the genesis of american technology 1790-1860

an essay in long-range perspective

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The history of technological advancement has taken few turns to compare with early national America. Suddenly, and quite unexpectedly, given the historical circumstances, Americans began expansively referring to themselves (and others to them) as pioneers in the march of industrial progress. Indeed, within a few decades, Eli Whitney had introduced interchangeable musket parts, Oliver Evans had produced bold new theories of automation, and a circle of Massachusetts inventor-industrialists had made the Waltham system of integrated production spectacularly successful. More significantly, perhaps, thousands of nameless mechanics had begun to modify European patterns and processes, adapting them to the tastes of a new society and the demands of a new environment. This was more than industrialization. It was an association between technology and culture, an association so intimate that it soon affected the very conception of the American character. Thus, there appeared that tantalizing phrase, "Yankee ingenuity," to prod and inspire generations of inventors and to set before the world a paradigm of industrial accomplishment. Historians have never ceased wondering why. It is the purpose of this paper to examine their collective discourse on the subject and to suggest a framework for bringing their observations together.

The historiography of early American technology may be broken down into roughly four kinds of analysis.[1] The first, the least popular, and yet certainly not the least plausible is the argument that American toolmen lifted their ideas part and parcel from Europe in general and Great Britain in particular. In the matter of interchangeable parts, for example, Eli Whitney's once-sure claim of paternity has been effectively disputed by Robert Woodbury, who simply called attention to the antecedent developments of Bentham and Brunel in England and Le Blanc in France.[2] Woodbury's is an important kind of corrective to bear in mind. Still, some rather difficult questions remain unanswered. For, even with the simplest case of technological "transfer," there arises novelties of application and use. It is true that wooden pully blocks were assembled interchangeably for the Royal Navy as early as 1793; but it is also true that Samuel Colt's Exposition of interchangeable parts manufacturing astonished the British in 1851. If Americans borrowed their ideas, they made good use of what they borrowed—such, at least, is the basic position of those who have seen American technology as unique. These historians have looked away from Europe for their answers, and with varying degrees of success, they have turned up useful ideas. In most cases, they have found the key influences to be endemic to the American situation itself: its particular patterns of production and distribution, its peculiar social and cultural institutions, or its singular physical environment.

The "economic school" of technological history has been, until quite recently, essentially a mode of assumption. Historians accepted it as given that technology developed in direct response to capital accumulation and labor scarcity. Accordingly, their individual interpretations confined themselves to the mundane questions of how capital was accumulated and why it was invested in this or that mechanical improvement. That American inventors, given the incentive, would come up with something new was taken for granted. That labor scarcity and the hope of financial reward provided sufficient incentive traditionally closed the case. It came down to a neat triangle of shrewd capitalist, bold entrepreneur and ambitious mechanic. In 1962 H. J. Habakkuk pulled the triangle out of shape a bit by arguing, in a well-documented monograph, that the conventional assumptions were oversimplified and that "dear labor," much more than "scarce labor," accounted for the inventive set of the American factor endowment.[3] The point conceded, we are still left with the essential weakness of economic historiography. The unadorned pushes and pulls of supply and demand simply cannot be made to explain enough. Too much stretching must be done in order to fit everything in. The blank assertion, for instance, that capital accumulation will automatically result in technological advancement obscures more about processes of human invention than it illuminates.

A third school of interpretation might be called "behavioral." Behavioral arguments are many and varied—and often eclectic—ranging from abstract questions of social motivation to such mechanical factors as the patent law, but a focus of sorts can be found in a general emphasis on institutions and their shaping influence. John Sawyer came close to the crux of the behavioral approach by presenting a list of social and cultural attributes which accounted, as he believed, for the distinctiveness of American technology:

> [There were] differences in the nature and diffusion of education in America; the absence of rigidities and restraints of class and craft; the freedom from hereditary definitions of the tasks or hardened ways of going about them; the high focus on personal advancement and drives to higher material welfare; and the mobility, flexibility, adaptability of Americans and their boundless belief in progress. These and closely related patterns are linked directly to economic behavior and economic results—to initiative, originality, systematic effort, and boldness; the "eager resort to machinery" and productive use of small capital, at a time when small capital was decisive; the ceaseless search and ready adoption of the new and more efficient; the intense responsiveness to shifting opportunities and expanding horizons; the "go-aheadism" that visitors from all categories so often placed at the root of the "immense drive" of American manufacturing.[4]

There is much to be said for the ideas of the behavioralists. They bring us closer to a satisfying account of the indefinables and imponderables of the technological puzzle, something that has eluded the economists. Yet something else is missing. With all of the well-honed linkages between technology and "American mission," or technology and "industrial consciousness," or technology and "democracy," there is still to be answered the question of why a certain plexus of changes—of which technological advancement is only one—takes place at a given time, in a given place, and by a given manner.[5] Often, what the behavioralists have succeeded in doing is documenting the complexity and interrelatedness of it all—without exactly explaining it.

If the behavioralists failed to tackle the most difficult issues, the defect has been corrected, and perhaps overcorrected, by my last category of writers. Historians who attribute American technology to native mechanical genius have thought in large terms. All want to trace the roots of that genius back into broad physical or geographical aspects of the national experience. Where behavioralists found historical explanations in the character of institutions, environmentalists find them in nature itself, and in its impact upon the human personality. Roger Burlingame, following Frederick Jackson Turner, found the ultimate explanation to be the American frontier. Where else would the European artisan be plunged back into a state of nature, be stripped of his Old-World preconceptions and find himself confronted by unheard-of technological problems? And where else would he encounter that endless winter solitude in which he was left free to whittle and tinker and scheme? "He came from crowds and found himself alone; his thought was translated from inches into miles, from little bounded squares into acres with vague lines. At the edge of the wilderness, myopia left him forever."[6] As with the behavioral approach, there were several variations possible. American exceptionalism has been characterized by John Kouwenhoven as a rediscovery of "the truth of function," by D. L. Burn as a cumulative process of "selective immigration," and by Daniel Boorstin as an omnicompetence bred of seafaring, this last an interesting twist on the Turnerians.[7] In every case, though, it was American geography which was under consideration and "American genius" as the outcome.

