At the time of this experiment, Franklin's period of concentrated electrical work had already come to a close. Already closely involved in a number of civic activities, he was elected a member of the Pennsylvania Assembly in 1751. This might be considered the formal beginning of his extremely active political and diplomatic career.

However, he did not desert electricity completely. He continued an active correspondence on the subject, served on a Royal Society lightning-rod committee, encouraged Joseph Priestley and others in their investigations, and even performed occasional experiments himself. But the era of his fundamental contributions had ended.

On the other hand, electricity did not desert him. When he went on his extended diplomatic missions to England and then France, he could walk into scientific circles as a respected peer, who had helped unlock fundamental natural mysteries. And he could walk among more ordinary folk as a hero who had tamed lightning. Clearly, such a reputation could be of assistance in his diplomatic maneuverings. And thus it would not be too far fetched to say that Franklin's electrical investigations played a more than casual role in the successful completion of the American Revolution.

The Electric Motor, the Telegraph, and Joseph Henry's Theory of Technological Progress

ARTHUR P. MOLELLA

Abstract—**Joseph Henry (1797-1878), America's foremost electrical physicist of the early nineteenth century, stood at the center of the developing science and technology of the newly discovered electric current. The electromagnetic telegraph and the battery-powered motor were two leading technological efforts of the period. Although Henry chose not to engage in the actual inventive process, he closely followed the development of both devices. While he fully supported the work on the telegraph, especially S.F.B. Morse's experiments, he stood opposed to the battery-powered motor on the grounds of impracticality. He stated these views forcefully to the numerous inventors who sought his expert advice on electricity. This paper explores the reasons for Henry's contrasting opinions of the telegraph and the motor. Underlying these opinions was a set of assumptions about the progress of technology and its proper relations to scientific knowledge and the current needs of society.**

I

ALTHOUGH DEDICATED to basic scientific investigation of electromagnetism, Joseph Henry had distinct roles in two leading areas of early nineteenth-century electrical technology: the attempts to develop a battery-powered motor and the electromagnetic telegraph. As America's foremost electrical physicist of that period, his involvement is not surprising. But his roles remain clouded, primarily for reasons stemming from his self-conscious identification as a scientist and not as an electrical inventor or the early equivalent of an electrical engineer. For both the motor and the telegraph, Henry built "philosophical" prototypes for the demonstration of basic principles, but in no case a finished piece of hardware. However intended, the prototypes still captured the attention of inventors and mechanics whose electrical devices have become part of the history of the technology. Obscuring Henry's contribution were long-standing priority disputes involving both inventions, particularly the telegraph. Moreover, Henry was an outspoken skeptic of the prospects of one of these technologies. Until the end of his career, he went on record against the development of the battery-powered motor as a practical source of power. He was considerably more sanguine about the telegraph. Toward these two concurrent areas of electrical technology, Henry took sharply contrasting views. The purpose of this paper is not to settle once and for all Henry's disputed contribution to the development of these two inventions. Rather his contrasting opinions toward them provide an opportunity for considering his general attitudes toward electrical technology. Although differing, his conceptions of the motor and telegraph flowed from a coherent set of convictions about the progress of technology, its relations to science, and finally its connections with society. Each of these aspects of Henry's views will be considered here. Since Henry both reflected and influenced the beliefs of his day, since beliefs often affect actions, and since men of practice looked to Henry for advice or submitted their devices to his judgment, these ideas take on historical importance.

Manuscript received January 2, 1976. This work was supported by the National Endowment for the Humanities.
The author is with the Smithsonian Institution, Washington, DC 20560.

II

It would be very surprising if Henry were unconcerned with the new technology centered on the electrical current and electromagnetism, the chief electrical discoveries of the early nineteenth century. Electrical science and electrical technology blossomed together in this period, with continual cross-fertilization between them. In the literature of the day, there was no clear-cut separation between scientific and applied topics. Each scientific discovery aroused immediate expectations of utility, and, in turn, inventive activity channeled and heightened interest in related areas of the science. Excitement accompanied every discovery in electromagnetism, theoretical or practical. The technological fascination presents no mystery. The electric current with its attendant magnetic forces was one of the most impressive new powers ever to come in view of science. Its energies lay in the immediate grasp of man. It was also a more consistent and tractable force than the powerful but often uncontrollable static charges studied by eighteenth-century electricians.

