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Conceptions of the Scientific Revolution from Bacon to Butterfield: A preliminary sketch

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> Since [the Scientific R]evolution overturned the authority in science not only of the middle ages but of the ancient world – since it ended not only in the eclipse of scholastic philosophy but in the destruction of Aristotelian physics – it outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom. Since it changed the character of men's habitual mental operations even in the conduct of non-material sciences, while transforming the whole diagram of the physical universe and the very texture of human life itself, it looms so large as the real origin both of the modern world and of the modern mentality that our customary periodisation of European history has become an anachronism and an encumbrance.[1]

Herbert Butterfield, writing thus in 1949, may have carried enthusiasm to an extreme. But he articulated a conception of the Scientific Revolution that had been gradually taking shape over a period of three hundred years and has since become almost canonical – namely, that the sixteenth and seventeenth centuries saw a radical transformation of scientific ideas, so decisive and influential as to constitute a turning point in the history of civilization. Let us consider the origins of this interpretation.

Humanism and the Renaissance

Butterfield's view was an outgrowth and continuation of historiographic traditions and European self-perceptions rooted in fifteenth-

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and sixteenth-century Italian humanism. Petrarch, Boccaccio, and their humanist contemporaries viewed themselves as instigators of a revival of classical art and letters after the long hiatus of the "Dark Ages."[2] In what became a standard humanist account, the decline and fall of Rome introduced a thousand-year period of cultural darkness and stagnation, during which classical art succumbed to religious symbolism while humane letters fell before the rude vulgarity of the scholastics. Scornful of scholastic discourse and medieval artistic conventions, humanists sought a restoration of ancient literary and artistic forms. Petrarch (1304–1374) was one of many who, despairing of the contemporary state of letters, found solace in the works of the ancients:

> I associate greedily with our ancients in the only way I can, and I forget most willingly those among whom an evil star decrees that I must live. And I strain all the powers of my mind to flee the moderns and to seek the ancients, because the sight of my contemporaries offends me deeply while the remembrance of the noble deeds and glorious names of the past fills me with . . . incredible delight.[3]

The return to antiquity was seen by many as marking the beginning of a new age. The goals were classicism in literature and the arts, educational reform, and the purification of religion through a return to primitive origins. Protestant authors were especially apt to see a connection between the return to ancient sources and the reformation of Christianity. By the end of the fifteenth century, the notion of rebirth had been enlarged to include the revival of Platonic philosophy as an alternative to scholastic Aristotelianism; and by the end of the sixteenth century technological developments were seen as an additional manifestation of the same phenomenon.[4]

The understanding that a philosophical renovation was under way – whether conceived strictly as a return to antiquity or viewed as the development of philosophical novelties – became commonplace in the sixteenth century.[5] Paracelsus (d. 1541) certainly understood his own work as representing a radical reformation of medical theory and practice. Francesco Patrizi gave the title *A New Philosophy of the Universe* (1591) to his principal work, an attack on Aristotle and an appeal for the restoration of Platonic philosophy within the university curriculum. Jean Bodin (1530–1596) made a determined attack on the idea of universal decay, defending the accomplishments of his age in comparison with those of the ancients. "No one, looking closely into this matter," he wrote, "can doubt that the discoveries of our men ought to be compared with the discoveries of our elders; many ought to be

placed first.''[6] And Peter Ramus (1515–1572), though he may not have defended the thesis (with which he is often credited) that everything Aristotle said was false, certainly found major flaws in Peripatetic logic as it was taught in his day, as well as in other aspects of contemporary learning – flaws that he proposed to remedy through a reform of the teaching of logic, mathematics, and physics.[7]

The seventeenth and eighteenth centuries

When, in the course of the seventeenth century, the new science (or, more exactly, the new natural philosophy) came in for appraisal, that appraisal was powerfully shaped by the historical categories and terminology devised by Renaissance humanists. It is no doubt true that attitudes toward the past were rapidly becoming more sophisticated, but sophistication did not lead to rejection of the humanists' tripartite division of history into ancient, medieval, and modern periods. In short, commentators on the new philosophy were quick to perceive it as an extension and outgrowth of the humanist revival.