Just how compelling is the idea of an American "inventive genius?" Historiographically, we have been given a choice of three ways to explain —or perhaps explain away—its existence. At first blush, the three may seem rather disparate. Yet they are not altogether beyond reconciliation. For example, the respective categories of "economic," "behavioral" and "environmental," which may appear valid enough for taxonomical purposes, are all rooted in a common assumption: that man is essentially a quiescent creature who, while able enough to create "inventions," must first be set into motion by some external inventive or penalty or, in the case of the behavioralists, by some reordering of the social mind. Each general theory, whether cast in terms of economic opportunity, environmental demand, or the impact of social institutions, assumes a passive role for the intellect, at least at the outset, and thus implicitly suggests that invention, as a collective human endeavor, had once been inhibited. But why should this be?

Here let me propose a modest hypothesis. Suppose that some sort of medieval inheritance tended to impede the processes of invention and discovery, and that because of this inheritance, a kind of inertial threshold had to be reached and crossed before the technological revolution could begin. If this were true, then the key to understanding "inventiveness" might be found in the various ways in which Western society has broken with its pre-industrial past—and the key to understanding American exceptionalism might be found in the unique, not to say revolutionary, way in which that break was effected on this continent.

What I am proposing is not precisely a new interpretation as such, but rather a context in which to place the interpretations we already possess. What I would attempt to explain is why these interpretations presently seem to lack causal sufficiency: why, granting the economic school its due, American inventiveness existed before the era of capital intensity and after the era of labor dearness; or, to change the argument, why liberal institutions did not bring "Yankee ingenuity" to the American South; or, to change it again, why the challenges of the frontier did not mechanize New France. And the best answer might be that none of these factors by itself could sustain a climate of technological innovation so long as the characteristic intellectual response to the stimulus in question was passive. So long as Western Man lived in a world which he was not encouraged to alter, obstructions and incentives could not liberate his inventive impulses. Thus, what is needed from the historiographical standpoint is a new long-range perspective (as opposed to a short-term explanation), and the way to achieve it might be by calling attention to that elusive element of dynamism which, in the space of a century or two, transformed Western Man from a passive, medieval figure who accepted the world as he found it, into a restless, kinetic figure who sought to impose upon the world his own sense of order. By such a minor theoretical adjustment, we might alter our conception of the technological revolution from an abstract play of external forces to an intensely human—and even morally significant—event. And it seems to me that only in such an altered frame of reference do our various explanations of "revolution" really become operative. Only within the context of an intellectual upheaval does the concept of a technological upheaval make sense. Only in bridging the psychological gap between, say, Hamlet and Faust do we glimpse the missing component of invention, and thus bridge the semantic gap between Necessity and Response. Once this much is granted, I believe it can then be shown how each school of technological history illuminates an important dimension of the complex reality.

The key to the problem lies in the impact of social breakdown upon human behavior. When we speak of preindustrial or "traditional" society, we use catchwords which, though related to structure, describe as well the effects of structure upon the mind. Words like "commonwealth," "hierarchy," and "deference" convey not only a description of life but also something of its inner meaning. Basically it was a meaning which embodied three ideals: Christian brotherhood, patriarchal order, and, above all, continuity. There was both a seamlessness and timelessness about the preindustrial "corporate commonwealth" that commended its inhabitants to a repose which modern man would find stultifying. Yet these psychological concomitants of traditional life did not vanish overnight. Although corporate societies themselves began to disintegrate long before the Renaissance, their consciousness and value structure lingered on erratically in Western thought. This was especially true of Northwestern Europe, where, amid island fragments and physical ruins of the old order, the ethos of traditional life continued to haunt the landscape well into the nineteenth century. Though the influence of this ethos was felt in many ways, the most significant was in the "deference community"—the tendency for individuals in modern industrial society to identify themselves with some surrogate for the old corporate commonwealth. Throughout the early nineteenth century, the deference community usually existed within a surviving manor or rural parish, but in the city as well as the country deference patterns also appeared, as workers in mine or factory clustered themselves into imaginary "commonwealths," paid various kinds of homage to patriarch figures, and, in psychological terms at least, continued to live very comfortably in the past.[8] This phenomenon and the interpersonal values it helped keep alive must have exerted a profound impact upon the course of European technology.

The American case, as one might expect, was distinguished by a relative absence of the traditional ethos, partly because of the difficulties of transplanting it, and partly because even when planted firmly, as in the Puritan "commonwealths" of Massachusetts, it could not long survive. In the New World atmosphere of makeshift and disarray, a combination of economic, institutional and environmental influences worked to loosen the bonds of community, rupture the status hierarchy, and atomize the "organic" structure of society—and in America there were no thatched cottages or ivied ruins to call back the lost mystique. Moreover, the immigration process itself tended to skim off the more rootless types and transport them to these shores. By the eighteenth century the colonies had become a locus of activity and movement, of competitive behavior, of social fluidity and cultural pluralism—a place where, as Cadwallader Colden put it, "the only principle of life . . . is to get money." It remained for the American Revolution, with its heady renunciation of political corporatism, and the subsequent "rise of the common man" to complete the dissolution of intellectual traditionalism. To be sure, the community remained upon the American landscape, but the medieval aura of community life, with its sense of harmony and balance, had been destroyed. Its disintegration, in part, released that intense energy for which the "Jacksonians" were to become known and through which the American spirit of innovation was to acquire its kinesthesia.

