HENRY ADAMS, THE SECOND LAW OF THERMODYNAMICS, AND THE COURSE OF HISTORY

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In 1910 Henry Adams penned *A Letter to American Teachers of History* in which he outlined a theory of history based on the Second Law of Thermodynamics. In short, the Second Law predicts the constant and irreversible dissipation of energy culminating in the "Heat Death" of the universe. Adams argued that man could not escape the fate of the universe and offered the decay and disorder of modern civilization as evidence that the process was already well underway. Coming from the "doyen" of American historians whose brilliance had been so recently displayed in *The Education* and *Mont Saint-Michel and Chartres*, Adams's amateur scientific dalliances proved most disturbing. Neither his contemporaries nor subsequent generations of historians have been able to decipher Adams's cryptic message, although most are certain that anything emanating from Henry Adams must be profound, even if wrong-headed. The confusion can partially be attributed to Adams's passion for protecting the privacy of his innermost feelings and thoughts. Nowhere was this passion more evident than in his love of the paradox, which he often employed but never as effectively as in his application of the Second Law of Thermodynamics to history. It has been the failure of "American teachers of history," both past and present, to unravel the riddle of the Second Law that has led to the misinterpretation of Adams's mixing of science and history.

Although every other aspect of Adams's life has been the subject of numerous revisionist interpretations, his scientific thought received its definitive treatment in William Jordy's thorough and authoritative study, *Henry Adams: Scientific Historian*, published in 1952.[1] Jordy was highly critical of Adams's attempt to apply the laws of science to history, particularly the Second Law. Jordy mustered as much scientific evidence as possible to demonstrate that Adams's application of the Second Law to history was based upon distortion, simplification, and just plain ignorance of science and the scientific method. He argued that the Second Law did not necessarily predict the inexorable dissipation of heat and attributed Adams's attraction to the law to his "irrational" obsession with finding an "inclusive, determinate, absolutist and simple scheme for history. . . ."[2]

Adams himself lent credence to Jordy's charges when he admitted

[1] William Jordy, *Henry Adams: Scientific Historian* (New Haven, 1952).
[2] *Ibid.*, 218.

that his failure to "fix for a familiar moment, a necessary sequence of human movement"[3] in history led him to seek in science a unifying formula or principle, like Newton's laws of motion, that would enable him to plot the course of history as one would the path of a comet, an anology of which Adams was particularly fond. After all, historians naively "arrange sequences—called stories or histories—assuming in silence a relation of cause and effect."[4] His own *History of the United States* contained numerous allusions to the mechanical nature of historical processes and inferences that history was determined by the laws governing the motions of material bodies. If he had hoped to cloak those inferences with science's authority, as historians have assumed, he soon learned that scientists no longer claimed either certainty or universality for their laws. As Adams phrased it, "Suddenly, in 1900, science raised its head and denied."[5]

Adams's disappointment was clearly visible in *The Education*, which was a long lamentation over the failure of a lifetime of "education" spent in search of unity and order, whether through history or science. Jordy contrasted Adams's despair over his failure to achieve the "larger synthesis" he so passionately sought with the patience of contemporary scientists who were similarly frustrated by their failure to detect the luminferous ether and reduce light to the laws of Newtonian mechanics. Although they eventually failed to do so, they did not, Jordy contends, succumb to the crippling despair that paralyzed Adams in the face of the increasing complexity of the modern world.[6]

That Adams should turn to science was not in itself irrational. The intellectual history of the nineteenth century is replete with examples of historians, philosophers, theologians, and just plain cranks attempting to deduce the laws governing human behavior from the laws of nature. Nor was Adams's fascination with Newton's laws of motion necessarily unreasonable. Ever since Newton had shown the way by explaining the "System of the World" in mechanical terms, scientists had successfully reduced almost all natural phenomena to matter in motion. To be sure, light remained a vexing problem, but the fact that mechanical models had been extended to other non-observable phenomena such as electromagnetism afforded scientists the comfortable assurance that finding a mechanical description of light was only a matter of time.[7]

[3] *The Education of Henry Adams* (Washington, D.C., 1907), 334. All references in this paper are to the original, privately printed edition, with the author's manuscript annotations, in the Henry Adams Papers, Massachusetts Historical Society, Boston, Massachusetts.

[4] *Ibid.*

[5] *Ibid.*, 396.

[6] Jordy, *Henry Adams*, 239-40.

[7] Lawrence Badash, "The Completeness of Nineteenth Science," *Isis*, 63 (1972), 48-

That the fruitfulness of mechanical explanations had a profound impact on other disciplines was shown by the prevailing materialism in biology, the social sciences, religion, and history.[8] Thus, the connection Adams made between mechanics and history was not unusual, especially since scientists referred to mechanical explanations as the "historical method" for the obvious reason that it permitted the physicist to trace effects back to their causes.[9] While Newton would have rejected the determinism implicit in such reasoning, mechanics had been associated with determinism ever since the eighteenth century, when the French mathematician La Place observed that a scientist armed with the laws of mechanics and a knowledge of the position of all the material bodies in the universe could recreate the past and predict the future.[10] Little wonder that Adams might have been attracted by such a simple yet powerful tool that would enable him to bring both man and nature under one comprehensive theory.

