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Narratives of Technological Revolution in the Middle Ages

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A. Introduction

Narratives of technological revolution in the Middle Ages are a distinctively 20th-century phenomenon. First articulated by a handful of influential French, British and American historians between the 1930s and 1950s, they can be genealogically linked to narratives of progress across a number of arts and social science disciplines which have invoked the language of revolutionary rupture to characterize a number of notable transformations in human cultures and societies between the Neolithic and modern periods.

Two kinds of technological revolution have been claimed for the European Middle Ages by 20th-century scholars: an 'agricultural revolution' of the 6th to 9th centuries, and an 'industrial revolution' of the 11th to 14th centuries. Scholarly claims for both an industrial revolution and an agricultural revolution in the Middle Ages can be traced back to the 1930s, although they did not become full-blown narratives until the 1950s. Such claims have a relatively complex lineage, but are perhaps best understood as part of a western intellectual tradition going back to the Enlightenment which has sought to account for the radical social and political changes that have occurred throughout the world since industrialization with reference to the marriage of practical and theoretical knowledge characteristic of the modern period.

The term 'revolution' gained currency and has been widely deployed during the modern period to denote a significant change in the politics, economy or culture of a given society or group of societies over a relatively short period of time. Generally speaking, revolutionary *political* changes have been identified with particular nations or countries, such as the French Revolution of 1789–1799, and the Russian Revolution of 1917, and are of comparatively short duration. Revolutionary *cultural* changes, on the other hand, such as the Scientific Revolution of ca. 1540–1690 and the Industrial Revolution of c. 1760–1850 transcend national boundaries, are generally held to be regional in character, and can occur over a period of a century or more.

This essay focuses on the use of a particular style of cultural revolution narrative – that of technological revolution – in historical writings from the

20th century about the European Middle Ages. It seeks to explain the social and political context within which such narratives first arose and how they appear to be genealogically related. The problems with and difficulties arising from individual revolutionary narratives are then flagged, with readers directed to the relevant critical literature. The article concludes with some generic observations about the use of such narratives in contemporary historiography.

B. Narratives of Cultural Revolution in the History of Science and Technology

Narratives of cultural revolution, particularly in relation to developments in science and technology, have been a common feature of western intellectual discourse since the early 17th century.

The use of titles such as *Physiologia Nova De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure* by William Gilbert (1544–1603), and the *Novum Organum* and *Instauratio Magna* by Francis Bacon (1561–1626), were squarely aimed at distinguishing the intellectual contributions of these early modern scholars from their scholastic and classical predecessors, and setting themselves up as the new authorities on the subjects about which they wrote.

Contemporaries of key figures in the Scientific Revolution, such as William Harvey (1578–1657) and Galileo Galilei (1564–1642), were already describing their contributions to natural philosophy, physiology, and the mathematical sciences as 'revolutionary:' not in the classical sense of an astronomical cycle or periodic return (as invoked by Renaissance humanists to describe their efforts to return to the Greek and Roman roots of European knowledge 'purified' of Islamic and scholastic influences), but in the sense of the overturning of traditional knowledge structures and authorities with long-term consequences. For example, a contemporary of Galileo, Raffaello Maggiotti (1597–1658), wrote to him in 1637 that Harvey's work on the circulation of the blood "will suffice to revolutionize all of medicine, just as the invention of the telescope has done for astronomy, the compass has done for commerce, and artillery has done for the whole military art" (Jerome Bylebyl, "William Harvey: A Conventional Medical Revolutionary," *Journal of the American Medical Association* 239 [1978]: 1295–98). Maggiotti's argument was a variation on those made by Bacon and others before him that "printing, gunpowder and the magnet [...] have changed the whole face and state of things throughout the world" (Francis Bacon, *Novum Organum*, 1620, Bk. 1, aphorism 129).

It was not until the Enlightenment, however, that the now widely accepted modern sense of revolution as the rapid or violent overthrow of existing political and cultural norms and institutions came into common usage. Contemporary historians of science such as I. Bernard Cohen, David Lindberg, and H. Floris Cohen have drawn attention to the fact that Enlightenment figures such as Voltaire (1694–1778), Jean le Rond d'Alembert (1717–1783), Immanuel Kant (1724–1804), and the Marquis de Condorcet (1743–1794) consciously deployed revolutionary rhetoric to distinguish the practical mathematical and experimental orientation of 17th- and 18th-century natural philosophers from those of their medieval and even ancient predecessors (I. Bernard Cohen, *Revolution in Science*, 1985, 197–261; David Lindberg, "Conceptions of the Scientific Revolution from Bacon to Butterfield," *Reappraisals of the Scientific Revolution*, ed. David Lindberg and Robert Westman, 1990, 6–10; H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry*, 1994, 22–27).

19th- and 20th-century proponents of progress and modernity accepted this rhetoric as an accurate description of the radical social and intellectual transformations that occurred between the 16th and 17th centuries, repeating, reinforcing and elaborating on such claims in history, philosophy and social theory (I. Bernard Cohen, *Revolution in Science*, 1985, 273–351; David Lindberg, "Conceptions of the Scientific Revolution from Bacon to Butterfield," *Reappraisals of the Scientific Revolution*, ed. David Lindberg and Robert Westman, 1990, 10–13; H. Floris Cohen, *The Scientific Revolution*, 1994, 21–121). Major schools of thought from Idealism and Positivism to Marxism embraced this vision of historical rupture, so much so that the term 'Industrial Revolution' had already entered common parlance long before it was clearly defined by Arnold Toynbee (1852–1883) in a series of lectures between 1878 and 1883 (*Lectures on the Industrial Revolution in England*, 1884), as had the term 'Scientific Revolution' before it was first clearly defined by the historian of science, Alexandre Koyré (1892–1964), in 1939 (*Études Galiléennes*, 1939–1940).

A common feature of narratives of revolutionary intellectual and technical change during the modern period is the assumption (usually explicit but sometimes not) that earlier periods – and, in particular, the Middle Ages – were marked by intellectual sterility and scientific and technological stagnation. Indeed, modernist exceptionalists of several philosophical and political persuasions across a number of disciplines have relied on narrative forms which sharply distinguish between the modern period and the medieval and ancient periods, emphasizing discontinuity over continuity in the social, political and intellectual spheres.

Thus, the Scientific Revolution marked a significant transformation in the aims, methods and techniques of natural philosophy and the physical sciences between the medieval and modern periods, while the British Agricultural (or Agrarian) Revolution was characterized by significant improvements in agricultural productivity and output over the essentially medieval techniques that had continued during the early modern period, thereby laying the foundations for, or occurring in parallel with, the Industrial Revolution. Likewise, the Industrial Revolution marked a period during the latter half of the 17th and first half of the 18th centuries when significant advances in agriculture, transport and manufacturing were accompanied by major reorganizations of the economy and labor force. Historians of the Industrial Revolution have generally tended to argue that the industry and technology of the early modern period were in most respects a continuation of medieval trends (Peter N. STEARNS, *Interpreting the Industrial Revolution*, 1991, chapters 1, 2, and 4).

