

Philosophy and Science: the Positive Physics of Auguste Comte

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요 약

이 논문은 프랑스철학자 오귀스트 콩트의 철학프로그램 실증주의와 19세기초의 프랑스 과학 및 과학공동체의 관계를 찾아 보려 한다. 그러기 위해 우선 콩트의 「실증주의철학과정」에 있는 물리학의 설명을 자세히 검토한다. 거기서 콩트가 물리학사 자체에서 실증주의에 의해 요구되는 과학이론의 철학적 속성들 — 효용, 반형이상학성, 예측성, 검증가능성, 수학적 — 을 얼마나 발견하는가를 분석한다. 둘 사이의 강한 상관성을 입증한 다음, 이 밀접한 상관관계에 기여했음지도 모르는 많은 요인들을 제안한다. 이 요인들에는 콩트의 사회과학을 창조하려는 관심, 프랑스 과학공동체에서 그 자신의 위치를 확립하려는 바람, 과학의 본질을 그가 실제로 지각하는대로 정확하게 반영하겠다는 관심, 그리고 그의 자연에 대한 수학적·공학적 접근 훈련이 포함되어 있다. 이 논문은 콩트의 철학프로그램의 많은 성격이 당시의 프랑스 과학공동체와의 가까운 개인적 관련에서 왔을지도 모른다는 것을 결론으로 주장한다.

The early philosophical works and career of Auguste Comte¹⁾ were situated within an extraordinary period of scientific creativity, the efflorescence of French science in the late eighteenth and early nineteenth centuries. Comte's background, career designs, and philosophical predilections all encouraged his strong interest in contemporary scientific developments and his own identification with the French scientific community. Nevertheless, the influences of that community on Comte have received scant attention from historians of science or, in recent years, from historians of any branch of learning.²⁾ Few attempts have been made to analyze

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1) See Appendix I for a short chronology of Comte's life.

2) Two important exceptions to this generalization are Henri Gouhier, *La Jeunesse d'Auguste Comte*, vols. 1-3, Paris: Librairie philosophique, 1933-1941, and Larry Laudan, "Toward a Reassessment of Comte's *Méthode Positive*," *Philosophy of Science*, (1977) 38 : 35-53.

the connections between Comte's ruminations on science and his own affiliations with the French scientific community.³⁾

In this paper I will attempt to rectify that omission and to use Comte's work on physics as a tool for increasing our understanding of his philosophical program. My purposes in examining Comte's thoughts on physics are twofold: to explore the insights that they provide into the nature of his philosophical program, and to discover some of the scientific influences that helped to shape that program. To accomplish these tasks, I will first describe Comte's conceptions of positive physics and positive science and the ways in which he connected them to the physics of his day. I will then analyze the influences of his connections with the French scientific community on the particular character that his philosophical program came to exhibit.⁴⁾

Comte was both a philosopher and an historian. Positivism, his philosophical system, like many developed during the early nineteenth century, was rooted in this association. Sharing with them a common belief that philosophy was immanent in history, positivism looked to the history of science in order to discover philosophy, and to the philosophy of science in order to understand history.⁵⁾ Like other nineteenth century philosophical systems, positivism included as well a strong emphasis on progress; positivism was both the philosophical encapsulation of a process of progressive development visible in each of the sciences, and the end toward which all sciences were progressing. Thus Comte's philosophical system, in its most general tendencies, had much in common with other contemporary philosophical schemes. Its novelty lay, rather, in the particularities of its focus. Science, more especially Comte's own conception of science, lay at the heart of his philosophy. Using this conception, which drew heavily on his perceptions of the contemporary French scientific community, Comte molded the general ideas that were "in the air" during this period into a highly original philosophical system. In the process, he also wove within positivism a partial portrait of a scientific community at a particular moment in its history. By dissecting Comte's conception of "positivity", therefore, we can learn something about how French science appeared to the knowledgeable outsider in the early nineteenth century.

What was positivity for Comte? In its most general sense positivity meant "utility," though

3) One of the few such examples is Barbara Haines, "The Inter-relations between Social, Biological, and Medical Thought, 1750-1850: Saint-Simon and Comte," *British Journal for the History of Science*, (1978) 11: 19-35.

4) In focusing on French physics, I have of necessity emphasized Comte's early writings (pre-1842), as Comte's only significant works on the character of the sciences were restricted to that period. Comte's investigations into the nature of science culminated with the publication of the six-volume *Cours de Philosophie Positive* between 1830 and 1842. The second half of volume two of the *Cours*, published in 1835, comprises Comte's most comprehensive statement on the nature of physics, and forms, consequently, the core text on which this paper has drawn. The date of publication of this volume as well as other internal evidence indicate that the picture that Comte presents is of physics as it appeared to him in the late 1820s to early 1830s, and this has consequently been taken as the period to which his insights are germane.

