirituality and the Establishment of the Jesuit Scientific Tradition

The Argument

Despite more than fifty years of debate on the Merton thesis, there have been few attempts to substantiate Merton's argument through empirically based comparative studies. This study of the Jesuit scientific tradition is intended to serve as a test of some of Merton's central claims.

Jesuit science is remarkable for its scope and longevity, and is distinguished by its markedly empirical and utilitarian orientation. In this paper I examine the ideological structure of the Society of Jesus and find at its core an "apostolic spirituality" that explains the legitimation of these forms of science within the Society. The values of apostolic spirituality (diligence, practicality, learning, etc.) strongly encouraged an activist mentality among Jesuits, which in turn led to the formation of apostolates in education, at court, and in the overseas missions. The values associated with apostolic spirituality led to the initial acceptance of active-empirical sciences within the Society, which became established as traditions because they were useful in fulfilling the goals of the Society's apostolates.

This study, by providing a qualified confirmation of Merton's central claims, suggests the importance of a supra-confessional sanctification of labor and learning in the growth of active-empirical sciences.

Introduction

In the fifty-odd years since its first publication, Robert Merton's *Science, Technology and Society in Seventeenth-Century England* has spawned a large and cantankerous collection of critical literature (Merton [1938] 1970, 266–72; Abraham 1983; Gieryn 1988; Shapin 1988). The result of nearly three decades of sustained critical attention is a list of commentaries, contentions, and glosses that runs to several score items (Cohen, forthcoming).

What I find curious about this literature is how little is devoted to extending Merton's historical research program.[1] The identification of a historically significant

[1] Morgan 1979, 1986 and Webster 1975 are the happy exceptions to this pattern.

group of actors, the elucidation of the scale of values uniting and motivating them, and the use of quantitative measures as indices of social and intellectual change compose the method that Merton employed in his study of seventeenth-century English Puritanism and science. Yet, despite the basic soundness of his method, his example has not been often followed. This is unfortunate, since studies conducted along similar lines and directed toward other religious groups could form the foundation for an illuminating comparative analysis.

Merton himself hints at – though does not pursue – the possibility of comparative studies in the preface to the 1970 edition of his work. Addressing those critics who he feels misunderstood the explanatory logic of his thesis, Merton claims that they wrongly attributed a necessary or causal role to the Puritan ethos in the legitimation of the "new science." Puritanism itself was neither a sufficient nor a strictly necessary condition for the rise of the new science, since "other functionally equivalent ideological movements could have served to provide the emerging science with widely acknowledged claims to legitimacy. . . . *As it happened,* Puritanism provided the major (not exclusive) support in that historical time and place. But that does not make it indispensable" (Merton 1970, xviii; Shapin 1988, 596). The necessary condition is instead an established set of values and social structures capable of granting legitimacy to a nascent science (Merton 1970, xviii). Although he does not pursue the matter further, the values and social structures of Merton's hypothetical "ideological movements" (what he also calls "conceivable functional alternatives") must in some way resemble those of the Puritan ethos. If we can find a coherent group of historical actors whose social values and structures resemble those of the Puritan ethos, and if we can show that these values worked to legitimize scientific activity within that group, we will then have a means of testing the Merton thesis and not merely criticizing it.

One of the most appropriate – if initially surprising – candidates for such a comparative study is the Society of Jesus. First of all, Jesuits were significant contributors to early modern science. Such an unusual – and perhaps unexpected – concentration of scientific activity in a manifestly religious organization would be reason enough to choose the Society as the object of our study. What makes it even more appealing, however, is that the Jesuits, as Catholic clerics and Continental Europeans, operated in doctrinal, cultural, and institutional settings quite remote from those of English Puritans. The historical distinctness of these two groups of scientifically inclined religious activists makes a study of Jesuit science one of the strongest possible tests of the Merton thesis.

With Merton's example in mind, I have employed quantitative methods to delineate the dominant patterns in Jesuit science and have examined a variety of primary and secondary sources concerning the social values and institutions of the Society. Relying mainly on Sommervogel's exhaustive bio-bibliography of Jesuit authors (1890–1910), I have compiled a two-part computer database. The first part contains detailed bibliographic information on the approximately 6000 titles in science written

by members of the Society from its foundation in 1540 until 1800.[2] The second part contains biographical information on the nearly 1600 authors represented in the first part. In order to get at the scale of values informing the Jesuit way of life, I have examined several of the normative documents of the Society. These include the seminal writings of Saint Ignatius of Loyola (founder of the Society), handbooks used in the ascetic and intellectual formation of Jesuit novices and scholastics, and several studies on daily life in the old Society (Ignatius 1955; Ignatius 1970; Stoeckius 1910, 1911, 1912, 1918, 1925).

This combined quantitative and documentary study yields a fairly detailed map of Jesuit involvement in early modern science and a picture of the religious values characteristic of the Jesuit mentalité. The contours of the map reinforce and extend the claims of several recent studies on Jesuit science; namely, that Jesuits were heavily engaged in the empirical and experimental aspects of early modern science while preserving (and transforming) traditional Aristotelian natural philosophy.[3] The Jesuits were members of a well-organized, hard-working, goal-oriented, closely disciplined, and elitist religious corporation dedicated to upholding the doctrines of the Counter-Reformation Church. If Jesuits like Clavius, Scheiner, Kircher, and Riccioli (to name but a few) found themselves deeply engaged in certain forms of early modern science (especially mathematics, optics, experimental philosophy, and observational astronomy), it was because they and their Jesuit superiors considered these forms of scientific practice to be legitimate and valued activities for members of the Society.[4]

How did these sciences achieve legitimacy? How did they become established as traditions in the Society? Of the several factors that might have been involved, I will argue that the most important was a set of values and institutional structures peculiar to the Society. Rivka Feldhay, in her pioneering work on Jesuit subculture, was the first to use the phrase "Jesuit ideology" to designate a network of religious values and goals (activity, practicality, education, intellectual elitism, etc.). She has argued for the importance of the Jesuit educational ideology in the Society's strategies for intellectual innovation and institutional legitimation within the Catholic church (Feldhay 1987). Moreover, her work suggests ways in which such values contributed to the development of Jesuit science.

While acknowledging the importance of her work and insights, I would like to modify the sense of the term "ideology" as she used it so it can encompass the many aspects of Jesuit life – the administrative, formative, disciplinary, and programmatic,

[2] Although the Society was suppressed throughout Europe in 1773 by papal decree, I have included biographical and bibliographical information to 1800 in order to examine how the falling away of the Society's institutional and disciplinary constraints affected publication and career patterns in the last generation of fully formed Jesuit scientists.

[3] See discussion of the works of Heilbron, Dear, Wallace, Jardine, Grant, Lohr, Feldhay, and Ashworth, below.

[4] Certainly for the first two hundred years of the Society's existence – and probably for its entire existence – one cannot speak of science as an autonomous cultural activity within the Society. Thus we may assume that the methods, practices, and goals of scientific activity within the Society were subservient to its religious program.

as well as the educational. In my formulation, "Jesuit ideology" means the set of overarching institutional structures that held the Society together as a living corporation of regular clerics. At its core Jesuit ideology consisted of a set of deeply held religious precepts and ideals that served to motivate much of Jesuit thought and action. These core-values included, in addition to those identified by Feldhay, universality, rationality, individuality, and adaptability. In the early Society, these ideals were part of what Saint Ignatius and his followers called "apostolic spirituality," or the spiritual values necessary for an active (apostolic) life in service to God. The forms of science that developed and thrived within the Society were those that resonated with the basic apostolic values of the Society and were useful in achieving the goals of its ideological program.

Clearly we cannot simply juxtapose Puritans and Jesuits and apply Merton's thesis to the latter as a sort of generic explanation capable of linking any set of religious values to every form of scientific activity. There are significant differences in cultural settings, institutional structures, and even in what we are trying to explain. Merton's main concern is to examine the influence of a set of widely held religious values (the Puritan ethos) on the legitimation of the "new science" as a cultural activity in English society as a whole. I, on the other hand, confine myself to the much more restricted task of explaining the legitimation of certain forms of early modern science *within the Society of Jesus only.* In this paper, I shall make no claims about the overall influence of Jesuit values on the acceptance of science – new or old – in Catholic culture at large. Nor am I claiming that Jesuit ideology was necessary for the rise of modern science.[5] Thus it would be both hasty and unwise simply to extract Merton's ideas from their English environment and transfer them wholesale to the Jesuit context. Before launching into an extended discussion of the Mertonian qualities of Jesuit science we need to examine Merton's ideas and methods critically, with an eye to modification and – if need be – rejection. For our purpose is not simply to transfer Merton's thesis to Catholicism, but to transpose his insights to a different key, a key suited to the Catholic subculture created by the Society of Jesus.

I shall begin with a brief critical review of some of the central methodological and theoretical elements of the Merton thesis. My purpose is not to vitiate Merton's thesis, but to illuminate the chief problems that have hindered a consensus in support of his thesis and to indicate alternative methods for the investigation of Jesuit science.

The Merton Thesis: Problems and Potentials

The first problem we must address is Merton's image of Catholicism and his attempts to use it as a foil for the Puritan ethos. In his discussion of the notion of "good works," Merton sets the sparkling dynamism of Calvinism against the black cloth of medieval Catholicism:

[5] In fact, Jesuit science distinguishes itself from the central accomplishments of the so-called Scientific Revolution in important ways, as anyone familiar with Jesuit opposition to Copernicanism, Galileo, and Cartesian natural philosophy would immediately recognize.

> Monastic limitations and an other-worldly orientation . . . were insuperable barriers to the utilization of the concept [of good works] 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. (Merton [1938] 1970, 58)

Similarly, when discussing the origin of seventeenth-century empiricism, Merton singles out the Calvinist understanding of good works – which, he again emphasizes, ought not to be confused with the very different Catholic notion – for special distinction (ibid., 108). As empirical support for these claims, Merton invokes data from late nineteenth-century Germany. He summarizes a series of tables showing correlations between religious affiliation and attendance at secondary schools in various German provinces and concludes that "the statistics point to a marked tendency for Protestants, as contrasted with Catholics, to pursue scientific and technical studies" (ibid., 130). As a statistical *coup de grâce,* he calls upon Alphonse de Candolle's study of foreign membership of the Paris Academy of Sciences and the Royal Society and interprets the relative paucity of Catholic academicians as further confirmation of the Puritanism-science linkage (ibid., 134–35).

The image of Catholicism one obtains from Merton's hasty sketch is not terribly flattering: whether retreating into medieval monasteries, shunning scientific education in nineteenth-century Germany, or discouraging would-be academicians, Catholicism as a cultural force emerges as poor patron of science. However, a bit of critical reflection suggests that Merton's treatment of Catholic culture is less than adequate – even for his limited purposes. The comparisons he presents lose considerable force because of their selectiveness and superficiality. We hear nothing, for example, about Catholic views on worldly service, good works, or clerical ideals from the most relevant period, namely, the seventeenth century. Nor do we hear anything at all about clerical involvement in seventeenth-century science. Apart from questions concerning the validity and relevance of comparisons involving such disparate times and places, one may ask how Merton justifies the implication that Catholicism can be treated as a monolithic culture. For surely there is sufficient evidence of Catholic factionalism, geographic diversity, and doctrinal controversy from the Middle Ages onward, to dispel any notion of a thoroughgoing uniformity or homogeneity in Catholic culture.

In the absence of a serious examination of the evidence from the "other side" of the confessional divide, it is not clear how seriously we should take Merton's implied thesis concerning Catholicism and science. Are we to assume that the medieval ideal of retirement from the world was the root, and the Catholic disinclination to pursue scientific vocations in the nineteenth century the branch, of a "Catholic ethos" that discouraged scientific activity in the early modern period? If it was the Calvinist practice of good works that encouraged empiricism, and if the Calvinist practice

distinguished itself so thoroughly from the Catholic, what ought we to conclude about the effects of Catholic values on the legitimation of science? It would seem that Merton's monograph contains an implicit counter-thesis concerning the neutral – or even negative – role of Catholicism in the growth of early modern science. But perhaps we do Merton an injustice by labeling his discussion of Catholicism a "counter-thesis." For it is certainly not well-developed and seems to serve primarily a rhetorical function; namely, as a foil for his exposition of Calvinist doctrine and Puritan sentiment. However, whether foil or thesis, his argument scarcely does justice to Catholic – and especially Jesuit – contributions to early modern science.

A second problem concerns the difficulty in defining "Puritanism" as a religious movement and identifying historical figures as "Puritans." Throughout the period under consideration, both "Puritan" and "Puritanism" were primarily terms of abuse and were thus used indiscriminately against religious activists of diverse persuasions. It is virtually impossible to apply them with absolute consistency to any individual actor or group.[6] Merton himself notes, perhaps somewhat coyly, that Puritanism is a "word of many shades." Wishing to circumvent the problems associated with attempts to delimit Puritanism in terms of doctrine and ecclesiology, he defines the movement not as "the logical implications of a system of theology" but as a "common attitude of mind and mode of life" and as a set of religious "sentiments and values [that] permeates the thought and action of believers" (Merton [1938] 1970, 57, 60). Although Merton does an admirable job characterizing the values and attitudes of the Puritan ethos, the fact remains that participation in a state of mind and way of life is a very difficult thing to establish.