Whereas many historians and archaeologists of the ancient world accepted modernist characterizations of their chosen time period as technologically (if not intellectually) stagnant until the late 1970s, medievalists were not so obliging.

In his efforts to trace the origins of modern science from an anti-positivist perspective, the French physicist, Pierre DUHEM (1861–1916), inadvertently discovered that some important developments in statics and mechanics had occurred during the 14th century in the work of Jean Buridan (1300–1358), Nicole Oresme (1323–1382), and others (*Études sur Léonard de Vinci: Ceux qui'il a lus et ceux qui l'ont lu*, 3 vols., 1906, 1909, and 191; rpt. 1955; *Le système du monde: Histoire des doctrines cosmologiques de Platon à Copernic*, 10 vols., 1913–1959). Indeed, DUHEM went so far as to locate the beginnings of the still-in-formation concept of the Scientific Revolution in the 14th rather than the 17th century, although he is one of the few scholars, apart from Herbert BUTTERFIELD (1900–1979), to have done so (*The Origins of Modern Science, 1300–1800*, 1949). Although a new generation of professional historians of science, from Lynn THORNDIKE (1882–1965) and John H. RANDALL, Jr. (1898–1980) to Annaliese MAIER (1905–1971), and Alistair CROMBIE (1915–1996) tended to stress the continuities between late medieval and early modern developments and downplay the discontinuities, DUHEM's work was an important point of departure from which these scholars sought to reconsider the role of medieval natural philosophy in the development of the sciences.

C. An 'Industrial Revolution' in the Middle Ages

Around the same time as the history of science became professionalized, a number of medievalists began taking an interest in the history of technology from a social and economic perspective. In a special issue of the *Annales d'histoire économique et sociale* published in 1935 and titled "Les techniques, l'histoire et la vie," Marc Bloch (1886–1944), and Lucien Febvre (1878–1956) put together a collection of articles outlining their views on the formation of a new discipline which they called the history of techniques.

In Febvre's introductory essay for the special edition, one of the three approaches that he recommended for the new discipline was to study the progress of techniques, whether that be slow and incremental, or rapid and precipitous: both technical 'evolutions' and technological 'revolutions' should be a focus for scholarly attention ("Réflexions sur l'histoire des techniques," *Annales d'histoire économique et sociale* 7 [1935]: 533–34). Febvre's recommendations were an expression of the revisionist historiographical aims of the Annales School, which were to move away from the 19th-century emphasis on regnal shifts and diplomatic history to a new form of history that drew on the insights of multiple disciplines to illuminate cultural mentalities, the lives of ordinary people, and medium and long duration historical processes.

In Bloch's contribution to this same edition of *Annales*, titled "Avènement et conquêtes du moulin à eau," he sought to establish the origins and development of the watermill from Roman times to the High Middle Ages. Apparently in an effort to put Febvre's proposal into practice about the need for historians to form empirically-grounded opinions about the relative progress of different techniques, Bloch made a novel observation: during the second half of the Middle Ages there was a rapid increase not only in the number of mills powered by water, but in the range of industrial processes to which waterpower was applied. He proposed that these developments signified a medieval revolution in the use of power technology that laid the foundations for the Industrial Revolution and the transformation of European society during the modern period ("Avènement et conquêtes du moulin à eau," *Annales d'histoire économique et sociale* 7 [1935]: 538–63; trans. "The Advent and Triumph of the Watermill," *Land and Work in Mediaeval Europe: Selected Papers by Marc Bloch*, 1967, 136–68). It is worth quoting him briefly on this point:

> The generations immediately before ours, as well as our own, have witnessed a tremendous revolution in transport, animal traction giving place to purely mechanical forms of energy. Not very different was the revolution that took place in another sphere with the coming of the watermill [...] (141).

Already convinced that the Romans had made relatively little use of watermill technology, BLOCH went on to argue that "although the invention of the watermill took place in ancient times, its real expansion did not come about until the Middle Ages" (143). The rest of the paper goes on to explain why the Romans supposedly failed to exploit waterpower, and how and why this medieval expansion came about.

The idea that revolutionary changes in technology had occurred during earlier periods than the Industrial Revolution had already been canvassed by V. Gordon CHILDE (1892–1957), John NEF (1899–1988), and Richard LEFEBVRE DES NOËTTES (1856–1936) in the 1920s and early 1930s.

In CHILDE's case, the concept of a 'Neolithic Revolution' was developed by him to denote the first of a series of major transformations in agricultural production in the Middle East that occurred roughly 12,000 to 8,000 years ago, whereas the concept of an 'Urban Revolution' was developed to denote the period following the Neolithic Revolution whereby small, non-literate, kin-based agricultural villages were transformed into large, literate, hierarchically-ordered urban centers: the first civilizations (*New Light on the Most Ancient East*, 1934; "Changing Aims and Methods in Prehistory," *Proceedings of the Prehistoric Society* 1 [1935]: 1–15; *Man Makes Himself*, 1936; *What Happened in History*, 1942).

In NEF's case, his proposal involved a reassessment of the role of coal in the growth of European industry, whereby the first of two 'industrial revolutions' in Britain was held to have occurred in the period from 1540 to 1640. Struck by the rapid increase in British coal output that accompanied the decline of the timber industry between the dissolution of the monasteries and the outbreak of the English Civil War, NEF sought to prove his case that these parallel developments were not simply a function of population growth. He argued, to the contrary, that they were the result of "a sharp expansion of native industrial enterprise", and that clear evidence for this expansion could be found in the ship-building, salt, and glass industries (*The Rise of the British Coal Industry*, 2 vols., 1932).

In LEFEBVRE DES NOËTTES's case, he proposed that the process of technological invention proceeds by sudden leaps rather than gradual transformations, and that such 'revolutions' are followed by long periods of inactivity. For example, in his two-volume work *De la Marine antique à la marine modern: La révolution du gouvernail, contribution à l'étude de l'esclavage*, first published in 1935, he proposed that the invention of the hinged sternpost rudder in the 13th century initiated a revolution in ship design that improved oceanic navigation, enabled enormous increases in tonnage, and made possible the later European voyages of discovery. This 'great technological leap forward' was analogous to the earlier medieval technical revolution which he believed had been brought about by the invention of the horse harness, to which he had first drawn attention in *La force motrice animale à travers les âges* (1924) and *L'attelage: Le cheval de selle à travers les âges, contribution à l'histoire de l'esclavage* (1931). This latter 'technological revolution' provided one of the bases for Lynn White, Jr.'s later articulation of an agricultural revolution in the Middle Ages (see below).