5) As Comte himself declared at the very beginning of the *Cours*, "no conception whatsoever can be well understood except through its history." *Cours*, vol. 1, p. 2.

utility of a very special kind. Rejecting the notion that science involved the accretion of knowledge merely for its own sake, Comte argued, instead, that it was a form of production, comparable to industry or manufacturing.⁶⁾ Like those more explicitly practical endeavors, the purpose of science, in his eyes, was to produce a product, in this case the creation of an ordered and harmonious relationship with nature. "One has to conceive of the study of nature," Comte declared, "as destined to furnish the true rational base for the action of man on nature."⁷⁾ Comte applied this standard to every theory and investigation; none could be considered truly scientific, he insisted, unless it possessed some demonstrable utility, contributing in some way to harmonizing man and nature.⁸⁾ The remainder of his account of positivity was devoted in essence to explaining how such harmony could be achieved. He attempted to elucidate the philosophical characteristics necessary to a theory in order that it be utilitarian and to discover in history examples that contained all such characteristics and were as well explicitly utilitarian. In the realm of physics, the thrust of Comte's analysis indicates that he considered four characteristics as essential to producing this harmony, and one theory to have unquestionably and most dramatically instantiated them.

The first and most general of these four characteristics was anti-metaphysicality, the rejection of any entity or explanation whose existence could not be independently verified by observation or experimentation. Comte's concerns in this regard were both ontological and epistemological. On the one hand, he railed against the introduction of metaphysical entities, such as "ineffable ethers" or "imaginary fluids", into the realm of physics. "what can be the scientific utility of these fantastic conceptions concerning fluids and imaginary ethers," Comte queried, "which still play so great a role, and to which are related the phenomena of heat, of light, of electricity and of magnetism?"⁹⁾ On the other hand, Comte saw these entities as mere instances of a much more pernicious resort to metaphysics, the search for causes. "Our real studies," he declared while describing the ideal scientific program of investigation, "are strictly circumscribed to the analysis of phenomena in order to discover their effective *laws*, that is to say their constant relations of succession or similitude, and can never consider their intimate natures, neither their *cause*, either first or final, nor their essential mode of production."¹⁰⁾

Comte's forceful denunciation of metaphysics corresponded to his perceptions of history. In terms of his general philosophical program, Comte viewed the transition from the metaphysical to the positivist stage of thought in the development of human ideas as crucial to the production of true knowledge.¹¹⁾ He argued that before the pioneering efforts of Bacon, Descartes, and Galileo¹²⁾ humanity was mired in the vague ideas and fantastic creations of

6) *Écrits de Jeunesse 1816-1828*, Paris: Archives Positivistes, 1970, pp. 56-57.

7) *Cours*, vol. 1, p. 51.

8) "I have a sovereign aversion toward scientific work of which I do not perceive the utility, either directly or distantly." Auguste Comte, *Correspondance Générale et Confessions*, vol. 1, Paris: Mouton, 1973, p. 64.

9) *Cours*, vol. 2, p. 341.

10) *Ibid.*, p. 338.

11) See, for example, *ibid.*, p. 495.

12) *Cours*, vol. 1, p. 15.

theology and metaphysics, unable to produce much useful knowledge or to progress substantially.¹³⁾ More specifically, Comte saw in such entities as the vortices of Descartes or the caloric of the heat theorists impediments that had retarded the growth of real knowledge in their subjects. Only when vanquished by the anti-metaphysical theories of Newton and Fourier, history taught him, did true progress in those fields commence.¹⁴⁾

The stridency and urgency of Comte's condemnation of metaphysics, however, cannot be traced alone to his response to the historical problems that he believed that it had engendered. Rather, Comte saw in contemporary French physics the same "mistaken" allegiance to metaphysical notions that he found in its history. Ontologically, Comte found this in the continued reliance on "ethers," "fluids," "unmeasurable corpuscles," and the like within such branches of physics as optics and the science of electricity. He was quick to attack these "imaginary hypotheses" as inimical to the development of real knowledge. Comte used his chapter on optics, for example, to excoriate the proponents of both Newtonian corpuscular theory (Biot) and Cartesian ether theory (Fresnel), arguing that no true progress could occur in optics until all such metaphysical suppositions had been abandoned.