Specifically, the rapid collapse of deferential order could have affected the consciousness and behavior of what I will call the Inventive Man in several ways. A few of them might be listed in the overlapping categories which follow.

i
individualism

The truly creative person must have a strong sense of his own individuality. If his identity is bound too securely to the larger society, chances are that he will defer to the aims and traditions of that society, and will avoid innovations which, however beneficial to himself, would throw time-honored relationships out of balance. As an autonomous individual, on the other hand, he will become emancipated both from the corporate interest and the confinement of tradition. He will become more mobile, more versatile, and more self-confident, trusting his own observations and intuitions more than the conventional wisdom of the day.

Individualism, so described, was a prominent feature of the early American industrial milieu. One striking evidence of it was found in the prevailing attitude toward "craftsmanship." Craftsmanship, of course, was the hallmark of the ancient guild system, and it was passed along reasonably intact to the trade unions which in Europe replaced that system. There was, apparently, very little of it to be found in

America. British observers constantly called attention to the want of "perfect skill" and to the crudity and flimsiness of American construction.[9] Often as not, machinery which in Britain was made of heavy metal and finished to gleaming perfection was in America made of wood, was "much simplified," and was, according to the standards of the day, rough-hewn at best. Yet, such jerrybuilding had its advantages. It cost less, required less time, and the item in question could be discarded more easily for an improved model. Moreover, the American de-emphasis of "craftsmanship" led to a corresponding emphasis of function—and efficiency. Only those parts of an engine for which "good fitting and fine workmanship are indispensable to the efficient action" were highly finished, commented David Stevenson; everything else was left "coarse." But this directness was a source of strength, allowing the American toolmen to get straight to the point. "There is a great simplicity, almost a quakerlike rigidity of form given to the [American] machinery," reported James Nasmyth; "no ornamentation, no rubbing away of corners, or polishing; but the precise, accurate, and correct results."[11] Thus, the Gilpin paper machine, copied after John Dickinson's English cylinder, was much simplified, more easily constructed, and wholly adaptable to the vagaries of local conditions. The American standard, or "Sellers," thread was by comparison to the English a hopelessly rustic affair, requiring but one cutter, one lathe and no craft skill at all to achieve its 60° angle. But precisely because it was so pedestrian, the American standard helped bring about interchangeability and mass production.[12] Similarly, the American cut nail and pointed screw violated craft notions of wrought perfection, while they immensely simplified basic processes. Even the sizes and shapes and costs of things could be tyrannized by the craft tradition, as Chauncey Jerome discovered when he attempted to mass-produce clocks: it was not the technical problem that stymied him; it was the social unacceptability of an inexpensive timepiece.[13]

Some inventions not only circumvented the craft tradition—they flew in the face of it. The Blanchard lathe, for example, which was developed for the making of gunstocks, brought together sixteen different machines for the turning of an irregularly shaped object. The essential point about this remarkable tool is that its sequence of steps did *not* correspond to human actions, nor did the individual lathes correspond to the carpenter's customary tools. It required a visualization de novo of both object and process in order to achieve such a breakthrough.[14] Then too it was the craft tradition that in Europe inhibited the process of rationalizing production. Where outwork and handicraft methods prevailed, artisans remained content—nay, adamant—to do their own traditional job, carefully isolating one step of production from another. At first Almy & Brown, like its European counterparts, respected such disjointedness. But soon the firm discovered that resident weavers under the supervision of mill operatives could produce cloth with many-fold greater efficiency and that their rate of production, which was now predictable, could be coordinated to that of yarn. In the absence of a strongly countervailing craft tradition, these discoveries quickly jelled into the "American System."[15] It was little wonder that "traditional methods," as one observer put it, "had little hold upon the American as compared with the English artisan," and thus that "processes holding out the least promise of improvement were quickly tested."[16]

Important as it was, the craft tradition—and its relative absence in America—was but one aspect of individualism. Another, certainly, was the dynamic impact of mobility. Exactly because the traditional crafts had no dominion in America, workers from all walks of life found themselves side by side. In Colt's factory, for example, "one had been a butcher, another a tailor, another a gentleman's servant. . . ."[17] Nor were they likely to pause long at a given pursuit. "The citizen of the United States," said Joseph Whitworth and George Wallace, "seems really to pride himself in not remaining over long at any particular occupation, and being able to turn his hand to some dozen different pursuits in the course of his life."[18] Accordingly, they were not comfortable with too high a degree of specialization and insisted upon mastering the broad principles of the task at hand.[19] Just what effect that mastery may have had can be seen in the high incidence of occupational mobility among the most gifted of the inventors. Matthias Baldwin, builder of locomotives, apprenticed as a jeweler and worked as an engraver and fine machinist before turning to steam technology. For George Henry Corliss, the path leading to the development of the Corliss engine wound through storekeeping, drafting and bootmaking. Charles Danforth tried soldiery, sailing and schoolteaching before inventing the "cap spinner" for the cotton industry; he went on to build machine tools and eventually locomotives. Three careers were especially involuted: those of Jacob Perkins, Samuel Luther Dana and Eli Whitney Blake. Perkins, it seemed, laid a hand to almost everything, from refrigeration to bank-note engraving. Dana, a pioneer of industrial chemistry, began as a physician and variously sallied into a host of disciplines, including geology, agronomy and occasionally even medicine. Blake got his start in Uncle Eli's arms factory. Then he developed an improved lock, a new system of geared power transmission, and the Blake stonecrusher, which made possible the American concrete industry. At the age of 92 he was studying aerodynamics and still going strong. The list goes on and on. Its point here is to demonstrate the startling versatility that grew out of constant change and adaptation. The jack-of-all-trades was a Rube Goldberg at heart.