In the 1830's, the decade of Henry's most active research, interest in electromagnetic technology had, as one scholar has put it, reached a level of euphoria in both Europe and America.[1] Investigation was especially intense and specialized journals devoted to the new phenomena proliferated with no sharp distinctions between the useful and the theoretical. The kind of experimental research pursued by Henry was most relevant to the technological expectations. As much as any other scientist of these early decades, he brought out the vast capabilities of the new forms of electricity and magnetism. His electromagnets were by far the strongest in existence. His impressively large induction coils drew the strongest sparks. His high voltage "intensity" circuits carried electricity unprecedented distances. It took no special perception to see that Henry had much to offer technology. This Henry recognized as well as anybody.

Amid the contemporary euphoria for electricity, Henry defined a particular role for himself as well as a course for the new electrical technology. Although always fascinated with technology in any form, he saw himself as a discoverer not an applier of knowledge. Early in his career he had made a decision not to indulge in practical invention, much less in the commercial exploitation of his discoveries.[2] Such was his image of the committed scientific discoverer, for which there were ample contemporary models.[3] Coupled with this conception was the belief that basic science constituted the true and only source of useful knowledge.[4] As a scientist, he took a paternal interest in efforts to apply electricity to useful ends, not engaging in applied endeavors himself but choosing to act, in effect, as the conscience of the technology. This was a serious calling, since Henry shared that era's unquestioned faith in the ability of technology to radically alter the human condition.[5] In his chosen role, Henry could become noticeably, sometimes painfully, moralistic. Above all, the era of electrical euphoria demanded clear attention to moral considerations. The high expectations left society particularly vulnerable to charlatans, commercial schemers, and well-meaning, but naive enthusiasts promising everything from the new power. Henry called for calm and a reasoned attention to what science deemed possible. These considerations are what led Henry to assume different stances toward the motor and telegraph technologies now under consideration.

Nowhere was Henry's scientific caution more evident than in his opinion of electricity as a moving power. His concerns in this area first surfaced in an 1831 article, "On a Reciprocating Motion Produced by Magnetic Attraction and Repulsion,"[6] describing a simple electromagnetic motor based on a rocking energized iron bar. The device was presented as no more than a philosophical toy demonstrating a way of rapidly reversing the poles of an electromagnet by a simple commutator. At the time Henry offered the prospect of utility, conjecturing that "in the progress of discovery and invention, it is not impossible that the same principle . . . may hereafter be applied to some useful purpose." He later added minor improvements to what has been described as "the first clear-cut instance of a motor capable of further mechanical development." As Henry knew, the possibility of an electric motor held a fascination for a number of contemporary scientists, including William Sturgeon, William Ritchie, and M. H. von Jacobi, all of whom experimented with early devices.[7]

But within a few years Henry had clearly changed his mind and was seriously doubting the practicality of further application with available battery sources. Laboratory work had already familiarized him with the unreliability and expense of galvanic batteries. These deficiencies were accentuated in comparison with competing power technologies. Improvements in the steam engine and the advent of railroad construction and steam locomotives no doubt dramatized for Henry and his contemporaries the immense advantage of steam power. Calculations were soon made along these lines. The zinc needed for a given amount of galvanic power was found to be much more expensive than the coal and water needed for the equivalent in steam. This judgment convinced Henry to forego further improvement of his own device. As early as 1835, he was actively discouraging would-be inventors of a workable motor, even though his own prototype and other scientific work in electricity continued to fuel their enthusiasm.[8] Corroborating comparisons of electrical and steam power continued to be made into the 1850's. Given the best available knowledge, these judgments of the battery-powered motor were accurate. Only the cheaper means for the distribution and production of electricity, afforded by the later invention of the transformer and dynamo, made the electric

[1] D. S. L. Cardwell, "James Prescott Joule, theories of power and the doctrine of energy," presented at the Colloquium on the Interaction of Science and Technology in the Industrial Age, Burndy Library, Norwalk, CT, Mar. 23 and 24, 1973, p. 2, to be published in N. Reingold and A. P. Molella, Eds., *The Interactions of Science and Technology in the Industrial Age* (a special issue of *Technology and Culture*).