If this seems a surprising claim, we owe our surprise to the wide influence of J. B. Bury and R. F. Jones, who have vigorously propagated the opinion that the seventeenth century ushered in a new attitude toward the past. According to Bury and Jones, whereas the humanists conceived themselves to be engaged in a restoration of ancient philosophy, seventeenth-century scholars, seized by the idea of infinite progress, came to understand that what was required was a repudiation of antiquity and a radical redirection of philosophical and scientific activity. The creators of the ''new philosophy,'' according to Bury and Jones, viewed it not as the old philosophy restored but as an altogether novel conception of reality and the philosophical enterprise, unprecedented in human history.[8] On this reading, the ''new'' in Kepler's *New Astronomy*, Francis Bacon's *New Organon*, and Galileo's *Two New Sciences* is to be taken at face value.[9]

The thesis of Bury and Jones, persuasively argued in the 1930s, still commands a following in the 1980s.[10] One reason for this remarkable longevity is undoubtedly the ease with which quotations seeming to confirm the thesis can be discovered; they are especially plentiful in the works of Francis Bacon, who, in the view of Bury and Jones, led the moderns against the ancients.[11]

In his *Novum organum*, Bacon (1561–1626) characterized his new method not simply as an alternative to medieval scholasticism but as a method altogether ''untried and unknown.'' Aristotle, Bacon argues,

> corrupted natural philosophy by his logic: fashioning the world out of categories; assigning to the human soul, the noblest of substances, a genus from words of the second intention; doing the business of density and rarity . . . by the frigid distinction of act and power; asserting that single bodies have each a single and proper motion, and that if they participate in any other, then this results from an external cause; and imposing countless other arbitrary restrictions on the nature of things; being always more solicitous to provide an answer to the question and affirm something positive in words, than about the inner truth of things.[12]

Indeed, if he can be judged by quotations such as the following, Bacon seems to have had little use for any of the sciences produced in antiquity:

> The sciences which we possess come for the most part from the Greeks. For what has been added by Roman, Arabic, or later writers is not much nor of much importance; and whatever it is, it is built on the foundation of Greek discoveries. Now the wisdom of the Greeks was professorial and much given to disputations, a kind of wisdom most adverse to the inquisition of truth.[13]

Similar quotations, almost without number, can be extracted from the scientific and polemical literature of the period.

But in order to have their intended effect, they need to be lifted out of context. Seventeenth-century attitudes toward antiquity, looked at as a whole rather than scoured for "proof texts," are more complex and nuanced, and far more positive in tone, than the carefully selected quotations suggest.[14] Even Bacon, although undoubtedly ambivalent in his attitude toward antiquity, on balance acknowledged its worth. The last-quoted passage is immediately followed by another, in which Bacon makes clear that he has no quarrel with the early Greek philosophers, who "with less affectation and parade . . . betook themselves to the inquisition of truth." Unfortunately, their work has been obscured by that of "slighter persons" who came after. Bacon objects to those who display an "extreme admiration" for antiquity but also to those with an "extreme . . . appetite for novelty"; his ideal is to strike the mean, "neither carping at what has been well laid down by the ancients, nor despising what is well introduced by the moderns."[15]

As Bacon looks back over human history, he finds three ages favorable to learning, each lasting about two centuries: that of the early Greeks, that of the Romans, and his own. The remainder of human history has been inhospitable to the sciences: "The intervening ages

of the world, in respect to any rich or flourishing growth of the sciences, were unprosperous. For neither the Arabians nor the Schoolmen need be mentioned, who in the intermediate times rather crushed the sciences with a multitude of treatises, than increased their weight."[16] Bacon has absolutely no use for medieval scholasticism, but to antiquity, and sometimes even to Plato and Aristotle, he grants grudging (and often more than grudging) respect.[17] In the battle between the ancients and the moderns, the point at issue was not whether the ancients were deserving of admiration but how much progress moderns had made toward equaling or surpassing the ancient achievement.