Perhaps nothing illustrates the problem of identification better than the various and ultimately disappointing attempts to count Puritan noses in the Royal Society. Although quantitative methods form an important part of Merton's study, he offers no detailed tallies of Puritan scientists – neither within the Royal Society nor without – and confines himself to a qualitative discussion of "the Puritan elements" in the Royal Society (ibid., 112). Others, however, have since rushed in where Merton feared to tread. They have arrived at figures ranging from fewer than five to many times this number (ibid., xxiv). It is, of course, a most onerous task for a historian to try to establish membership in a group that possessed neither an explicit institutional structure nor an unambiguous test of adherence to group values. Thus we ought not be too surprised at the disparate results of such nose-counts; nor should we place too great confidence in any of them, since such tallies are informative only if one knows what one is counting.[7]

[6] In his 1986 study of English Puritanism, John Morgan devotes an entire chapter to the problem of definition (Chap. 1). Nicholas Tyacke's arguments, however, have been especially damaging to the attempt to establish an unambiguous definition of Puritanism (1973, 1978).

[7] Abraham warns us that "in Merton's thesis Puritanism should not be understood as a particular doctrine whose effect on science can be gauged by the number of scientists who were also Puritans, or by a change in the internal content of science" (1983, 372–73). However skillfully one might argue the subtleties of the sociological theory underlying the Merton thesis, it seems obvious that if Puritan values helped legitimize the practices of the "new science," then one ought to see such practices among those who adhered to those values. Otherwise we are faced with the odd challenge of trying to explain why Puritans

I do not think it unfair to say that Merton has managed to construct a thesis based on a set of disembodied, if coherent, social values guiding the thought and action of a group of unidentified, though historically significant, actors. The inability to anchor the Puritan ethos to the "concrete historical movement" he seeks does not necessarily vitiate his characterization of the Puritan mentality, nor destroy the postulated parallels between Puritan values and the new science. It does, however, severely limit the options Merton has to pursue his argument further. If the Puritan commitments of a given historical figure cannot be convincingly demonstrated, it is difficult to imagine how one can offer compelling evidence of the consequences these commitments had on that person's interest in, and contribution to, science. And if this cannot be established for the individual Puritan, then certainly the scientific interests and contributions of Puritans as a group cannot be convincingly established either. What Merton has given us is, as Lawrence Stone has pointed out, a "statistically based group biography, rather than a group portrait pieced together from a series of case studies" (1971, 51). This is because Merton does not have a self-consistent collection of Puritan biographies from which to assemble such a group portrait. He must rest content with a generalized description of the "Puritan ethos" and forgo a rigorous Puritan prosopography.

The problem of identification leads immediately to a criticism of the quantitative components of Merton's study. In order to establish broad-scale shifts in cultural interest, Merton indexed the career-choices of the approximately six thousand English men and women of the seventeenth century whose lives are recorded in the *Dictionary of National Biography.*[8] Seeking to corroborate these results with evidence from an independent source, he then tallied the scientific discoveries and inventions by seventeenth-century Englishmen. Each English invention and discovery is taken to be a unit of "scientific output" and thus a correlate of interest in science (Merton [1938] 1970, 39). Finally, in order to establish the distribution of interest within science, Merton classified some two thousand papers published in the *Philosophical Transactions.*[9]

As valuable as these studies are, each component of Merton's quantitative study is essentially a single-source, single-parameter tally independent of the others; none of them rests on any primary material or on a sufficiently broad mixture of secondary sources. More seriously, the components do not interconnect in significant ways; consequently they lack both depth and integration.[10] One would like to know how

did not practice the sort of science their values helped legitimize. If the Merton thesis is to be compelling, there must be a demonstrated correlation between being Puritan and practicing science.

[8] The assumption is that career-choice accurately reflects social values and that a relative increase in the number of persons choosing careers in science may be taken as a measure of the social acceptability of scientific activity as a vocation. Merton is thus able to identify the 1640s and 1650s as the pivotal decades for the growth of interest in science ([1938] 1970, 8–13).

[9] The number of papers in each category, reduced to a percentage of all papers for that year, is taken as "index of interest" in that particular branch of science (Merton [1938] 1970, 45–54).

[10] In fairness to Merton's achievement, it must be noted that these weaknesses are surely the result of practical limitations. When we consider that Merton's tallies were performed without the services of IBM, his statistical labors assume truly herculean dimensions.

vocations, inventions, and publications connect to one another and to historical figures. For example, of the six thousand biographies, how many were of Puritans? And, among Puritans, who chose careers in science? Among the six thousand, who made the discoveries and inventions listed in Darmstaedter? Who contributed articles to the *Philosophical Transactions?* Who witnessed or took part in the experiments and demonstrations performed during meetings of the Royal Society? That is, one would like to see the biographical statistics become more detailed, the bibliographic data less anonymous, and both biography and bibliography united as a single, integrated prosopography.[11] For prosopography, as the method most appropriate for a systematic study of the general character of a collectivity, would be the best means of establishing the correlation that Merton sought between Puritan religious values and involvement in the "new science."[12]

The fourth criticism of the Merton thesis concerns its dual nature, one part treating religious values and the other economic utility (Merton 1970, xi–xiv; xix). He presents his investigation of seventeenth-century English science and society as a case study of how religious and social values helped direct cultural interest toward scientific activity. Yet he also wishes to consider fluctuations in interest within science and suggests that such intra-scientific shifts may also be due, in part, to sociological factors (ibid., 38–43). By dividing the problem into two parts, Merton has, in effect, set himself two distinct sociological tasks. One leads him to his famous exposition of the "Puritan ethos" and the other to his less-famous discussion of the influence of economic and military needs on problem choice within the various branches of science and technology.[13]

What is disturbing about the dual nature of the Merton thesis is not so much the eclectic joining of "idealistic" and "materialistic" interpretations of cultural activity but the strict division of labor between the two sociological explanations. The Puritan ethos, after having established the acceptability of science as a cultural activity, is not permitted to have any significant role in the distribution of interest within science; this is reserved for economic and military needs.[14] Conversely, economic and military desiderata are not presented as having contributed significantly to the general shift of

[11] Pyenson notes that "one would not underrate the significance of Merton's pioneering effort to note that the statistics he introduced to illustrate the practical and military orientation of mid–seventeenth-century English science remain as suggestive, but as unconvincing, as his incomplete prosopography" (1977, 166).

[12] Concerning the potential of prosopography in historical research, Lawrence Stone asserts that it is a method well suited to reconciling "history to sociology and psychology [and it] could [help] to tie . . . intellectual and cultural history down to the social, economic, and political bedrock" (1971, 73).

[13] Merton himself complains of the unequal share of critical attention the two parts of his thesis have received. He estimates that "nine of every ten discussions of the book . . . have centered on just one part, the one dealing with the interrelations between Puritanism and the institutionalization of science" even though both parts received approximately equal space in his monograph (1970, xi–xiii). As understandable as Merton's consternation over the neglect of his "other" thesis may be, the fact that critics have consistently treated one part independently of the other only underscores their fundamental distinctness.

[14] In making the transition from one thesis to the other, Merton observes that "if this congeniality of the Puritan and the scientific temper partly explains the increased tempo of scientific activity during the later seventeenth century, by no means does it account for the particular foci of scientific and technological investigation" ([1938] 1970, 137).

cultural interest toward science. This strict separation of the social process of legitimation from that of problem choice, though perhaps analytically useful, is somewhat artificial. Surely one encourages work in a particular area of science by deeming it legitimate, and necessarily grants a particular problem some measure of legitimacy by choosing to work on it.

The fifth and final criticism concerns Merton's notion of ethos. The Puritan ethos functions as a sort of cultural patron of the new science; it acknowledges that diligence and utility are an important part of scientific activity and grants the new empirically grounded science a measure of cultural approbation. The notion of ethos carries the main burden of explanation for the cultural legitimation of the "new science." Hence we need to know what an "ethos" is and how it functions as a social entity – or at least we need to understand how Merton wants it to function in his explanatory scheme. It seems that both the strengths and limitations of the theoretical underpinnings of Merton's thesis can be brought into contrast by casting the Puritan ethos as an example of what Clifford Geertz has called strain theory.[15]

According to Geertz, strain theory envisions an ideological movement as a response to, and an effort to correct, chronic sociopsychological dysfunction. A movement is triggered by widespread maladjustment to existing social structures; it arises in the flight from anxiety and strives to alleviate the social and psychological strain (1964, 55). Merton's portrayal of the dynamics that propelled Puritans into a life of good works rests largely on the presuppositions of strain theory. Following Weber, he argues that the Calvinist position on predestination teaches that "God grants salvation to some purely of his own free will, irrespective of the faith or virtues of the elect" (Merton [1938] 1970, 62). The anxiety arising from not knowing whether one was among the elect made it a "psychological imperative" to find an indication or sign of one's status in God's eyes. The psychological strain was relieved through the agency of "good works," since these came to be seen as the "outward signs of an inward state of grace." Moreover, "good works" were understood to mean "achievements which are useful and profitable in the worldly sense"; i.e., works of social utility or that lead to success in one's vocation (ibid., 62–64). If Puritan minds wracked by spiritual uncertainty could construe success in mundane activities as evidence of salvation, they were certain to value diligence and industry in their daily labor. The scale of values associated with the Puritan ideology, by directing activity into channels deemed pleasing to God, helped alleviate the psychological strain induced by not knowing whether one was numbered among the elect. And, Merton argues repeatedly, science became one of those blessed activities.

> Scientific investigation, viewed from the rationalized Puritan system of ethics, seemed to possess those qualities characteristic of activities which were effective means for the attainment of accepted goals. . . . Science embodies patterns of behavior which are congenial to Puritan tastes. Above all, it embraces two highly

[15] Although Geertz himself does not specifically direct his criticism toward Merton, his analysis can be easily applied to the Puritan half of Merton's thesis (1964, 47–76).

> prized values: utilitarianism and empiricism. . . . [Moreover,] the puritan insistence upon empiricism, upon the experimental approach, was intimately connected with the identification of contemplation with idleness, of the expenditure of physical energy and handling of material objects with industry. Experiment was the scientific expression of the practical, active and methodical bent of the Puritan (ibid., 79, 90, 93).

What is crucial here is not so much the logic of Merton's strain-theory explanation but his admission that the legitimation of science was an *inadvertent consequence* of the Puritan movement. Merton boldly acknowledges that his thesis "proposed that Puritanism inadvertently contributed to the legitimacy of science as an emerging social institution" (1970, xvi). He notes with irony the secularizing influence of a scientific movement the seeds of which (he argues) were watered by unsuspecting Reformers ([1938] 1970, 79, 101). Certainly part of the fascination with the notion of "unintended consequences" is its familiarity; we often try to "explain" such quirks in our personal experience by appealing to serendipity (Merton 1936). However, a historical thesis that invokes such a notion as a fundamental component of an explanatory scheme runs the risk of merely labeling what it cannot explain.

The problem of unintended consequences encountered in Merton's argument is representative of one of the chief weaknesses of strain theory. Geertz characterizes this weakness in the following way:

> A pattern of behavior shaped by a certain set of forces turns out, by a plausible but nevertheless mysterious coincidence, to serve ends but tenuously related to those forces. A group of primitives sets out, in all honesty, to pray for rain and ends up by strengthening its social solidarity; a ward politician sets out to get or remain near the trough and ends by mediating between unassimilated immigrant groups and an impersonal government bureaucracy. (1964, 56)

The central problem, Geertz maintains, is that strain theory rests content with parallels instead of connections.

Unfortunately, the relationship adduced by Merton between the Puritan ethos and the new science follows just such a pattern. The anxiety-induced ethos of hard work and good works leads to – but does not cause – consequences quite out of line with original intentions. Thus, to Geertz' examples we might add: "A member of a Protestant sect sets out, in God-fearing earnestness, to work diligently to assure himself of his own salvation and ends by legitimizing empirical science and assisting in its institutionalization."[16]

Most of the above criticisms can be reduced to two basic "flaws" in Merton's study. First, he attempted to fit his sociological analysis to a highly nebulous group whose membership and institutional structure can neither be convincingly demonstrated

[16] The usual means employed by strain theorists to circumvent this problem – and Merton is no exception – is to invoke the notion of "latent function," i.e., the idea that ideological movements carry with them unintended consequences. But, again, this seems to do no more than label, not explain, it (see Merton 1936).

nor clearly demarcated. Second, he chose to rely on a strain-theory model of social action, which limits the explanatory power of his thesis. Puritanism was neither a sufficient nor strictly necessary condition for the rise of the new science, and the admittedly indirect effects of the former on the latter (legitimation, etc.) were wholly unintended. Although the idea of "sympathetic resonance" between Puritan values (diligence, utility, esteem for learning, etc.) and the active-empirical-utilitarian orientation of the new science is both intriguing and quite plausible, it cannot turn parallels into connections.

These criticisms are not meant to demolish Merton's edifice but to examine its theoretical and methodological components so that we can transpose some of them to the Jesuit context. From Merton's study we may take his basic questions about the impact of deeply held religious values on the encouragement (or discouragement) of scientific activity. We ought to be alert to the specific values he has tried to deduce from Calvinist doctrine and the Puritan ethos, and we should refine and extend his use of quantitative methods as measures of scientific involvement. By choosing the Society of Jesus as the subject of our study, the problem of defining the group and its membership almost takes care of itself. Finally, we must avoid the pitfalls of strain theory, by discarding the notion of ethos altogether and relying upon the broader and more powerful concept of ideology. By doing so, I hope to replace parallels with connections and unintended consequences with deliberate strategies.