[2] For Henry's early electrical work see N. Reingold *et al.*, *Papers of Joseph Henry*, vol. 1. Washington, DC: Smithsonian Press, 1972. For his scientific vocation, see p. 367.

[3] This self-denial greatly impressed one of Henry's eulogists, W. B. Taylor, who compared Henry to Michael Faraday in this respect in *A Memorial of Joseph Henry*. Washington, DC: G.P.O., 1880, p. 232.

[4] N. Reingold and A. P. Molella, "Theorists and ingenious mechanics: Joseph Henry defines science," *Science Studies*, vol. 3, pp. 323-351, Oct. 1973.

[5] Reingold, *Henry Papers*, vol. 1, pp. 163-179, 380-397.

[6] *Silliman's Journal*, vol. 20, pp. 340-343, 1831.

[7] Henry's motor is so described and the other motors are discussed in W. J. King, *The Development of Electrical Technology in the 19th Century: I. The Electrochemical Cell and the Electromagnet.* Washington, DC: United States National Museum Bulletin 228, 1962, pp. 260ff. Also, W. Sturgeon, "Historical sketch of the rise and progress of electromagnetic engines for propelling machinery," *The Annals of Electricity, Magnetism, and Chemistry* . . ., vol. 3, pp. 429-437, Mar. 1839.

[8] Henry reiterated these beliefs until the end of his career. One of his first statements to this effect occurs in his letter to Benjamin Silliman of September 10, 1835, dealing with the motor of the Vermont inventor Thomas Davenport. Reingold, *Henry Papers*, vol. 2, 1975, pp. 445-451.

motor a practical possibility. No longer dependent on battery power, the motor was ready for its explosive industrial development.[9]

Henry's negative opinion of the electric motor, therefore, arose not from any denigration of utility but from his best reading of current science, which, according to his deepest convictions, must determine what is practically feasible. By the 1840's Henry was able to perceive basic principles militating further against electricity in any competition with steam power. For Henry, these principles had implications for the future of all electrical technology. In 1844 Henry offered speculations to the American Philosophical Society on "the classification and origin of mechanical power," suggesting notions of force conversion that presaged approaching theories of the conservation of energy.[10] He first listed what he called "natural motive principles," which encompassed all the familiar prime movers. Along with water, tide, and wind power, he included steam, animal power, and combustion. Electricity and magnetism he considered not of this class. Relegated to the status of "intermediate powers" were the so-called imponderable forces, which included electricity. Powers of this category, he asserted, normally exist in quiescence and therefore cannot serve as an original source of power: " . . . these principles in themselves are not the primary sources of power, but are merely secondary agents in producing mechanical effects. . . ." To excite them, one must apply an equivalent outside force and, ultimately, the agency of a true prime mover. This was a puzzling kind of taxonomy, more speculative and metaphysical than empirical. The notion of the prime mover is essentially arbitrary.[11] But the general thought was certainly not original with Henry. Ideas about the relations of forces had long been in the air and Henry had probably picked them up in the general literature. Soon James Joule and other scientists would be applying quantitative notions of energy conservation to similar effect, providing definitive figures showing the immense economic advantage of steam.[12]

A decade later Henry sharpened these ideas, significantly, in a public lecture to an artisan and mechanics association in Washington, DC.[13] Henry made special reference to mechanical invention, with some characteristically acid asides about the current state of electrical technology:

> Gravitation, electricity, galvanism, magnetism, and chemical affinity can never be employed as original sources of power. At the surface of the earth they are forces of quiescence, the normal condition of which must be disturbed before they can manifest power, and then the work which they are capable of performing is only the equivalent of the power which was communicated to them. . . . [I]f we are to judge from the constant announcement in the papers of new motors . . . of contrivances by which electricity is to develop itself and do work by its own force–we shall be convinced that on projects which are in opposition to the best-established truths of science hundreds of thousands of dollars are squandered and years of thought and labor wasted.[14]

There is no mistaking Henry's low opinion of the proliferating attempts to devise a working electric motor. It may add an element of irony and confusion to this story that Henry nevertheless demanded recognition for his own early motor. Early histories of electrical technology that all too frequently omitted his reciprocating prototype never failed to provoke a self-righteous letter or two in protest.[15] Part of this was Henry's life-long craving for personal recognition. But, more basic was Henry's honest belief that no significant advance had been made beyond his first scientific application of electromagnetism to mechanics. Not a surprising opinion for one so deeply committed to a scheme according priority to scientific theory.

