CULTURAL CLIMATES AND TECHNOLOGICAL ADVANCE IN THE MIDDLE AGES

by Lynn White, Jr.

To establish facts, and the more obvious relations among facts, has never satisfied the consciences of historians. We are driven to ask not only what happened but also why it happened. Historical explanation, of course, is seldom a matter of one billiard ball striking another, of "causes" in the narrow sense. It is much more often a process of gradual illumination of the fact to be explained by gathering around it other facts that, like lamps, seem to throw light on it. At last the historian arrives at a sense that the central fact on which he is focusing has become intelligible.

In 1959 when I finished the manuscript of a book on medieval technology, I was painfully aware of its greatest defect: it identifies and describes a few major aspects of the unprecedented technological activity that occurred in the medieval West, but it fails to explain the phenomenon observed. To tell the truth, I was much more sure of the *what* than the *why*. Four years later I had become bold enough to publish a preliminary inventory of possible reasons, not all of equal weight but none mutually exclusive, for medieval technological advance. This is not, however, the sort of problem that stands still. The present state of scholarship demands a new effort to understand it.

I

There is much to be understood. The technological creativity of medieval Europe is one of the resonant facts of history. Beginning obscurely as early as the sixth century, within three hundred years the northern peasantry created a novel agricultural system that, in proportion to expenditure of human labor, was probably the most productive in the world. In the eighth century the Franks revolutionized their methods of warfare, and thereafter their descendants consistently maintained the initiative in improving military technology, as distinct from military organization. From about the year 1000 onward—although the movement was foreshadowed in the ninth century—the West produced new labor-saving mechanical devices and explored new applications of power to production, thus providing the industrial basis for burgher capitalism. Starting in the sixth century, but particularly after 1200, Europe led in the development of ship design and the nautical arts.

While the medieval West's cousinly cultures, Byzantium and Islam, long remained more sophisticated in most other respects, in technology they were laggards as compared with Europe. Only contemporary China—from which the West borrowed much—could compare with Europe in inventiveness and eagerness for useful novelties. The emergence of the mechanical clock in the second quarter of the fourteenth century, however, by enlarging the number of craftsmen skilled in making and correlating moving metal parts in machines, led in Europe to heightened activity that soon gave to the Occident a clear technical superiority even over China.

Romans had been no less predatory than were Europeans of the late Middle Ages, but the Caesars were so ill equipped that they could not extend their rapacity greatly beyond the basin of the Mediterranean. By 1492, however, Europe had developed an agricultural base, an industrial capacity, a superiority in arms, and a skill in voyaging the ocean which enabled it to explore, conquer, loot, and colonize the rest of the globe during the next four centuries and more. This unification of

world history was a unique event. Its implementation, and that of the Imperialist Age, 1500 - 1950, was provided largely by the Middle Ages.

Moreover, modern technology is the extrapolation of that of the Western Middle Ages not merely in detail but also in the spirit that infuses it. The later thirteenth century in Europe marks the moment of crisis in the history of mankind's relation to the natural environment: it produced "the invention of invention" of which the practical effects were soon felt. The earlier record of technology around the globe is scattered and often lacking in continuity; it recounts a generally slow accumulation of isolated specific inventions, their spread and elaboration. But in the Middle Ages, in Europe alone, invention became a total and coherent project. From the later Middle Ages onward, world technology was increasingly European technology.

Technicians at that time in large numbers began to consider systematically all the imaginable ways of solving a problem. About 1260, the Franciscan Roger Bacon, pondering transportation, confidently prophesied an age of automobiles, submarines, and airplanes. Since arrow wounds were then a medical problem, about 1267 Theodoric, successively bishop of Bitonto and Cervia, in his treatise on surgery noted that for the extraction of arrows "[[new instruments, new skills, and new ways [for extracting arrows] were being found by physicians everyda y.]]" Clocks were a great problem, and proposals for their improvement were frequent before the solution was found. On the basis of the recently introduced Chinese mariner's compass, and inspired by the novel Hindu concept of perpetual motion, in 1269 Roger Bacon's friend, the military engineer Peter of Maricourt, proposed a magnetic clock to replace all others. In 1271 Robert the Englishman, talking about plans for a weight-driven clock, admitted that the problem of the escapement had not been entirely conquered, but he was confident that it would be." Almost at the same moment, at the court of Alfonso el Sabin of Castile, Rabbi Isaac ben Sid of Toledo described not only new kinds of waterclocks, which he claimed to be much better than any earlier models; he also depicted as an absolute novelty a weight-driven clock with a mercury brake. Indeed, this was a fairly practical solution for the escapement, as a subsequent tradition of such clocks shows. Before 1313 someone invented the sandglass. But technicians labored from the 1260s until the 1330s before the true mechanical clock was invented.