The radical emptiness of these antiscientific conceptions ... has no need to be formally stated: it suffices to demand of them... whether the luminescent faculty of bodies is really explained, in any way, by the fact that one has transformed it into consisting of the movement with an incomprehensible speed of chimerical molecules or of the vibrations of immobile particles in an imaginary fluid with an imperceptible elasticity. Is it not evident, on the contrary, that one piles up thus mysteries upon mysteries?¹⁵⁾

In the realm of epistemology, as well, Comte was deeply troubled by certain "metaphysical" tendencies in contemporary physics. These resided primarily in the misuse of mathematical analysis through its application to situations in which sufficient quantitative knowledge had yet to be developed. "But it is manifest," he asserted in 1822, "that any application of mathematical analysis, if attempted before this preliminary condition of the discovery of certain laws of quantity has been fulfilled, would be entirely illusory."¹⁶⁾ Comte saw this improper application of mathematics being prosecuted by a group of mathematicians whom he called "*algèbristes*," as opposed to "*géomètres*,"¹⁷⁾ and who were primarily interested in employing the principle of universal attraction, from astronomy, to explain all terrestrial phenomena.

Several physicists have already considered it (capillarity) so, but for different motives independent

13) See, for example, *ibid.*, pp. 8-10 and *passim*.

14) On Descartes and Newton, see *Cours*, vol. 2, pp. 349-351 and on calorics and Fourier see *ibid.*, pp. 396-397.

15) *Ibid.*, p. 499.

16) Auguste Comte, "Plan of the Scientific Operations Necessary for Reorganising Society," in *System of Positive Polity*, vol. 4, London: Longmans Green & Co., 1877, p. 579.

17) "I want to speak of the influence of the *géomètres*, or more precisely, of the *algèbristes*, who in our time have so abused mathematical analysis in applying it to chimerical hypotheses." *Cours*, vol. 2, p. 353 below.

of the nature of phenomena and only related to their current mode of explanation, by virtue of a vague analogy between weight, linked to universal *attraction*, and the molecular force to which these remarkable effects are attributed. I avow that such a relationship affects me little, because it seems to me to reside essentially in the use of the unfortunate word *attraction* to designate heaviness generally.¹⁸⁾

Who were these "*algèbristes*"? Comte specifies only one by name, Laplace, but was clearly referring to the entire Laplacian school of physics.¹⁹⁾ To him their work, though mathematically elegant, was physically vacuous; metaphysical rather than substantial. As he remarked in the *Cours*, "in spite of the imposing appearance of exactitude with which Laplace has invested it (his theory of capillarity), and enfolding it in such grand analytic luxury, it has always appeared to me very unsatisfactory, because of its vague, obscure, and even, at the base, essentially arbitrary character."²⁰⁾

The problem with metaphysics, then, was that it was arbitrary; it possessed no necessary connection to the world of observable phenomena. The history and contemporary practice of physics taught Comte that such arbitrariness produced not steady progress toward the systematization of observed phenomena, but irresolvable dissension over basic principles. His philosophical predilections informed him that knowledge, like that in mathematics *qua* mathematics, must above all be accurate and certain. Thus Comte demanded the complete abjuration of metaphysics in the development of positive physics. It could be avoided, he argued, only by relying on two closely related attributes, predictiveness and verifiability.

Believing that a metaphysical hypothesis involved the elaboration of uninvestigable suppositions and unverifiable entities, Comte emphasized that a scientific theory must be predictive and verifiable to be positive. A predictive theory, for Comte, was one that would "predict, as exactly as possible, all the phenomena that a body placed in any ensemble whatsoever of given circumstances will present."²¹⁾ The possibility of checking those predictions against the actual occurrence of the phenomena constituted a theory's verifiability and every positive theory, Comte declared, must be open to "a positive verification, more or less distant, but always clearly inevitable."²²⁾ Thus, Comte strove to connect the ontological content of positive theories specifically with observational data, and the epistemological meaning of such theories with phenomenal events. "For all philosophical spirits," as he explained in the *Cours*, "science consists henceforth essentially in the most complete and most exact real systematization possible of observed phenomena."²³⁾ Comte realized, however, that this demand for exact-

18) *Ibid.*, p. 380.

19) For further discussion of the Laplacian school of physics see Robert Fox, "The Rise and Fall of Laplacian Physics," *Historical Studies in the Physical Sciences*, (1973) 4 : 89-136, Eugene Frankel, "J. B. Biot and the Mathematization of Experimental Physics in Napoleonic France," *Historical Studies in the Physical Sciences*, (1978) 8 : 33-72, and J.W. Herivel, "Aspects of French Theoretical Physics in the Nineteenth Century," *British Journal for the History of Science*, (1966) 3 : 109-132.

20) *Cours*, vol. 2, pp. 380-381.

21) *Ibid.*, p. 311.

22) *Ibid.*, p. 337.