A Prosopography of Jesuits Active in Science

Among the factors that facilitate a prosopography of Jesuit science, the most important is that there is very little ambiguity about the institutional and administrative organization of the Society of Jesus or about the identity of its members. What is more, the formative and disciplinary structures of the Society helped enforce a high level of group coherence and loyalty. The Society was a legally recognized and formally constituted religious corporation, with a clearly delineated administrative apparatus. Membership in the Society was explicit and, at the discretion of Jesuit superiors, reversible.

Candidates for admission to the Society had to undergo a long and stringent period of ascetic and intellectual formation, during which time the ideals, values, customs, and goals of the Society were systematically inculcated into them.[17] Jesuit masters-of-novices and teachers kept a close eye on their charges for signs of deviation from Jesuit norms of conduct or for the slightest evidence of willfulness or disobedience (Stoeckius 1918, passim). Moreover, the hierarchical structure of the Society concentrated an unusual amount of authority in the hands of a comparatively small number

[17] The Jesuit "novitiate" lasted two years (twice as long as in any other religious order) and was intended to introduce the candidate to the Society's rules and discipline and to test his aptitude for the Jesuit way of life. For those applicants destined for the priesthood, the novitiate was followed by several years of academic training typically at one of the Society's colleges. After the satisfactory completion of his theological training the candidate, who was still not officially a member of the Society, underwent ordination as priest and a third year of the novitiate, called the "tertianship." Only then was the candidate formally accepted into the Society (see Knowles 1966, 61–68; Evennett 1968, 78–80).

of leaders. Thus Jesuit superiors had at their disposal highly effective means for enforcing discipline: e.g., censorship, reprimand, demotion (or the refusal of timely promotion), "internal exile" (i.e., the transfer of wayward members to remote missions), and expulsion (Knowles 1966, 64–65; Evennett 1968, 81–83). Given such mechanisms of formation and discipline, we may confidently postulate a strong correlation between membership in the Society and commitment to its spiritual and worldly goals. This does not mean that membership in the Society automatically guaranteed either uniformity of beliefs or conformity of opinion – as every Jesuit general from Ignatius onward has known, Jesuits have not always been of one mind. But when we compare these institutions with those of Puritanism (whatever they might have been), we may certainly assume a greater degree of consensus and solidarity among Jesuits than could have obtained among seventeenth-century English Puritans.

These institutional facts of Jesuit life mean that the identification of Jesuits is a trivial matter. Of central interest, however, are the biographical details and literary accomplishments of those Jesuits who were active participants in the science of the day. Fortunately, the modern Society's enduring awareness of the importance of its own past has rendered the construction of a prosopography of Jesuit scientists a relatively straightforward task.[18] Drawing on Sommervogel and other sources, we can determine who were the most productive authors in Jesuit science, what they wrote, when they published, and where they worked. We can begin to assess the range of scientific topics treated by Jesuit authors, the central traditions of Jesuit science (i.e., the main genres of the Society's scientific publications), and the shifts in scientific interest over time.

Without a doubt, the most striking aspect of Jesuit science is the sheer magnitude of its literary output. Between 1600 and 1773 (the year of the Society's general suppression) Jesuit authors wrote more than 4000 published works, 600 journal articles (almost all of which appeared after 1700), and 1000 manuscripts. Thus the Society's known scientific corpus consists of nearly 6000 original works, in fields ranging from Aristotelian natural philosophy to astronomy, mathematics (including "mixed" mathematics), physics (experimental philosophy), natural history, medicine, and engineering. The first four categories constitute the dominant traditions of Jesuit science and account for approximately 80 percent of the total number of original works.

Some 1600 Jesuits contributed at least one item to this corpus. However, fully half of the total literary output came from just 200 authors, each of whom wrote seven scientific items or more. If we ask who these authors were and what were their duties

[18] The analytic tables compiled by Rivière (Sommervogel 1890–1910, vol. 12) provide a topical classification of every publication and manuscript recorded in Sommervogel. This allows for the assembly of a complete list of Jesuit publications (including journal articles, editions, and translations) and manuscripts treating scientific topics. When these data are coupled with the biographical information Sommervogel provides and augmented with information drawn from a variety of other Jesuit sources, one obtains a remarkably complete image of the Jesuit scientific corpus. And of course the relative completeness of this bio-bibliographic information is a tribute to the excellent state of the Society's historical record.

in the Society, we find an unambiguous pattern: the vast majority were Jesuit educators. Thus the institutional base of Jesuit science was unquestionably the Jesuit college and university. This basic fact of Jesuit science is highlighted by the following figures: on the eve of the Society's suppression Jesuits occupied more than eighty-five chairs in mathematics, oversaw more than a dozen physical cabinets (most of which were established in conjunction with chairs in experimental physics), and operated a total of twenty-five teaching observatories, most of them founded and funded by the Society (Fischer 1978, 1980, 1983a, 1983b; Fischer et al. 1983; Sommervogel 1890–1910, passim).

These numbers provide a reliable measure of the Society's intellectual, institutional, and material commitment to scientific activity. Preliminary studies of the literary output of contemporary Catholic religious orders suggest that the Jesuits produced more scientific writings than all the other orders combined.[19] Although the astronomical observatories at Greenwich and Paris were superior to the best of the Jesuit installations, no other organization of the day – including the Royal Society and the Paris Academy of Science – could lay claim to a more extensive network of permanent observers. Thus, it is abundantly clear that Puritans and their Protestant kin were not the only religiously motivated individuals who participated in the scientific culture of early modern Europe.

The quantifiable dimensions of Jesuit science do not, of course, necessarily provide a reliable means of assessing its quality. It is only in the last ten years or so that the efforts of a small group of scholars have revealed how high that quality was (e.g., Heilbron 1979, Dear 1987, Wallace 1984, Jardine 1979, Grant 1984, Lohr 1976, Feldhay 1987, Ashworth 1986).

Despite the great value of these efforts, I fear we have only just begun to grasp the range and significance of Jesuit involvement in early modern science. The most telling indication of the inadequacy of our knowledge is the dearth of research on eighteenth-century Jesuit science. With the exception of a few studies on Roger Boscovich, very little has been done in recent years to expand our knowledge of Jesuit involvement in science in the hundred years after 1680. Ashworth's claim that by the end of the seventeenth century Jesuit science had become "irretrievably isolated from the main currents of the scientific revolution" has remained both unproven and unchallenged simply because we know so little about what happened to Jesuit science "after the revolution" (Ashworth 1986, 160).

The following tally of Jesuit publications (figs. 1, 2, 3, 4), arranged and graphed chronologically from 1560 to 1800,[20] suggests that the matter of eighteenth-century Jesuit science is worth pursuing. Although there are many features to attract our attention (e.g., the explosive initial growth after 1580, or the near total domination

[19] Tallies of members of religious orders who appear as entries in Lohr 1988, Gillispie 1970, and Poggendorff 1863 indicate that for the period 1550–1775 Jesuits account for more than half of the total number of clerical entries. Throughout this period, the Society ranked as the fourth or fifth largest order, far behind the Franciscan and Dominican orders.

[20] Very few works that could be classified as scientific appeared before 1560.

of the scientific literature by Aristotelian categories until about 1640), I wish to mention only the most obvious – namely, the astounding increase in total numbers of publications after about 1720. Following the general decrease for all scientific categories between 1680 and 1700,[21] there was a dramatic and sustained growth in the number of publications in all the traditional genres of Jesuit science, which lasted until 1773. This "boom" is remarkable not only for the sheer numbers but also for the increased variety of topics treated.[22] This remarkable growth resulted primarily from an increase in productivity per author rather than from an increase in the number of Jesuits contributing one or two scientific publications each. Whatever reasons we may find to explain this explosion in scientific literature, and whatever qualitative judgments we may eventually attach to it, it seems safe to say that the last fifty years of the Society's existence was marked by a deliberate, vigorous, and sustained revival of the Jesuit scientific tradition.

What were the enduring qualities of Jesuit science? The first and most obvious feature is that it was in fact a tradition. Despite fluctuations in annual output and shifts of interest, Jesuit scholars produced an uninterrupted stream of commentaries, treatises, textbooks, cursus, disputations, opuscules, articles, and manuscripts on a broad range of scientific topics for more than two hundred years. Second, the main genres of Jesuit scientific writings fall fairly neatly into six or seven general categories: (1) commentaries, disputations, and lecture notes on the natural philosophical books of the Aristotelian corpus; (2) textbooks and treatises on Euclidian geometry and "mixed" mathematics;[23] (3) treatises, opuscules, and (in the eighteenth century) journal articles on observational astronomy; (4) a variety of largely academic publications on experimental and natural philosophy; (5) a miscellany of publications (including many published "letters" and articles in learned journals) in natural history (often on the flora, fauna, and geography of foreign lands); and (6) a small and irregular collection of treatises on medical and pharmaceutical topics.

As a third and final characterization, we may note that, like the mathematics at which Jesuits excelled, their tradition in science as a whole was "mixed." The collective Jesuit achievement in science cannot be easily categorized and many seemingly coherent labels fail to stick when applied to the Jesuit tradition. If Jesuit astronomers are to be labeled "scholastic" because of their opposition to Copernicanism (Grant 1984), then we must first acknowledge the profound changes Jesuit

[21] This quantitative decline would seem to correspond to the late seventeenth-century qualitative decline Ashworth refers to (1986).

[22] In total numbers, there were fully twice as many scientific works published in the eighteenth century as in the sixteenth and seventeenth centuries combined. Of course some of this increase is due to the creation of the scientific journal article (Jesuits wrote about six hundred scientific articles, 90 percent of which appeared in the eighteenth century) and the fact that publication was probably easier in the eighteenth century than in the sixteenth and seventeenth. Neither of these considerations, however, mitigate the basic fact of a "boom" in Jesuit science.

[23] "Mixed" mathematics covers a number of practical sciences that require the application of mathematical principles to problems and tasks in the real world, and includes surveying, navigation, mechanics, instrument making, military and civil architecture, and hydraulic engineering. It is "mixed" because the abstract categories of mathematical thought are mixed with the countable and measurable properties of the real world.

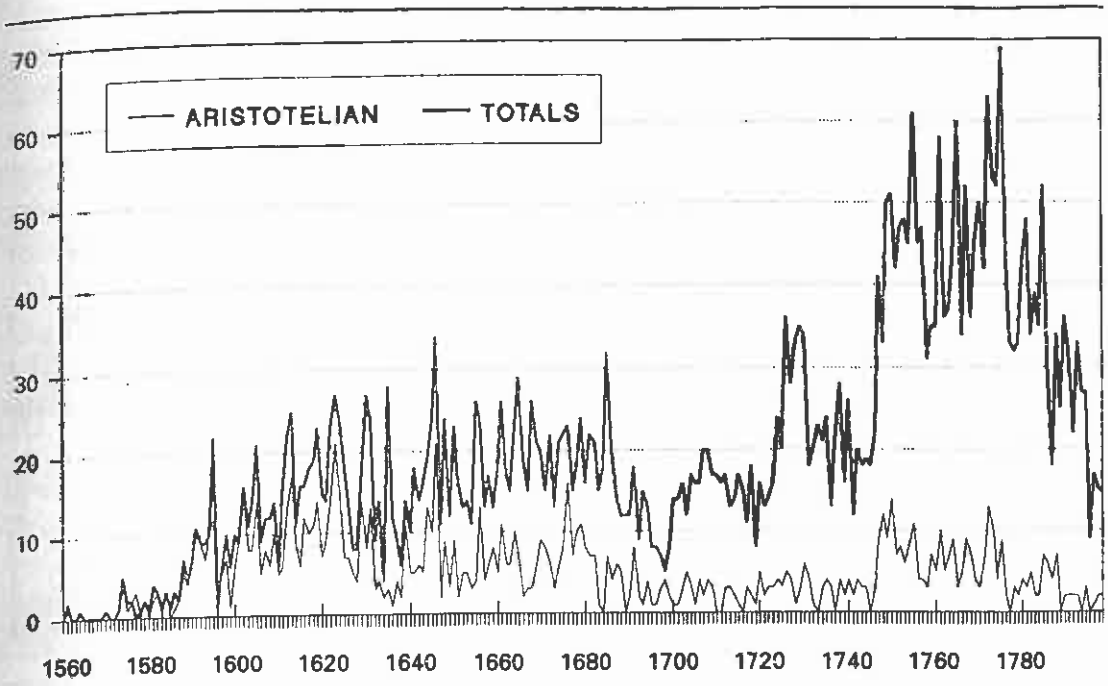

Figure 1. Jesuit publications and manuscripts in science, 1560–1800 – by topic. (Thin line: Aristotelian; heavy line: totals.)