In a sermon on repentance preached at Santa Maria Novella in Florence on 23 February 1306, the Dominican Fra Giordano of Pisa, while providing our best evidence of the invention of eyeglasses in the 1280s, incidentally sang the praises of the recent invention of invention. "Not all the arts," he said, "have been found; we shall never see an end of finding them. Every day one could discover a new art . . . indeed they are being found all the time. It is not twenty years since there was discovered the art of making spectacles which help you to see well, and which is one of the best and most necessary in the world. And that is such a short time ago that a new art, which never before existed, was invented . . . I myself saw the man who discovered and practiced it, and I talked with him."

By the early fourteenth century, then, Europe showed not only an unmatched dynamism in technology: it also arrived at a technological attitude toward problem solving which was to become of inestimable importance for the human condition. The profound contrast between this ,..aspect of the Occident and the relative passivity toward technology in the Near East is the more significant because Byzantium, Islam, and the Western world were related societies, all in great measure, but in varying proportions, built of elements found in the Greek and Semitic legacies from Antiquity. The fact that thirteenth-century theologians in Cairo, Constantinople, and Paris were all commenting on Aristotle helps us to grasp the unity of the triune Middle Ages. The fact that in the time of Saint Thomas Aquinas labor-saving machinery was little developed in the Near East and concern for invention was minimal, whereas in the West a new sort of engineering" was being pursued with an enthusiasm amounting to passion, helps us to understand why the Occidental third of the Middle Ages generated what we call the modern world.

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IV

The most thoughtful analysis of the presuppositions of Western technology has been provided by a medieval historian, Ernst Benz of the University of Marburg. Study of Buddhism and personal experience of it in Japan—especially of the anti-technological impulses in Zen—led him to find the genesis of Europe's technological advance in Christian beliefs and attitudes. The Christian Creator God, the architect of the cosmos and the potter who shaped man from clay in his own image, commands man to rule the world and to help to fulfill the divine will in it as a creative cooperator with him. History, far from being cyclical as it is in most religions, in Christianity is unique and unilineal; it is accelerating toward a spiritual goal; there is no time to lose; therefore, work, including manual work, is an essential and pressing form of worship. Moreover, matter was created for a spiritual purpose and it is neither to be transcended nor despised: the dogmas of the incarnation and of the resurrection of the flesh vouch for this. The sense that in telligent craftsmanship is shown in the world's design, and that we participate in the divine by being ourselves good artisans; the conviction that we follow God's example when we use substance for righteous ends, that time must be saved because every moment is a unique psychic opportunity: these are characteristics of the Judeo-Christian view of reality and of destiny. They are alien to all the other major religions except Islam, which belongs to the same spiritual phylum, and possibly Zoroastrianism, a related species. Since in Hellenistic times and in China there were notable and sometimes rapid advances in engineering, Christianity obviously is not essential to technological dynamism. What Benz suggests, nevertheless, is that Christianity provided, historically in Europe, a set of assumptions, a cultural climate, unusually favorable to technological advance.

One may expand Benz's thesis somewhat. In 1956 Robert Forbes of Leyden and Samuel Sambursky of Jerusalem simultaneously pointed out that Christianity, by destroying classical animism, brought about a basic change in the attitude toward natural objects and opened the way for their rational and unabashed use for human ends. Saints, angels and demons were very real to the Christian, but the *genius loci,* the spirit inherent in a place or object, was no longer present to be placated if disturbed.

Undoubtedly also, there has been an element of Christian compassion motivating the development of power machinery and labor-saving devices: as early as the sixth century an abbot in Gaul, troubled by the sight of his monks grinding grain in querns, built a water mill, "[[this.. is the labor of monks]]." Pity, however, is not exclusively a Christian virtue: Antipater's pagan poem, which is our second document for the existence, of water mills in the ancient Mediterranean, celebrates the new machine harnessing the water nymphs to save the aching backs of slave women.