23) *Ibid.*, p. 529.

tness was at best an ideal and that there would always be some gap between a theoretical prediction and a phenomenal verification. He argued therefore that every truly positive scientific theory must show an awareness of its approximate nature and attempt to describe the boundaries within which its predictions were accurate.²⁴⁾

Comte found corroboration for these demands, as for his strictures against metaphysics, in the history and contemporary practice of physics. History, Comte argued, proved that only those theories able to generate verifiable predictions, like Newton's theory of gravitation, the mathematical laws of sonorous vibrations, Snell's sine law of refraction, or Mariotte's and Boyle's pressure/volume gas law had served as the lasting foundations for scientific investigation.²⁵⁾ Contemporary practice confirmed this perception for Comte. In the over-reliance on mathematical analysis and speculation Comte saw a mistaken rejection of observation and the careful verification of theories.²⁶⁾ Comte's concern with the need for predictive, verifiable theories also manifested itself in the emphasis he bestowed on those contemporary investigations, including Fourier's theory of heat and Ampère's theory of electromagnetism, that he believed exemplified these characteristics. Ampère's electromagnetic theory, for example, was lauded by Comte as "a memorable example of this judicious combination of the physical spirit and the mathematical one,"²⁷⁾ because Ampère united observations on electrical phenomena with mathematical analyses.

Predictiveness and verifiability, therefore, constituted for Comte related criteria that together would ensure that a scientific theory remained closely tied to observational phenomena. In so doing, they also served as crucial preconditions for the final characteristic necessary to a positive scientific theory, mathematicality.

Although Comte did not argue that all positive theories must be mathematical,²⁸⁾ he did assert that for physics specifically and the sciences in general mathematics was the preferred language in which to synthesize observational facts.²⁹⁾ This was true, he argued, because precision could be most easily attained through the quantification of observational data, and mathematics was the language of quantity. "One will conclude from this examination," he wrote in 1819, "that the arithmetical language is an improvement over ordinary language with regard to ideas of quantity, and that the algebraic language is itself another improve-

24) See, for instance, *ibid.*, p. 521.

25) Of Newton's gravitational theory, for example, Comte declared that it assigned "henceforth, as the only necessary goal of truly rational scientific effort, the exact reduction of a system more or less extended of particular facts to one unique and general fact. *Ibid.*, p. 498.

26) In describing the current state of optics, for instance, Comte declared that physicists for too long have been concerned with "prolonging the empire of antiscientific hypotheses through inopportune and badly conceived (mathematical) analyses, where moreover a great abstract value sparkles sometimes... which has unfortunately no other ordinary effect than to make more pernicious their influence on the philosophy of science. *Ibid.*, p. 507.

27) *Ibid.*, p. 535.

28) "The application of mathematical analysis is in no degree necessary to render politics a positive science." Comte, "Plan of the Scientific Operations Necessary for Reorganising Society," p. 577.

29) "The fundamental principle for the perfecting of physics," Comte asserted, "resulted from the more or less complete application of mathematical analysis." *Cours*, vol. 2, p. 315.

ment over the arithmetical language and presents immense advantages over the two."³⁰ Mathematics, nonetheless, was not without its limitations in Comte's eyes. Of most critical importance, it could only be applied after the requisite observational data in numerical form had been gathered and regularities had begun to emerge.³¹ Also, all applications of mathematics themselves has always to be considered approximate, subject to some small error.³² Nonetheless, mathematics remained for Comte "the most powerful instrument that the human spirit can employ in research into the laws of natural phenomena."³³

What convinced Comte of the power of mathematics? Historically, Comte noted that the great majority of the important advances, at least in the realm of the inorganic sciences, occurred through the articulation of theories written in the language of mathematics. Newton's theory of gravitation, Archimedes' investigations into hydrostatics, Galileo's work on falling bodies, and all of the other highly predictive, verifiable theories already noted were expressed mathematically. The inductive historical lesson for Comte was clear: mathematics, properly applied, was invaluable to the creation of a positive theory. Comte's understanding of contemporary physics confirmed this outlook as well. Although dismayed by the misuse of analysis, Comte saw in the work of Ampère, Fourier, Chaldni and Savart, and Coulomb examples of the power of mathematics when properly combined with observation. Thus Comte described Fourier as having "this profound feeling for the true mathematical philosophy, of which Fourier perhaps was more completely penetrated than any other great mathematician (*géomètre*),... (and which) consists above all in the intimate and continuous relation of the abstract and concrete."³⁴

Mathematics, therefore, served for Comte as the method that generated precise predictions whose accuracy could then be verified by observation. When developed properly, on the basis of regularities discovered in accurate data, these mathematical laws were completely anti-metaphysical. Consequently they provided valid information about the phenomenal world, information that could be utilized in harmonizing man's relationships with nature. Thus utility developed in Comte's system out of positivity, and the whole philosophical program fit together seamlessly. These intimate connections among anti-metaphysicality, predictiveness, verifiability, mathematicality, and utility are best illustrated by that example that Comte used most often to exemplify his conception of a positive scientific theory, Fourier's analytical theory of heat.

30) Auguste Comte, "Essais sur quelques points de la philosophie des mathématiques," in *Ecrits de Jeunesse 1816 - 1828*, Paris: Archives Positivistes, 1970, p. 502.