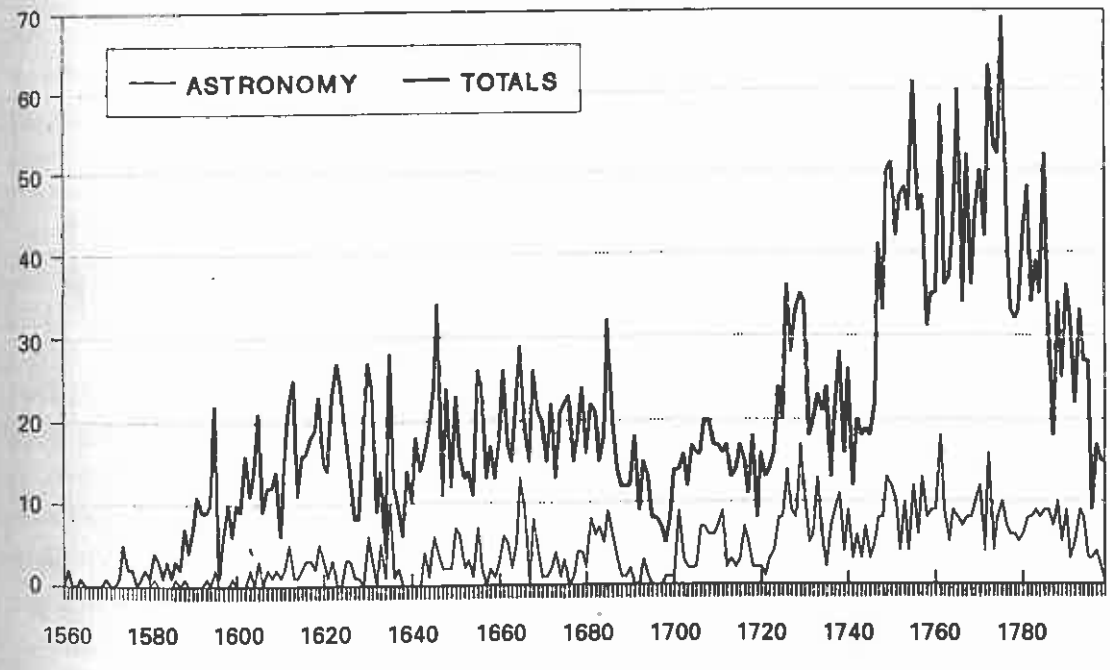

Figure 2. Jesuit publications and manuscripts in science, 1560–1800 – by topic. (Thin line: astronomy; heavy line: totals.)

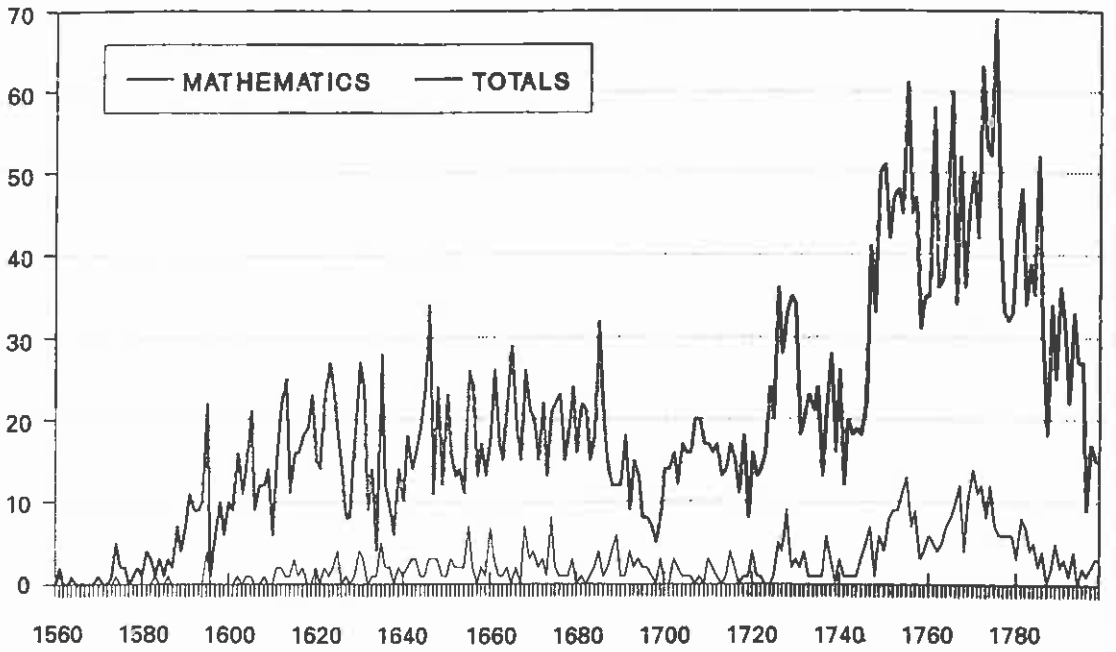

Figure 3. Jesuit publications and manuscripts in science, 1560–1800 – by topic. (Thin line: mathematics; heavy line: totals.)

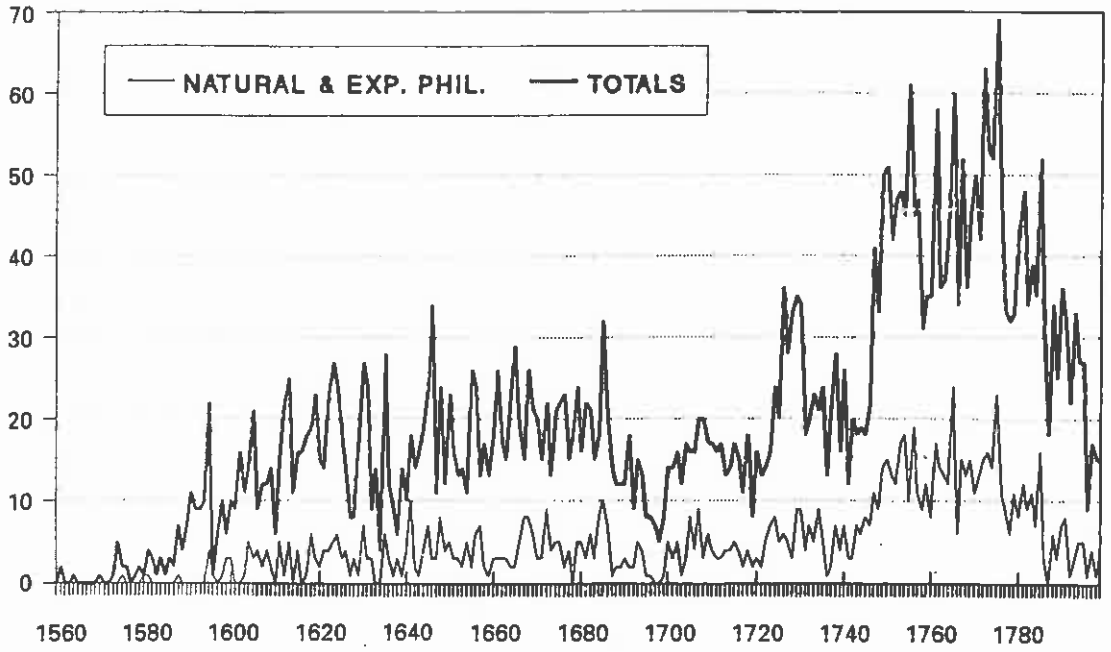

Figure 4. Jesuit publications and manuscripts in science, 1560–1800 – by topic. (Thin line: natural and experimental philosophy; heavy line: totals.)

scholars wrought upon Aristotelianism (Lohr 1976, Wallace 1984). If we consider Kuhn's "classical" and "Baconian" labels, we are forced to apply both since the Jesuits' pedagogical exposition of Aristotelian natural philosophy and Euclidian geometry was scarcely separable from their empirical explorations of electrical, magnetic, optical, and mechanical phenomena and their mastery of mixed mathematics.[24]

The foregoing characterization of Jesuit science raises a host of questions about the "fine structure" of career-patterns, publications, and institutions. However, I wish to focus only on what I believe to be the two most fundamental problems; namely, the initial acceptance of scientific activity as a legitimate activity within the Society and the subsequent institutionalization of certain forms of science as traditions. The former concerns the attention Jesuits preferentially directed toward "classical" and "Baconian" sciences and the latter the expansion and longevity of Jesuit science. I wish to argue that both legitimation and institutionalization can be understood in terms of the central religious values animating Jesuit ideology. To this end I must first explain what I mean by "ideology."

Ideology: Theory and Application

In essence, an ideology is a more or less coherent body of values, ideals, beliefs, and goals capable of evoking deep sentiment in its adherents and propelling them to concerted action.[25] It arises from a spirit of alienation and a belief that the world is in need of reform. An ideology typically crystallizes around a charismatic leader possessing – or possessed by – a powerful, simplified, and expansive vision of an improved world. The ideological vision tends to center around a few ultimate principles or eternal truths and often has a transcendent reference. Adherents develop a deep sense of commitment to the ideological movement since they perceive themselves to be in contact with supra-personal forces. This perception, in turn, functions as a powerful psychological motivation to action, since adherents believe that they neither act alone nor solely for themselves, but together and toward universal or historic ends. Thus a deeply personal sense of meaning and purpose are the rewards of ideological involvement. Although driven by psychological needs, an ideology is essentially a social phenomenon and is always associated with a collectivity; it therefore assumes some form of corporate or institutional embodiment. Admission and initiation into the ideological group carries with it a strong sense of corporate identity and demands a high level of solidarity, consensus, and obedience. Ideological values are explicit, authoritative, and totalistic; and their systematic inculcation is of central importance for the continued existence of the movement. Moreover, an ideology requires of its adherents a life of action: it channels their

[24] In addition to the works by Heilbron, Dear, and Ashworth cited above, see also Koyré 1955 and Renaldo 1976.

[25] The literature on ideology is enormous; and I have relied chiefly on Bell 1960, 393–407; Shils 1961, 66–76; Geertz 1964; and Kelley 1981, 1–7.

collective energies into an explicit program of reform and enjoins them to work fervently toward the realization of corporate, rather than personal, goals.[26] The programmatic thrust of an ideology and its need to perpetuate itself compel adherents to carry the ideological message to the general public and to win recruits (i.e., to preach and proselytize). Finally, leadership within an ideology is typically in the hands of an intellectual elite.

The appropriateness of "ideology" as a model for the Society is, I believe, self-evident. Ignatius' vision of an elite corps dedicated to the reform program of the Church Militant, was both the foundation of the Society's institutional organization and the secret of his ability to extract the utmost dedication and commitment from his followers. The long and exacting period of ascetic and intellectual formation served, among other things, to inculcate the values and ideals of Jesuit ideology. And the Society certainly had an explicit and urgent program. Even on the question of leadership, the Society fits the ideological model quite well, since it possessed an extremely hierarchical governing structure that concentrated power in an inner core of "professed" Jesuits.[27]

However important these idealistic, sociological, and administrative elements may be for understanding the ideological character of Jesuit activity, there are two elements that, for our purposes, stand above the rest; namely, the central values animating the Society and the programs into which Jesuit intellectual energies were directed. That is, we need to know how Jesuit ideological values impinged upon the world of Jesuit ideas and specifically upon the selection and production of scientific knowledge. We also need to examine how the Jesuit ideological program affected the establishment of traditions in Jesuit science.[28]

It is not difficult to imagine how ideological values perform normative functions for social conduct within an ideological group – this is essentially the function Merton asks the "Puritan ethos" to perform among seventeenth-century English Puritans. But how do ideological values affect the world of ideas? Quite directly. The totalistic pretensions of an ideology enable it to claim jurisdiction over intellectual activity,

[26] Bell emphasizes that "ideology is the conversion of ideas into social levers. . . . It is the commitment to the consequences of ideas. . . . For the ideologue, truth arises in action, and meaning is given to experience by the 'transforming moment.' He comes alive not in contemplation, but in 'the deed'" (Bell 1960, 400).

[27] One of Ignatius' most controversial innovations was the introduction of grades into religious life. Fully formed members (i.e., those who had completed the period of formation and probation and who had been fully accepted into the Society) were divided into three groups; "temporal coadjutors," "spiritual coadjutors," and "professed of the fourth vow." The first group, also called "lay brothers," were neither priests nor, as a rule, educated. They served as cooks, gardeners, secretaries, apothecaries, etc., and their purpose was to take care of the mundane affairs of the Society. Spiritual coadjutors and professed were ordained priests and received advanced training in theology, though the latter studied longer than the former. The "fourth vow" of the professed was another of Ignatius' innovations. It was a special vow (in addition to the three traditional vows of poverty, obedience, and chastity) of obedience to the Pope. Participation in the General Congregation (the Society's legislative body responsible for amending the *Constitutions* and electing a new general) and the highest offices of the Society were open only to the professed (Knowles 1966, 63–64).