Benz has pointed a direction by which historians can make intelligible the technological dynamism of the Middle Ages. His hypothesis, however, is defective because he fails to recognized that the Greek church held the fundamentals of the Christian faith as ardently as did the Latin, yet after Kallinikos's invention of Greek fire just before 673 the 'highly civilized regions dominated by Eastern Orthodoxy were unadventurous in technology. If, as Benz believes, the vigor of Western medieval technology is an expression of religion, the sources of that dynamism must be found less in the broader aspects of Christianity than in the distinctive qualities and moods that differentiate Occidental from Byzantine Christian piety.

It may seem ludicrous to claim that the distillation of alcohol, the trebuchet, the functional button, the suction pump, the wire-drawing mill, and the myriad other medieval inventions are ultimately *gesla* Christi [[achievements of Christianity]] where Christ was worshiped with a Latin accent. Nevertheless, the processes of the human mind are so curious that our judgment of the forces that produced Western technology must be based upon what appear to be the relevant facts even when the result contains elements of irony. Since people are often comic, so also history may be.

Historians of spirituality have long been aware of a basic contrast of tonality between the two great segments of Christendom which surely affected the development of their respective technologies. The Greeks have generally held that sin is ignorance and that salvation comes by illumination. The Latins have asserted that sin is vice, and that rebirth comes by disciplining the will to do good works. The Greek saint is normally a contemplative; the Western saint, an activist.

This difference, largely subliminal, emerges clearly in the iconography of the Creator God. During the first Christian millennium. in both East and West, God at the moment of creation is represented in passive majesty, actualizing the cosmos by pure power of thought, Platonically. Then, shortly after the year 1000, a Gospel book was produced at Winchester which made a great innovation inspired by Wisdom 11 : 20 , "[[Yea, and without these might they have fallen down with one blast, being persecuted of vengeance, and scattered abroad through the breath of thy power: but thou hast ordered all things in measure and number and weight]]," the monastic illuminator showed the hand of God—now the master craftsman—holding scales, a carpenter's square, and a pair of compasses. This new representation spread and, probably under the influence of Proverbs 8.27, "[[He set a compass upon the face of the depth]]," the scales and square were eliminated leaving only the compasses—the normal medieval and renaissance symbol of the engineer—held in God's hand. This tradition, which culminated in William Blake's "Ancient of Days," was never adopted in the Eastern Church. It was the perfect expression of Western voluntarism, but it violated Greek intellectualist sensibilities about God's nature.

As medieval machine design became more intricate, God the builder developed into God the mechanic. The term "machina mundi" [[univers as machine]] is at least as old as Lucretius, but was rejected on religious grounds by Arnobius Afer. By the thirteenth century, however, it was commonly used by Latin clerical scientists and had strongly affirmative overtones. The first to foreshadow the Deist concept of the clockmaker God was Nicole Oresme who died as bishop of Lisieux in 1382. He proposed that, to prevent the celestial spheres from accelerating as they turned, the Creator had provided the equivalent of a clock's escapement mechanism to keep them rotating at a constant speed. The subsequent success of the simile indicates the direction of Europe's thought about God, nature and man.

Students of the history of scriptural exegesis are as helpful as art historians in laying bare structures of values that lie so deep that they are not often verbalized explicitly. For our purposes the varying treatments of Luke 10.38-42, the Mary-Martha episode, are full of meaning. Since the time of Origen at least, the Greek East has invariably assumed that Martha represents the active and Mary the contemplative life, and that Christ's rebuke to Martha validates the superiority of the contemplative over the active. In the West, however, a quite different style of exegesis emerges early. Saint Ambrose, once himself a Roman official and now a bishop, feels that the sisters of Bethany are symbols of *actio* and *intentio:* both are essential, and one cannot rightly be considered better than the other. Then Saint Augustine, a revolutionary in so many ways, entirely subverts the Greek exegesis, the structure of values inherent in it, and, one must, add, the literal meaning of Christ's words. To him, Mary and Martha represent two stages in the perfect life: Martha, the life of the soul in time and space; Mary, in eternity."[[In Martha was the image of the present, in Mary the future. What Martha was doing, that we are now; what Mary was doing, that we trust to become]]." Yet, since we mortals dwell in time and not eternity, we must be Marthas, troubled about many things, rather than Marys.