Of course, there was something more than adaptation at work too. American mechanics on their endless peregrinations were constantly talking to one another, exchanging ideas, cross-fertilizing from industry to industry. "The successful application of mechanical means to one manufacture has been, as a matter of course, stimulative of their application to another, however different. . . ," observed Wallis.[20] To an extent unimaginable in Europe, the Americans traded successfully in both information and inspiration.[21] Thus, the clock-makers, Eli Terry and Chauncey Jerome, learned from the arms-makers, their Connecticut neighbors. (Jerome, incidentally, learned from Terry as well, by applying the principles of wooden movements to brass.) Elisha King Root, the man who perfected Colt's marvelous machinery, got his start with the Collins brothers and adapted the principles of their ax manufactory to the production of six-shooters. Elias Howe got the idea of a sewing machine from his work on textile equipment. A few places became nerve centers in the dissemination of ideas. The machine tool industry sprouting up around Springfield, Vermont is one example. Almy & Brown, with its generations of prolific inventors, is another. But the clearest case of technological spin-off was to be seen at Lowell, where the perfection of textile machinery demonstrably led to machine tool production, to the development of locomotives, to the Worcester wire industry, and, through Jonas Chickering, to the wire piano. To be sure, some of this proliferation represented piracy of a sort, but most of it did not. From the extant records, the exchange of information in America—unlike Europe—seems to have been free, open and untrammeled, for the most part, protected by a sense of national pride. Jacob Perkins, for example, kept the American mechanical world in a constant state of excitement, not with his accomplishments, which were meager, but with his ideas and his projects, which circulated as freely as advice to the lovelorn. This attitude of intellectual free trade was, according to Eugene Ferguson, America's secret weapon in the battle for technological supremacy.[22]

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egalitarianism

It was not enough to release the Inventive Man from the constraints of a tradition-minded society. He had to become convinced of his own human worth as well. He had to be able to approach any of his contemporaries with any idea and be given a hearing. He had to believe in himself to the extent of assuming considerable personal risks, just as he had to persuade others to believe in him. All societies have their potentially creative individuals, the would-be or could-be Inventive Men. And, if these are fortuitously situated, they may stand a fair chance of seeing their dreams come true. But *only* the fortuitously situated—most of the others will carry their great notions to the grave. Here it is well to note what Crevecoeur observed about the effect of the American experience upon the very sort of people who would soon be tending the lathes. "Every thing has tended to regenerate them; new laws, a new mode of living, a new social system; here they are become men: in Europe they were as so many useless plants. . . ."[23]

Indeed, it was probably no accident that the period of American technological take-off and the Age of the Common Man were one. What was said above about cross-fertilization, for example, could not have applied to a rigid and highly stratified social system, no matter how mobile geographically. Ideas had to be able to move up and down as well as outward. Similarly, the flexibility and adaptability of the American workingman was a reflection of his altered socio-political status, just as the division of labor, so prominent a feature of the European scene, was a reflection of the reverse. "Since the great mass are fitted to do one thing well," said Wallis of the English mechanics, "the great fact of such sub-division must ever be imperatively insisted upon."[24]

Nowhere was the contrast more apparent than in the matter and significance of basic education. The British Commissioners who were so struck by the absence in America of an apprenticeship system were equally struck by the pervasiveness of public education. American mechanics, they noted, were "educated up to a far higher standard than those of a much superior social grade . . . in the Old World." The result, as they saw it, was a particular "vivacity" in "inquiring into the first principles" of things, a "theoretical knowledge of the processes," which stood in marked contrast to the European mechanics.[25] The effects of free education have been extensively explored by John Sawyer and others, but the nexus between education and social fluidity needs more attention. One might note, for example, that within a brief span of time there sprung up in both England and America analogous institutions of "industrial education" and analogous vehicles for disseminating information at large.[26] But there was a crucial difference in the way these new developments related to the two societies respectively. In England, where craft and apprenticeship were still firmly entrenched, there is reason to believe that the mechanics institutes and technical journals merely supplemented the "real" instruments of education, which were found within the social order of the individual trades. But in America, where there was little of that order, the mechanics institutes, and especially the technical journals, received as they were by comparatively well-educated workingmen, might well have become the *principal* means of industrial education and so produced a more "vivacious" working populous. In any case, in America, unlike England, the lack of education did not hold a man back. The chief repairman of the Globe Company in Tiverton, Rhode Island, was thirteen. Another boy, aged fifteen, was dispatched from Massachusetts to Burrillville, Rhode Island, to supervise the equipping of a mill there and to put it in operation. The superintendent of the Pawtucket Thread Company, aged nineteen, was a man with eleven years experience. While England certainly knew child labor, it could offer but few such examples as these. "Wherever education and an unrestricted Press are allowed full scope," said Wallis with a touch of envy, "progress and improvement are the certain result. . . ."[27]

Democracy, to be sure, was more than free education, and a cataloguing of all possible forms of its influence is beyond the scope of this paper. It is well to note, however, that it was not just that in America there was a different spirit to invention. The inventions themselves were of a significantly different type. British ordnance officials, among many others, concluded that the kinds of machinery "usually employed by engineers and machine-makers"—let us say the "aristocratic" kinds—"were generally behind those of England." The great English lathes, the sophisticated planing, shaping and drilling machines, the very types of equipment that one would expect to find in use among the highly trained, were far in advance of their American counterparts. American innovation, in other words, was not really happening at the top—it was happening at the bottom, at the level of the ordinary workingman, who was applying "special apparatus to [the] single operation" before him.[28] This, at least, was the description given by the British Commissioners to the most wondrous of the American devices:

> A peculiar shaped screw augur. . . . Extensive rope spinning machinery. . . . An apparatus for cleaning metal. . . . A new sort of trip hammer. . . . A new sort of steam tilt hammer. . . . Machine for polishing lasts. . . . A vertical saw, for cutting irregular forms. . . . An apparatus for testing the quantity of power required to work a machine. . . . A machine for sifting sand. . . . Patent magnetic sewing machine. . . . Yankee chaff cutter. . . . Tourbine waterwhell. . . . Machine for cutting files. . . Cask-making machinery . . . Packing-up machinery.[29]