[28] I do not wish to imply that ideological values were the only factors that counted in the formation of the Jesuit scientific tradition. Rather, I mean only that these factors are my chief concern in this paper.

since ideas can incorporate and give expression to ideological values. Moreover, certain ideas are useful in propagating the message and achieving the goals of the ideological program, while others are not. The programmatic use of ideas thus requires coherent standards for the evaluation of "legitimate" knowledge; i.e., knowledge resonant with the spirit and purpose of the ideological movement. Just as a group's shared scale of ideological values serves as a guide to behavior by sanctioning certain modes of conduct and censuring others, those same values can serve as a guide to thought by sanctioning certain modes of intellectual activity and disallowing others. That is, an ideology entails an "image of knowledge" in the sense developed by Yehuda Elkana (1981, 13–21; Elkana forthcoming, 6–8).[29] An image of knowledge is a more or less explicit expression of group consensus on matters relating to "acceptable" or "permissible" knowledge. It provides the criteria for evaluating the sources, methods of acquisition, division and organization (or hierarchical ranking), and purposes of knowledge. The image of knowledge characteristic of a particular ideological movement guides the selection of ideas from the body of existing knowledge and, just as importantly, sanctions acceptable modes for the genesis of new knowledge. Moreover, the decision to incorporate a particular idea, interpretation, method, or theory into the group's canon of legitimate knowledge is, as Elkana emphasizes, essentially a social phenomenon: it is the outcome of a consensus established among acknowledged authorities within the group. An image of knowledge may be thought of as a "cognitive lens" that focuses and filters the intellectual energy of the members of an ideological group; it is what mediates between ideological values and intellectual activity.

Feldhay's pioneering work on the sociological and institutional conditions of Jesuit subculture can help us relate Elkana's model to the concrete structures of the Society of Jesus. In her exploration of the implications of what she calls the "Jesuit educational ideology," Feldhay frames a series of questions that strike at the heart of the problem of the emergence of Jesuit science: "On the intellectual level one may ask whether [the Jesuit educational] ideology entailed any specific attitudes towards the contents of knowledge? Did it influence the preference for certain intellectual activities over others? Could it give birth to new images of knowledge?" (1985, 5a).[30] She argues that "the practical orientation of the Jesuit cultural milieu enabled Jesuit scientists . . . to modify . . . traditional images of knowledge" (Feldhay 1987, 195) and that this orientation helps explain "the move to new directions of intellectual interest [especially toward] . . . practical mathematics and the 'mixed sciences'" (Feldhay 1985, 6). Finally, she examines the consequences of this new image of

[29] My introduction to the notion of "image of knowledge" came through a series of lectures given by Professor Elkana at the Ludwig-Maximilian Universität in Munich in the summer of 1986. I wish to express my thanks for the criticism he then offered of my initial efforts to apply his ideas to Jesuit science and for a typescript of his paper "The Scientific Revolution as a Revolution in Reflexivity."

[30] I wish to thank Dr. Feldhay for her kindness and generosity in making this paper available to me in manuscript form. These are, quite obviously, the questions I wish to address, and though my answers may differ from hers, I gratefully acknowledge the important influence her ideas have had on the development of my own line of thinking.

knowledge in the astronomy-cosmology-mathematics nexus of sciences that became a central part of the Jesuit scientific tradition and concludes that Clavius was the chief proponent of the view that hypothetical (i.e., mathematical and astronomical) entities could be the objects of certain knowledge and, consequently, that the mixed mathematical sciences ought to be accorded the same epistemological status as speculative branches of knowledge (Feldhay 1987, 210).

I would like to build on Feldhay's foundation by expanding the notion of ideology to cover more than just the Jesuit educational program, developing the value-structure of the Society, and exploring further the institutional ramifications of the Jesuit image of knowledge.[31] I will argue that the Jesuit image of knowledge encouraged a strongly active-empirical bent in all branches of Jesuit science and that this empirical orientation thrived alongside the Jesuits' enduring adherence to classical authorities (especially Aristotle and Euclid). For it was this particular mixture of "classical" and "Baconian" sciences that was most compatible with the spirit and purpose of the Society. These were the forms of early modern science that received the approbation and positive encouragement of the Jesuit leadership. The most important criterion for the initial emergence of these sciences was affinity with the ideals and values of Jesuit "apostolic spirituality." However, the establishment of the main categories of Jesuit science depended primarily on the usefulness of these sciences in achieving the religious goals of the Jesuit ideological program. The dominant traditions of Jesuit science were those forms of scientific activity that demonstrated their usefulness in the three main theaters of Jesuit activity; namely, in the Jesuit "apostolates" in education, at court, and in the foreign missions. Thus apostolic spirituality and apostolates are the basic forces that shaped the general character of Jesuit scientific activity.

Apostolic Spirituality and the Jesuit Image of Knowledge

At the core of Jesuit ideology was "apostolic spirituality," a phrase used by Ignatius and his companions to designate that distinctive approach to religious life that Ignatius had developed in light of his own religious experiences and which he bequeathed to his Society.[32] In essence, the Ignatian ideal of apostolic spirituality required that members of the Society – like the apostles of Jesus – devote their energies to worldly labor, performed in service to their fellow-men and for the honor

[31] It seems that the chief differences between Feldhay's analysis and my own owe more to the very different methodological techniques we have employed than to any fundamental disagreement about the nature or influence of the Jesuit image of knowledge. Feldhay's analysis is grounded in detailed, philosophical analysis of selected texts from the late sixteenth century and informed by her sensitivity to sociological and institutional factors. My work – though also sociologically and institutionally oriented – has been conducted largely on the macroscopic level. The fact that I have identified patterns in seventeenth- and eighteenth-century Jesuit culture similar to those outlined by Feldhay strongly suggests that what she has discovered is no artifact but the beginnings of a long and distinctive scientific tradition.

[32] The values of apostolic spirituality are found throughout the normative documents Ignatius composed for the organization and guidance of his Society (see esp. Ignatius of Loyola 1955, 1970).

and greater glory of God. Ignatius envisioned a highly disciplined intellectual elite who, as fellow-workers of Christ,[33] would labor for the redemption of mankind and the preservation of the Roman Catholic Church.[34] In marked contrast to the monastic ideal of retreating from the sorrows and temptations of a corrupt world in order to concentrate exclusively on spiritual perfection and personal salvation, the Ignatian ideal demanded that Jesuits work in the world for the salvation of their neighbors' souls, while at the same time striving to preserve their own souls from worldly corruption.[35] It was the special "burden of the Society" to maintain inwardly the monastic ideals of spiritual perfection while actively engaging in worldly service. Ignatius stressed repeatedly the importance of, and difficulty of, upholding this ideal in Jesuit religious life.[36] The fundamentally dynamic nature of apostolic spirituality and the emphasis it placed on Christian service channeled religious sentiment outward and into worldly activities not usually associated with the religious life. For the "sons of Ignatius," the standards of sanctity were not to be found in contemplative prayer or the quiet observance of ritual but in purposeful action and godly labor. As a religiously motivated drive to *do and succeed* on behalf of God, apostolic spirituality sanctified those qualities of character and mind necessary for the successful execution of worldly tasks. Thus diligence, industry, efficiency, and the active use of one's intellectual and physical abilities were highly esteemed within the Society and vigorously inculcated during the long period of Jesuit formation. Although Ignatius invented neither the concept nor the phrase "work as prayer," it captures well the dynamic, activist mentality he sought to instill in his followers.

Active engagement with the world leads naturally to an appreciation of, and respect for, experience – or more precisely, the knowledge resulting from experience. Apostolic spirituality engendered an intense goal orientation within the Society; whatever could contribute to the attainment of practical results was highly valued. Jesuits perceived their work as God's work; success in doing God's work was a sure sign of the legitimacy and validity of the means one had employed to attain those

[33] The Spanish name Ignatius originally used to designate his followers belies his vision, "Compañia de Jesùs" (which was later latinized to "societatis").

[34] In the "Formula" to the Jesuit *Constitutions,* Ignatius writes, "whoever desires to serve as a soldier of God beneath the banner of the cross of our Society . . . should . . . keep the following in mind. He is a member of a Society founded chiefly for this purpose: to strive especially for the defense and propagation of the faith and for the progress of souls in Christian life and doctrine" (Ignatius of Loyola 1970, 66).

[35] How very different the ideals and methods of the Society were from those of the religious life in monasteries is made clear by the following passage from Ignatius. "The reason which impels us to establish greater experiences and to take more time and care that are customarily employed in other congregations [i.e., religious orders] is the following. If someone lives in a well-ordered and organized monastery, he will be more separated from the stains of sin because of the cloister, tranquility, and good order there than in our Society. He does not have that cloister, quiet, and repose, but travels from one place to another. . . . [Thus] in our Society it is necessary that one be well experienced and extensively tested before being admitted" (1970, 96 [n. 7]).

[36] The apostolic goals of the Society, which differed so markedly from those of the monastic and even the mendicant orders, caused considerable distress among those candidates who sought in the Society a retreat from the world. For a detailed discussion of "the burden of the Society," see Martin (1988, chap. 2). I would like to express my thanks to Professor Martin for providing me with a manuscript of this work and for his advice on matters of Jesuit ideology.

good results. Thus "testing against experience" and "proof by trial" became standards of evaluation; if something – or someone – proved effective, reliable, or useful in practice, it had demonstrated its legitimacy and was incorporated into the Society's program.[37] Ignatius called the period of ascetic formation for Jesuit novices the time of "experiences and probations," and it was designed to test the novice's obedience, fervor, and aptitude for Jesuit life (Stockius 1918, 2–4, 101–2, 125–26; 1925, passim). At the other end of the Jesuit hierarchy, those fully formed Jesuits who were to be admitted to the ranks of the "professed" were not admitted automatically. Ignatius had stipulated that "they should be tested at length in their life and habits" (1970, 82). By the same token, the teaching methods outlined in the early versions of the "Ratio studiorum" were subjected to extensive testing in Jesuit classrooms, modified, and again tested before being accepted as the code of Jesuit pedagogy. In these and many other cases, the notion of "testing against experience" emerges as a standard for the evaluation of legitimacy.[38]

The other crucial element of the Jesuit image of knowledge is esteem for learning. One of the things that made the Society distinctive as a religious order is that Ignatius and his followers understood the importance of advanced education for the conduct of practical, mundane affairs. In the monastic and especially in the mendicant orders, learning had enjoyed a long and noble history. But in the Society of Jesus learning underwent a change in status. No longer merely an auxiliary component of religious life, it became an essential part thereof, an aide to self-perfection and even salvation. Feldhay has argued that, largely because the Jesuit leadership saw the tremendous potential of the apostolate in education for achieving the ends of the Church, learning within the Society was elevated from "officium docendi" to "ministerium" (1987, 199–201). To Feldhay's argument we may add three pieces of supporting evidence. First, the *Constitutions* specify that all Jesuits (with the exception of the temporal coadjutors) must study. Indeed, full admission into the Society was contingent upon the satisfactory completion of studies; unsatisfactory progress was sufficient grounds for dismissal. Moreover, admission to the grade of the "professed" depended not only on experience but also on the quality and length of advanced study in theology.[39] Second, and more important, Ignatius stated explicitly in the

[37] Critics of the Society have faulted Jesuits for having lived by the dubious moral rule that "the end justifies the means." Although clearly intended as a condemnation, this complaint is nevertheless an insightful – if crude and unsympathetic – formulation of basic Jesuit values. From the perspective of Jesuits, the ends of the Society were manifestly good. Thus, success is not a test of the ends – the goodness of which is never in question – but of the means. If the means were not just, they never could have led to the attainment of divine ends. In this sense, the successful attainment of divine ends does indeed justify the means. Thus we might speak of the "sanctification of practicality" as one of the most unusual of Jesuit inventions.

[38] Even the *Constitutions*, though written by Ignatius himself, had to undergo – at his insistence – a period of testing in the field before he would allow them to be accepted as official and binding. See Ganss' "Technical Introduction on the *Constitutions* of the Society of Jesus" in Ignatius 1970, 49–54.

[39] According to Knowles, "the fully professed are chosen from the others by an assessment of qualities similar to that which would govern the choice of a Fellow of a college from among a group of candidates who were schoolmasters" (1966, 64–65).

Constitutions that learning is to be regarded as a valuable means for obtaining the purely religious ends of the Society.

> The aim which the Society of Jesus directly seeks is to aid its own members and their fellow men to attain the ultimate end for which they were created [i.e., to honor God and work for one's salvation]. *To achieve this purpose . . . learning and a method of expounding it are also necessary.* (1970, 171–72; italics mine)

Finally, learning itself was elevated in status to take its place in the Ignatian scale of values alongside the hallowed religious activities of prayer, meditation, and mortification of the flesh. In Ignatius' exhortations to his future scholastics, he warns that

> there will not be much place for mortifications and long prayers and meditations. For [the scholastics'] devoting themselves to learning, which they acquire with a pure intention of serving God and which in a certain way requires the whole man, will be not less but rather more pleasing to God our Lord during this time of study. . . . They should keep their resolution firm to be thoroughly genuine and earnest students, by persuading themselves that while they are in the colleges they cannot do anything more pleasing to God our Lord than to study with the intentions mentioned above; likewise, that even if they never have occasion to employ the matter studied, their very labor in studying, taken up as it ought to be because of charity and obedience, is itself work highly meritorious in the sight of the Divine and Supreme Majesty. (Ibid., 183, 190)

Nothing could make the elevated status of learning clearer than Ignatius' stark declaration that learning is a legitimate alternative to mortification, prayer, and meditation.