The Middle Ages grew increasingly restless over this pericope. In the middle of the twelfth century Richard of Saint Victor, while acquiescing in Christ's praise of Mary's choice on the Augustinian

ground that contemplation anticipates our heavenly condition, nevertheless shows by his phrasing where his own sympathies lie: "[[Mary was intent to be fed by the Lord; Martha was intent on how to feed the Lord. This is the day to prepare a feast for the Lord]]." Two hundred years later the European affirmation of the primacy of action reaches almost absurd heights in one of Meister Eckhart's vernacular sermons on this text. Martha, the older and wiser sister, fears lest the adolescent Mary may become so ecstatic in contemplation that she will not mature spiritually by realizing that action is essential to holiness. Christ's apparent rebuke to Martha and praise for Mary are, in Eckhart's opinion, the exact reverse: they are his way of telling the perceptive Martha not to be troubled by Mary's sentimental condition; she will grow out of it. The Greek Church could not have produced, much less tolerated, such a sermon. The mood of activism which Eckhart reflects surely fostered technological growth in the West.

Some degree of respect for manual labor is, along with activism, integral to massive technological development. It was generally lacking, at least among the literate classes, in the Greco-Roman world. The Jews, however, considered God's command to labor six days of the week to be as binding as that to rest on the seventh. In the late third century, massive conversions of pagans to Christianity around the eastern Mediterranean threatened to corrupt the Church, and quite naturally a few zealots tried to purify it by returning to its primitive, that is Jewish, tradition. One result was monasticism, which from the beginning asserted the originally Jewish thesis that work is worship, indeed, that it is an essential kind of worship. With con siderable constancy the monks of both East and West continued through the Middle Ages to work with their hands. Many of them likewise were well read; indeed, for centuries monks were the most learned men of the West. This combination of education with practical work would seem theoretically, by joining head and hand, to provide communities in the monasteries where technological innovation would thrive. Yet the contrast in this respect between the sons of Saint Basil and those of Saint Benedict is notable.

One voice of dissent in the West may illuminate the basic situation. The sole instance in Christian monasticism of an antipathy toward the mechanic arts appears in *Scholica graecarum glossarum* by Martin of Laon (died 875) who derives *mechanicus* not from *prixavococ* but from *potxdc* "adulterer": "[[The adulterer is always defiled; the art of the mechanical is also a defiler; how else would she [mechanical arts] be so clever and so very subtle and almost invisible as to the point that we do not easily penetrate her ingenuity]]." Martin was an immigrant Irish monk. The rule of Saint Columba is the only monastic code of East or West in which manual labor is regarded as pure penance for sin, unconnected with prayer and praise. Moreover this etymology offered by Martin is the only Western occurrence of the Heronic concept of technology as primarily producing machines to deceive and awe the populace: one among several indications of connections between early Christian Ireland and the Greek culture of Alexandria."[2] Yet this Irish mediation of Greek secular alienation from labor and technology was to have small influence in the West.

Part of the reason for this differential development between Latin and Greek monasticism lies in the fact that in the Byzantine world a literate laity continued to preserve the worldly aspects of high culture, with the result that Greek monks felt able to devote themselves more exclusively to sacred studies. In the West, the level of civilization for a time sank so disastrously that the monks assumed almost sole responsibility for preserving and encouraging all aspects of culture, profane as well as churchly. Thus in the Occident monks tended to be more deeply involved in secular matters than in the East. The Slavic and Germanic regions into which the missionary monks of each Church penetrated were equally primitive. The Greek evangelists were very theological in their emphasis, and their labors were almost entirely religious. The Benedictines, however, concerned

themselves less with doctrine than with ethics, and carried with them not merely a new religion but also new practical arts.

This monastic technical tradition finds its greatest written expression in *De diversis artibus* produced by a theologically sophisticated and technologically learned German Benedictine, Theophilus, in 1122-1123. It is a religiously motivated codification of all the skills available for the embellishment of a church, from the enameling of chalices and the painting of shrines to the making of organ pipes and the casting of great bells for the tower. In Theophilus's mechanisms the first flywheels appear; he is the first to record a new and cheaper way of making glass, which largely accounts for the expansion of glazed windows in his time; he is the first to mention a wiredrawing plate and likewise the first to describe the tinning of iron by immersion, a technique that continued in use until the Japanese capture of Malaya in 1941 caused such a scarcity of tin elsewhere that the electrolytic process was developed.