Thus, we can see how the social milieu in which western scholars were working during the Interwar Period favored conceptions of revolution and radical rupture when describing major cultural transformations in history and prehistory.

Only a year before Bloch's aforementioned paper appeared in *Annales*, a fellow exponent of the new sub-discipline of the history of technology, Lewis Mumford (1895–1990), had also alluded to the idea that there had been an industrial revolution in the Middle Ages based primarily upon waterpower. In his highly influential book *Technics and Civilization* (1934, rpt. 1963) Mumford argued in the book's third chapter – titled "New Sources of Power" – that if power machinery is regarded as one of the primary manifestations of the new capitalist economy, "the modern industrial revolution began in the twelfth century and was in full swing by the fifteenth" (112). Like Bloch, Mumford listed the many industrial processes to which waterpower was applied in the latter half of the Middle Ages, not only grinding grain and pumping water, but pulping rags for paper, hammering and cutting iron, sawing wood, beating hides, spinning silk, felting woolen cloth, sharpening tools and weapons, pulling wire, crushing ore and powering bellows (114–15).

Mumford argued that parallel developments were taking place in the application of windpower to agriculture and land reclamation between the 12th and 16th centuries, and that although the "development of wind and water power did not reach its height in most parts of Europe until the seventeenth century [...] [p]lainly, the modern industrial revolution would have come into existence and gone on steadily had not a ton of coal been dug in England, and had not a new iron mine been opened" (117–18). Mumford's views were, therefore, certainly not in agreement with those of his contemporary, Nef, for example.

However, Mumford's and Bloch's speculations, as suggestive as they may have been, were (to quote Bloch) but "working hypotheses" ("Les 'inventions' médiévales," *Annales* 7 [1935]: 642).

In 1941, the English medievalist, Eleanora Carus-Wilson (1897–1977), provided some empirical evidence to back up Mumford's and Bloch's thesis. In her widely read paper "An Industrial Revolution of the Thirteenth

Century" (*The Economic History Review* 11 [1941]: 39–60) Carus-Wilson argued that during the 13th century, woolen cloth production had moved from the urban cloth manufacturing centers of England to a number of rural wool-growing centers due to the rapid process of mechanization of the fulling process: traditional methods of fulling by hand and foot had been replaced by waterpowered fulling mills. Although she did not provide any evidence for the supposed higher profitability of mechanized fulling over manual fulling, she argued that the shift from urban manual production to rural mechanical production led to large-scale social and economic changes that were comparable to those that occurred in the English textile industry during the 18th and 19th centuries (52). She supported these observations with a clear analogy between the widespread social disruption caused by the mechanization of the English fulling industry in the 13th century, and the adverse consequences of the mechanization of the English textile industry in the 18th and 19th centuries:

> the [13th] century [...] witnessed, in fact, an industrial revolution due to scientific discoveries and changes in technique: a revolution which brought poverty, unemployment, and discontent to certain old centres of industry, but wealth, opportunity and prosperity to the country as a whole (39).

In a later paper on the medieval woolen industry, Carus-Wilson wrote that the mechanization of fulling "was as decisive an event as the mechanization of spinning and weaving in the eighteenth century" ("The Woollen Industry," *The Cambridge Economic History*, vol. II, ed. Edward Miller, Cynthia Postan, and Michael Postan, 1952, 409). Clearly, this statement was intended as further endorsement of her earlier thesis.

The striking vision of medieval technological progress proposed by Mumford, Bloch, Lefebvre des Noëttes, and Carus-Wilson appears to have had a galvanizing influence on a younger generation of scholars in the emergent field of the history of technology, among the most prominent of whom were Robert J. Forbes (1900–1973), Lynn White, Jr. (1907–1987), and Bertrand Gille (1920–1980).

Between the 1940s and 1960s, White and Gille articulated the outlines of a persuasive narrative about an innovative technical culture that emerged in the latter half of the European Middle Ages. In his earliest essay on the topic, the technologies invoked by White ranged across examples from the domestic and agricultural spheres, the textile industry, shipbuilding and navigation, to military and mechanical innovations, and advances in architecture and engineering ("Technology and Invention in the Middle Ages," *Speculum* 15 [1940]: 141–59). In his mature work, White developed many of the themes and insights of this early essay into a more extended argument, focusing on advances in agricultural and mechanical technologies: the stirrup, horseshoe, horse harness, and horse collar; the heavy plough, open fields, and three-field crop rotation; water- and windpower; and the cam, crank, and clockwork (*Medieval Technology and Social Change*, 1962; "The Medieval Roots of Modern Technology," *Perspectives in Medieval History*, ed. Katherine Drew, and Floyd Lear, 1963, 19–34; "The Expansion of Technology 500–1500," *The Fontana Economic History of Europe*, vol. 1, ed. Carlo Cippola, 1972, 143–71). Gille's invocation of medieval technological innovations largely mirrored those described by White, and included "the use of hydraulic energy on a large scale, the practice of iron shoeing as well as modern harnessing, textile developments, the transformations in iron and steel making, and […] the appearance of new types of ships" (Bertrand Gille, *Histoire des Techniques l'Encyclopédie de la Pléiade*, 1978, trans. *The History of Techniques*, 2 vols., 1986, 487).

White and Gille were adamant that the technological changes they described were so profound in their effects that they initiated a revolution in medieval social and economic conditions. The most compelling evidence for this medieval technological revolution was, they claimed, the rapid growth in the use of 'non-human sources of power' from the 10th or 11th century onward (Bertrand Gille, "Le moulin à eau: Une révolution technique medieval," *Techniques et civilisations* 3 [1954]: 1–15; Lynn White, Jr., *Medieval Technology and Social Change*, 1962, 88–89).

Gille developed these ideas in a number of essays between the early 1950s and late 1970s, the earliest of which was a short monograph titled *Esprit et civilisation techniques au moyen âge* (1952) which explicitly stated that there was a mechanical revolution during the latter half of the Middle Ages, the most striking feature of which was the widespread development and application of waterpower. White, on the other hand, appears to have first clearly articulated the notion of an industrial revolution of the Middle Ages in a 1960 essay titled, "Tibet, India and Malaya as Sources of Western Medieval Technology" (*AHR* 65 [1960]: 515–26).