Unfortunately, Adams's faith in science was not requited. As he explained in *The Education*,

> he insisted on a relation of sequence, and if he could not reach it by one method, he would try as many methods as science knew. Satisfied that the sequence of men led to nothing . . ., while the mere sequence of time was artificial, and the sequence of thought was chaos, he turned at last to the sequence of force; and thus it happened that, after ten years pursuit, he found himself lying in the Gallery of Machines in the Great Exposition of 1900, his historical neck broken by the irruption of force totally new.[11]

The forces to which he was referring were the rays emitted by radium recently discovered by the Curies. The fact that the radium atoms seemed to explode spontaneously without apparent cause suggested that randomness was operative at a fundamental level in nature. His search for a single, simple law governing the forces of history was dashed by the realization that the chaos that lay repressed just beneath the surface of society, waiting to erupt, was the stuff of which nature itself was made.

Adams labeled the rays "wicked," "anarchical," "parricidal," and "chaotic" for their willful disobedience of the laws of mechanics. Equally

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→ Martin J. Klein, "Mechanical Explanation at the End of the Nineteenth Century," *Centaurus*, 17 (1972-3), 58-82.

[8] For two excellent studies of the nineteenth century's fascination with the Second Law see Stephen G. Brush, "Thermodynamics and History," *The Graduate Journal*, 7 (1967), 477-565; a→ Erwin Hiebert, "The Uses and Abuses of Thermodynamics in Religion," *Daedalus*, 95 (1966), 1046-80.

→ P. M. Heimann, "Molecular Forces, Statistical Representation, and Maxwell's Demon," *Studies in the History and Philosophy of Science*, 1 (1970), 200.

→ Stephen G. Brush, "The Development of the Kinetic Theory of Gases. VIII. Randomness and Irreversibility," *Archive for the History of the Exact Sciences*, 12 (1974), 33.

[11] *Education*, 334.

disturbing was the fact that the rays "played no part in man's consciousness."[12] There were no corresponding observable phenomena to which they could be compared in formulating a mechanical model of their behavior. Instead of a universe composed of sensible masses moving in paths determined by known laws, Adams had entered a world of infinitesimally small particles travelling at fantastically high speeds and encountering one another in chance collisions which could only be described in statistical or probabilistic terms. "In plain words, Chaos was the law of nature; Order was the dream of man."[13]

According to Jordy, it was at this point that Adams turned to the Second Law of Thermodynamics to explain the chaos he encountered in both nature and society.[14] Entropy, or the irreversible dissipation of energy predicted by the Second Law, seemed to offer the only explanation of the decay and disorder so painfully visible in the modern world. While he had attempted to measure that decline from the twelfth to the nineteenth centuries with the two volumes *Mont-Saint-Michel and Chartres* and *The Education*, he portrayed it most poignantly in his *Letter* to his fellow historians.[15]

In that essay Adams cited mounting evidence of man's decline in the form of increasing rates of suicide, insanity, alcohol and drug abuse, and other aberrations that belied the prevailing faith in the infinite and uniform upward evolution of mankind. Even more disturbing was the continuing "enfeeblement" of man's mental powers as reflected in the deterioration of his noblest instincts—religion, law, manners, morality, and art. Man had succeeded in stemming temporarily the tide by capturing and putting nature's forces to work, but those forces, like his mental powers, were also subject to the dissipative tendencies of the Second Law. As more and more energy was expended in a furious attempt to avoid the inevitable, the dissipation of energies, both mental and physical, would accelerate until a deadening, faceless equilibrium was reached among men and molecules alike.

The shrillness of Adams's warnings certainly support Jordy's contention that Adams's attraction to the Second Law was "irrational." Although a few historians have suggested that Adams was only attempting to stand modern science on its head by carrying its mechanical determinism to its logical, if absurd, extreme, most have accepted Jordy's premise.[16] For example, George Hochfield treated the *Letter* as the cul-

[12] *Ibid.*, 333.

[13] *Ibid.*, 395.

[14] Jordy, *Henry Adams*, 137.

[15] Henry Adams, *A Letter to American Teachers of History* (Baltimore, 1910).