Theophilus was not exceptional in his interests. In his contemporary life of Saint Bernard, Abbot Arnold of Bonneval pictures the rebuilding of Clairvaux in 1136 without mentioning the church but with a delighted account of all the abbey's waterpowered machines for milling, fulling, tanning, blacksmithing, and other industries. Another quite- independent- monastic description of Clairvaux in the same period shows the same enthusiasm: the author is particularly taken by an automatic flour sifter attached to the flowermill; he makes a little monkish joke, saying that the stamps of the fulling mill have remitted the penalty for the sins of the fullers; then he thanks God that such machines can alleviate the oppressive labors of both man and beast; and at last he offers a picture of the abstract power of water flowing through the abbey seeking every task: "[[baking, watering, washing, grinding, softening, and all without complaining and with excellent compliance]]."

Nor was the commitment of Western ascetics to holy labor confined to crafts and mechanized industry: it extended to major engineering. In 1248, for example, while giving the decayed abbey of Lorsch to a community of Premonstratensian canons, the archbishop of Mainz says of them: "[[We have found the men of our own heart… in fact these people are not only religious and holy in their lives, but also in the building of highways, aqueducts, draining of swamps and marshes to build monasteries, as well as being generally practiced and experienced in the mechanical arts]].” Thus far no similar documents have been produced from the entire Orthodox Church.

The 1120s, in which Theophilus produced his *De diversis artibusm* witnessed a moment of change in Europe's at,det wards manual labor and technology. Theophilus himself was concerned soley with the dignity of the technical arts in the life of a monk. Some of his ascetic contemporaries made labor the prime act of religion: Abbot Rupert of Deutz, (died 1130) rebukes fanatics who spurn liturgical worship and "[[who place almost all hope in their work]].” But at that time the concept of "religion" was broadening and spreading from the monastic to the lay life, particularly through channels provided by the newly vitalized groups of regular canons. It was spiritually essential to transfer dignity explicitly from monastic labor to labor in the world outside the cloister.

This task was undertaken by the Victorines in Paris. At the end of *De civitate Dei*, Saint Augustine discusses technology in a mood of complete ambivalence: he exclaims over the ingenuity and variety of the arts, but considers many of them "[[unnecessary and, indeed, dangerous and destructive]]"; medicaments and skills of healing are cancelled by "[[many kinds of poison, many weapons, many machines]]." In the face of Augustine's vast authority, Hugh of Saint Victor, one of the most original minds of the Middle Ages and, like Theophilus, a German, very deliberately developed a new and affirmative attitude toward technology.

His first effort was made in the early 1120s in the form of a curious dialogue on the nature and scope of philosophy in which Hugh's alter ego is none other than Dindimus, the leader of the Indian Brahmins who had long been regarded in the West as "instinctive" Christians, living saintly lives without the grace

of revelation. His intent is clear: to provide a secular schematization of all human knowledge which, for the first time, includes the mechanic arts. On Hugh's behalf Dindimus argues vehemently against the purists who would narrow the concept of philosophy to exclude not only mechanics but also grammar and logic: "[[they tried to tear the whole body of philosophy [by removing the mechanical arts] because they could not see the beauty of the whole thing that they [the people] were not accustomed to [i.e, new mechanical arts]]]." The unity of philosophy arises from its function of remedying man's three basic defects: ignorance, vice, and physical weakness. Speculation provides truth; ethics aids virtue; technology supports our bodily needs; recently logic or semantics (including grammar) has been added to philosophy to give it clarity and elegance of expression. Of these, *mechanica* is the least in dignity; yet it is integral to philosophy not, as regards its practice but because of the wisdom inherent in it.

In the later 1120s Hugh expanded and elaborated his concept of the nature and elements of philosophy in his influential *Didascalicon:* at least 88 manuscripts of it are extant, of which not fewer than 50 are of the twelfth and thirteenth centuries. Between 1153 and 1162 Richard of Saint Victor, probably a Scot, in his widely read *Liber exceptionum,* repeated and reinforced Hugh's fourfold division of the intellectual life. Naturally both Hugh and Richard recognized that, in the hierarchical society of their day, inclusion of the mechanic arts in a total scheme of knowledge might not be cordially received, so they disclaimed any revolutionary intent. Things like architecture and agriculture are proper topics for theorizing by a philosopher, but the doing of them is different: "[[one can philosophize about agriculture, but farming is for peasants]]." Nevertheless, by giving an unprecedented psychic dignity and speculative interest to the mechanic arts, the Victorines provided one of the theses for an egalitarian movement which, centuries later, spread eastward to destroy a great part of the less flexible Orthodox Church.