And the suspicion that a different, more "common," type of inventor was at work in America is clearly borne out not only by the specific instances we know of—the slide lathe, the cap spinner, the woodworking machines—but by the more significant fact that we know of so few: that so little of the work of the American inventors was at the time dignified as "invention" and passed along as such to posterity. One is hard pressed, in fact, to come up with *any* creation of the American mechanic-inventors truly analogous to those of the European scientist-engineers. Partly because their ambitions were high, partly because their jobs were secure, but partly too because they lived in an unfettered society, the American mechanics made a different kind of response to the problems they faced. They literally "bombarded" their employers with innovative suggestions, some of them outlandish, some of them brilliant.[30]

Then too, in Jacksonian America the common man was becoming, in addition to a political phenomenon, a symbol of the Machine Age, the ideal person to embrace mechanism and make it respond, and as such he was culturally encouraged to express his creativity as few creative people have ever been. In less than two generations these halcyon days would vanish, and the common man would be counted a Machine-Age casualty. But in those few decades when labor was dear and machinery new, it was doubly fortunate for the workingman that a new phase of American folk myth coincided with that stage of Western technological development in which "tinkering" on a broad front could produce astonishing results—as it never could before or would again.

iii
ambition

A favorable economic climate undoubtedly supplies the "opportunity" necessary to stimulate innovation. But in order to perceive opportunity as such, one must first possess certain kinds of ambition, and one must feel that certain ways of gratifying that ambition are "acceptable." Thus, the mother of invention is not necessity in the abstract—that is, capital intensity or labor bottlenecks—but a widespread eagerness to get ahead in the world and a widespread belief that "ingenuity" provides an acceptable way of doing it. Where traditional society, with its order and stability, could offer only limited avenues for individual advancement, modern society, with its imbalance and fluidity, makes advancement a personal obligation and endlessly multiplies the "acceptable" avenues for it. One result is the idea of the Inventive Man, who makes his way not by wealth or position, but by boldness, shrewdness, and "ingenuity."

In order for the idea to become a working reality, it had to be embodied in specific role-models, and these, in order to fire the ambitions, had to possess a distinct rags-to-riches appeal. Such was the folklore of American invention. The humble origins and proud achievements of the "great" inventors has been sung often enough to preclude review here. Suffice it to say that the Fords and the Edisons and the Wrights and the Bells were one and all middle-class people lacking the advantage of a high-powered education. But what about the second and third echelons of American inventors, and what about those anonymous tinkerers who added bits and pieces here and there? An exhaustive study of such figures and their movements along the socio-economic scale would be a valuable asset for technological historiography, but, to my knowledge, it is an asset we still lack. On the other hand, such information as we do have points clearly to the conclusion that "inventiveness" was indeed widely regarded as one of the principal routes upward. "You may be sure," de Tocqueville wrote, "that the more democratic, enlightened, and free a nation is. . . , the more will discoveries immediately applicable to productive industry confer on their authors gain, fame, and even power."[31]

So let me pass over the Fords and the Edisons and try to give some indication of how the less well-known served as exemplars of success. Samuel and David Collins were Hartford blacksmiths who, in the 1820s, succeeded in mechanizing the production of axes—and eventually came to command a world-wide market. Ichabod Washburn, a mechanic of Worcester, began experimenting with wire production in the early 1830s; he became the father of the American wire industry and one of the early industrial giants of Massachusetts. John Brandt, another blacksmith, this time from Lancaster, Pennsylvania, began puttering with automation, became master mechanic of the Erie Railroad and eventually set up his own locomotive works. The Merrimack area fairly sparkled with Cinderella stories. There was Paul Moody, a weaver from Newbury, who after convincing Francis Cabot Lowell of his mechanical genius, was made superintendent of the Waltham Corporation. Or there was Samuel Batchelder, another textile mechanic, who invented the dynamometer and went on to become manager and president of the Hamilton Company. A Lowell physician who began wondering about the use of cow dung as a bleaching agent wound up as the chief chemist of the Merrimack Manufacturing Corporation. The examples could be multiplied endlessly: Joseph Glidden, the farmer, invents barbed wire and becomes a millionaire; Solomon Willard, the stone cutter, devises new quarrying techniques and establishes the Vermont granite industry; Danforth, the schoolteacher, and Baldwin, the jeweler, develop new machine tools and become the founders of rival manufacturers; Eli Terry, the peddler, perfects interchangeable parts and dies among the richest men in America. And so forth.

What was uniquely American about all of this? For one thing, its ubiquity. We are not dealing with limited areas or isolated instances, but rather with a pattern that by 1850 had become recognized and well-established. The example, in other words, of "ingenious men who have solved economic and mechanical problems to their own profit and elevation" was, in the words of one British toolman, "constantly before" the American mechanic, engendering a "restless activity of mind and body," an "anxiety to improve his own department":

> It may be said that there is not a working boy of average ability in the New England states, at least, who has not an idea of some mechanical invention or improvement in manufactures by which, in good time, he hopes to better his position, or rise to fortune and social distinction.[32]

But even more distinctive is the fact that in America personal ambition came first—literally taking precedence over order and stability. Consider the matter of pulling up stakes. Since contracts customarily required the mechanic to renounce patent rights to his own discoveries, he was left with but two alternatives: to accept a gratuity of some kind as fair recompense for his new idea, or to take the idea, whatever it was, and bolt from the company. Ambition made him choose the latter, routinely. Thus, when Chauncey Jerome had mastered Terry's secrets and knew that he could apply them to a slightly different process, he went out on his own. Seth Thomas, another Terry prodigy, did the same, and wound up buying out his mentor's company. Sam Slater, in whose incredible memory the Arkwright machinery was smuggled into the United States, came in for a surprise when the mill hands he had patiently schooled suddenly revolted, devised their own machinery, and set up a host of rival manufacturies. George Henry Corliss was working for Fairbanks, Bancroft & Co. when he got the idea for his improved steam engine valve; the result was not a promotion within the existing corporation, but the formation of Corliss, Nightingale & Co. in 1848. Elisha King Root departed from Collinsville with his hard-won ideas and sold himself, as it were, to the highest bidder, Samuel Colt. A Scotch mechanic who had worked for the Waltham Company discovered one group of his shopmates running their own mill in the South and another operating a factory at Medway. Similarly did the machine-tool industry around Springfield, Vermont proliferate, while Almy & Brown, as noted above, became a veritable hothouse for mechanical improvement. Moreover, if the gifted mechanic was hesitant in the least about cutting his ties, there were plenty of others to encourage him. Kirk Boott, for one, was a talent scout of rare ability, annually scouring the country and bringing to Lowell inventors at whatever price he had to pay. Where advancement within the system was impossible, in other words, Americans driven by ambition were willing to abandon the system itself. This looseness stands in direct contrast to Europe, where a man's job was a settled part of his community experience, and where there was, as one European confessed, "a certain degree of timidity resulting from traditional notions, and attachment to old systems."[33]