However, the "sanctification of learning" was not something separate and distinct from the Jesuit ideal of worldly labor. Apostolic spirituality, as conceived by Ignatius, required an educated elite to engage in worldly labor and obtain practical results in the realization of spiritual goals. Ignatius himself viewed labor and learning as two facets of a single religious endeavor, or better, of a single form of "active prayer":

> In the midst of *actions and studies,* the mind can be lifted to God; and by means of this directing everything to the divine service, everything is prayer. . . . The distracting occupations undertaken for His greater service, in conformity with His divine will . . . can be, not only the equivalent of the union and recollection of uninterrupted contemplation, but even more acceptable, proceeding as they do from a more active and vigorous charity. (Ibid., 184; italics mine)

Within the Society, the acquisition of knowledge and the performance of useful mundane labor, when undertaken for the "greater glory of God," came to be regarded as spiritually profitable tasks in themselves. Thus we may speak of the essential values of apostolic spirituality as involving the "sanctification of learning and labor."

In the image of knowledge that emerged from these core values of Jesuit ideology, both experiential and rational standards were used in the evaluation of legitimate

knowledge. Testing against experience, proof by trial, and the standards of rationality expounded by traditional academic authorities (e.g., Aristotle and Euclid) became the intertwined cognitive values by which leading Jesuit intellectuals judged the acceptability of ideas for inclusion in the Jesuit canon of knowledge.

The great emphasis the Society placed on learning necessarily brought Jesuit intellectuals into contact with the several currents of contemporary natural philosophy and science. In the last quarter of the sixteenth century, as Jesuit scholars were beginning to enter into European intellectual life, there was a variety of divergent – even contradictory – approaches to the investigation and interpretation of the natural world. Paracelsian, Hermetic, and Neoplatonic theories of nature blended with Renaissance astrological and alchemical traditions; all seemed to inveigh against the various subspecies of academic Aristotelianism, even as these jousted among themselves. In addition to the cacophony of academic doctrines and tangle of diverging methods, the very possibility of certain knowledge was thrown into doubt by the claims of a revived classical skepticism (Popkin 1979; Dear 1988). Finally, the decrees of the Council of Trent (1545–1563) had effectively ratified the great doctrinal schism separating Protestant from Catholic and elevated questions of orthodoxy to the highest level, thereby driving the intellectual turmoil of the age even deeper into the minds of men.

Jesuit intellectuals entered this scene with a clearly articulated scale of values and an urgent program. The pressing tasks for them were primarily those of selection and interpretation; i.e., separating the orthodox wheat from the heretical chaff in the existing body of knowledge and, where possible, reformulating the ideas of orthodox authority to conform to the spirit of the new order. Much of the work of sifting and reinterpreting was accomplished by that remarkable generation of Jesuit scholar-teachers active between 1580 and 1620.[40] The collective literary efforts of these authors, which typically took the form of authoritative textbooks and commentaries (genres which would have the widest possible readership in the rapidly expanding Jesuit educational system), helped establish the intellectual foundations – and boundaries – of the Jesuit tradition in science.

In addition to creating an orthodox pedagogical corpus, Jesuit scholars frequently targeted specific authors (typically – but not invariably – Protestants) and ideas for concerted literary attacks. The scientific controversies in which Jesuits engaged – especially in the early seventeenth century but also later – are excellent indicators of the limits of the Jesuit image of knowledge. Such intellectual border disputes signal Jesuit attempts to define the boundaries of orthodox Catholic science. Thus, for example, interpretations of nature that seemed to deny the rationality and comprehensibility of creation (e.g., skepticism in its more extreme form), that admitted agencies hidden to human reason (certain forms of alchemy), that threatened human freedom and dignity (judicial astrology), or that seemed to challenge the doctrines of

[40] A partial list of these architects of Jesuit intellectual orthodoxy would include Christopher Clavius (Feldhay 1987, 206–10), the Jesuit natural philosophers at the "Collegio Romano" (Wallace 1984), Bellarmine, Molina, Suarez, and the Spanish and Portuguese authors of the "Coimbra Commentaries."

the post-Tridentine Church (e.g., atomism, Cartesianism, and the Copernican theory) were anathematized.[41]

Jesuits were not, however, interested in mounting only negative campaigns. In addition to defending the borders, they also sought to erect an orthodox citadel built, in part, upon a view of nature and knowledge compatible with the Society's own values and goals. Thus, interpretations of nature that celebrated the rationality and order of creation and upheld the authority of the Church (for example, Aristotelian natural philosophy and the classical sciences of geometry, astronomy, optics, etc.) were especially attractive to the Jesuit mind. Similarly, modes of investigating God's creation that entailed systematic labor and the active manipulation of natural objects (collection), testing against experience (experiment, observation, measurement), or usefulness (invention) were seen as ideal outlets for the Jesuit virtues of industry, diligence, and utility.

Thus the peculiar structure of the image of knowledge associated with Jesuit apostolic spirituality, combining as it did the sanctification of learning and labor, preferentially directed Jesuit attention to those forms of early modern science that embodied both classical (i.e., Aristotelian and Euclidian) and active-empirical elements. The perceived affinity between Jesuit values and classico-empirical methods enabled certain forms of science to win initial acceptance as legitimate activities for members of the Society. Affinity and initial approbation do not, however, explain the establishment of the main traditions of Jesuit science. In order for a particular science to be fully incorporated into the Society, that science, like a novice in training, had to demonstrate its fitness for, and usefulness to, the Jesuit program.

The Apostolates

As noted above, the ideals and values of apostolic spirituality served to redirect religious sentiment into worldly activities. In fact, it demanded organized, collective labor undertaken in service to God and the Mother Church; or, to use the Jesuit term, it demanded "apostolates." Primarily for historical reasons, the Jesuit drive for apostolic activity found its worldly expression in three main areas; in education, at (Catholic) European courts, and in the foreign missions. These apostolates constituted the institutional settings for the bulk of the Society's activity and accounted for much of its character as a mature religious order. The astounding increase in the size and power of the Society in the first hundred years of its existence (i.e., between 1540 and 1640) was intimately bound to Jesuit success in exploiting the opportunities presented in these three theaters. The apostolate in education was a shrewd response

[41] Clavius spearheaded the rebuttals-and-attacks concerning the acceptance of the Gregorian calendar; the Jesuit Jean Roberti and several of his confreres mounted a sustained literary attack on Gogelinius and later on van Helmont for their adherence to the theory of magnetic cures and the weapon salve; Kircher wrote harshly against alchemists, and Jesuit astronomers of the caliber of Scheiner, Grienberger, Inchofer, Kircher, and Riccioli were repeatedly called upon to refute not only Copernicanism but also judicial astrology.

by the Society's leadership to the demands of sixteenth-century nobles and burghers for university education for their sons. By quickly responding to the wave of requests and by providing quality and free education, the Society nearly monopolized Catholic higher education. By the first quarter of the seventeenth century, the educational apostolate had become a central component of the Society's religious program. However, involvement at court was an equally important part of Jesuit strategy. The court was the locus of Baroque cultural and political power, and Jesuit leaders, from Ignatius onward, saw the success of the Society as closely tied to the patronage of both the secular and church aristocracy. Jesuit exploitation of opportunities in the foreign missions was essentially a concomitant of Portuguese and Spanish (and later, French) overseas exploration and colonial expansion. The generations of anonymous Jesuit missionaries who labored in North and South America and the Philippines for nearly two hundred years, as well as the spectacular success of Francis Xavier in India and Matteo Ricci in China, attest to the Society's early and enduring commitment to the foreign apostolate.[42]

For the seventeenth and eighteenth centuries, I would argue that the educational, court, and foreign apostolates were the dominant institutional forces affecting the growth of scientific traditions within the Society. Particular forms of early modern science could take root and thrive in the Society because they were found to be useful in fulfilling the immediate and penultimate goals of these apostolates.[43]

The battle for minds in Counter-Reformation Europe was scarcely separable from the battle for souls or territory; the Jesuits were quick to see the potential contribution of education to the conduct of this intellectual war. The decision by the Jesuit leadership to make the education of "externs" (i.e., those not destined to become members of the Society) the Society's primary apostolate was not easy, nor was it part of Ignatius' original scheme. Nevertheless, by the end of the seventeenth century the Society was operating over seven hundred colleges and seminaries in Europe and in the foreign missions, making it the largest unified educational system the world had ever seen. More importantly, Jesuits controlled the theology and philosophy faculties of several major universities and had established themselves as the teaching masters of Catholic Europe. In these colleges and universities, the explanation of the structure and operation of the natural world was an important vehicle for the transmission of orthodox Catholic interpretations of God's creation to the next generation of secular elites. Neo-Aristotelianism thrived in Jesuit schools because it offered the most sophisticated natural philosophy capable of providing the pedagogical framework required by the Jesuit educational program and, at the same time, of supporting the conceptual intricacies of orthodox Catholic theology.[44]

[42] There are several standard histories of the Society that depict its early expansion in education, European cultural life, and the foreign missions. I have relied primarily on Fülöp-Miller 1930; Koch 1934; Harney 1941; Ganss 1954; and Bangert 1972.

[43] Their ultimate goals were, of course, the salvation of souls and preservation of the Catholic Church.

[44] Aristotelian matter theory was, for example, essential to the orthodox Catholic doctrine of transubstantiation. The classical sciences were also university-based. But they did not command as much interest

Jesuit lecture halls were also where Jesuit "scholastics" (as candidates still in intellectual formation were called) were given a solid grounding in Aristotelian natural philosophy and training in the mathematical sciences. Even before completion of their formation as Jesuits, older scholastics deepened their knowledge of these, and other, subjects by teaching them to younger "externs" and junior confreres. After their training was finished, many remained teachers for the rest of their lives. Professors at larger Jesuit colleges and universities were often the ones responsible for the production of textbooks on logic, geometry, astronomy, geometry, and "mixed mathematics." They also oversaw the typically – but not exclusively – Aristotelian-oriented disputations, dissertations, and theses.[45]

Jesuit colleges and universities also served occasionally as centers for other sorts of scientific activity. Gaspar Schott, following the practice of his teacher Athanasius Kircher, assembled a large collection of scientific instruments during his years of teaching at the Jesuit college in Würzburg and often used them in lecture-hall demonstrations. (By the second quarter of the eighteenth century, physical cabinets and experimental demonstrations were common at most of the larger Jesuit colleges.) Ingolstadt and Paris, as well as Rome, served as centers for the training of Jesuit mathematicians and astronomers bound for the Indian, Chinese, and southeast Asian missions. By the second third of the eighteenth century, the largest Jesuit-run astronomical observatories (in Rome, Vienna, and Prague) were considered by contemporaries to be among the finest on the Continent (Lalande [1792] 1794, xxxiv–xliv; Bernoulli 1771, 57–64).[46]

The battle for minds did not, however, take place only within the classrooms and lecture-halls of Jesuit colleges. It also extended into the very centers of Baroque culture – the courts of Catholic princes. The Society's strategy of advancing its religious program by maintaining the closest possible contacts with the Catholic ruling elite – as confessors, tutors, and preachers – required the Jesuit leadership to pay close attention to the intellectual fashions and tastes of the aristocracy. Thus Jesuit superiors occasionally permitted talented Jesuit astronomers and mathematicians to accept invitations to join the courts of powerful Catholic princes.[47] While attending to the aristocratic virtuoso's fashionable thirst for wonder, amusement, and natural curiosities – or to the hard-headed prince's demand for fortifications and

or attention as Aristotelian natural philosophy since their contents did not relate as directly to theological issues as Aristotelianism did.

[45] Academic publications (i.e., textbooks, theses, disputations, etc.) constitute the vast majority of Jesuit publications in science during the first half of the seventeenth century, though their relative and absolute numbers drop significantly by the end of the seventeenth century.

[46] It is important to note that the dates of foundation for most of these observatories coincide with the period of rapid growth in the number of Jesuit scientific publications. In fact, the directors of most of these observatories were among the most productive Jesuits publishing in science. These facts lend additional support to the claim of a dramatic eighteenth-century revival of Jesuit science.

[47] With permission of the Jesuit General, Christopher Scheiner left his teaching duties in mathematics and Hebrew at Ingolstadt in order to join the court of Archduke Maximilian (brother of Rudolph II). Gregoire de St. Vincent, who had replaced Clavius as professor of mathematics at the "Collegio Romano," was called to Prague by Ferdinand II; and he later gave lessons in mathematics at the court of Philippe IV.

accurate maps of his domain – the Jesuit court scientist was, at the same time, able to stay close to the centers of power, where he could exercise his duties as priest and preacher with particular effectiveness. Thus those forms of scientific activity that Catholic princes found either useful (e.g., navigation, surveying, hydraulics, military architecture) or entertaining (the "virtuoso" sciences, curiosity cabinets, and telescopic astronomy) became part of the Jesuit scientific repertoire.

Intimately related to both the educational and court apostolates was what we might call the Society's "intellectual apostolate"; that is, its attempt to gain intellectual prestige for itself and assert intellectual hegemony over Catholic cultural life. As part of the Society's strategy in this apostolate, the Jesuit leadership occasionally allowed outstanding Jesuit scientists to pursue their scientific researches with little distraction, in the hope that their renown as scientists would bring glory to God and distinction to the Society.[48] Athanasius Kircher is perhaps the best-known example of a Jesuit scientist so privileged. Among those who came to be amazed and bedazzled by Kircher's scientific wizardry were scholars, nobles, and princes from virtually every Catholic land. Although historians of science have justly criticized his boundless credulity, aimless empiricism, and exasperating eclecticism, he was nevertheless master of his craft. And his craft was the "virtuoso science" designed for the entertainment, wonderment, and curiosity of the most powerful members of the Catholic ruling elite.