31) "The first condition (necessary) so that phenomena will permit the possibility of mathematical laws being discovered is evidently that the diverse quantities which they present can give rise to constant values." *Cours*, vol. 1, p. 125.

32) As Comte declared in describing Mariotte's and Boyle's pressure/volume law, "it is thus always necessary in the application of our abstract conceptions to the interpretation of nature, that true mathematical laws can never be known to us except through analogous approximations, their limits being only more or less narrowed, even in regard to the most simple and best studied phenomena." *Cours*, vol. 2, pp. 375 - 376.

33) *Cours*, vol. 1, p. 92.

34) *Cours*, vol. 2, p. 456.

Even a brief perusal of the *Cours* discloses the significance of Fourier's theory to Comte.³⁵⁾ Not only does the name "Fourier" dominate Comte's description of physics,³⁶⁾ but his theory is consistently employed as an ideal to which other theories are compared. When Comte wanted an example of an effort that had vanquished metaphysical entities from its domain, for instance, he turned to Fourier; when he needed a properly positive scientific theory to place in contrast to those in optics, he used the theory of heat.³⁷⁾ In fact, at one juncture Comte described Fourier's theory as a model for all future attempts to apply mathematics to physical phenomena:

Outside of its (Fourier's theory's) immediate importance for the truly rational and positive study of an order of phenomena so universal and so fundamental, it tends to raise our philosophical hopes with regard to the future extension of the legitimate applications of mathematical analysis.³⁸⁾

Comte could employ Fourier's theory as a model because it dramatically embodied all of the characteristics necessary to a positive scientific theory, as he took pains to demonstrate. Anti-metaphysicality, predictiveness, verifiability, and mathematicality resided in the theory of heat's very character as a physical theory. Comte considered the object of the theory to have been "to discover the function that expresses, at each instant, the temperature of any point whatsoever of a solid mass."³⁹⁾ Fourier accomplished this, Comte argued, not by relying on "calorics" or other chimerical ideas, but by creating a series of differential equations that could accurately predict all measurable thermological phenomena at any instant.⁴⁰⁾ Fourier's theory, Comte explained, accounted as well for most of the empirical thermological discoveries made up to that point,⁴¹⁾ and formed thereby a comprehensive encapsulation of all current scientific knowledge about heat. As Comte described it at the very beginning of the *Cours*:

In effect, in this work (of Fourier's), whose philosophical character is so eminently positive, the most important and most precise laws of thermological phenomena have been unveiled, without the author having himself inquired a single time into the intimate nature of heat, without him having mentioned, other than in order to indicate its vacuity, the agitated controversy between the partisans of the caloric material and those who believe that consists in the vibrations of a universal ether. And nevertheless the most important questions ...are treated in this work.⁴²⁾

35) As J.W. Herivel has noted, "when we remember that Comte took Fourier as his model in that part of his philosophy which dealt with physics, the close resemblance between their views on the subject no longer appears fortuitous." J.W. Herivel, *op. cit.*, p. 124.

36) See Appendix II, Table 1.

37) *Cours*, vol. 2, pp. 352, 508.

38) *Cours*, vol. 1, p. 117.

39) *Cours*, vol. 2, p. 431.

40) "The equation expresses more generally and more profoundly simply what the phenomena offer, the continual exchange of heat between all the molecules of the system in virtue of their current temperatures." *Ibid.*, pp. 440 - 441.

41) See, for example, *ibid.*, pp. 449 - 450.

42) *Cours*, vol. 1, pp. 13 - 14.

The utility of Fourier's theory is also quite evident within Comte's account. Implicitly, it lay in the ability of the theory of heat to answer those "most important questions" about heat, thus increasing man's understanding of and control over his physical world. Explicitly, the utility of Fourier's theory was demonstrated clearly by its avoidance of the traditional controversies over the nature of heat; the analytical theory contributed thereby to harmony within the scientific community.

In Fourier's theory of heat, therefore, Comte found a collection of mathematical laws that were both predictive and verifiable, that had explicitly banished from physics a major metaphysical conception, and that were demonstrably utilitarian. A more perfect example of a positive scientific theory could scarcely have been hoped for, and Comte took it as such. He thereby demonstrated not only that his conception of positivity was coherent, but that it was practicable as well: history and philosophy remained united. Nonetheless, this portrait of a positive theory did not in and of itself complete Comte's picture of positive science. Although with the model of Fourier's theory of heat Comte had adequately characterized the individual theory, he had not yet explained how new theories are created and connected to older ones, how they are woven into a science.