Also unlike his European contemporaries, the American mechanic did not think of himself as a permanent wage earner, not before mid-century, at least.[34] His career at labor was seen only as a tour of duty, a preparation for the greater things to come. And come they did for so many of his acquaintances that, as Wallis remarked, he had an example of success constantly before his eyes. Whatever else the spirit of equality bequeathed him, it generated, as de Tocqueville noted, "an all-pervading and restless activity, a super-abundant force, and an energy which is inseparable from it. . . ." Such activity, force and energy, he added, could "produce wonders."[35]

iv
open-endedness

Traditional society existed in a closed and finished universe within which it was not only futile but, in a sense, blasphemous to advocate change. Men lived and died within a system of relationships so well ordered as to make all innovation glacial, rarely perceptible. From the disordering of this society there resulted a new image of the universe, one of openness and contingency. Nature gradually lost its medieval sanctity and became malleable to the hand of man. Traditional values, like faithfulness, honor and charity, were eclipsed by the more utilitarian values of industriousness and creativity. And "invention"—the filling out of the cosmos of possibilities—became something like an end in itself.

Nowhere was open-endedness more evident than in the American attitude toward change. Indeed, the words "change" and "improvement" appeared to be synonyms in the national cultural idiom. John Anderson of the Ordnance Department was only one of a host of British observers who commented upon "the avidity with which any new idea is laid hold of, and improved upon," a spirit, he added, which was "occasionally carried to excess."[36] "Everything new is quickly introduced here, and all the latest inventions," wrote Friedrich List in the 1820s. "There is no clinging to the old ways, the moment an American hears the word 'invention' he pricks up his ears."[37] The very word was magic.

This, of course, was only natural in what John L. O'Sullivan termed "the great nation of futurity."[38] After all, America was, as Harvard Professor Levi Frisbie said in 1818, "full of youthful freshness. We are free from any of those institutions by which other nations are enthralled."[39] He doubtless agreed with Noah Webster that "Europe is grown old in folly, corruption, and tyranny—in that country laws are perverted, manners are licentious, literature is declining, and human nature is debased."[40] On the other hand, "Many hundred years must roll away before we shall be corrupted," John Adams confided to his friend Jefferson, adding, "Our pure, virtuous, public spirited, federative republic will last forever, govern the globe and introduce the perfection of man."[41] What this all amounted to was, if not an unqualified self-confidence exactly, certainly an unqualified confidence in the future. As O'Sullivan put it, "We are the nation of human progress, and who will, what can, set limits to our onward march?"

This optimism is usually recalled in political terms, but there is no evidence that contemporaries so conceived it. In 1797 Joseph Perkins predicted that America would become "the seat of Muses, the Athens of our age, the admiration of the world."[42] The nation would, said Jeremy Belnap of New Hampshire, "shine Mistress of the Sciences, as well as the Asylum of Liberty."[43] Timothy Walker was still more specific: "We do entertain an unfaltering belief in the permanent and continued improvement of the human race, and we consider no small portion of it, whether in relation to the body or the mind, as the result of mechanical invention."[44] But it was probably Samuel Colt who put the American case most succinctly. "There is nothing," he said, "that cannot be produced by machinery."[45]

Destiny, progress, machinery, they were inextricably connected in a logical sequence which only the despair of the twentieth century could undo. It was a logic particularly appropriate to the spirit of innovation. De Tocqueville observed that "from a conviction that their country is unlike any other and that its situation is without precedent in the world," Americans look upon theirs as "a land of wonders, in which everything is in constant motion and every change seems an improvement."[46] An example or two will illustrate his point. The Americans altered everything, constantly, almost compulsively. There was an "American design" of the merchant vessel, an "American design" of the locomotive and an "American design" of the reaper.[47] Some of the handiest of the American "inventions," like the Blake stonecrusher, were simply New World versions of European tools. Others, like the Gilpin paper cylinder or the Corliss steam engine, presented modifications so essential that they vastly improved the original. The water turbine was invented by the French, but only in the hands of such restless Yankees as Uriah Boyden did it revolutionize water-power utilization. But the striking example was the Maudslay lathe slide rest. Smuggled out of England at great cost and against impressive odds, the slide rest was worth a king's ransom to its new owners, for independent efforts to duplicate it had failed repeatedly. Yet, no sooner had they wiped the sweat from their brows than they consigned the new wonder to the Mason and Tyler Machine Shop—for alteration and "improvement."