Unlike the educational apostolate, Jesuit involvement in the foreign missions was part of Ignatius' conception for the Society from the very beginning. Precisely because service in foreign missions involved hardship and isolation, it became the ultimate test of devotion to Jesuit ideals.[49] The missions' remoteness from Rome and the difficult conditions often prevailing in them presented Jesuits with a common set of challenges and stimuli quite unlike those found in either the educational or court apostolates of Europe. These factors helped give Jesuit science three of its most distinctive qualities; namely, its markedly empirical, cooperative, and practical (or instrumental) orientations.

Compared to the contributions by the educational and court apostolates, the contribution to the Jesuit scientific corpus by scholars working in the foreign apostolates is quite small. But given the remoteness and physical hardships of life in the missions, this should not be surprising. Scientific publications written in or about the foreign missions constitute about 5 percent of the total Jesuit literary output in science (about three hundred publications). Around 40 percent deal with astronomy and another 40 percent with natural history; both categories are dominated by reports, descriptions, measurements, and observations of natural phenomena from virtually every region of Jesuit missionary activity. Although few scholars in the

[48] Conversely, Jesuit superiors also had to be on their guard to prevent a potential scientific blunder (like Saint Vincent's attempt to square the circle) or worse, a scientific heresy (like Copernicanism or Cartesian matter theory), from embarrassing the Society.

[49] It is a tribute to the enduring idealism of the Society that the number of Jesuits serving in overseas missions was never limited by a lack of volunteers. Every year the Society's hierarchy was forced to deny large numbers of written requests from members who eagerly sought foreign service.

foreign missions were able to devote much time and energy to scientific pursuits, those who did were responsible for a number of the Society's most important empirical contributions, including the first accurate map of China, the first crossing of the Himalayas by a European, the furthest penetration of the Nile until the nineteenth century, the first exploration of the Amazon and Mississippi rivers, and the first systematic exploration of the Baja Peninsula.[50] Jesuit apothecaries were the first to describe scores of plants and animals from China, the Philippines, and South America; they also introduced quinine into Europe.[51] The eclipse observations by Jesuit astronomers stationed around the world helped establish the shape of the earth. The first map showing ocean currents was compiled by Athanasius Kircher from reports received from his far-flung confrères.

Contact with the unknown and unexplored natural world outside Europe excited the already pronounced empirical tendencies of Jesuit scholars. No less remarkable however was their ability to communicate their findings to one other. This was in part due to the Society's exceptionally well-developed bureaucratic and administrative organization. Jesuit superiors stationed in the foreign missions were obliged to send detailed reports to Rome and "edifying news" to the various Jesuit houses in Europe at regular intervals. This system of internal communications, established primarily for purposes of administration and morale, made it possible for Jesuits to send scientific information back to Europe.[52] The inclination to observe, describe, and collect, together with the accessibility of extensive intra-ordinal lines of communication, meant that scientific information was gathered and shared within the Society in a manner not unlike a scientific society.

The instrumental uses of science in the missions is nowhere more clearly illustrated than in the use made of astronomy and mathematics in the China mission (Dehergne 1973; D'Elia 1960; Pfister 1932; Rowbotham 1942). By exploiting the apparent superiority of European astronomical theory over contemporary Chinese astronomical knowledge, Ricci and the many Jesuit mathematicians who followed him were able to gain access to the highest levels of the Beijing court. First as mandarins, then as presidents of the "Mathematical Tribunal," Jesuits maintained a presence at court for nearly two hundred years. The key to their continued success was the Society's ability to recruit, train, and send from Europe talented mathematicians who became fluent in Chinese and were willing to subject themselves to the dangers of the long and difficult journey. By offering their services as superior mathematicians and by

[50] In almost all of these cases, the explorations and map making expeditions were either at the direct request of Jesuit superiors or prompted by the missionary zeal of Jesuit fathers located at the edges of the known world (see Wessels 1924; Stitz 1934; and Noti 1906).

[51] Jesuit botany has received very little scholarly attention. However, seventeenth- and eighteenth-century Jesuit missionaries described literally hundreds of Asian and South American plants and in several instances Jesuit naturalists provided Europeans with the first descriptions and discussions of the uses of these plants (see Bretschneider 1880; Gicklhorn and Gicklhorn 1954; Gicklhorn 1973).

[52] The majority of the scientific reports contained in the French Jesuit publication series *Lettres édifiantes*, the Austrian Jesuit Joseph Stoecklein's serial *Neue Welt-Bott*, and the *Mémoires de Trévoux* were obtained through these "in-house" channels.

ingratiating themselves with the ruling elite of China, the Jesuit fathers hoped to win opportunities for conversion.

Another example of the practical advantage of science for the Jesuit missions is the Society's involvement in medicine and pharmacy. The rigors of harsh and unfamiliar climates and the strains imposed by alien diets threatened the health of Jesuit missionaries and, consequently, the Society's missionary effort. Competent healers were thus in great demand.[53] Although a few Jesuits who served as healers in the foreign missions had been trained in medicine before they entered the Society, it was Jesuit apothecaries who provided most of the medical services in the missions. Almost without exception, these Jesuit apothecaries were temporal coadjutors (or "lay brothers") recruited from German lands (Gicklhorn 1973). By the beginning of the eighteenth century, a small but talented group of German Jesuit apothecaries were dispensing herbal remedies in Jesuit provinces as widely scattered as Mexico, Peru, Brazil, Paraguay, Vietnam, China, and the Philippines.

In each of the cases discussed – geographical exploration in the most remote missions, astronomy at the Beijing court, medical care in South America and the Philippines – scientific knowledge was employed as a means of achieving the Society's programmatic ends. However, just as in the educational and intellectual apostolates, the Society's use of science in the foreign apostolates was not coldly exploitative or purely instrumental. Astronomical observations from China, India, and South America found their way to Kircher in Rome in the seventeenth century and to a number of scientific journals scattered throughout Western Europe in the eighteenth century. Maps and geographical reports of new and unexplored regions filtered back to Europe through the Society's chain of correspondents. Apothecaries sent descriptions of new plants and recipes for new medications from remote missionary stations in South America and the Philippines. Empirical in origin and practical in orientation, the scientific information that arose from the Society's missionary needs flowed back to Europe and substantially enriched contemporary scientific culture.

The institutional constraints and opportunities provided by the educational, court, and foreign apostolates shaped many of the dominant characteristics of the Jesuit scientific tradition. Jesuit schoolmasters tailored the Aristotelian corpus and the classical sciences to meet the needs of the Society's enormous educational program; the "virtuoso" sciences and mixed mathematics helped Jesuits satisfy the intellectual and technical desiderata of their worldly patrons; and several empirical and practical sciences (especially mathematics, astronomy, and pharmacy) were valuable instruments in preserving and furthering the Society's goals in the foreign missions.

[53] Johann Schreck (or Terrentius), doctor of medicine, former member of the Lincei, and Jesuit, sought to spread not only European astronomical knowledge among the Chinese but also European knowledge of human anatomy. He was aided in this endeavor by Jacques Rho. The tradition of Jesuit medicine in China continued through the efforts of Joachim Bouvet, Dominique Parennin, and Jean de Fontaney in the late seventeenth and early eighteenth centuries. In 1738 Johann Siebert was summoned from Macao to serve as both court mathematician and royal physician to the king of Cochinchina (Vietnam), whom he attended for seven years (see Huard 1953; Huonder 1899, 183).

Despite the utilitarian and empirical bent of much of Jesuit scientific activity, we must remember that this rather unusual admixture of "Baconian" scientific activities with the (expected) traditions of Aristotelianism and the classical sciences did not come about because of the Society's adherence to some grand Baconian scheme for the advancement of knowledge. Rather, it arose from the Society's own notion of utility – utility not in the sense of economic or military advantage or power over nature, but in the sense of instrumentality. These forms of science were found to be useful in attaining the essentially religious ends of the order. Jesuit science, in all its various guises, was, at bottom, science in service of the Catholic Church – or, more precisely, science in service of the Society's apostolic program, undertaken on behalf of the Church.

Conclusions

Having completed my exposition of Jesuit science, I wish to return briefly to the Merton thesis. We can briefly summarize the differences between that study and this one: The explicit institutional structure of the Society, in contrast to the nebulous structure of "Puritanism," has allowed us to identify explicitly Jesuits who were active in early modern science and to assemble a fairly complete record of their careers and publications. This, in turn, has made it possible to perform a bio-bibliograpic analysis more detailed and rigorous than Merton's. Finally, the notion of ethos has been replaced with a sociological model of ideology. This substitution allows for a certain economy of explanation with regard to the problems of legitimation and problem choice since it is unnecessary to invoke, as Merton does, two separate theses, one appealing to religious sentiment and the other to material (or technological) interest. Apostolic spirituality not only functioned in the legitimation of active-empirical and classical forms of science within the Society, it also exercised, through the needs of the apostolates, a profound influence on the selection of problems and methods within Jesuit science. Furthermore, we have been able to argue that Jesuit scientific activity was not an inadvertent consequence of some doctrinally-inspired anxiety. Rather, it was part of a deliberate strategy; the strands of the Jesuit scientific tradition were woven into the very fabric of the Society's religious program.

Despite manifest differences in the historical, cultural, and doctrinal contexts of Jesuits and Puritans, there are striking parallels at the level of ideological values. The Puritan values of industry, diligence, and utility find their counterparts in Jesuit "sanctification of labor" and the Ignatian ideals of efficiency and practicality. The Puritan notion of "good works" (which, as Merton claims, was the prime mover of Puritan diligence) is not unlike the Jesuit ideal of apostolic service. Because of its formal structure, however, the Society was able to institutionalize and magnify personal "good works" into the collective "good works" of the apostolates. Puritan esteem of "blessed reason" has its correspondence in Jesuit "sanctification of learning." And both Puritans and Jesuits saw to it that their apprentices were well

educated – though (characteristically) education in the Society of Jesus assumed an explicit and highly effective institutional structure. Both Jesuits and Puritans shared the same special attachment to the formula, *ad maiorem Dei gloriam* ("to the greater glory of God"), and members of both groups strove to order their lives accordingly. Indeed, the Weberian notion of "intramundane asceticism," which underlies the whole of Merton's Puritan thesis, bears a marked resemblance – but is by no means identical – to the fundamental Ignatian ideal of "apostolic spirituality." Each demanded of its adherents active engagement with the world and systematic, rationalized labor, while insisting that followers preserve the highest personal standards of moral and spiritual conduct. Most importantly, the parallels between Puritans and Jesuits seem to extend into their shared interest in the sort of empirical and utilitarian sciences that involved the systematic expenditure of labor – what Bacon aptly called "active philosophy."

If we accept Merton's argument that Puritan religious values encouraged a markedly empirical and utilitarian form of science (what he calls the "new science"), and if we accept my characterization of Jesuit science as being distinctly (though not solely) empirical and practical in orientation, we have a striking, if paradoxical, confirmation of the Merton thesis. For there seems to be approximately the same sort of correlation between religious values and scientific activity within the Society of Jesus that Merton postulates for English Puritans. The paradox, of course, is that the confirmation of his argument should come from within the Catholic culture he claims was so very different from Calvinist culture.

The paradox may not, however, be as serious as it first appears. For we can certainly dispense with Merton's "Catholic foil" without harming his essential insights. At the core of Merton's thesis is the realization that ideologically motivated groups (like Puritans) who adopt a scale of values that entail good works, diligence, utility, education, etc., are predisposed to accept active-empirical forms of science as legitimate cultural activities. Moreover, operationally equivalent values are not necessarily tied to a single doctrinal base; thus religious values may be severed from their theological matrix without harming the thrust of his thesis.[54] Even according to Merton's own logic, we need not view the great confessional division separating Protestant from Catholic Europe as being so fundamental and absolute that it precludes the possibility of parallel cultural developments. The case of Jesuit science does in fact seem to be a (qualified) confirmation of a (generalized) version of the Merton thesis.

The confirming case of Jesuit science suggests that among Puritans and Jesuits – and perhaps among other religious groups of the early modern period as well – a supraconfessional doctrine of the sanctity of mundane labor, in conjunction with a high esteem for learning and reason, provided fertile ground for the acceptance and development of active-empirical forms of early modern science. The idea that Jesuits

[54] Merton happily notes that he has found "abundant confirmation of Max Weber's dictum that 'similar ethical maxims may be correlated with very different dogmatic foundations.'" Though, of course, the dogmatic foundations he considers are all well within the Protestant camp ([1938] 1970, 63).

and Puritans resemble each other in their modes of behavior and belief is nothing new; it has been discussed by economic historians. Weber explores these parallels in his original study of the Protestant ethic and capitalism (Weber 1930, chap. 4); Robertson persuasively argues for the Protestant-like modernity and "capitalist spirit" of Jesuit economic practice (Robertson 1935); Trevor-Roper openly supports Robertson's claims and even suggests that the allegedly "Calvinist" spur to the empirical study of nature might well be found among Catholic groups – should historians of science ever decide to look there (Trevor-Roper 1963, 43–44 [n. 35 and n. 40]).