A development akin to the Benedictine and Victorine sense of the significance of technology was the increasing Western acceptance of mechanisms as aids to the spiritual life. The Church Fathers, both Greek and Latin, had passionately opposed the use of all musical instruments, including the organ. While in Byzantium organs habitually graced secular ceremonies, the Greek Church forbade them in its liturgies, insisting that only the unaccompanied human voice can worthily praise God. Yet in the later tenth century, in the cathedral at Winchester where, about the same time, the iconography of the Creator God holding scales, square, and compasses appeared, Benedictines installed the first giant organ: 70 men pumped 26 bellows supplying 400 pipes. Before the invention of the mechanical clock the organ was the most complex machine. In sharp contrast to the East, great organs became integral in the West first to processions, interludes, and the like, but, by the middle of the twelfth century, they were admitted to the central act of divine service, the Mass. A hundred years later, in the mystery plays that by that time were presented outside the churches, an organ was the indispensable accompaniment of any representation of Paradise; indeed, it became almost a symbol of Heaven.

In a separate building outside Hagia Sophia, Justinian placed a clepsydra and sundials, but clocks were never permitted within or on Eastern churches: to place them there would have contaminated eternity with time. As soon, however, as the mechanical clock was invented in the West, it quickly spread not only to the towers of Latin churches but also to their interiors, often as astronomical planetaria designed to demonstrate visually the godly order of the cosmos.'" Clearly, by the later Middle Ages, Western men felt perfectly compatible with machines.

And not simply in religious contexts: the *Mittelalterliche Hausbuch,* a German manuscript of *circa* 1480, shows a garden enclosed in which garlanded youths and maidens are sporting about a fountain, while at the right, quite unobscured, appears the waterpowered force-pump that operates the fountain. To the Middle Ages all the arts, including the mechanic arts, were a part of the good life —*teste* [[according to]] Leonardo. Modern suspicion of technology is a reversion to the ambivalence of Saint Augustine.

The earliest indication that men thought advancing technology to be an aspect of Christian virtue appears in the Utrecht *Psalter,* illuminated near Rheims *circa* 830, almost certainly by a Benedictine monk. The illustration of Psalm 63 (64) shows an armed confrontation between a small body of the Righteous, led by King David himself, and a distressingly larger host of the Ungodly. In each camp a sword is being sharpened conspicuously. The Evildoers are content to use an old-fashioned whetstone. The Godly, however, are employing the first crank recorded outside China to rotate the first grindstone known anywhere. Obviously the artist is telling us Is that technological advance is God's will.

About 1450 European intellectuals began to become aware of technolo gical progress not as a project (as indicated above, this came in the late thirteenth century) but as an historic and happy fact, when Giovanni Tortelli, a humanist at the papal court, composed an essay listing, and rejoicing over, new inventions unknown to the ancients. At almost that moment the artists of Burgundy reaffirmed the thesis of the illuminator of the Utrecht *Psalter* that an advancing technology is morally salutary: they clothed Temperance, who had displaced Charity as the chief Virtue with major symbols of late medieval inventiveness. On her head she wore a mechanical clock, produced some 120 years earlier; in her right hand she held eyeglasses, invented, as we have noted in the 1280s as the greatest boon to the mature and presbyopic intellectual; she stood on a tower windmill, which first appeared in the 1390s and which was the most spectacular power machine of that era. To the artists who painted those pictures, and to their patrons—clerical, aristocratic and burgher—it was axiomatic that man was serving God by serving himself in the technological mastery of nature. Because medieval men believed this, they devoted themselves in great numbers and with enthusiasm to the process of invention.

Probably there were forces other than the religious which stimulated technological progress during the Middle Ages. The tradition of illustrated calendars has been secular. Their usual pattern from Roman times until the ninth century showed the months as static personifications holding sym - bolic attributes. This convention continued unbroken in Byzantium. Among the Franks, however, by 830 a new form appeared which set the style for the rest of the Middle Ages in the West. The pictures now show active scenes: plowing, haying, the harvesting of grain, wood chopping, men knocking acorns from oaks so that pigs can eat them, pig slaughtering. The new illustrations breathe a coerciveness towards nature which is, indeed, consonant with Christianity but which may have arisen independently. Man and nature are two things, and man is master. Technological aggression, rather than reverent coexistence, is now man's posture toward nature.