Bacon had a number of causes to suggest for the sorry state of learning in the dark middle period between antiquity and his own day. The devotion of men of "wit" to theology; the loss of contact between the specific sciences and their philosophical roots; failure to set a proper goal for the sciences; immoderate religious zeal, superstition, vanity, arrogance, and despair were all factors. But the most prominent cause was the lack of "the true method of experience, . . . commencing . . . with experience duly ordered and digested, not bungling or erratic, and from it educing axioms, and from established axioms again new experiments." New discoveries, Bacon argued, "must be sought from the light of nature, not fetched back out of the darkness of antiquity."[18] Bacon elaborated at great length, of course, on his new method. But the important point is that in his view the sciences were about to enter a period of great fertility, and the source of that fertility would be his new method.

Bacon's methodological campaign and his interpretation of the course of learning were taken over by innumerable seventeenth-century commentators. The Royal Society of London absorbed the Baconian outlook, and Thomas Sprat expressed it in his history of the Royal Society (1667): in contrast to the futile labors of the "Moncks" are the procedures of the new philosophers, "who have not only disagreed from the *Antients*, but have also propos'd to themselves the right course of flow, and sure *Experimenting:* and have prosecuted it as far, as the shortness of their own Lives, or the multiplicity of their other affairs, or the narrowness of their Fortunes, have given them leave."[19] The controversialist Joseph Glanvill, writing in the very next year, maintained that the Royal Society had no intention of derogating the ancient scientific achievement, but no intention, either, of allowing the ancients "*absolute Empire* over the *Reasons of Mankind*." Nature, he argued, is "inexhaustible" in its treasures, providing opportunity for ingenious investigators to make new discoveries to the end of the world. But to obtain these rewards, they must possess the proper

tools. Although the ancient philosophers had ample wit, they got caught up in the labyrinth of disputation and never attended to "material, sensible events."[20]

The squabble near the end of the century between Bernard le Bovier de Fontenelle, Sir William Temple, and William Wotton about the relative merit of the ancients and the moderns reveals how slowly the terms of the argument changed. None of the combatants saw fit to denigrate the ancient achievement; on the contrary, all saw antiquity as a time of artistic and intellectual excellence. Moreover, all viewed the intervening centuries as a dark period in which learning and taste were debased. And all acknowledged, finally, that the moderns had recovered at least some of the ground lost during the Middle Ages. The point of disagreement was the kind and quantity of acreage regained: had the moderns surpassed the ancients, or were the moderns doomed to lesser achievement? Those, like Temple, who minimized modern accomplishments tended to do so on the basis of either a cyclical view of history or a theory of universal deterioration. Those who fought for the superiority (or at least equality) of the moderns, like Fontenelle and Wotton, found the most impressive modern successes in the realms of technology and natural philosophy, attributing these accomplishments not to greater intellectual capacity or moral superiority but to the utilization of a new Baconian (or perhaps Newtonian) method.[21]

No crucial piece of evidence could adjudicate between the two opinions, of course, and no critical argument emerged to resolve the issue. The position of Temple and the defenders of ancient superiority simply lost its plausibility in the glare of eighteenth-century optimism about the advance of civilization. Secularization during the Enlightenment eroded belief in divine providence as a moving force in history and discredited Christian teleology as a theme by which to structure the course of historical change. The historiographic void was filled by the idea of progress, based on faith in the development and application of human reason. If the relative merit of the ancients and the moderns in literature and the arts could still be debated, it seemed incontestable that in natural philosophy the moderns had achieved superiority.[22]

The theme of progress dominates the influential historical works of François Marie Arouet de Voltaire (1694–1778): his *Essay on the Manners and the Spirit of Nations* (1747–1751) and his *Age of Louis XIV* (1752), which together comprise what has sometimes been regarded as the first "modern" history of civilization.[23] Voltaire's aim was to write a history of the human spirit, of manners and customs, based on the premise of indefinite progress. Nor would God put in an

appearance: "Let us leave, with the utmost reverence," he wrote, "the divine part in the hands of those with whom it is deposited; and confine ourselves solely to that which is historical."[24]