[16] See especially Howard M. Munford, "Henry Adams and the Tendency of History," *New England Quarterly*, 26 (1959), 79-90. Nevertheless, Adams's major biographers have uncritically accepted Jordy's contention that Adams seriously intended to apply physical laws to history, even though they all recognize the paradoxes inherent in Adams's scientific

mination of the quest for unity that Adams had initiated twenty years earlier with his presidential address to the American Historical Association in 1894 entitled "The Tendency of History." As Hochfield concluded, "Having failed to establish unity within the limits of his own experience or within the range of his practical ideas, Adams turned to science as a way of fixing a meaning for all of history and hence, by indirection, for his own apparently pointless life."[17] If Hochfield and the others are right, then Adams had selected the wrong vehicle to convey his message, for the Second Law was neither mechanical nor deterministic. In fact its paradoxical nature had proven so baffling to scientists that it had become the center of controversy among physicists at the very time Adams began his flirtation with science. On the other hand it just may have been the Second Law's paradoxical nature that appealed to Adams as the perfect riddle with which to confound his colleagues. Before that possibility can be explored, a reassessment of the Second Law and its relationship to developments in modern physics is necessary.

The Second Law was given its first, albeit incomplete, expression, by the French engineer Sadi Carnot in 1827. Carnot was concerned with improving the efficiency of steam engines, but he laid the foundation for the formulation of the Second Law by establishing that heat always flowed spontaneously and irreversibly from hotter to colder bodies, resulting in the irretrievable loss of heat available for work.[18] The fact that, once lost, the heat was not recoverable, was a matter of great concern to nineteenth century engineers, who plumed themselves on the increasing efficiency and power of their machines. It is easy to see how they could label this natural tendency of heat "dissipation" or "degradation," and associate it with "disorder." Not only did the irreversibility of heat flow limit the efficiency of their machines, it was essentially uncontrollable and, more importantly, defied the laws of Newtonian mechanics.[19]

Newton's laws of motion are reversible; that is, any sequence of actions is the same whether it is run forward or in reverse, much like reversing a film of the collision between two billiard balls. However, if heat flows from a hotter to a colder body until state of equilibrium is reached, nothing can return the heat to its original form. Thus, the loss of heat or "mechanical effect" through such processes as conduction posed a challenge not only to technology but to the very foundation of classical physics.

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approach to history. See, for example, Ernest Samuels, *Henry Adams: The Major Phase* (Cambridge, Mass., 1964), 474-96; Elizabeth Stevenson, *Henry Adams, A Biography* (New York, 1955), 356-60; R. P. Blackmur, *Henry Adams* (New York, 1980), 263-77.

[17] George Hochfield, *Henry Adams: An Introduction and Interpretation* (New York, 1962), 131-32.

Martin J. Klein, "Carnot's Contribution to Thermodynamics," *Physics Today*, 27 (1974), 22-28.

[19] Brush, "Randomness and Irreversibility," 6.

This was particularly vexing to nineteenth-century physicists who hoped to find a mechanical explanation of heat. The difficulty could be partially overcome by assuming that heat was a form of energy which was transferred through the motions of a body's constituent parts, that is, its molecules. Although the molecular nature of matter was not yet established, that heat was a measure of a substance's molecular motions raised the possibility of a mechanical explanation of heat.[20] The only stumbling block was the irreversibility of heat flow, a problem that led to the introduction of one of the most imaginative analogies in modern physics by the British physicist James Clerk Maxwell in the form of his nimble fingered "demon."

Maxwell was brought to thermodynamics by his work on the kinetic theory of gases. In 1860 Maxwell advanced his theory that the molecular velocities of a gas were not uniform but were randomly distributed along a normal or bell shaped curve. Maxwell was influenced by probability theory, which had become quite popular in the nineteenth century in the analysis of birth, death, suicide, and crime and divorce rates.[21] Indeed, the analogy between social statistics and Maxwell's distribution theorem is illuminating. Although individual murders or deaths were random phenomena, the average number of such events displayed a remarkable stability over time. Similarly, the average molecular velocity of a gas conceals the fact that there are molecules with velocities significantly faster or slower than the average. In other words the behavior of individual molecules cannot be extrapolated from the behavior of gases treated in mass.[22]

Maxwell guessed that the random distribution of molecular velocities might explain the irreversibility of the Second Law. To demonstrate his point, Maxwell conjured his famous "demon" and stationed it at an aperture between two gases with different kinetic energies or temperatures. The demon is instructed to allow to pass from the hotter to the colder gas only those molecules that have a lower velocity than the average velocity of the molecules in the colder gas. Conversely, he will allow only those molecules to pass from the colder to the hotter gas which have velocities higher than the average velocity of the molecules in the hotter gas. In this way the average molecular velocity or temperature of the hotter gas will increase at the expense of the colder gas. More precisely, heat will have flowed from a colder to a hotter body in violation of the Second Law.[23]

[20] Crosbie Smith, "A New Chart for British Natural Philosophy: The Development of Energy Physics in the Nineteenth Century," *History of Science*, 16 (1978), 234-41.