Open-endedness accounts not only for the pace of American invention, but for its idiosyncrasies as well. Because the Americans worked in a universe of boundless possibilities, their artifacts had a certain boundlessness about them. Everything was bigger and faster and more powerful. When George Escol Sellers was taken, at his request, to see the boring machine on which the largest steamboat engine in England was being honed, he was disappointed. "The cylinder struck me as a mere pigmy compared with the cylinders of the North River and Long Island Sound boats." Pigmies also were the lathes of the celebrated Maudslay Machine Shops—not half the size of his father's in Philadelphia.[48] Scale became a kind of quest. As each new engine edged by its precedessor in bore and stroke and horsepower, the American toolmen unconsciously embarked on an odyssey which even now the world fails to comprehend. Their *ne plus ultra* was John Ericsson's mammoth "caloric" engine. Fourteen feet in diameter and eight feet long, its cylinders were, said the proud mechanics of Hogg & Dalamater, the largest attempted anywhere, a boast which is still true. That the machine itself did not work seemed somehow less important. At any rate, its beautifully-crafted zaniness nicely illustrates the American spirit of improvement "carried to excess."[49]

Transcending the limitations of size was but one way of transcending the limitations of history. There were others. Many of the classical American inventions departed conspicuously from the one-step-at-a-time process of development so characteristic of European engineering. They literally sailed off into the unknown—often with results like Ericsson's. In the case of the Tudor-Wyeth ice-harvesting equipment or the reciprocating mortising machines, there was more than a touch of plain naivete in the American leap, and yet, somehow, contrary to all sophisticated expectations, the contraptions worked. What struck the British Commissioners repeatedly—and with considerable impact—was just this: that the Americans were *not* doing the next logical thing in a process of gradual improvement, but doing something unheard of and unexpected. The woodworking machines in particular were startling in their conceptual novelty.[50] Like the Blanchard lathe, the Evans flour mill and the Fulton steamboat (and unlike the Fitch, which didn't work), they did not duplicate a familiar manual process so much as they transformed it into something new.

Even the design of the American machines reflected discontinuity. It was, after all, the Americans who first scrapped the scrollwork and filigree and made the machine stand forth in the starkness of functional simplicity. "There is no country in the world," said Oscar Wilde in 1883, "where machinery is so lovely as in America:

> I have always wished to believe that the line of strength and the line of beauty are one. That wish was realized when I contemplated American machinery. It was not until I had seen the waterworks at Chicago that I realized the wonders of machinery; the rise and fall of the steel rods, the symmetrical motion of great wheels is the most beautifully rhythmic thing I have ever seen.[51]

This was more than a new esthetic. It was a new and open-ended imagination. It was Eli Whitney and Mark Twain, Samuel Colt and Louis Sullivan, Thomas Edison and Charles Sheeler, all rolled into one. And "mechanism" lay at the very heart of it.

In 1885 Henry James looked back upon the United States antebellum, and saw a land which had:

> No sovereign, no court, no personal loyalty, no aristocracy, no church, no clergy, no army, no diplomatic service, no country gentlemen, no palaces, no castles, nor manors, nor old country houses, nor parsonages, nor thatched cottages, nor ivied ruins; no cathedrals, nor abbeys, nor little Norman churches; no great universities nor public schools . . . ; no literature, no novels, no museums, no pictures, no political society.

In short, a land with no past. Though in some ways the indictment was unfair, the America of Andrew Jackson had undeniably divested itself of an Old-World past which, as James suggested, still lived on in Europe. In truth, the American experience can be described as a revolution against the past, a revolution in which the trappings of the Christian corporate commonwealth were cast aside in favor of a newness whose implications are with us still. It is, I believe, against the backdrop of this revolution that we can see most clearly the context in which American technological progress, American "inventiveness," cut itself away from the larger processes of the western industrial revolution and adopted an independent course. It is within this ambience of disorder and reorder that we can appreciate most clearly how the abundance of the American environment, the advantages of a favorable economic endowment and the opportunities afforded by progressive institutions could each contribute to the American "inventive genius." Thus, it becomes clear that while science and engineering in this country could lag far behind European standards of the day, it is still fair to appraise the "genius" as genuine: for in terms of playing out the Industrial Revolution to its logical consequences—both for good and evil—the brash, rough-hewn, Faustian society of the early republic had few peers. By the time of Henry Ford, as Aldous Huxley foresaw, America had truly become the land of the future, where the machine might well yet be king.

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footnotes

1. There is no pretense here of being comprehensive. The attempt is only to identify the principal schools of interpretation and present a particularly clear illustration of each.

2. Robert S. Woodbury, "The Legend of Eli Whitney and Interchangeable Parts," *Technology and Culture,* I (Summer 1960), 235-253.

3. H. J. Habakkuk, *American and British Technology in the Nineteenth Century* (Cambridge, Massachusetts, 1962).

4. John E. Sawyer, "The Social Basis of the American System of Manufacturing," *Journal of Economic History,* XIV (1954), 361-379.

5. See Charles L. Sanford, "The Intellectual Origins and New-Worldliness of American Industry," *Journal of Economic History,* XVIII (March 1958), 1-16; Samuel Rezneck, "The Rise and Early Development of Industrial Consciousness in the United States, 1760-1869," *Journal of Economic and Business History,* IV (1931-1932), 784-811; and Hugo Meier, "Technology and Democracy, 1800-1860," *Mississippi Valley Historical Review,* VLIII (March 1957), 618-640.

6. Roger Burlingame, *March of the Iron Men* (New York, 1940).

7. See John A. Kouwenhoven, *Made in America* (Garden City, New York, 1948); D. L. Burn, "The Genesis of American Engineering Competition, 1850-1870," *Economic History,* II (January 1931); and Daniel J. Boorstin, *The Americans: The National Experience* (New York, 1965).

8. The importance of the "deference community" to English life and thought in the nineteenth century has been repeatedly stressed by D. C. Moore. See, for example, "The Sociological Premises of the First Reform Act," *Historical Journal,* IX (1966), 39-59.

9. Joseph Whitworth and George Wallis, *The Industry of the United States in Machinery, Manufactures, and Useful and Ornamental Arts* (London, 1854), iii-iv. The phrase "British observers," which appears throughout this essay, refers loosely to any or all of the several groups, most of them official, who attended the London Exhibition of 1851 or visited the United States on special missions of investigation in 1853 and 1854. Most of these reported directly to committees of Parliament. A few of them, such as Whitworth and Wallis, published their observations independently as well. Quoted material will be noted where appropriate from this point forward. However, bibliographical information on the original sources used for the technical examples has been deleted in the interest of space. If further information is desired, I will be happy to supply it upon request.