By the late 1960s, Gille, White, and their followers had fleshed out a relatively detailed account of how an 'industrial revolution of the Middle Ages' had unfolded, the basic elements of which appear to have been derived from Bloch. The first of these elements was that the Romans had not made any widespread use of waterpower, although they had perfunctorily deployed watermills and water-raising devices for at least half a millennium before the Empire collapsed. The second was that Christian monasteries had led the way in the reintroduction of Roman watermilling technology to

Western Europe during the Middle Ages. The third involved an invocation of monkish inventiveness as the primary spur to the rapid growth in the use of water- and windpower from the 10th or 11th century onward. BLOCH's views on these matters can be found in the English translation of "Avénement et conquêtes du moulin à eau" titled "The Advent and Triumph of the Water-mill" (*Land and Work in Mediaeval Europe: Selected Papers by Marc Bloch*, 1967, 141–42, 143–46, 148, 150–52, 182). Perhaps the clearest expression of this argument can be found in WHITE's "Cultural Climates and Technological Advances in the Middle Ages" (*Viator* 2 [1971]: 171–201), although it first appears in "Dynamo and Virgin Reconsidered" (*The American Scholar* Spring [1958]; rpt. *Dynamo and Virgin Reconsidered*, 1968). GILLE's and WHITE's narrative appears to have been at least partially informed by the Annaliste insight that the role of longstanding cultural institutions such as the Church in historical development should receive more attention.

While BLOCH's 1935 paper seems to have provided some of the major themes for the narrative framework of an industrial revolution in the Middle Ages, CARUS-WILSON's work was deployed by historians of technology as an exemplar of rapid medieval industrial development and the new, positive attitude to technical activities which, they claimed, had clearly emerged by the 13th century (see, for example, Lynn WHITE Jr., *Medieval Religion and Technology*, 1978, 54, 66; Bertrand GILLE, "The Problems of Power and Mechanization," *A History of Technology and Invention: Progress Through the Ages*, vol. I: *The Origins of Technological Civilization*, ed. Maurice DAUMAS, 1969, 456).

A second key piece of empirical evidence drawn upon by proponents of an industrial revolution of the Middle Ages to support the idea of revolutionary growth in the use of waterpower was Margaret HODGEN's calculation that 5,632 watermills are recorded in Domesday Book ("Domesday Water Mills," *Antiquity* 13 [1939]: 261–79). This figure continued to be cited in the history of technology literature until the early 1990s, despite Reginald LENNARD having stated that the figure was too low in the late 1950s (*Rural England: 1086–1135*, 1959, 278–80), and H. C. DARBY and his colleagues having calculated the now accepted figure of 6,082 mills in the late 1970s (*Domesday England*, 1977, 361).

The third, and perhaps the most widely emulated, supporting strategy deployed by proponents of an industrial revolution in the Middle Ages was the creation of long lists of different types of industrial watermill, and where and when they are recorded in the manuscript sources. The most extensive of such lists was created by a student of WHITE's, Bradford BLAINE, in his doctoral thesis titled "The Application of Water Power to Industry During the Middle Ages" (UCLA, 1966). BLAINE's work, along with that of the medievalist, Anne-Marie BAUTIER, was frequently cited by proponents as crucial evidential support for an industrial revolution in the Middle Ages (Anne-Marie BAUTIER, "Les plus anciennes mentions de moulins hydrauliques industriels et de moulins à vent," *Bulletin Philologique et Historique* 2 [1960]: 567–626). This strategy, too, appears to be ultimately derived from BLOCH.

Thus we can see how a narrative first articulated by BLOCH, and to a lesser extent, MUMFORD, was developed by GILLE and WHITE, and embellished with empirical evidence primarily provided by CARUS-WILSON, HODGEN, BAUTIER, and BLAINE, to create a compelling case for an industrial revolution in the Middle Ages based on waterpower.

In its 'mature' form, the argument ran as follows: Although the vertical-wheeled watermill was invented in the ancient Mediterranean, it was used exclusively for grinding grain, and then only sporadically due to the prevalence of slaves, negative attitudes toward the banausic arts, and insufficient water resources. It was medieval European 'engineers' (trained by, or working in traditions established by, Christian monasteries) who developed the 'Roman' watermill's full potential through their ingenious incorporation into the milling apparatus of a variety of mechanical innovations, including the cam, crank and trip-hammer. The incorporation of these innovations into medieval watermills allowed them to be applied to a range of industrial processes, from fulling cloth and crushing bark and hemp, to forging iron and powering bellows, thus freeing human labor for other purposes, just as the steam engine had done in the late 18th and 19th centuries. The widespread mechanization of industry that occurred in the second half of the Middle Ages led to similar transformations in the medieval economy and society to those seen in the 'later' Industrial Revolution.

Although WHITE's *Medieval Technology and Social Change* was instrumental in popularizing and disseminating the idea that there had been an industrial revolution in medieval Europe, it was given additional impetus by, and can in some respects be seen as culminating in, a widely read work of popular history by Jean GIMPEL, *La Révolution industrielle du moyen âge* (first published in 1976; trans. *The Medieval Machine: The Industrial Revolution of the Middle Ages*, 1988). Although GIMPEL invoked Oswald SPENGLER's *Der Mensch und die Technik* (1931; trans. *Man and Technics*, 1932) as his main inspiration for the idea that "the foundations of our present technologically oriented society were laid not in the Italian Renaissance or in the English Industrial Revolution, but in the Middle Ages" (viii), the first three chapters of the book on energy, agriculture, and mining are heavily indebted to the narrative articulated by earlier social and economic historians and historians of technology, although frequently without adequate acknowledgement of that scholarly debt.

Two other influential books that either openly or tacitly accepted the industrial revolution of the Middle Ages thesis are Carlo CIPOLLA's *Before the Industrial Revolution* (1976; rpt. 1981, 1993), and Terry REYNOLD's *Stronger Than A Hundred Men* (1985). The popularity and influence of the theory can still be discerned in recent publications, such as John H. MUNRO's "Industrial Energy from Water-Mills in the European Economy, 5th to 18th Centuries: the Limitations of Power" (*Economia e Energia*, ed. Simonetta CAVACIOCCHI, 2003, 223–69).

While the general scholarly reaction to the thesis appears to have been generally more positive amongst historians of technology than amongst medieval historians and archaeologists, there do appear to have been some national and theoretical divergences. Historians working in the neo-Malthusian tradition most popularly expounded by Michael POSTAN (1898–1981) tended to be critical or dismissive of the theory, as their assessment of medieval technological achievements was generally negative. Marxists and neo-Marxists also tended to be critical of the theory, not because their assessments of medieval technical abilities were negative, but because they reacted against the theory's lack of engagement with questions of social class and power. Perhaps owing to the stronger evidence for technological progress in medieval France and Italy, French and Italian medievalists appear to have been more receptive of the theory than were British medievalists (see, for example, Robert PHILIPPE, "L'église et l'énergie pendant le XI^{e} siècle dans les pays d'entre Seine et Loire," *Cahiers de Civilisations Médiévale* 27 [1989]: 107–17). The more critical reactions to the theory are outlined below.