[21] Ian Hacking, "Nineteenth Century Cracks in the Concept of Determinism," *Journal of the History of Ideas*, 45 (1983), 455-75.

[22] Heimann, "Molecular Forces," 201.

[23] Martin J. Klein, "Maxwell, His Demon, and the Second Law of Thermodynamics," *American Scientist*, 58 (1970), 84-97.

Maxwell's purpose was to demonstrate that on a molecular level, violations of the Second Law could take place. Although such violations were statistically unlikely, they were possible since there was nothing to prevent the process he described even without the assistance of a demon. Thus the Second Law had only a statistical rather than an absolute certainty. The significance of this conclusion becomes more apparent if the analogy is carried one step further and, once the demon has completed his task, the partition is removed. The result would be the reestablishment of an equilibrium with a kinetic energy or temperature equal to the average kinetic energies of the two gases before the mixing. The establishment of a new equilibrium through the mixing of the two gases is the fundamental irreversible process described by the Second Law. The process cannot be reversed except in highly improbable situations such as the appearance of a "demon" with the ability to determine the paths and velocities of an enormous number of molecules.[24]

In the absence of such assistance, the molecules would spontaneously move from a more ordered state, with most fast molecules in one area and most slow ones in another, to a more disordered state with a normal distribution of molecular velocities. More importantly, the inability of mere mortals to determine the direction and velocity of molecules makes it impossible to apply the laws of mechanics on a molecular level except in a statistical or probabilistic sense, since those values are necessary for any mechanical description. Thus, it appeared not only that molecules possessed some natural tendency toward disorder but that tendency suggested that there was something essentially non-mechanical (read "indeterminate") about their behavior.[25]

It should be noted that Maxwell did not intend to suggest that molecular motions were random. He did not believe that chance was involved at a microscopic level despite the usefulness of statistical methods in kinetic theory and now thermodynamics. Rather, statistical methods were made necessary by our ignorance of molecular behavior. Indeed, some form of determinism was necessary if his demon was able to "determine" the directions and velocities of molecules in order to sort them.[26] Nevertheless, the very fact that he had to conjure a "demon" to reverse the irreversible suggested that the laws of "rational" mechanics which governed the motions of visible bodies did not apply at a microscopic level. The laws of mechanics permitted the reversal of molecular motions, but they could not explain the low probability of such an event. The motions of molecules could not be reversed as simply as one might reverse the collision of two billiard balls. Molecules, both before and after such

[24] Heimann, "Molecular Forces," 204; Brush, "Irreversibility and Indeterminism," 614; and "Randomness and Irreversibility," 41.

[25] Brush, "Randomness and Irreversibility," 57-67.

[26] Brush, "Irreversibility and Indeterminism," 614.

collisions, appeared to act capriciously, making it difficult for Maxwell and others to avoid applying such adjectives as "irregular" to molecular motions.[27]

Indeed, by the 1890's the German physicist Ludwig von Boltzmann, then the chief and nearly sole defender of a mechanical description of the Second Law, conceded that irreversibility could only be explained by positing a state of molecular "disorder" or "chaos." In mass, molecules tended irreversibly toward a state of disorder, but that macroscopic tendency was a function of the "unwillingness" of molecules to return to their initial states except in extremely rare cases. The possibility of molecules moving from a disordered to an ordered state, or heat being transferred from a colder to a hotter body, was subtly transformed from an anomalous fluctuation in an otherwise determined system to merely another chance occurrence amidst an infinite number of random or indeterminate events. In other words irreversibility raised the paradoxical possibility that processes such as entropy that appeared to be mechanically determined were, at bottom, functions of random events.[28]

Thus, at the very time that Adams supposedly turned to the Second Law for its mechanical determinism, the paradoxical nature of irreversibility was forcing scientists to introduce, however grudgingly, hitherto unacceptable concepts such as randomness and indeterminacy. Although Adams's scientific knowledge has been considered amateurish at best, his readings were extensive and quite sophisticated, especially in the area of physical chemistry and energy physics, the two areas in which irreversibility posed the greatest challenge to extending the mechanical world view. Consequently, he could not have been unaware of the controversies swirling about the Second Law.

It is well known that Adams was introduced to these issues through the writings of the American physical chemist Willard Gibbs. It was Gibbs's "phase rule" that Adams first attempted to apply to history in his "The Rule of Phase Applied to History" written in 1909.[29] However, it has escaped the notice of Adams's biographers that Gibbs played a pivotal role in the application of statistical methods to thermodynamics.[30] Moreover, Adams was perceptively aware that the adoption of statistical

[27] James Clerk Maxwell, "On the Dynamical Evidence of the Molecular Constitution of Bodies," *The Scientific Papers of James Clerk Maxwell*, ed. W. D. Niven (New York, 1965), 41.

[28] Brush, "Irreversibility and Indeterminism," 615-18; "Randomness and Irreversibility," 57-71.