10. David Stevenson, *Sketch of the Civil Engineering of North America* (London, 1838), 258-259.

11. James Nasmyth, *Engineer: An Autobiography* (London, 1883), 426.

12. The Whitworth, or "English Standard," thread required flat sides at an angle of 55° with rounded bottoms and tops. The 55° angle was difficult to gauge with consistent accuracy. The rounded top required three kinds of cutters and two lathes to produce, necessarily with a high degree of craft skill. Moreover, the 55° angle, which had no functional justification, was arrived at arithmetically, a compromise based upon accumulated knowledge and practice—tradition in other words. See Bruce Sinclair, "At the Turn of a Screw: William Sellers, the Franklin Institute, and a Standard American Thread," *Technology and Culture,* X (January 1968), 20-34.

13. The relative absence of this tyranny in America was often noted by British observers. See Burn, "Engineering Competition," 306.

14. See Peter F. Drucker, "Work and Tools," *Technology and Culture,* I (Winter 1960), 28-37.

15. For a broader discussion, see John B. Rae, "The 'Know-How' Tradition: Technology in American History," *Technology and Culture,* I (Winter 1959), 139-150.

16. *New York Industrial Exhibition: Special Report of Mr. George Wallis,* Parliamentary Papers, House of Commons, Command Paper, 1854, XXXVI, 5.

17. James Nasmyth, *Select Committee on Small-Arms,* Parliamentary Papers, 1854, XVIII, Q. 1367.

18. *Industry of the United States,* iii-iv.

19. Wallis Report, 3.

20. *Ibid.*

21. J. Fraser, *Report to School Inquiry Commission,* Parliamentary Papers, 1867, XXVI, 496.

22. See Eugene S. Ferguson, "On the Origin and Development of American Mechanical 'Know-How,'" *Midcontinent American Studies Journal,* III (Fall 1962), 2-15.

23. J. Hector St. John de Crevecoeur, *Letters from an American Farmer* (Philadelphia, 1782), 48.

24. Wallis Report, 3.

25. *Ibid.* Zachariah Allen, *Sciences of Mechanics* (Providence, Rhode Island, 1829), 349.

26. Compare, for example, the *Journal* of the Franklin Institute with the *Mechanics' Magazine* of London, which preceded it by a few years.

27. *New York Industrial Exhibition; Special Report of Mr. Joseph Whitworth,* Parliamentary Papers, House of Commons, Command Paper, 1854, XXXVI, 146-147.

28. *Report of the Commission on the Machinery of the United States,* Parliamentary Papers, House of Commons, Accounts and Papers (21), 1854-55, L, 578, 621.

29. *Ibid.,* 547-551.

30. In the *Manufacturers' and Farmers' Journal,* October 19, 1820, an inventor modestly admitted that the "improvement" craze was getting out of hand, and that many of the improvements being urged upon manufacturers were worthless. However, his own idea, he added, possessed unqualified merit.

31. Alexis de Tocqueville, *Democracy in America,* Corrected and Edited by Phillips Bradley, 2 vols. (New York, 1945), II, 46.

32. Wallis Report, 3.

33. Nasmyth report, Q. 1367.

34. See Norman Ware, *The Industrial Worker, 1840-1860* (Boston, 1924).

35. Tocqueville, *Democracy in America,* 47.

36. *Commission on Machinery,* 85.

37. Quoted in Stuart Bruchey, *The Roots of American Economic Growth, 1607-1861* (New York, 1965), 166.

38. John Louis O'Sullivan, "The Great Nation of Futurity," *The United States Magazine and Democratic Review,* November, 1839, 426-430.

39. Levi Frisbie, "Professor Frisbie's Inaugural Address," *The North American Review,* VI (January 1818), 224-241.

40. Noah Webster, *A Grammatical Institute of the English Language, Part I* (Hartford, 1784), 14.

41. John Adams to Thomas Jefferson, November 13, 1813, quoted in Hans Kohn, *American Nationalism* (New York, 1957), 13.

42. Joseph Perkins, *An Oration Upon Genius, Pronounced at the Anniversary Commencement of Harvard University in Cambridge, July 19, 1797* (Boston, 1797), 9.

43. Belnap to Ebenezer Hazard, February 4, 1780, *Belnap Papers,* I, 255, cited in Brooke Hindle, *The Pursuit of Science in Revolutionary America, 1735-1789* (Chapel Hill, 1956), 278.

44. "Defense of Mechanical Philosophy," *The North American Review,* XXXIII (July 1832), 132-136.

45. Quoted in Ferguson, "Mechanical 'Know-How,'" 14.

46. Tocqueville, I, 443.

47. The "American Design" of the merchant vessel was known as the "clipper ship," of course, and was regarded as highly irregular. The American design of the locomotive was noted for its loose-jointedness, a quality dictated by the hasty construction of American tracks. On the American design of the reaper, see Paul David, *The Landscape and the Machine,* A paper presented to the Mathematical Social Science Board Conference on British Economic History, Cambridge, Massachusetts, September 1-3, 1970 (Stanford, 1970), 4-13.

48. *Memoirs of George Escol Sellers,* Peale-Sellers Papers, American Philosophical Society Library, Book 4, 37.

49. See "John Ericcson and the Age of Caloric," *United States National Museum Bulletin 228* (Washington, D.C., 1961), 41-60.

50. Whitworth Report, 116. The "muley-saw," for example, seemed to defy all of the known principles of reciprocal motion. Instead of stretching the saw blade across a cumbersome frame, the muley-saw allowed the blade to operate freely, under no tension whatever.

The result was that rather than binding and breaking, as one might expect, the saw cut truer and lasted longer.

51. Oscar Wilde, *Impressions of America,* ed. Stuart Mason (Sunderland, 1906), 24.