Such opinions showed Henry to be insensitive to advances in design, which practical men considered of utmost importance in the search for a workable motor. Early proposals for an axial rotating motor by the British electrician Ritchie or the American inventor Davenport left Henry unimpressed and angry with their presumption. The alleged improvements were deemed mere variations on the "appearance of the machine by the addition of wheels &c. so as to make it appear like a new article."[16]

Theoretical arguments leveled by Henry and others against the motor were not universally accepted, even by scientifically knowledgeable electricians. More empirically minded investigators such as Henry's friend Charles Page still dreamed of electromotive power in the face of contrary estimates. Distrusting "mathematical reasoning," Page insisted on giving the motor a practical trial, feeling that the scientific principles involved were still at an elementary level, not unlike the knowledge of heat and steam in their early stages.[17] Henry might have believed this, if it were not for the overriding considerations of force conversion discussed above. Page continued to put forth his motors. In spite of his convictions, Henry did not try to bar the inventors from what they loved

[9] *Encyclopaedia Britannica*. 8th ed., s.v. "Voltaic electricity," p. 643. King, *Development*, pp. 269–270.

[10] "On the origin and classification of the natural motors," reprinted in Joseph Henry, *Scientific Writings*, vol. 30 of *Smithsonian Miscellaneous Collections*. Washington, DC: Smithsonian Institution, part 1, pp. 220–223.

[11] The concept of a prime mover in technology eludes precise definition. Dictionary definitions only specify "a machine which receives and modifies motive-power supplied by some natural source"–*Oxford English Dictionary*. Common usage, as it has evolved historically, generally applies the term to the windmill, water wheel, and steam engine, notably the latter. The essence of Henry's rather strained taxonomy seems to be, using his terms, that the natural motive principles are those which create states of disturbance and instability, while the secondary or intermediate powers tend toward stability and equilibrium. Interestingly, W. J. M. Rankine's *A Manual of the Steam Engine and Other Prime Movers* (London and Glasgow: Richard Griffin and Co., 1859, p. xv) includes the "electro-magnetic engine" among prime movers, "by whose aid power or energy is derived from natural sources. . . ." By any of these criteria, there is no clear way of distinguishing machines which exploit "natural" sources of motion from those which merely modify it at a later stage. My colleague Otto Mayr suggests a relationship between the concept of mechanical prime movers and the *Primum Mobile* of medieval astronomy, since both seem to refer to some metaphysical first cause.

[12] Among the most pessimistic about electrical power, the British scientist Robert Hunt calculated in 1850 that it was 25 times more expensive than steam power. King, *Development*, p. 269.

[13] "The improvement of the mechanical arts. Closing address at the Exhibition of the Metropolitan Mechanics' Institute of Washington," in Joseph Henry, *Scientific Writings*, part 1, pp. 306–324. The talk was delivered on March 19, 1853, and was published as a pamphlet in the same year by the Metropolitan Mechanics' Institute.

[14] *Ibid*., pp. 311, 313.

[15] For example, in a letter of October 31, 1838, to Charles Page, Henry objected to Page's attributing the first prototype to Sturgeon. Joseph Henry Papers, Smithsonian Archives.

[16] Letter to Jacob Green, February 17, 1834, printed in *Henry Papers*, vol. 2, p. 162.

[17] I am indebted to Robert C. Post for various suggestions, including ideas in the manuscript of his forthcoming *Physics, Patents, and Politics: A Biography of Charles Grafton Page*. New York: Science History Publications (USA), pp. 105–106, 125.

to do. Implicit in Henry's reciprocating motor, even though a toy, was the same curiosity, perhaps even the inventor's impulse. In fact, through the inspiration this work gave to men like Davenport and Page, Henry had contributed significantly to what can be described as the prehistory of the electric motor. His caution signified not categorical opposition but a deep concern for the proper nurturing of technology.