[29] Adams, "The Rule of Phase Applied to History," in *The Degradation of the Democratic Dogma* (New York, 1920), 267-311.

[30] Martin J. Klein, "Josiah Willard Gibbs," in *Dictionary of Scientific Biography*, ed. Charles C. Gillispie (New York, 1972), 5: 386- Elizabeth W. Gardner, "James Clerk Maxwell," *American Journal of Physics*, 37 (1969), 146-55.

methods undermined the certainty of any theory of history or science.[31] Adams also read *L'Energie* by the German physical chemist Wilhelm Ostwald, the leader of the "energeticists" whose attacks on classical mechanics for its failure to accommodate irreversibility virtually ostracized Boltzmann from the German scientific community.[32] So vituperative were the attacks that they alledgedly led to Boltzmann's suicide in 1906, a clear measure of the seriousness of the debates raging over thermodynamics at the time of Adams's interest in the theory. Adams's library also contained well annotated copies of the British physicist Alexander Findlay's *The Phase Rule and Its Applications* and the Scottish physicist Balfour Stewart's *La Conservation de L'Energie*, both of which discussed the problems of describing energy in mechanical terms.[33] But in truth all of Adams's scientific readings at that time contained discussions of the obstacles to extending the mechanical world view to a variety of phenomena, including entropy.[34]

Of particular importance in this regard was Henri Poincaré's *La Science et l'hypothèse* and Lucien Poincaré's *La Physique moderne*. Both volumes contain discussions of the problems posed by irreversible phenomena. Indeed, irreversible phenomena were of such concern that Henri Poincaré considered them "beaucoup plus rebelles" than light, a passage which Adams underlined.[35] Poincaré himself was embroiled in the controversy over the Second Law and attempted to demonstrate that entropy could be reversed.[36] Adams also highlighted a passage from Lucien Poincaré's volume which noted that irreversibility was a function of the laws of probability and so was distinguished from the absolute certainty accorded the laws of classical mechanics.[37] Both books contained discussions of other examples of the "mouvements irreguliers" of "materière subtile," such as the kinetic theory of gases, Brownian motion, and the discontinuous nature of radioactivity that required statistical rather than

[31] *Education*, 351-52, 447, 451, 501.

[32] Adams's library in the Massachusetts Historical Society contains only Ostwald's *Vorlesungen über Naturphilosophie gehalten im Sommer 1901 an der Universität Leipzig* (Leipzig, 1902). However, he made frequent reference to Ostwald's *L'Enérgie* in the *Letter*.

[33] Findlay, *The Phase Rule and Its Applications: An Introduction to the Study of Physical Chemistry* (London, 1906); Stewart, *La Conservation de l'énergie* (Paris, 1899).

[34] Of greatest significance was Ernst Mach's *Science of Mechanics*, with its criticism of classical mechanics, which had a profound effect on an entire generation of physicists, including the young Einstein. Although his library does not contain a copy, Adams's notes from it are contained in an undated notebook in the Henry Adams Papers in the Massachusetts Historical Society. To this should also be added John B. Stallo's *La Matière et la physique moderne* (Paris, 1899), an annotated copy of which is contained in Adams's personal library in the Massachusetts Historical Society.

[35] H. Poincaré, *La Science et l'hypothèse* (Paris, 1902), 207.

[36] Brush, "Randomness and Irreversibility," 67-77.

[37] L. Poincaré, *La Physique moderne* (Paris, 1906), 84.

purely mechanical explanations.[38] And both authors vainly struggled to explain how such apparently random phenomena were actually mechanically determined.

As we have seen, the kinetic theory was directly related to the controversy over irreversibility, as was Brownian motion, while Max Planck's quantum theory of radiation grew out of concern over the failure to find a mechanical explanation for irreversibility.[39] All three suggested a fundamental randomness to nature. Adams made frequent reference in his correspondence and writings to the kinetic theory, to Brownian motion, and to radiation as examples of the failure of classical mechanics. He even referred to Maxwell's demon and recommended it for the presidency, presumably for its ability to sort order out of chaos.[40] Clearly, Adams was aware of the problems that irreversible phenomena and the indeterminate behavior of molecules created for classical mechanics when he challenged his fellow historians to escape the dire predictions of the Second Law.

Indeed, Adams began his *Letter* with the observation that the three-hundred-year ascendancy of the "mechanical theory of the universe" had ended with Kelvin's and Clausius's announcement that the universe was running down.[41] Adams was also careful to inform his readers that the dissipation of energy was not a simple linear process, for "Energy had a way of coming and going in phases of intensity much more mysterious than the energy itself."[42] According to Adams, these "phases" consisted of "contractions" or concentrations of energy against its natural tendency toward equilibrium or disorder, followed by explosions or "catastrophes" that returned the system to a state of equilibrium.[43]

Adams clearly was describing the process effected by Maxwell's demon. In reality, however, the whole process was dependent upon the random behavior of individual molecules, which meant that the stability of any equilibrium was always tenuous and subject to those explosions, leaps, or catastrophes that fascinated Adams. The random behavior of individual molecules could be attributed to "hidden variables" or disguised by treating them in the average. But Adams, like many scientists of that time, including Planck and Einstein, chose not to dismiss them so easily. Instead, he focused on the "catastrophes" of nature and history to challenge the naive faith of his fellow historians in the uniform, upward progression of mankind.