This second aspect of positive science, its method, was distinguished by Comte from theory in an essay he wrote in 1820. "In all positive sciences," he said, "one can distinguish two sorts of works: those that relate to the science in itself, that is to say, to the principles and to the deductions and applications of the principles, and those that relate to the method, that is to say, to the means for arriving at new principles."⁴³ Thus method connoted for Comte the process by which new data is generated and then used to develop positive scientific theories. Methods were subdivided within Comte's account into two kinds: that method common to all positive sciences, mathematics, and those unique to each of the particular sciences.⁴⁴

The first method, mathematics, has been thoroughly discussed and requires little additional analysis. Applicable in Comte's view only after phenomenal data had already been gathered, it constituted the most exact method for analyzing such data and articulating fixed relations among the phenomena being studied. As Comte asserted in the *Cours*, "it is through mathematics that the positive philosophy commenced to develop: it is from that that the *method* comes to us."⁴⁵

The specific methods, on the other hand, were dependent on the science being investigated; in the case of physics, experimentation. "This art of combining intimately analysis and experiment," Comte declared, "without subordinating the one to the other is still almost unknown; it constitutes naturally the last fundamental improvement in the method proper to the thorough study of physics."⁴⁶ Experimentation involved the investigation of a given phenomenon under artificial conditions, normally with the goal of producing a quantitative

43) Comte, "Essai sur la philosophie des mathématiques" in *Écrits de Jeunesse 1816 - 1828*, p. 534.

44) *Cours*, vol. 2, p. 334.

45) *Cours*, vol. 1, p. 133.

46) *Cours*, vol. 2, p. 321.

record of the investigation's results.⁴⁷⁾ To achieve this, Comte argued that the development of suitably accurate quantitative instruments was a necessary preliminary, as only with precise instruments could experiments produce numerical data sufficiently accurate for mathematics to be applied with any hope of success.⁴⁸⁾

This vision of positive physics, a science both mathematical and experimental, was historically most completely realized, Comte believed, not in the subject area of Fourier, heat, but in the specialty of Archimedes, weight.⁴⁹⁾ Comte chose barology (the science of weight) as the model for a positive branch of physics because it included the most complete combination of physics' two essential methods. He saw in the work of Archimedes on hydrostatics,⁵⁰⁾ Stevin on the statics of liquids,⁵¹⁾ Galileo and his followers on the dynamics of solids,⁵²⁾ and Huygens on the motion of the pendulum⁵³⁾ the articulation of accurate mathematical laws based on detailed experimental investigations into the phenomena in question. Such laws, Comte argued, alone served as the basis for all subsequent refinements in each of their fields.

This premier branch (barology) presents to all philosophical spirits a powerful and special attraction, as it illustrates the most perfect model... of that fundamental method suitable to physical researches: ... sharpness of observation, good institution of experiments, healthy construction and rational usage of hypotheses, and finally judicious application of mathematical analysis.⁵⁴⁾

Thus in barology Comte found an example within the realm of contemporary physics of a completely positive science. He had thereby succeeded not only in defining the characteristics of a positive theory and a positive science, but in demonstrating that they were both actually discoverable in the practice of physics as well. His philosophy of positivism continued to meld theory and history into one.

The general picture that Comte presented of positive physics, in sum, was one of a discipline centered on utility, on providing man with a knowledge of nature's laws with which he could better harmonize his actions to the constraints of nature and extend his powers within those constraints. Positive physics could accomplish this, he argued, because its goal was to ascertain the general laws of natural phenomena from a study of the phenomena themselves. By requiring that these theories be anti-metaphysical, predictive, verifiable, and mathematical and that data be collected through quantitative experimentation, Comte attempted to tie positive physics completely to the phenomenal world. This would ensure, he believed,

47) *Ibid.*, p. 313.

48) In fact, the development of any new positive branch of physics was always associated, in Comte's view, with the creation of a new instrument and the corresponding accretion of accurate observational data. See *ibid.*, p. 415 n.

49) "This fundamental study (barology)," Comte wrote, "constitutes really today, seen in the generality and simplicity of its phenomena, the only part of physics of which the positive character is perfectly pure." *ibid.*, p. 361.

50) *Ibid.*, p. 364.

51) *Ibid.*, pp. 367 - 372.

52) *Ibid.*, pp. 383 - 384.

53) *Ibid.*, p. 387.

54) *Ibid.*, p. 361.

that all knowledge in physics, by being bound to phenomena, would aid man in anticipating and correlating his actions with the physical world. Through positive science, Comte concluded, man would learn to understand and to perfect the order of his existence within nature.⁵⁵⁾ Such contemporary examples as Fourier's analytical theory of heat, with regard to positive theories, and the science of barology, with regard to positive sciences, met these criteria, Comte argued, and hence demonstrated the validity of his suppositions. Thus it is fairly clear what Comte thought positive physics ought to consist of. The question that remains is why. Why did Comte choose this characterization for an ideal physics, and more generally, for science as a whole? Although it is difficult to provide a complete answer, factors can be adduced that seem to have strongly influenced the direction of Comte's thought.