Although Voltaire offered no connected account of the development of natural philosophy, his many passing comments added up to an influential interpretation. After the fall of the Roman Empire, barbarian invasion led to decay and degeneration of the human spirit: "At that time the human mind was possessed by a capricious medly of cunning and simplicity, of brutality and artifice, which was a strong characteristic of general decay and degeneracy."[25] Europe was overtaken by an appalling state of ignorance and darkness; literacy itself was in jeopardy. The general ignorance of the populace allowed the clergy, who had "a little knowledge," to acquire "that kind of authority over other minds, which a superiority of understanding naturally gives a master over his scholars."[26] Nonetheless, even such darkness did not snuff out all creativity, as we see from the invention of eyeglasses, windmills, clocks, the compass, and paper.[27]

The arts began to reappear in Italy at the end of the thirteenth and beginning of the fourteenth century, owing to the strength of Italian genius. Elsewhere, "scholastic divinity, . . . the bastard offspring of the Aristotelian philosophy, badly translated, and as ill understood, did more injury to understanding . . . than ever the Huns and Vandals had done."[28] In the sixteenth century, Copernicus at last "discovered the true system of the world." But it "was not till the end of this glorious century [the sixteenth] that true philosophy began to beam upon mankind; Galileo was the first who made natural philosophy speak the language of truth and reason."[29] Unfortunately, Galileo ran afoul of the Inquisition, which condemned his doctrine and thereby retarded the further development of philosophy.

In the long run, philosophical leadership was seized by the English, who advanced knowledge by their resistance to speculative ideas and their determination to investigate nature experimentally:

> But it is in philosophy that the English have particularly had the mastery over all other nations. Ingenious and speculative notions were out of the question. The fables of the Greeks had been long laid aside, and those of the moderns were to appear no more. Chancellor Bacon first led the way, by asserting that we should search into nature in a new manner, and have recourse to experiments. Boyle employed his whole life in making them. . . . After three thousand years of vain enquiries, Newton was the first who discovered and demonstrated the great law of nature, by which every part of matter tends towards the center, and all the planets are retained in their

> proper course. He was the first who truly beheld light; before him we knew not what it was.[30]

As for the ancients–moderns controversy, Voltaire considered it sufficiently current to merit his attention, assuring his reader of the "prodigious superiority of our age over the ancient times" and pointing for evidence to the achievements of Locke, Hevelius, Mercator, the Bernoullis, Leibniz, Boerhaave, the Cassinis, and others.[31]

Enlightenment optimism about the perfectibility of human nature in both its intellectual and social manifestations reached its zenith in the *Esquisse d'un tableau historique des progrès de l'esprit humain* (1795) of the marquis de Condorcet (1743–1794). The *Esquisse* is a hymn to the advancement of the human race from barbaric and superstitious origins to a state of reason and enlightenment. Condorcet was convinced that "nature has set no term to the perfection of human faculties"; he was certain, moreover, that the scientific progress thus far achieved was now a permanent possession of the human race, owing to the establishment of the proper scientific method, the successful application of scientific theories to practical needs, the growth of a scientific community, the development of suitable connections between the sciences, and, above all, to the existence of printed books.[32]

Condorcet's history of science follows the main lines laid out by Voltaire, though with various refinements and considerably greater detail. Condorcet congratulates the atomists and Pythagoreans for the "felicitous ideas" of atomic theory and mathematization of nature. He notes that mathematics and physics succeeded, to some extent, in separating themselves from philosophy and taking "refuge" in Alexandria. Elsewhere superstition, ignorance, and the quest for "systems" prevailed; Aristotle was guilty of "disfiguring physics with those hypothetical principles which in their vague generality explain everything with facility because they can explain nothing with precision."[33]

The ancient achievement, such as it was, fell before barbarian invasions and the triumph of Christianity. Although others had already identified the medieval church as villain, in Condorcet there is a sharper tone of anticlericalism, a more sweeping condemnation of Christianity, and a considerable boost in the rhetorical volume. In Condorcet's view, "the triumph of Christianity was the signal for the complete decadence of philosophy and the sciences." "Man's only achievements were theological day-dreaming and superstitious imposture." The growth of priestly power