Trevor-Roper's challenge points the way for future research: the correlation between the supraconfessional sanctification of labor and learning and involvment in active-empirical sciences can be tested only through additional comparative studies. And the most appropriate places to pursue such comparative investigations are precisely where we have not bothered to look before; namely, within other Catholic religious orders.[55] If a configuration of ideological values similar to those found among Puritans and Jesuits can be discovered among scientifically active orders, this would lend additional support to the generalized form of the Merton thesis presented above.

References

Abraham, Gary A., 1983. "Misunderstanding the Merton Thesis," *Isis* 74:368–87.

Ashworth, William, 1986. "Catholicism and Early Modern Science," in *God and Nature: Historical Essays on the Encounter between Christianity and Science,* ed. David C. Lindberg and Ronald L. Numbers, 136–66. Berkeley: University of California Press.

Bangert, William J., S.J., 1972. *A History of the Society of Jesus.* St. Louis: The Institute of Jesuit Sources.

Bell, Daniel, 1960. *The End of Ideology.* New York: The Free Press.

Bernoulli, Johann, 1771. *Lettres astronomiques où l'on donne une idée de l'état actuel de l'astronomie pratique dans plusieurs villes de l'Europe.* Berlin.

Bretschneider, E., 1880. "Early European Researches into the Flora of China," *Journal of the North China Branch of the Royal Asiatic Society,* 1–195.

Chrisman, Miriam Usher, 1982. *Lay Culture, Learned Culture: Books and Social Change in Strasbourg.* New Haven and London: Yale University Press.

Cohen, I. Bernard, forthcoming. *Puritanism and the Rise of Modern Science.* New Brunswick, N. J.: Rutgers University Press.

Dear, Peter, 1987. "Jesuit Mathematical Science and the Reconstruction of Experience in the Early Seventeenth Century," *Studies in the History and Philosophy of Science* 18:133–75.

[55] With the exception of Whitmore's work on French Minims (1967; though highly useful, it is by no means a monograph study of Minim science), I know of no other book-length work that examines scientific activity in n early modern religious order.

—, 1988. *Mersenne and the Learning of the Schools.* Ithaca, N.Y. and London: Cornell University Press.

Dehergne, Joseph, S.J., 1973. *Répertoire des jésuites de Chine de 1552 à 1800.* Rome: Institutum Historicum S.I.; Paris: Letouzey and Ane.

D'Elia, Pasquale M., 1960. *Galileo in China: Relations through the Roman College between Galileo and the Jesuit Scientist-Missionaries (1610–1640),* trans. Rafus Suter and Matheu Sciascia. Cambridge, Mass.: Harvard University Press.

Elkana, Yehuda, 1981. "A Programmatic Attempt at an Anthropology of Knowledge," in *Science and Cultures,* ed. Everett Mendelsohn and Yehuda Elkana, 1–76. Dordrecht: Reidel.

—, forthcoming. "The Scientific Revolution as a Revolution in Reflexivity."

Evennett, H. Outram, 1968. *The Spirit of the Counter-Reformation.* Cambridge: Cambridge University Press.

Feldhay, Rivka, 1985. "The Jesuits' Educational Ideology: From 'officium docendi' to 'ministerium'" (typescript).

—, 1987. "Knowledge and Salvation in Jesuit Culture," *Science in Context* 1(2):195–213.

Fischer, Karl Adolf Franz, 1978. "Jesuiten-Mathematiker in der deutschen Assistenz bis 1773," *Archivum Historicum Societatis Iesu* 47:159–224.

—, 1980. "Jesuiten in Breslau: Quellen zur Geschichte der Breslauer Jesuitenakademie und Jesuitenuniversität, 1640–1755," *Archiv für Schlesische Kirchengeschichte* 38:121–74.

—, 1983a. "Jesuiten-Mathematiker in der Französischen und Italienischen Assistenz bis 1762 bzw. 1773," *Archivum Historicum Societatis Iesu* 52:52–92.

—, 1983b. "Die Astronomie und Naturwissenschaften in Mähren," *Bohemia* 24(1):19–103.

Fischer, Karl Adolf Franz, and Peter Hibst, 1983. "Die Astronomie an den Hochschulen in Brünn," *Bohemia* 24(2):295–98.

Fülöp-Miller, René, 1930. *The Power and Secret of the Jesuits,* trans. F. S. Flint and D. F. Tait. New York: Viking Press.

Ganss, George, S.J., 1954. *St. Ignatius: The Idea of a Jesuit University: A Study in the History of Catholic Education.* Milwaukee: Marquette University Press.

Geertz, Clifford, 1964. "Ideology as a Cultural System," in *Ideology and Discontent,* ed. David E. Apters, 47–76. New York: Free Press.

Gicklhorn, Joseph, and Renée Gicklhorn, 1954. *Georg Joseph Kamel, S.J. (1661-1706): Apotheker, Botaniker, Artz und Naturforscher der Philipineninseln.* Eutin: Holstein.

Gicklhorn, Renée, 1973. *Missionapotheker: Deutsche Pharmazeuten in Lateinamerika des 17. und 18. Jahrhunderts.* Stuttgart: Wissenschaftliche Verlagsgesellschaft.

Gieryn, Thomas F., 1988. "Distancing Science from Religion in Seventeenth-Century England," *Isis* 79:582–93.

Gillispie, Charles Coulston, ed., 1970. *Dictionary of Scientific Biography,* 16 vols. New York: Charles Scribner's Sons.

Grant, Edward, 1984. "In Defense of the Earth's Centrality and Immobility: Scholastic Reaction to Copernicanism in the Seventeenth Century," *Transactions of the American Philosophical Society* 74(4):1–69.

Hall, A. Rupert, 1963. "Merton Revisited, or Science and Society in the Seventeenth Century," *History of Science* 2:1–15.

Harney, Martin P., S.J., 1941. *The Jesuits in History: The Society of Jesus Through Four Centuries.* New York: The American Press.

Heilbron, John, 1979. *Electricity in the Seventeenth and Eighteenth Centuries.* Berkeley: University of California Press.

Hill, Christopher, 1965. *The Intellectual Origins of the English Revolution.* Oxford: Clarendon Press.

—, 1974. "Puritanism, Capitalism and the Scientific Revolution," in *The Intellectual Revolution of the Seventeenth Century,* ed. Charles Webster, 243–53. London: Routledge and Kegan Paul.

Huard, P., 1953. "La diffusion de l'anatomie européenne dans quelques secteurs de l'Asie," *Archives Internationales d'Histoire des Sciences* 6:266-78.

Huonder, Anton von, S.J., 1899. "Deutsche Jesuitenmisionäre des 17. und 18. Jahrhunderts: Ein Beitrag zur Missionsgeschichte und zur deutschen Biographie," *Ergänzungsheft zu den Stimmen aus Maria-Laach,* vol. 74. Frieburg in Briesgau.

Ignatius of Loyola, 1955. *The "Spiritual Exercises" of Saint Ignatius of Loyola and the "Directorium in Exercita,"* ed. W. H. Longridge. London: A. R. Mowbray & Co.

—, 1970. *The Constitutions of the Society of Jesus,* ed. George Ganss, S.J. St. Louis: Institute for Jesuit Sources.

Jardine, Nicholas, 1979. "The Forging of Modern Realism: Clavius and Kepler against the Sceptics," *Studies in the History and Philosophy of Science* 10:141–73.

Kelley, Donald R., 1981. *The Beginning of Ideology: Consciousness and Society in the French Reformation.* Cambridge: Cambridge University Press.

Knowles, David, O.S.B., 1966. *From Pachomius to Ignatius: A Study in the Constitutional History of the Religious Orders.* Oxford: Clarendon Press.

Koch, Ludwig, S.J., 1934. *Jesuiten-Lexikon; die Gesellschaft Jesu einst und jetzt.* Paderborn: Bonifacius-Druckerei.

Koyré, Alexandre, 1955. "A Documentary History of the Problem of Free-Fall from Kepler to Newton," *Transactions of the American Philosophical Society* 45:329–95.

Kuhn, Thomas S., 1977. "Mathematical versus Experimental Traditions in the Development of Physical Science," in his *The Essential Tension,* 31–65. Chicago: The University of Chicago Press.

Lalande, M. de., [1792] 1794. *Astronomie,* 2 vols. Paris: Desaint and Gaillant.

Lohr, Charles, S.J., 1976. "Jesuit Aristotelianism and Sixteenth-Century Metaphysics," *Paradosis* 32:203–20.

—, 1988. *Latin Aristotle Commentaries: Renaissance Authors.* Florence: Olschki.

Martin, A. Lynn, 1988. *The Jesuit Mind: The Mentality of an Elite in Early Modern France.* Ithaca, N.Y. and London: Cornell University Press.

Merton, Robert K., 1936. "The Unanticipated Consequences of Purposive Social Action," *American Sociological Review* 1:894–904.

—, [1938] 1970. *Science, Technology and Society in Seventeenth-Century England.* New York: Howard Fertig. Originally published in *Osiris* 4:360–632.

—, 1970. "Preface: 1970," in Merton [1938] 1970, vii–xxix.

Morgan, John, 1979. "Puritans and Science: A Reinterpretation," *The Historical Journal* 22:535–60.

—, 1986. *Godly Learning: Puritan Attitudes Toward Reason, Learning and Education, 1560–1640.* Cambridge: Cambridge University Press.

Noti, S., 1906. "Joseph Tieffenthaler: A Forgotten Geographer of India," *East and West* (Bombay) 5:400–413.

Pfister, Louis, S.J., 1932. *Notices biographiques et bibliographiques sur les Jésuites de l'ancienne mission de Chine, 1552–1773.* Shanghai.

Poggendorff, J. C., 1863. *Biographisch-Literarisches Handwörterbuch zur Geschichte der Exacten Wissenschaften.* Leipzig: Johann Ambrosius Barth.

Popkin, R., 1979. *The History of Scepticism from Erasmus to Spinoza.* Berkeley: University of California Press.

Pyenson, Lewis, 1977. "'Who the guys were': Prosopography in the History of Science," *History of Science* 15:155–88.

Renaldo, John J., 1976. "Bacon's Empiricism, Boyle's Science, and the Jesuit Response in Italy," *Journal for the History of Ideas* 37:689–95.

Robertson, H. M., 1935. *The Rise of Economic Individualism.* Cambridge: Cambridge University Press.

Rowbotham, Arnold Horrex, 1942. *Missionary and Mandarin: The Jesuits at the Peking Court of China.* Berkeley: University of California Press.

Shapin, Steven, 1988. "Understanding the Merton Thesis," *Isis* 79:594–605.

Shils, Edward, 1961. "Ideology: The Concept and Function of Ideology," in the *International Encyclopedia of the Social Sciences,* 7:66–76. New York: MacMillan.

Sommervogel, Carlos, S.J., 1890–1910. *Bibliothèque de la Compagnie de Jésus,* 12 vols. Brussels: Oscar Schepens; Paris: Alphonse Picard.

Stitz, Peter, 1934. "Kalifornische Briefe des P. Eusebio Francisco Kino (Chini) nach der Oberdeutschen Provinz, 1683–85," *Archivum Historicum Societatis Iesu* 3:108–28

Stoeckius, Hermann, 1910. *Studien über die Pädagogik der Gesellschaft Jesu im 16. Jahrhundert: Das Prinzip der Trennung in der Ordnung des Verkehrs zwischen den Ordenangehörigen und den Externen,* Dissertation der Universität Erlangen. Nördlingen: C. H. Beck.

—, 1911. *Forschungen zur Lebensordnung der Gesellschaft Jesu im 16. Jahrhundert.* Munich: C. H. Beck.

—, 1912. *Die Reiseordnung der Gesellschaft Jesu im 16. Jahrhundert.* Heidelberg: Carl Winter's Universitätsbuchhandlung.

—, 1918. *Untersuchungen zur Geschichte des Noviziates in der Gesellschaft Jesu,* Dissertation der Universität Göttingen. Bonn: Albert Falkenroth Verlag.

—, 1925. "Ignatius von Loyola Gedanken über Aufnahme und Bildung von Novizien," in *Pädagogisches Magazin,* ed. Friedrich Mann, Heft 808. Langensalza: Hermann Beyer und Söhne.

Stone, Lawrence, 1971. "Prosopography," *Daedalus* 100:46–79.

Trevor-Roper, H. R., 1963. "Religion, the Reformation, and Social Change," in *Historical Studies IV,* ed. G. A. Hayes-McCoy. London.

Tyacke, Nicholas, 1973. "Puritanism, Arminianism and Counter-Revolution," in *The Origins of the English Civil War,* ed. Conrad Russel, 119–43. London: MacMillan.

—, 1978. "Science and Religion at Oxford before the Civil War," in *Puritans and Revolutionaries,* ed. Donald Pennington and Keith Thomas. Oxford: Oxford University Press.

Wallace, William A., 1984. *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science.* Princeton: Princeton University Press.

Weber, Max, 1930. *The Protestant Ethic and the Spirit of Capitalism,* trans. Talcott Parsons. New York: Charles Scribner's Sons.

Webster, Charles, 1975. *The Great Instauration.* London: Duckworth.

Wessels, Cornellius, S.J., 1924. *Early Jesuit Travellers in Central Asia 1603–1721.* The Hague: Nijhoff.

Whitmore, P., S.J., 1967. *The Order of the Minims in Seventeenth-Century France.* The Hague: Nijhoff.

Department of the History of Science
Harvard University