The most general of the interests clearly consonant with Comte's conception of positivity was his desire to reform society. The ultimate goal of the *Cours* and, in a sense, of Comte's entire life's work,⁵⁶⁾ was to articulate the methods necessary to discover the laws of society and then to initiate a positive search for such laws.

Now that the human spirit has founded celestial physics, terrestrial physics, either mechanical or chemical, organic physics, either vegetable or animal, it remains to complete the system of the sciences of observation by founding *social physics*. Such is today, under several principal relations, the greatest and most pressing need of our intellects: such is, I dare to say, the premier goal of this course, its special goal.⁵⁷⁾

Social physics, or sociology, was conceived of by Comte as the science that would, through observation, comparison, and above all historical analysis, elucidate the underlying laws of society and provide man, thereby, with the ability to increase the order in his chaotic social world.⁵⁸⁾ Comte saw in contemporary political debates an acrimony and inconclusiveness that seemed to preclude the possibility of significant advances in social theory; he argued, therefore, that harmony and unanimity of opinion were necessary concomitants of progress. Such unanimity would develop, in Comte's view, only when politics was removed from the realm of personal opinion and anchored in the world of predictive, verifiable truth. "The entire philosophical principle of such a (scientific) spirit can necessarily be reduced... to always conceiving of social phenomena as inevitably subject to true natural laws admitting

55) "In a word, it is essentially a question of contemplating order, to the end of suitably perfecting it, and not of creating it, which would be impossible." *Cours*, vol. 4, p. 278.

56) As he wrote in 1825, "I have decided to work my entire life for the formation and the triumph of the positive philosophy, because that is my vocation, and consequently my happiness." *Correspondance*, p. 112.

57) *Cours*, vol. 1, p. 18.

58) As Gertrude Lenzer has noted, "his (Comte's) entire work was dedicated to the development and elaboration of a system that would resolve, once and for all, the disruptive and anarchic tendencies in the society of his time and the societies of the future." "Auguste Comte and Modern Positivism" in *Auguste Comte and Modern Positivism: The Essential Writings*, New York: Harper & Row, 1975. p. xx xii.

rational prediction."⁵⁹⁾

The connections between Comte's interest in the creation of social order and harmony, including his desire to limit the possibilities of dissension and dispute, and his positive account of physics are fairly obvious. The core of Comte's definition of "utility," the goal of every positive scientific theory, was the creation of order and harmony out of the chaos of existing phenomena. His attack on metaphysical ideas arose out of a conception that such ideas were "vague," "obscure," and above all "arbitrary." They were unacceptable because they were open to multiple interpretations and produced, consequently, little but dissension. True science, Comte argued, did not allow such debates; it demanded complete assent. "In astronomy, physics, chemistry, and physiology there is no such thing as liberty of conscience; that is to say everyone would deem it absurd not to place confidence in the principles established for these sciences by competent thinkers."⁶⁰⁾ As with utility, Comte's interest in uniformity of opinion, or objectivity, with regard to social questions was reflected in his depiction of positive science.

Along with this general concern for reforming society, Comte also held other interests that were consonant with the elaboration of his positivist program. If he desired to dedicate himself to the creation of the perfect society for the loftiest of reasons, he also sought, on far more self-serving grounds, to establish a comfortable position for himself within that perfect, or any other conceivable, society. Comte was obsessed during his early career, as his letters quite clearly indicate, with acquiring a permanent position, status, and an assured income.⁶¹⁾ Such comforts, he believed, could most easily be garnered by finding a permanent niche within the French academic or administrative bureaucracy. Two positions, because of his own intellectual predilections and training, were particularly appealing: a membership in the Institute, or a professorship in the *École polytechnique*.⁶²⁾ Comte, in applying for these positions, did not present himself to these organizations as a philosopher, but as a mathematician, prepared by his study of the philosophy of mathematics either to explore the connections between the various isolated sciences (for the Institute) or to regenerate the teaching of mathematics (for the *École*). While frantically applying for the chair of transcendental analysis and rational mathematics (to which he had been connected as *répétiteur*) at the *École polytechnique* in 1836, for example,⁶³⁾ Comte described his work on the philosophy of science as pedagogical, constituting "the most special didactic titles possible, in the eyes of anyone (who) has gone sufficiently in depth into the true general theory of mathematics teaching."⁶⁴⁾ Comte was also quite open about his reasons for desiring such positions. As he

59) *Cours*, vol. 2, p. 253.

60) Comte, "Plan for the Scientific Operations Necessary for Reorganising Society," p. 531.

61) This excerpt from a letter of 1833 is typical: "it is well time, at thirty years of age, to worry about a fixed and suitable position." Comte, *Correspondance*, p. 245.