[38] H. Poincaré, *Science et l'hypothèse*, 176.

[39] Brush, "Irreversibility and Indeterminism," 618-; Martin J. Klein, "Thermodynamics and Quanta in Planck's Work," *Physics Today*, 19 (1966), 23-32.

[40] Adams to Brooks Adams, 2 May 1903, *Henry Adams and His Friends*, ed. Harold Dean Cater (Boston, 1947), 545.

[41] *Letter*, 1-2.

[42] *Ibid.*, 14-5.

[43] *Ibid.*, 127.

In the *Letter*, he offered numerous examples of deviate behavior—suicides, insanity, murders, idiocy—all purely random events which could not be explained by any mechanical social theory, pessimistic or optimistic, without taking into account the underlying "heterogeneity" of history. He cited other discontinuities—geological catastrophes, evolutionary mutations, the extinction of species and stars—to counter uniformitarian theories that ignored the discontinuities which produced historical changes. Aside from their irreversibility, these examples had no apparent relationship to the Second Law. That is, they were discontinuous events which produced radically altered states and could not be reversed. To do so would require the exact reversal of the whole train of preceding causes, a situation as improbable as the intervention of Maxwell's demon.

Adams's most telling example was Dollo's law, which amounted to an application of probability theory to evolution. The French biologist Louis Dollo postulated that evolution was irreversible since evolutionary development was a function of discontinuous mutations which were not likely to recur in an order precisely inverse to that in which they originally appeared.[44] Dollo's Law was the biological analogue of the Second Law, for both evolution and entropy were functions of discontinuities with extremely low probabilities of recurrence. History could also be viewed as a function of singular, discontinuous, non-recurring events which could not be subsumed into any deterministic mechanical theories. Just as the apparent determinism of the Second Law dissolved, under closer scrutiny, into the randomness of individual molecules, so the "necessary sequences" that historians tried to establish were like Zeno's arrow, "continuous from the beginning, of time, but discontinuous at each successive point."[45]

These discontinuities were certainly perplexing to scientists and historians alike, but they helped Adams explain

> . . . much that had been most obscure, especially the persistently fiendish treatment of man by man; the perpetual effort of society to establish law, and the perpetual revolt of society against the law it had established; the perpetual building up of authority by force, and the perpetual appeal to force to overthrow it; the perpetual symbolism of a higher law, and the perpetual relapse to a lower one; the perpetual victory of the principles of freedom and their perpetual conversion into the principles of power. . . . The physicists had a phrase for it, unintelligible to the vulgar: "All that we win is a battle,—lost in advance,—with the irreversible phenomena in the background of nature."[46]

In sum, irreversible phenomena based on random events, whether the

[44] Stephen Jay Gould, "Dollo on Dollo's Law: Irreversibility and the Status of Evolutionary Laws," *Journal of the History of Biology*, 3 (1970), 189-212.

[45] *Education*, 400.

[46] *Ibid.*, 401.

"anarchist's bomb" or the "metaphysical bomb of radium," were the forces that determined the course of time which history eventually chronicled. Without them the universe would settle into a stable equilibrium. But, as Adams warned, "if one physical law exists more absolute than another, it is the law that stable equilibrium is death. A society in stable equilibrium is . . . one that has no history and wants no historians."[47]

History was not a record of civilization's unbroken upward progression but a series of futile attempts to concentrate "mankind into a single dense mass like the sun" in order to increase the energy or force at society's disposal.[48] They were futile since irreversibility required that any attempt to concentrate energy against its will would at best be only a temporary reversal, much like that effected by Maxwell's demon, and would not prevent the ultimate reversion of energy to its natural state of disorder. As Adams warned, "order was an accidental relation obnoxious to nature; artificial compulsion imposed on motion; against which every free energy of the universe revolted. . . ."[49] Hence, the "explosions" and "contractions" of history were the inevitable and irreversible result of the rebellion of "individual forces" against the centralizing forces of society.[50]

The irony of this predicament Adams had originally discussed in *The Education*. Increasing a society's forces required the expenditure of an enormous amount of energy that quickly became unavailable for work according to the requirements of the Second Law. Thus progress, if it was to be achieved and measured by the amount of energy at a society's disposal, was an illusion, and history was the unfortunate tale of man's pursuit of that illusion. From the very beginning, man had sought to impose order on his environment by expanding the arsenal of forces at his disposal, whether it was a bow, gunpowder, steam, electricity, or the Cross. The first victim had been the Roman Empire:

> The economic needs of a violently centralising society forced the empire to enlarge the slave system to enlarge its slave system until the slave system consumed itself and the empire too, leaving society no resource but further enlargement of its religious system to compensate for the losses and horrors of the failure.[51]

The pursuit of force inevitably resulted in the irrecoverable waste of human "energy," whether in the form of Roman slaves or defenders of the Cross or the millions more that Adams feared would soon be sacrificed

[47] *Letter*, 186.
[48] *Ibid*., 127.
[49] *Education*, 401.
[50] *Letter*, 127.
[51] *Education*, 419.

in Europe to secure a supply of coal for the dynamos, like the sacrifices offered to the gods by pagan priests.

Nevertheless, man blindly continued the pursuit, perhaps in the name of a higher law, larger synthesis, or simply progress, but always under the vain mechanical illusion that the motions of masses, molecular or human, could be determined much as Maxwell's demon reversed the molecular tendency toward disorder.

> What was far more serious, he had seen the number of minds, engaged in pursuing force.—the true measure of its attraction,—increase from a few scores or hundreds, in 1838, to many thousands in 1905, while they chased nature into hiding-places where nature had never known it to be, making analyses that contradicted being, and syntheses that endangered the elements. No one could say that the social mind now failed to respond to new force, even when the new force annoyed it horribly. Everyday nature violently revolted, causing so-called accidents with enormous destruction of property and life, while plainly laughing at man who helplessly groaned and shrieked and shuddered, but never for a single instance could stop.[52]

Man had sacrificed his freedom to science as he became increasingly dependent upon forces beyond his control. The tragedy had been compounded with the appearance of an "avalanche" of new forces in 1900, before which "the man of science stood . . . as bewildered and helpless, as in the fourth century, a priest of Isis before the Cross of Christ."[53] Regardless of how much force man amassed, he could no more determine the course of history than he could the direction of molecules.

In seizing upon the Second Law, Adams attempted to expose the fallacy of the determinism and materialism which dominated the nineteenth century and which Adams had captured in his powerful image of the Dynamo. The Second Law had proven something of an embarrassment to scientists who prided themselves on their ability to reduce all of nature to matter in motion governed by the laws of rational mechanics. The irrational elements in either nature or history could no longer be ignored or buried under an "ocean of statistics."[54] Indeed, it was the attention that scientists paid to the indeterminate behavior of an increasing number of natural phenomena that led to such major developments in modern physics as quantum mechanics, with its indeterminacy principle. Similarly, Adams looked to singular historical events to demonstrate that there was no necessary or predetermined direction to history. One such episode was the Gothic "explosion" of the twelfth century which produced the cathedrals devoted to the Virgin, the antithesis of the nineteenth century's Dynamo.

To Adams, both the Virgin and the Dynamo symbolized the mys-

[52] *Ibid.*, 431-32.
[53] *Ibid.*, 425.
[54] *Letter*, 188.

terious forces that had "dragged," "wrenched," and "coerced" man throughout history. The ability of the dynamo to create electricity from steam and coal was no less mysterious than the power of reproduction symbolized by the Virgin. However, her fecundity was not only responsible for the underlying continuity between successive generations, it was also the wellspring of mankind's wonderful diversity and consequent resistance to order and uniformity. Thus, she symbolized both unity and multiplicity, order and anarchy, the basic antinomies of history; and there was no doubt in Adams's mind that her sympathies lay with man's constant rebellion against the laws of science, society, or religion. As Adams wrote in *Mont-Saint-Michel and Chartres*:

> Man concentrated in herself the whole rebellion of man against fate; the whole protest against divine law; the contempt for human law as its outcome; the whole unutterable fury of human nature beating itself against the walls of its prison house, and suddenly seized by the hope that in the Virgin man had found a door to escape. The convulsive hold which Mary to this day maintains over human imagination was due . . . to her sympathy with people who suffered under law—divine or human. . . . She cared not a straw for conventional morality, and she had no intention of letting her friends be punished . . . for the sins of their ancestors or the peccadilloes of Eve.[55]

In return, man responded with thousands of cathedrals and chapels dedicated to the Virgin. Her compassion had liberated man's imagination, a freedom, expressed in Gothic architecture, which "knew no mathematical formula of precision."[56] This was a far cry from Francis Bacon's pronouncement that "The imagination must be given not wings but weights," which, Adams contended, had led to man's slavish worship of the machine.[57] But, "All the steam in the world could not, like the Virgin, build Chartres."[58]

The Gothic outburst of the twelfth century was one of those spontaneous, irreversible events that, like all irreversible phenomena, defied simple cause and effect, mechanical explanations. More importantly, the fact that this "explosion" created "four-fifths" of man's "noblest art" suggested that creativity itself was an act of rebellion. If so, then the twelfth century's devotion to the Virgin certainly stood in poignant contrast to his own century's worship of the Dynamo.