III

This same attitude worked to the opposite effect in the case of the electromagnetic telegraph, which indeed enjoyed a more successful early history. Henry's unequivocal and continuing support for the telegraph project in no way contradicted his position on the motor. As with the motor, his first personal involvement took the form of philosophical demonstration, reputedly a mile-long bell-ringing device strung up in his lecture hall at the Albany Academy in 1831.[18] Application was also on his mind in one of his first electricity articles, in which he noted in passing "the fact, that the magnetic action of a current from a trough is, *at least*, not sensibly diminished by passing through a long wire, is directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph. . . ."[19] These interests continued to surface throughout his career, notably on an 1837 European trip when Henry witnessed telegraphic experiments by the English physicist Charles Wheatstone, who went on to patent a device. Talking over his work on electromagnets and intensity circuits with Wheatstone, Henry may have given the latter the idea of applying the electromagnetic relay to his invention.[20] There were efforts by other scientists along these lines which Henry followed with interest.

When Samuel F. B. Morse, on the urging of a scientist friend, first approached Henry for advice in 1839 at a critical stage of his invention, Henry not only aided him but backed his project enthusiastically. Henry closely monitored its progress and took every opportunity to advise Morse of useful facts from his ongoing scientific researches on induction and intensity circuits.[21] Henry's involvement with the telegraph was a more straightforward story than his interest in the electric motor. From start to finish, he supported this particular application of electricity. Only his famous priority dispute with Morse, erupting in 1846, could sour him on his involvement with the invention. The priority issue was again over Henry's prior enunciation of scientific principles underlying the telegraph, which Morse and his supporters willingly acknowledged but considered too general for Henry to deserve any immediate credit for the actual working device.[22]

Unlike his thoughts on the motor, Henry believed theoretical science could do everything for this eminently feasible new application of electricity. In this, Henry was again allied with the best scientific opinion, as evidenced by the telegraphic researches of notables such as Gauss and Weber in Germany and Wheatstone in England. Henry never claimed that Morse was on the wrong track. In Henry's eyes, Morse had initially done just the right thing to seek the advice of learned men in the scientific community. His fault was to underestimate, in retrospect, the importance of the scientific contribution.

This paper is not the place to argue the "true" paternity of the telegraph. Conceivably there were a number of routes, scientific and otherwise. Rather the question concerns Henry's underlying attitudes. His support arose from his simple conviction that electrical science had now found an appropriate application. While electricity could in no way supplant prime movers such as steam as a source of power, "from its extreme mobility and high elasticity it affords the means of transmitting power with scarcely any loss and almost inconceivable velocity to the greatest distance."[23] Science and practice were in harmony. Electricity was one of those powers ideally suited to operate between the primary power and the work that needed to be done. A neat comparison of the motor and telegraph appears in an 1842 letter from Henry to Morse, before their break:

> . . . [I]n the minds of many, the electro-magnetic telegraph is associated with the many chimerical projects constantly brought before the public and particularly with the schemes so popular a year or two ago for the application of electricity as a moving power in the arts—all schemes for this purpose, I have from the first asserted, are premature and formed without proper scientific knowledge. The case however is entirely different in regard to the electro-magnetic telegraph. The science is now fully ripe for such an application of its principles, and I have not the least dout [sic], if proper means be afforded, of the perfect success of the invention.[24]

Implicit in this statement is a critical element of Henry's conception of the relationship between science and technology. Science, like technology, was progressive. Furthermore, a given scientific field could not be put to technological use until it had reached a certain level of maturity. Before fully formulated, scientific theory lacked the predictive capabilities necessary for manipulating real objects in a real world. It was a compelling progressivist view of science and technology that even today continues to influence interpretations of their relationship.[25] According to this view, electromagnetic science was prepared for problems of telegraphic communication, but, by the nature of things, would perhaps never yield a practical source of mechanical power.

Moreover, as soon as a science was fully mature, there was no problem explaining the resulting technological concepts. Utilitarian ideas would drop from the science like ripe fruit. Henry's statements on the telegraph illustrate this point. Once the science was ready, he argued to Morse, any knowledgeable investigator of electricity would foresee the possibility of an electromagnetic telegraph. The mere proposition of a telegraph by an inventor took no special ingenuity. The real genius lay in discovery.[26]

[18] Thomas Coulson, *Joseph Henry, His Life and Work*. Princeton, NJ: Princeton University Press, 1950, p. 63.