> gave rise to many absurdities: monks inventing ancient mira-

> cles or manufacturing new ones, feeding the ignorance and stupidity of the people with fables and prodigies, deluding them in order to despoil them; doctors of the Church exhausting all their ingenuity in an effort to find some new piece of nonsense with which to embellish their faith or to outdo their predecessors; priests compelling princes to burn any man who dared doubt one of their dogmas, unmask their impostures or denounce their crimes, or who wavered for a moment from the course of blind obedience.[34]

Three events ultimately combined to produce a rejection of authority and a revival of learning, Condorcet asserted. First, the invention of printing shifted the balance of power, creating a "new sort of tribunal" that "favours truth and justice, . . . and whose verdict it is impossible to evade." Second, scholars fleeing Constantinople in 1453, when it fell to the Turks, brought Greek letters and science with them. Third, discovery of the New World enlarged Western horizons and provided opportunity for studying the human race in different habitats.[35]

Under these new circumstances, the progress of physical and biological science was dramatic. Copernicus "set up the extreme simplicity of real [planetary] movements . . . in contrast to the almost fatuous complexity of those demanded by the Ptolemaic hypothesis." Kepler discovered the true orbital shape and the laws governing planetary motion. Galileo discovered the law of falling bodies. Experimental physics, anatomy, chemistry, and natural history all experienced astonishing progress. Three men in particular, Condorcet thought, represented the transition to modern science. Francis Bacon outlined the proper scientific method, but he gave no examples, and therefore managed to influence philosophers without affecting the course of science. Galileo revealed by example how nature was to be explored. "He founded the first school in which the sciences were studied without any admixture of superstition in favour of either popular prejudices or authority, and where all methods other than experiment and calculation were rejected with philosophical severity." Finally, Descartes "joined example to precept and gave a method for finding and recognising truth." If Descartes was guilty of wild speculation, "still the very audacity of his mistakes served to further the progress of the human race." It was Descartes who "commanded men to shake off the yoke of authority, to recognise none save that which was avowed by reason."[36] If humanity had some distance to travel for the realization of this ideal, nonetheless, after Descartes, arrival at the final destination was assured.

As we look back over early interpretations of the course of science, what is most remarkable is the near unanimity of opinion. From the humanists of the fifteenth century to the eighteenth-century philosophes, there is scarcely any deviation from a common conception of the progress of knowledge and a shared periodization of history. Everybody who addressed the question accepted a tripartite division of cultural history into ancient, medieval, and modern periods. All agreed that the glories of antiquity had been followed by medieval darkness, and that darkness had finally yielded to light with the humanist recovery of ancient learning, which substituted reason for medieval superstition. The scientific revival was dated to the days of Copernicus, in the first half of the sixteenth century, or, if one sought more secure scientific foundations, to the achievements of Galileo and Bacon in the seventeenth; and on French soil, Descartes was introduced to round out an international triumvirate. Finally, eighteenth-century historians agreed that the achievements of the seventeenth century were continuous with the achievements of their own age. What is important and striking in all of this is the longevity of the humanist vision of the course of science. Although the humanist picture was sharpened, enriched, and qualified, the original outlines were still visible four hundred years later.[37]

Positivism and idealism in the nineteenth century

The philosophical and historiographic developments of the nineteenth century are much too rich and complex to be treated more than superficially in this brief introductory essay. But two philosophical and historiographic constants deserve our attention: first, the continuing division of European history into ancient, medieval, and modern periods; second, the universal belief that the seventeenth century, employing the methods of Bacon and Galileo, had at last produced firm and permanent foundations, which might require adaptation and minor remodeling but no major reconstruction.

One finds these opinions in thinkers as diverse as Auguste Comte (1798–1857) and William Whewell (1794–1866). Comte, a member of the generation of French philosophers whose lot it was to rethink and reconstruct French society and culture in the aftermath of the Revolution and in the light of the progress of science, produced an influential philosophy of science, directed ultimately toward the establishment of the social sciences and the amelioration of human suffering. According to Comte, all sciences pass inevitably through three stages: the theological, or "fictitious," stage, in which the human mind seeks essences and ultimate causes, which it finds in super-