The capture and control of nature's forces, symbolized by the Dynamo, necessarily required the capture and control of man's own creative energies. According to the Second Law, there could be no uncompensated increase of energy. In other words increasing the force at society's disposal could only be achieved at the "cost of the intensity of individual forces."

[55] Adams, *Mont-Saint-Michel and Chartres* (Cambridge, Mass., 1927), 276-77.

[56] *Ibid.*, 353-54.

[57] *Education*, 423.

[58] *Ibid.*, 339.

As Adams explained, "The individual, like the crystal of salt, is absorbed in the solution, but the solution does the work which the individual could not do."[59] However, the Second Law also required that any concentration of energy against its will could only be temporary and that, once those individual energies were expended, they could never be recovered.

The choice confronting modern civilization was "the same old dilemma of Saint Augustine and Descartes—the deadlock of free-will."[60] The individual's energies could either be expended freely and creatively as in the twelfth century or sacrificed in society's quixotic and potentially destructive crusades, such as the one he predicted would soon engulf Europe in war. Adams did not intend to sit idly by and watch the wanton waste of human energy. As he explained shortly after writing the *Letter*, "My idea is that the world outside—the so-called modern world—can only pervert and degrade the conceptions of the primitive instinct of art and feeling, and that our only chance is to accept the limited number—the one-in-a-thousand born artists and poets—and to intensify the energy of feeling within that radiant center."[61] In a sense Adams seemed to be trying to reverse the irreversible. And why not? Progress was the result of man's willful disobedience of the laws of nature and society. It was through acts of sheer will that man was able to transform "himself from a hypothetical eocene lemur . . . into a man speaking an elaborately inflected language."[62] Free will was the source of those "variations" or leaps upon which both evolution or history depended. On the other hand, " 'Thou shalt not' is the beginning of law."[63]

Unfortunately, Adams's weapons in this battle were limited to his pen. He wrote the *Letter* as an appeal to the "classical historian, with his intuition of free-will and art," in hopes of attracting him into the lists against the "socialist frame of mind which we are already floundering in. . . ."[64] Adams deplored the tendency of modern society, whether socialism or corporate capitalism, toward a suffocating uniformity. He worried aloud in the *Letter* that the "social organism, in the recent views of history, is the cause, creator and end of the Man, who exists only as a passing representative of it, without rights or functions except what it imposes. As an organism, society has always been peculiarly subject to the degradation of energy."[65] The role of the historian in this struggle was to teach that history was not "a force resulting in motion which

[59] *Letter*, 123.

[60] *Ibid.*, 160.

[61] Adams to Albert Stanborough Cook, 6 August 1910, *Letters of Henry Adams (1892-1918)*, ed. Worthington Chauncey Ford (Boston, 1930), 546-47.

[62] *Letter*, 94-95.

[63] *Ibid.*, 123.

[64] Adams to Charles Milnes Gaskill, 14 March 1910, *Letters (1892-1918)*, 537.

[65] *Letter*, 260.

cannot be other than what it is."[66] Any presumption of necessity to the course of history only strengthened the forces of "collectivism" at the expense of those pockets of resistance to society's increasing demands for uniformity.

If there was a certain stridency to Adams's appeal to his colleagues, it was because they seemed ready and even willing to acquiesce in the stifling conformity required by modern society. Indeed, it was only to elicit some response, some sign of "energy" or "motion" among his fellow historians, that he "kicked" them "in the stomach as violently and insultingly" as he could with the Second Law.[67] He explained to James Franklin Jameson, to whom he had forwarded the "Letter" for distribution, that "they would prove me wrong if they were to show any reaction to me."[68] He begged to be "annihilated by a competent hand" but never to be taken seriously.[69] He always referred to his science as "illustrative," a "jigsaw puzzle," or simply a "joke." Even in his 1894 presidential address to the American Historical Association, when he first alerted his colleagues of the dangers of emulating science too closely, he offered his observations "in the paradoxical spirit of casual conversation."[70] Unfortunately, Adams's joke failed; his colleagues never did resolve the paradox of the Second Law, which was also the paradox of history. But to have expected otherwise would have required historians to teach that time, whether measured by entropy or history, was not a "necessary sequence of cause and effect" but a series of indeterminate and irrepressible "explosions."

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[66] Adams, "The Tendency of History," in *Degradation*, 129.
[67] Adams, to Charles Milnes Gaskill, 2 August 1910, *Letters (1892-1910)*, 546.
[68] Adams to James Franklin Jameson, 3 April 1910, *Adams and his Friends*, 680.
[69] *Ibid.*, 646-47.
[70] Adams, "Tendency," 133.