[19] "On the application of the principle of the Galvanic multiplier to electro-magnetic apparatus, and also to the development of great magnetic power in soft iron, with a small Galvanic element," *Silliman's Journal*, vol. 19, p. 404, Jan. 1831.

[20] Entries of April 1 and August 2, 1837, Henry European Diary, Smithsonian Institution Archives. Also A. D. Bache to Henry, June 7, 1837. Henry made the claim of aiding Wheatstone in a deposition for subsequent litigation with Morse. Coulson, *Joseph Henry*, p. 108.

[21] The initial contact is recorded in a letter from Morse to Henry, April 24, 1839, Henry Papers, Smithsonian Archives. Subsequent correspondence was extensive. An example of Henry's research feeding into Morse's invention is in Henry to Morse, January 24, 1844, Morse Papers, Library of Congress.

[22] See Coulson, *Joseph Henry*, for details of the dispute. Morse's position can be examined in his letter to Sears Walker of January 31, 1848, Morse Papers, Library of Congress.

[23] Henry, "Improvement of the Mechanical Arts," pp. 311-312.

[24] February 24, 1842, Henry Papers, Smithsonian Archives.

[25] For example, H. J. Steffens, "Science as a Creative Art," in Steffens and H. N. Muller, III, Eds., *Science, Technology, and Culture*. New York: AMS Press, Inc., 1974, pp. 91-93.

[26] Henry to Morse, February 24, 1842, Henry Papers, Smithsonian Archives. Although Henry also stressed the necessity of a practical plan for realizing the device, he clearly attributed the act of discovery to science.

There were interesting corollaries to this assumption of the "ripeness" of science as a precondition to successful invention. I have already stressed that Henry's scientific vocation did not preclude a genuine and serious interest in technology. If subservient to scientific theory, technological application played a very important part in Henry's conceptual scheme. Looking at his scheme from the other direction, successful invention was one important measure of the maturity of its patron science. A successful telegraph would prove the validity of certain central aspects of electrical theory. In 1853, Henry wrote, "There can be no reality in science if at this late day it cannot predict that certain proposed inventions are impossible, as well as declare that others are in accordance with established principles."[27] The motor and the telegraph constituted a dual test of the underlying science. In introducing his students to his natural philosophy course at Princeton, Henry would define science as "the knowledge of the laws of phenomena or change," and add that "the test of Science is the power of predicting phenomena" in a world of constant change.[28] Actually manipulating nature for useful ends was to Henry the ultimate test of these predictive powers.

Technology also mattered to Henry in another way. Science and its client technologies were bound in a moral and social context. As mentioned above, it was part of the wisdom of the times that, jointly, science and technology had the unique capability of shaping civilization for the good. The ultimate basis of this assertion was that the final principles sought by scientific theory were in fact God's imperishable laws. Contemplation of these laws was in itself a cultural and spiritual good. But it was the visible achievements of technology that provided a direct linking of theoretical knowledge, the common mind, and the progress of civilization, by both spiritual and material measures. In an important sense, the scientifically dependent useful arts were a social and moral vindication of science. This optimistic, almost spiritual vision of technology, so much a part of the times, provided a context for Henry's understanding of the electrical technology most directly related to his researches.

Science existed in itself and for eternity. But electrical technology, along with other useful arts, had important social and temporal roots for Henry. His belief in the flow of pure knowledge downward to the applied may seem naive or even self-serving in retrospect. But his more mature thoughts on this relationship included social and historical considerations which showed considerable subtlety. Note that not only scientific principles argued against the realization of a practical motor. Henry also stressed the related question of economic receptivity. By 1853 Henry was able to systematize the criteria for a successful technology, giving in effect a theory of technological progress. First of all, the art must be feasible in principle, that is, it must rest on valid and well understood scientific laws or, at least, not contradict established ones. Secondly, society and the times must be ready for its introduction:

> The invention must be wanted; or in other words, it must be called for by the character and intelligence of the times, or rendered especially desirable in a particular place by some peculiarity of climate, topography, &c.[29]

On both criteria, the motor was premature, probably impossible, while theoretical knowledge and society were both ripe for the invention of the telegraph.