D. Critiques of the Industrial Revolution of the Middle Ages

Despite an apparent reluctance amongst historians of science and technology to explore the validity of the thesis that there was an industrial revolution in the Middle Ages until comparatively recently, critical scholarship that has exposed the weaknesses of its central claims and evidential support has grown in size and scope over the last two decades.

Amongst the central claims that have been questioned and/or proven to be incorrect are:

1. technological stagnation was a characteristic of Greco-Roman civilization, along with the associated claim that Roman use of water technology was sporadic and infrequent;
2. the technological contributions of the Romans, Chinese, and/or Islamic societies to medieval European industry were not significant or comparable to those originating in Europe;

3. Christian monasteries were primarily responsible for reintroducing Roman watermilling technology to Western Europe, and dominated the industry until well into the Middle Ages; and
4. monastic innovation can account for many of the technical advances that occurred in industry during the Middle Ages.

Questions surrounding the evidential support used by proponents of an industrial revolution in the Middle Ages have focused on the following issues:

a. the piecemeal fashion in which medieval European data on industrial milling was compiled by proponents, and their lack of systematic analysis of those data;
b. the geographically restricted evidence for a rapid growth in the industrial uses to which waterpower was applied across most of Western Europe; and
c. the geographically restricted evidence for industrial milling being a more profitable activity than grain milling.

With respect to argument [1] above that technological stagnation characterized the ancient world, there is now a substantial body of evidence compiled by archaeologists such as Kenneth D. White (*Greek and Roman Technology*, 1984), Örjan Wikander (*Exploitation of Waterpower or Technological Stagnation? A Reappraisal of the Productive Forces in the Roman Empire*, 1984), and Kevin Greene ("Perspectives on Roman Technology," *Oxford Journal of Archaeology* 9 [1990]: 209–17) which supports the revisionist view that the technological achievements of the Hellenic Greeks and Romans were far more extensive and impressive than was previously accepted by scholars of the ancient world, such as Benjamin Farrington (*Science in Antiquity*, 1936; rpt. 1969), Moses Finley ("Technology in the Ancient World," *Economic History Review* 18 [1959]: 120–25; "Technical Innovation and Economic Progress in the Ancient World," *Economic History Review* 18 [1965]: 29–45), and H.W. Pleket ("Technology and Society in the Graeco-Roman World," *Acta Historiae Neerlandica* 2 [1967]: 1–25). Greene has further developed these insights in "Technology and Innovation in Context: the Roman Background to Medieval and Later Developments" (*Journal of Roman Archaeology* 7 [1994]: 22–33), and "Technological Innovation and Economic Progress in the Ancient World: M. I. Finley Re-Considered" (*Economic History Review* 53 [2000]: 29–59).

Furthermore, Wikander ("The Watermill," *Handbook of Ancient Water Technology*, ed. Örjan Wikander, 2000, 401–12) and the historian of technology, Michael J. T. Lewis (*Millstone and Hammer: The Origins of Water Power*, 1997), have demonstrated that Roman use of waterpower was also far more widespread and innovative than was previously accepted, and that such use included factory-scale flour production and almost certainly some industrial applications in iron mining and stone quarrying.

With respect to argument [2] above, Adam Lucas ("Industrial Milling in the Ancient and Medieval Worlds: A Survey of the Evidence for an Industrial Revolution in Medieval Europe," *Technology and Culture* 46 [2005]: 1–30) has summarized the manuscript and archaeological evidence for the widespread use of waterpower by the Romans, Chinese, and Islamic societies, long before an 'industrial revolution' is supposed to have occurred in medieval Europe. His paper argues not only that the industrial use of waterpower had clear precedents in earlier civilizations, but that the mechanical innovations required for industrial milling were almost certainly conveyed from those cultures to medieval Europe via Islamic Spain or the Byzantine Empire in the 10th or 11th centuries. Lucas's book, *Wind, Water, Work: Ancient and Medieval Milling Technologies* (2006) contains a compilation and analysis of all of the reliable manuscript and archaeological evidence for ancient and medieval industrial mills that he was able to collate at the time of publication.

With respect to argument [3] above, Lucas ("The Role of the Monasteries in the Development of Medieval Milling," *Wind and Water in the Middle Ages*, ed. Steven A. Walton, 2006, 89–127) has summarized the manuscript and archaeological evidence for the continuation of Roman watermilling practices in early medieval Italy and France, and for watermill usage in Ireland prior to the 7th century. This evidence strongly suggests that Christian monasteries did not, in fact, 'reintroduce' the watermill to Western Europe, but were, to the contrary, very much involved in the process of feudal appropriation of existing lands and watermills from communal interests and less powerful social groups. The paper also discusses the English manuscript evidence suggesting that while the Church may have held as many mills as the Crown around the time of the Norman Conquest, that was the peak of its influence, and it does not appear to have ever dominated the powered milling sector in medieval England.

With respect to argument [4] above, the two aforementioned papers by Lucas examine the evidence for Benedictine and Cistercian involvement in mill innovation, and conclude that there is indeed some evidence that the Cistercians were innovators in industrial milling, as some previous scholars such as Gille, White, and Gimpel have claimed. There appears to be very little systematic research on the topic of medieval monastic innovation, however.

The most systematic effort to address the adequacy of the evidential support used by proponents of an industrial revolution in the Middle Ages (issues a, b, and c above) is by LUCAS in his aforementioned paper on industrial milling, although important research examining the evidence from medieval England was undertaken by Richard HOLT (*Mills of Medieval England*, 1988, chapter 9) and John LANGDON ("Water-Mills and Windmills in the West Midlands, 1086–1500," *Economic History Review* 44 [1991]: 424–44; "Lordship and Peasant Consumerism in the Milling Industry of Early Fourteenth Century England," *Past and Present* 145 [1994]: 3–42). LUCAS argues that a detailed examination of the manuscript evidence drawn on by proponents of an industrial revolution in the Middle Ages, even when augmented by more recent systematic studies, does not warrant the conclusion that a pan-European industrial revolution ever took place. To the contrary, the most intense areas of industrial milling activity appear to have been certain regions of what we now call France and Italy between the 13th and 15th centuries. The main industries to which waterpower was applied in these regions were cloth, hemp, leather, and timber, as well as some metallurgical processes. In the later Middle Ages, this extended to forging iron and pulverizing and polishing ores. The evidence for the relative profitability of grain milling versus industrial milling appears to have been a factor in determining the extent to which industrial milling was implemented in different regions. In England and Wales, for example, where industrial milling was largely restricted to the fulling industry, fulling mill revenues were significantly lower than those for grain mills, whereas in northern Italy, fulling mill revenues were higher than those for grain mills, and their share of the overall milling sector was significantly higher than in Britain. The generic factors which appear to have made these developments possible included already well-developed local industries in specific commodities or products which had access to regional, national and/or international markets, as well as access to plentiful supplies of running water that could be harnessed for industry.