Such aggression is the normal Western Christian attitude toward nature. It may be that the emergence of this stance in the Carolingian age can be explained apart from religion. Slightly before that time a basic change in agricultural methods had occurred in Northern Europe, especially between the Loire and the Rhine, the heartland of the Frankish Empire. As early as the sixth century a new heavy plow began to spread from the Slavic East. It was far more efficient than the earlier light plow, but in place of a pair of oxen it normally required as many as eight, at least in newly cleared or sticky soil. No peasant owned eight oxen. The only way to power such a plow was to organize several peasants to pool their oxen, and to distribute plowed strips to them in proportion to their contribution. Previously land had been parceled to peasants in allotments sufficient to support a family equipped with two oxen and a light plow. The assumption was subsistence farming, plus enough surplus to pay rent. Now, however, with the heavy plow and the pooling of oxen the standard of land division was not human need but rather the capacity of a new power machine to till the soil. No more profound reversal of the peasant's relation to the land can be imagined. Formerly he had been part of nature; now he became an exploiter of nature. This alteration of attitudes might be guessed from the heavy plow itself. The iconography of the new calendars confirms the change. Neither the heavy plow nor the new style of calendar was known in Byzantium. In historical analysis, even of a very religious era, we cannot credit to religion, any more than to social relations or to any other single element in culture, absolute sovereignty over every aspect of life.

Nevertheless, it can scarcely be coincidence that the miniature in the Utrecht *Psalter* (816-834) which announces the morality of technological advance appeared simultaneously with, and in the same region as, the new style of calendar illustration (shortly before 830). It can scarcely be coincidence that in 826 Louis the Pious, who, as a contemporary remarks, was always eager to introduce to his realm "[[things that they[the peasants] were not accustomed to [i.e., new mechanical arts]]," commissioned a Venetian priest named George, who had learned his skills presumably in Byzantium, to construct the first organ built in the medieval West for secular use in his palace, and that from Aachen organs spread so quickly among the churches of South Germany that in 873 Pope John VIII wrote to Freising to secure both an organ and an organist. Many forces shaped the Middle Ages, but of these the most powerful was religion.

The Semitization of the Greco-Roman *oikoumene,* which was accomplished in the fourth century by the victory of Christianity, marks the most drastic change of world view, both among intellectuals and among the common people, that, before our own time, has ever been experienced by a major culture. In China the indigenous Confucian-Taoist symbiosis was supplemented, not displaced, by Indic Buddhism. In India itself, Vedic Brahmanism slowly broadened and diversified to engulf all rivals except the Islamic intrusion that was totally unassimilable and which produced two societies in tragic confrontation. The Muslim annexation of the southern shores of the Mediterranean had no such result because, as Dante rightly saw *(Inferno* 28.22-31), Muhammad was a Judeo-Christian schismatic, not the founder of a new religion. In the regions thus overrun, the faith of the *Koran* confirmed basic Jewish views of the nature of time, the cosmos, and destiny which had already been spread at all levels of society by Christianity, Judaism's daughter.

The historians' habit of terminating what we call ancient history with the chaos of the third and early fourth centuries in which Christianity rose to dominance is not arbitrary: it recognizes a major alteration in the cultural climate of classical civilization. During the Middle Ages, both Eastern and Western, this new religion was the essential novelty and stimulus to innovation as well as to the decay of some forms of creativity which had thrived in the Greco-Roman world. It is therefore, not surprising that so many religious and parareligious phenomena illuminate both the high rate of technological advance in the West, and, by contrast, its slow pace in the Byzantine world.

No great religion is an entirely uniform species. As Christianity spread it accommodated to local circumstances but it likewise developed spontaneous genetic mutations which as yet cannot be explained by Lamarkian adaptation to preexisting cultural climates: to an extraordinary degree, medieval religion created the climate of its own environment. Part of the fascination of the Middle Ages lies in the observation, within an essential unity extending from Greenland to Jaxartes, of the variety of cultural subclimates that can often be interpreted according to regional variants in the temper of religion. The slight but significant differences between Greek and Latin piety in this period help not only to make historically intelligible the accomplishment of the medieval West in technology but likewise to expose the psychic foundations of our modern technology which rests on that achievement.