This conceptualization of technological progress provided a basis for a broad theory of historical development, outlined by Henry in the same lecture:

> Every age of the world since the commencement of the historic period has been characterized by some leading or dominant idea, and each age has bequeathed something of value to—or made some abiding impression on—that which followed.[30]

The outstanding accomplishment of the eighteenth century, he believed, was the discovery of the "great principles of nature from which we are now reaping so rich a harvest of practical results. . . ." The ideas were too new to that century to have any significant impact on everyday life, but were gradually absorbed into society, making Henry's century the great age of "the application of science to art." Basic discoveries were now completely "interwoven with the thoughts of the common mind."[31]

This theory does much to explain some otherwise cryptic comments by Henry in the same lecture. Henry described a familiar semimythic figure: the ingenious inventor of some marvelous device which the contemporary public either scorns or ignores. Such disappointed men are often said to live before their time. To Henry these men were more quixotic than brilliant. For him it was obvious that "The man of true genius never lives before his time; he never undertakes impossibilities, and always embarks in his enterprise at a suitable place and period."[32] In general, men said to be ahead of their time do more harm than good to the cause of technology. Although Henry specified no one, it has been suggested that Henry had in mind Charles Page, the irrepressible inventor of over one hundred battery-powered motors, or that at least Henry's audience would have suspected Page as the butt of his remarks.[33]

These comments were revealing of Henry's notions of technological progress. Technology was serious business. Irresponsible speculation of any sort was intellectually dishonest and morally reprehensible. The premature inventive genius is often simply ignorant of scientific principles. At the same time, he manifests an ignorance of the needs of his times, that is, he is socially irresponsible. The scientist defines nature's laws and is responsible to truth; the man of practice applies these laws and is responsible to society. Technology does not progress in isolation. It is the child of speculative science, but it matures as a ward of society. In a way, the birth of a particular invention was a trivial matter for Henry, since it was already implicit in theory. Once theoreticians demonstrated the possibility of an invention, it was left to society and the times to call it into being and to see it to maturity. If one were to weigh the factors which in Henry's scheme determine "true" technological progress, it could be argued that technology did not proceed so much from a scientific push but from the pull exerted by civilization at a particular time and place. In short, science provided the opportunity, civilization the need. So, in this sense, social factors were more important to the ultimate realization of a

[27] "Improvement of the Mechanical Arts," p. 310.
[28] Taken from the 1847 natural philosophy notes of Henry's student Henry Wurts, New York Public Library.
[29] "Improvement of the Mechanical Arts," p. 315.
[30] *Ibid.*, p. 318.
[31] *Ibid.*, pp. 318–319.
[32] *Ibid.*, p. 317.
[33] Post, *Physics, Patents*, p. 131.

particular invention or technology, in Henry's eyes, than the antecedent science.

These beliefs ran deep in Henry. Technology's practitioners inevitably fell short of his moral ideal. He charged that too many inventors were ignorant of science or, even worse, unappreciative of the scientist's unique role in uncovering the basic principles so necessary to technology. The cardinal sin that an inventor could commit against this moral code was vanity. The following statement, from Henry's 1853 lecture, could have been made at any time in his career:

> Indeed the facts and elementary principles of science, as well as the application of the rules which have been deduced from its higher generalizations, are now so familiar that art has become vain of her attainments, has set herself up as the architect of her own fortune, and disregards the counsel of her more learned and sagacious sister.[34]

Dissatisfied as he was with the common run of mechanics and inventors, Henry still recognized the necessity of their function. He knew that no invention emerged fully formed from the parent science. For the practical development of an invention, Henry envisioned an ideal practitioner: not surprisingly, a man capable of both theory and practice. James Watt served as his best example. Among his contemporaries, Henry nominated his friend and frequent collaborator Joseph Saxton, Philadelphia's premier instrument maker and a man comfortable with science and scientists.[35]

What Henry was calling for was the modern image of the engineer. Like his contemporaries, he drew no sharp distinctions between the scientific and engineering function, yet he was clearly looking ahead to some basic separation of responsibility. In this the hierarchy of science and technology still obtained. What Henry commended in Saxton and even in Morse (at least when he first knew Morse) was not notable theoretical ability but simply a willingness to defer to scientists as the bearers of technological wisdom. This deference rested upon some very basic distinctions. Lecturing the mechanics of Washington in 1853, Henry linked the opposing processes of discovery and invention to two types of personality.