E. The Agricultural Revolution of the Early Middle Ages

In a further development that was analogous to the intellectual move made by TOYNBEE in his invocation of an earlier Agricultural Revolution which laid the foundations for the Industrial Revolution, and of CHILDE with his invocation of the 'Neolithic Revolution' which laid the foundations for his 'Urban Revolution,' Lynn WHITE, Jr. proposed in "Technology and Innovation in the Middle Ages" (1940) that there had been an agricultural revolution in the early Middle Ages which laid the foundations for an industrial revolution in the later Middle Ages. However, it was not until the publication of *Medieval Technology and Social Change* (1962) that he fully developed this theory, arguing that the revolution had occurred between the 6th and 9th centuries.

The claim that there had been a major transformation, if not a revolution, in early medieval agriculture had been made by a number of medievalists between the 1890s and 1950s, the most notable of whom were August MEITZEN (*Siedlung und Agrarwesen der Westgermanen und Ostergermanen, der Kelten, Römer, Finnen und Slaven*, 1895; rpt. 1963), Marc BLOCH (*Les Charactères originaux de l'histoire rurale française*, 1931; rpt. 1988), and Georges DUBY ("La révolution agricole médiévale," *Revue de géographie de Lyon* 29 [1954]: 361–66). However, according to the medievalist, Michael TOCH, it was WHITE who "presented a theory lucid enough to become part of our understanding of medieval history and sophisticated enough to explain a very complicated process spanning at least three centuries" ("Agricultural Progress and Agricultural Technology in Medieval Germany: An Alternative Model," *Technology and Resource Use in Medieval Europe*, ed. Elizabeth BRADFORD SMITH and Michael WOLFE, 1997, 158–69).

Amongst the central arguments made by WHITE in support of his theory of an agricultural revolution in early medieval Europe were:

1. the diffusion of the stirrup throughout Europe from Asia enabled the development of 'mounted shock combat', which in turn provided the basis for the development of 'feudalism' in Europe;
2. the replacement of the Mediterranean 'scratch plow' with the 'heavy plow' in Francia during the 7th century led to the development of the three-field crop rotation system, as well as open-field, communal agriculture;
3. the introduction of horseshoes and the new horse collar and harness, combined with the growing availability of horse feed, rapidly led to the replacement of less efficient oxen by horses in plow teams; and
4. the growth in the use of the plow and other farm implements (as well as weaponry) was made possible by the opening up of new iron mines in Carolingian times.

WHITE first clearly articulated his theory in the first two chapters of *Medieval Technology and Social Change*. Premised on an argument that appears to have been derived from LEFEBVRE DES NOËTTES ("La 'nuit' du moyen âge et son inventaire," *Mercure de France* 235 [1932]: 572–99), WHITE contended in the first chapter of the book that:

> [t]he stirrup, by giving lateral support in addition to the front and back support offered by pommel and cantle, effectively welded horse and rider into a single fighting unit capable of a violence without precedent. The fighter's hand no longer delivered the blow: it merely guided it [...] Immediately, without preparatory steps, it made possible mounted shock combat, a revolutionary new way of doing battle (2).

Essentially, WHITE argued that the Franks were responsible for a "drastic shift from infantry to the new mode of mounted shock combat" in the 8th century (27), and that this transition was made possible by the invention of the stirrup. According to WHITE, the 'key' to feudal institutions was the duty of knight's service, and the primary duty of the newly created knightly class was to defend the realm through mounted shock combat (31).

Apart from the influence of LEFEBVRE DES NOËTTES, WHITE's views about the significance of knight's service to the 'feudal revolution' were also partially shaped by earlier medievalists such as H.A. CRONNE ("The Origins of Feudalism," *History* 24 [1939]: 251–59). Although the debate about what constitutes this 'feudal revolution' and whether such a revolution occurred at all, continues in the scholarly literature to this day (Thomas BISSON, "The 'Feudal Revolution'," *Past and Present 142* [1994]: 6–42; Dominique BARTHÉLEMY, "The 'Feudal Revolution': I," *Past and Present* 152 [1996]: 197–205; Stephen D. WHITE, "The 'Feudal Revolution': II," *Past and Present* 152 [1996]: 205–23), few contemporary medievalists would endorse WHITE's technologically deterministic view of how this revolution first came about. The reactions of some of the more prominent scholars who were critical of WHITE's views are detailed in the section below.

Having laid the foundations, as it were, for his conception of revolutionary technological change in the early Middle Ages, WHITE's second chapter explores the key technological developments which he identified as constituting an agricultural revolution in early medieval Europe.

WHITE opens the chapter with an invocation of the notion of the British Agricultural Revolution as a precursor to the Industrial Revolution before stating that "northern Europe from the sixth to the ninth century witnessed an earlier agricultural revolution which was equally decisive in its historical effects" (40). He goes on to argue that the replacement of the Mediterranean 'scratch plow' with what he dubbed the 'heavy plow' in Francia during the 7th century led to the development of the three-field crop rotation system as well as open-field, communal agriculture, vastly improving productivity. Northern European farmers were subsequently able to plant oats in summer as well as spring, increasing the supply and reducing the price of horse feed, thus making horse ownership more widespread. The open-field system enabled the pooling of oxen and horses for plowing, increasing communal solidarity and the need for collective decision-making. The introduction of horseshoes and the new horse collar and harness, combined with the growing availability of horse feed, rapidly led to the replacement of less efficient oxen by horses in plow teams. The growth in the use of the plow and other farm implements (as well as weaponry) was made possible by the opening up of new iron mines in Carolingian times. These technical and organizational innovations vastly improved agricultural productivity and contributed to a rapid increase in northern Europe's population, breaking the previous nexus between low agricultural productivity and low living standards.