> Generally . . . the two faculties [i.e., discovery and invention] exist in the greatest degree of development in separate individuals. The successful investigation of a new principle in science generally requires much previous study and preparation and a logical training, which few men–however vigorous may be their native intellect, can dispense with, and to acquire which the opportunities of the workmen are inadequate. On the other hand the successful introduction to common use of an invention requires a contest with the world from which the sensitive student of abstract science shrinks with repugnance.[36]

Statements such as this were in part the individual expressions of a personality already inclined to speculative science and contemplation, but they were also symptomatic of the times and of developing social conflicts.

Surely there were mechanics in Henry's audience who took a degree of heroic pride in his description of their "contest with the world." Yet the implicit condescension bruised the egos of inventive minds with significantly more exalted self-images.

[34]"Improvement of the Mechanical Arts," p. 319.

[35]*Ibid.*, p. 320. For Saxton, see Henry's necrology, "Memoir of Joseph Saxton, 1799-1873," *Biographical Memoirs, National Academy of Sciences*, vol. 1, 1877.

[36]"Improvement of the Mechanical Arts," p. 320.

Henry's assertions were provocative, especially in an age when the popular images and functions of scientists and inventors were ill defined, and often in contention. The righteousness of Henry and many of his fellow scientists often met with indignation from an inventive community skeptical of the practical and even cultural value of science pursued for its own sake. Fairly typical was this sentiment by one reader of the *Scientific American*, the leading journal of American inventors:

> We need physical discoveries and revere those who seek truth for its own sake. But mankind with keen instinct saves its warmest acclaim for those who also make discoveries of some avail in adding to the length of life, its joys, its possibilities, its conveniences.[37]

Other inventors were puzzled by and unwilling to accept Henry's exclusive claim to the scientific principles underlying technology. Men such as Morse accepted Henry's notion of a scientific technology on its own terms but refused second-class status. Hearing of Henry's distinction between "men of mind" and "men of action," Morse resented being cast in what he deemed an inferior role.[38] Insisting that he was a thinking man, Morse indignantly pointed out to supporters in his priority dispute with Henry the accolades and certificates he had received from leading *scientific* organizations of Europe. The foreign praise allegedly testified to not only the originality but the scientific nature of his discoveries with the telegraph.[39] Though none were so explicit as Morse, many involved with electric motor technology were likely to respond in the same way to Henry's claims. While never in overt conflict with Henry, Charles Page certainly believed that his numerous articles on electrical science preceding his preoccupation with the electric motor placed him in a class with Henry. Interestingly, Page's most recent biographer brings these nineteenth-century conflicts up to date with a case against Henry's elitist image and in defense of Page's scientific respectability.[40]

It is certain that these two practitioners, Morse and Page, of the two leading electrical technologies of the first half of the nineteenth century had much to do with shaping Joseph Henry's conception of technology. Harder to determine is how heavily personal factors and social status weighed in his beliefs. Confident as he was of his scientific role, he was still anxious for his reputation in the history of the motor and the telegraph. Even allowing for personal concerns, Henry outlined a theory of technology, including social factors, sufficient to justify his opposing positions on these two important inventions. His idea of a technology strictly dependent on scientific theory bespoke a somewhat parochial vision of a man dedicated to science. Electrical technology could and did advance in other ways, often by processes internal to the art itself. Yet, Henry's concomitant linking of technological progress to the demands of society showed a broader sophisticated understanding. His assessments of the futures of two particular technologies in terms of this theory provided an important perspective on the coming electrical age.

[37]Quoted in Edward L. Morse, *Samuel F. B. Morse: His Letters and Journals in Two Volumes*. Boston and New York: Houghton and Mifflin, 1914, pp. 56-57.

[38]Morse to Sidney Morse, January 12, [1859], Morse Papers, Library of Congress.

[39]See, for example, Morse to Kendall, January 21, 1859, Morse Papers, Library of Congress.

[40]R. C. Post, *Physics, Patents*, ch. 1. See also Post, "Stray, sparks from the induction coil: The volta prize and the page patent," this issue, pp. 1279-1286.