F. Critiques of the Agricultural Revolution of the Early Middle Ages

Scholarly reaction to White's thesis that there had been an agricultural revolution in the early Middle Ages was far swifter and more polarized than it was to the notion of an industrial revolution of the later Middle Ages. The less favorable pole of these reactions is represented by the earliest critique of White's *Medieval Technology and Social Change* by the medievalists Peter H. Sawyer and Rodney H. Hilton in "Technical Determinism: The Stirrup and the Plough" (*Past and Present* 24 [1963]: 90–100), while the more favorable pole can be seen in the assessment of Toch cited above, and in John Langdon's *Horses, Oxen and Technological Innovation* (1986), although both scholars are far from uncritical in their reassessments of White's thesis in the light of recent scholarship. Because Sawyer's and Hilton's review and Toch's aforementioned paper provide the most cogent criticisms of White's theory, the following section summarizes the main elements of those criticisms, using a similar framework of argument to that provided in the section on critiques of an industrial revolution in the Middle Ages.

In the aforementioned review of White's book, Sawyer addressed White's argument about the impact of the invention of the stirrup on the development of 'feudalism' [argument 1 in the previous section], while Hilton addressed White's claims for an agricultural revolution of the early Middle Ages [arguments 2 to 4 above]. Interestingly, neither scholar appears to have felt qualified to address the case made by White for major advances in medieval mechanical technology made in Chapter Three.

With respect to argument [1] above, although continental scholars have drawn attention to the defeat of the Magyars by Otto I in 955 after spending ten years training his army for mounted shock combat (for the most recent scholarly reassessment of this literature, see Charles R. Bowlus, *The Battle of Lechfeld and its Aftermath, August 955: The End of the Age of Migrations in the Latin West*, 2006), Sawyer's critique centers on the fact that mounted shock combat did not become a common Western European military tactic until the 12th century: four centuries later than that proposed by WHITE. Amongst the weaknesses in WHITE's argument to which SAWYER draws attention is that although WHITE acknowledged that the Anglo-Saxons were using stirrups prior to the Norman invasion and did not use them in battle against the Normans, he failed to account for why their use was so decisive in shaping the new feudal society on the other side of the Channel. SAWYER also points out that the Frankish evidence for the adoption of the stirrup is considerably later than that suggested by WHITE, and that other Germanic peoples may have used the stirrup earlier, but did not develop feudal societies.

With respect to argument [2] above, HILTON begins by pointing out that although it had been argued by medievalists such as Georges DUBY (*L'économie rurale et la vie des campagnes dans l'occident médiéval*, 1962; trans. *Rural Economy and Country Life in the Medieval West*, 1968) that the population growth, urbanization, and commercial expansion of Western Europe between the 11th and 13th centuries was the result of improvements in agricultural productivity per head, DUBY's "chronology differs substantially from Mr White's and his handling of evidence conforms to scholarly standards" (95). He then goes on to question WHITE's use of the terminology 'scratch plow' and 'heavy plow' to differentiate between Mediterranean and Northern European variants, and points out that the Belgic plough (a kind of heavy plow according to WHITE's definition) was used as early as the 1st century B.C.E., long before its supposedly widespread use in the Frankish heartland in the 7th century.

HILTON also notes that open-field, communal agriculture was practiced in 7th-century England, and that WHITE's claim that open-field agriculture and the heavy plow were introduced to England by the Danes rests on faulty reasoning and misinterpreted evidence. HILTON argues that there was no sharp distinction between the two and three field systems, and that both practices continued simultaneously for some centuries. In support of the earlier point made by HILTON, TOCH notes that the process of reshaping European agriculture through the spread of three-field rotation, grain growing, and open fields did not occur until the 11th and 12th centuries, as DUBY had suggested (*Rural Economy*, 90–9, 103–12). This process occurred within the economic framework of the manor, and the power of lords to enforce such changes on their own and tenants' holdings: a framework which WHITE tended to minimize or misconstrue. Most of the improvements in productivity which occurred in later medieval agriculture can be attributed to more intensive applications of labor than to technological improvements.

With respect to argument [3] above, HILTON points out that the Carolingian evidence indicates no significant improvement in crop yields, or that the large scale sowing of oats was intended to provide fodder for horses. He also contends that the reduction of the fallow in 13th-century England as a result of population pressure reduced feed for beasts and therefore their availability for work and manuring pastures. For example, he cites evidence from Bedfordshire that the use of oxen as draught animals remained the preference of lords, while peasants used horses. In his aforementioned paper, TOCH has presented more substantial evidence, partially based on LANGDON's research, that the replacement of the ox by the plow-horse in Europe took considerably longer than three centuries and up to seven centuries in Germany. As noted previously by HILTON and demonstrated most clearly by LANGDON, different regions and social groups continued to use both animals in different contexts and for different functions, depending on local environmental and economic conditions. In England, the increased use of horse power for plowing was not really evident until the 12th and 13th centuries, although the transition was somewhat quicker with respect to vehicle hauling.

With respect to argument [4] above, HILTON questions WHITE's evidence for the opening of 'great new iron mines' during Carolingian times, pointing out that "there is no quantitative evidence cited from archaeological research" (96), and that the references which WHITE did cite do not indicate what he claimed. HILTON concludes that the iron used by the Franks more likely came from the Swedes. TOCH adds that there is no evidence that iron farm implements and weaponry became far more widespread during Carolingian times, and that the diffusion of improved agricultural implements did not occur until the later Middle Ages, along with a more abundant supply of iron.

The current scholarly consensus on these issues is well summarized in a collection of essays edited by Grenville ASTILL and John LANGDON titled *Medieval Farming and Technology: The Impact of Agricultural Change in Northwest Europe* (1997).

G. Conclusion

From a historiographical perspective, it now seems clear that both the agricultural revolution and the industrial revolution of the Middle Ages narratives were squarely aimed at recuperating the technical contributions of medieval Europe to the modern period. While their proponents accepted the traditional view that technological stagnation in the ancient world was due to the institution of slavery and unfavorable attitudes toward technical knowledge amongst ancient elites, they argued that technological development in the medieval West was enabled by the decline of slavery under Christianity and the marriage of contemporary practical and classical theoretical knowledge in the monasteries. In the case of the agricultural revolution of the Middle Ages thesis, the new feudal system which made improvements in agricultural production possible was founded on a number of improvements in military and agricultural technology. In the case of the industrial revolution of the Middle Ages thesis, the harnessing of 'new sources of power' (i. e., water, wind, and the tides) during the Middle Ages was analogous to the harnessing of coal and steam during the Industrial Revolution.

WHITE's dual theses that an agricultural revolution in the early Middle Ages had made possible an industrial revolution in the later Middle Ages provided a complementary explanation to those revolutionary accounts of discontinuous scientific change popularized by Thomas KUHN in *The Structure of Scientific Revolutions* (1962). WHITE's account is complementary in the sense that it provides an explanation for some aspects of the 'pre-paradigm phase' of the scientific disciplines of mechanics and statics, when certain crucial technical attitudes and developments were laid down which provided some of the foundations for the later Scientific and Industrial Revolutions. The second thesis in particular provides some evidence for the relative ubiquity of semi-automated machinery in late medieval Europe and for the beginnings of factory production.

According to standard accounts of the Scientific Revolution, the social and economic changes that occurred during the Renaissance (including the rise of Protestantism, a renewal of interest in classical learning, and the invention of the printing press) weakened the authority of the Church and absolute monarchs and enabled the intellectual freedom and social mobility which led to the Scientific Revolution. A narrative accounting for the discontinuity between the medieval industrial revolution and the Scientific Revolution was available via the argument that medieval Europe failed to capitalize on its technical advances owing to the Church's intolerance of intellectual debate and dissent, and the irrationalist tendencies of natural philosophical discourse under scholasticism. The curtailment of ecclesiastical power and authority during the early modern period provided a neat explanation for why the marriage of theory and practice that had begun under the scholastics did not bear more fruit until the 16^{th} and 17^{th} centuries. Such arguments can be seen as having provided a space within which it was possible for proponents of the industrial revolution of the Middle Ages thesis to avoid close scholarly scrutiny by their peers for a number of years.

In a recent contribution to the *Encyclopaedia of the Scientific Revolution*, the historian of early modern science, John SCHUSTER, suggested that evidentially challenged modernist narratives about the Scientific Revolution continue to maintain some credibility in the history of science because their postmodern competitors have been reluctant to entertain, let alone articulate, alternative 'grand theories' or metanarratives. To briefly summarize SCHUSTER's assessment of what such an alternative might look like, it would start from the assumption that "knowledge is made in evolving traditions of practice or subcultures that have their own synchronic density and diachronic dynamics" ("Internalist/Externalist Historiography," *Encyclopaedia of the Scientific Revolution*, ed. Wilbur APPLEBAUM, 2000, 334–36). In the absence of any vigorous scholarly contestation over what might constitute more historically accurate grand narratives about the unfolding of that period called the Scientific Revolution, the discipline and the wider public have lacked the conceptual tools to adequately interrogate the plausibility of these established modernist narratives.

A similar case could certainly be made for the narratives of technological revolution that have been the topic of this essay. The most commonly circulated and recognized representations of premodern technology continue to be those provided by a relatively small group of post-War historians of ancient and medieval technology, despite the emergence of more sophisticated scholarship in recent years. Lewis MUMFORD, Robert FORBES, Moses FINLEY, Lynn WHITE, Jr, Bertrand GILLE, and Jean GIMPEL have largely shaped the contours of scholarly awareness about premodern technology in the history of science and technology, and also to some extent in archaeology and social and economic history: an observation that can be verified by examining the work of a number of different scholars working across these disciplines during the 1980s and 1990s.

The publications in which these historians' narratives appear have, in the words of the archaeologist, Kevin GREENE, had "an extraordinary influence beyond their immediate subject areas, irrespective of their changing status within academic history and archaeology," primarily because they contained ideas that captured the public imagination and could be promoted in books for a popular or more general readership ("V. Gordon Childe and the Vocabulary of Revolutionary Change," *Antiquity* 73 [1999]: 97–109).

During a period in which radical political positions and revolutionary rhetoric were both intellectually *de rigeur* and part of everyday discourse, it is perhaps not surprising that a number of socially progressive historians should have embraced and promoted revolutionary narratives in their work. Considering the intellectual milieu of the 1950s, '60s and '70s, it should also not be too surprising that certain affinities of style, methods of reasoning, and explanatory schema should characterize this scholarship, and that these features should parallel developments in the history of science.

At the same time, it seems clear from the previous discussion that the modernist historians of technology who articulated these narratives of medieval technological revolution were guilty of a sin that is typical of the humanities and social science disciplines: they insulated themselves from other disciplines with similar or overlapping concerns and developed their own positions on those concerns. It was left to later generations of scholars with less investment in disciplinary boundary maintenance and entrenched theoretical positions to reassess the relevant arguments and evidence.

On a more general level, while the use of revolutionary terminology to describe technological change in premodern as well as modern societies has diminished in contemporary scholarship, the question of what characterizes genuinely 'revolutionary' change in the technological development of a given society or region, and how it should be characterized, remains as unresolved in the history of technology as it is in the history of science.

As Schuster (*The Scientific Revolution: An Introduction to the History and Philosophy of Science*, 1995, chapter 25) has noted, scholars will bring with them their linguistic and theoretical baggage when using the terminology of revolution to describe developments in the history of science: while political revolutions may be relatively easy to define and to identify, cultural revolutions are in the eye of the beholder. It nevertheless remains clear that there are instances in the history of human cultures when radical transformations in their ways of being and doing occur over comparatively brief spans of time, and that our theoretical constructs and language are hard pressed to the task of adequately describing, let alone explaining them.

The problems for scholars attempting to grapple with these issues revolve around such epistemological concerns as the nature and availability of evidence, standards of proof, and the explanatory adequacy of theories and narratives that seek to illuminate our understanding of rapid cultural change. Although none of the key elements of the narratives of medieval technological revolution which have been examined in this essay have withstood the test of time, recent scholarship has revealed that technological development in some regions of medieval Europe during certain key periods was significant, impressive, and perhaps in some instances might even warrant the appellation, 'revolutionary', if suitably qualified.

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Adam Lucas

Narratology and Literary Theory in Medieval Studies

A. Definition

‘Narratology’ designates the study of narratives according to their formal structures rather than their themes or values. Modern narratology began with the Russian formalists as a method for analyzing strictly literary texts, but scholars since the peak of French structuralism do not restrict its scope to literary (fictional, aesthetically self-conscious) narratives. Rather, they understand narrative discourse to include any account of contingent events and the actions and attitudes of associated agents. In recent decades, narratology has informed the efforts of medievalists studying forms as disparate as romance, hagiography, chronicle, ballad, and pictorial narratives in books and plastic arts. Medievalists in the fields of literature and history have also enriched narratology by challenging the ahistorical assumptions that underlie its traditional structuralist mode. In a process of mutual enrichment, medievalists have fixed cultural and historical horizons constraining supposedly universal narrative structures, while the analytical approach of narratology illuminates new aspects of medieval texts.

B. Origins and Forerunners: From Aristotle to Russian Formalism

Tzvetan Todorov coined the term “narratology” (*Grammaire du Décaméron*, 1969), but the field’s intellectual origins go back to such practical observations in Aristotle’s *Poetics* as his distinction between “diegesis” (telling, as in epic) and “mimesis” (showing, as in drama). In the modern period, the first major precursor of narratology was Russian Formalism, emerging from the Moscow Linguistic Circle of the 1910s. The Russian Formalists desired (like North America’s New Critics) to isolate ‘literary’ elements from their socio-