62) During 1833, however, Comte was primarily interested in a slightly different position. He attempted to persuade the government to create a new chair expressly for himself, the chair of General History of Physical and Mathematical Sciences, at the Collège de France. See *ibid.*, p. 244.

63) Comte wrote ten letters in one month urging his appointment.

64) *Ibid.*, p. 256.

wrote to his friend Valat in 1819:

I have the ambition of being, as soon as possible, through my work, a member of the Institute, because then I will be almost sure of creating for myself a comfortable and assured existence. I avow to you that I find it simpler to obtain thus my existence through some works and the reputation that they can make for me, than by going to beg at the gate of some titled simpleton.⁶⁵⁾

The connection of Comte's depiction of positive physics with this desire to gain access to academic status and security is, unlike the connection with his interest in social reform, not obvious. Nevertheless, in a variety of ways the specifics of Comte's philosophical program, both in terms of orientation and content, would clearly have aided his chances of reaching his goal of occupational security. In the first place, the emphasis in positive philosophy on mathematics and science, though not in vogue with the more romantic sentiments of the French philosophers of his day, would have been quite in keeping with the interests of those whom he wished to impress, the mathematicians and physical scientists who were important in the Institute and École polytechnique and who helped determine the admission of new members. That he was consciously orienting his work toward such figures can be inferred from the dedications of his early works to such illustrious contemporary scientific figures as Poinot, Arago, Gay-Lussac, Hachetté, Ampère, Blainville, and Fourier; from the emphasis in his work on the contributions of such individuals to the progress of positivity; and from his explicit intention of reaching an audience composed of such individuals. "The *Cours de Philosophie Positive*," he wrote in 1831, "which I conceived and executed several times in the last five years, has permitted me to expose my ideas on the mathematical philosophy especially to several members of this Academy (of Science), who have responded by encouraging me with their public approval."⁶⁶⁾

In addition, Comte imbedded within his philosophical program a series of recommendations that, if carried out, would almost certainly have contributed to his prospects for attaining a permanent position within one of the institutions of French scholarship. Comte argued in the *Cours* and elsewhere for the necessity of a new intellectual speciality that would have as its aim the elucidation of the relationships between the various specific sciences, asserting that "up until now, the diverse theoretical sciences have always been isolated, they have never formed a system."⁶⁷⁾ Such a situation, Comte argued, was inimical to the continued progress of positive science,⁶⁸⁾ and could never be rectified by scientists themselves because of the necessary narrowness of their own interests.⁶⁹⁾ Thus, he concluded, a new type of pursuit

65) *Ibid.*, p. 63.

66) *Ibid.*, p. 221.

67) Comte, "Programme d'un travail sur les rapports des sciences theoriques avec les sciences d'application," in *Écrits de Jeunesse 1816 - 1828*, p. 59.

68) See *Cours*, vol. 1, p. 36.

69) "A mathematician, who is normally never concerned with anything but calculus, who always employs his mind to deducing one theorem from another, acquires in this endeavor an extraordinary skill; but he becomes more and more incapable of raising himself to general views." Comte, "Essais sur quelques points de la philosophie des mathématiques," p. 494.

was necessary, one that would concern itself only with the general methods and structures of positive science.

It suffices, as a result, to make a great speciality out of the study of scientific generalities. Let a new class of savants, prepared by a suitable education, without surrendering itself to the special culture of any particular branch of natural philosophy, concern itself uniquely with considering the diverse positive sciences in their present state, in order to determine exactly the spirit of each, to discover their relations and their connections, to summarize, if it is possible, all their own principles in a small number of common principles while conforming them ceaselessly to fundamental maxims of the positive method. Let, at the same time, the other savants, before surrendering themselves to their respective specialities, be rendered apt henceforth, to profit immediately from the ensemble of positive knowledge, to profit immediately from the light spread widely by the savants dedicated to the study of generalities.⁷⁰⁾

And who was fit to prosecute such a pursuit? In Comte's view, "this purely philosophical career demands, evidently, an entirely particular system of long and difficult preliminary studies, at times historical and dogmatic, on the rational development and the real coordination of human knowledge."⁷¹⁾ In other words, it demanded Comte himself.

Comte's specific career ambitions, therefore, were incorporated within the very fabric of his philosophical analysis of science. He crafted an account of positivity that, if not designed specifically to further his personal ambitions, was at the very least consonant with such goals. It would have, if generally accepted, strongly aided his quest for a permanent, high-status position, as well as have promulgated ideas in which he unquestionably deeply believed. Although the specific characteristics of positive physics may not have been shaped by his search for security, the general framework into which positive physics was placed most certainly was.

The third factor that may have contributed to Comte's portrait of positive physics was the influence that the actual history of the science, as he perceived it, had on him. Dedicated to an historical approach to philosophy and trained in mathematical science, Comte relied heavily on the history of physics to illustrate and provide verification for his positivist theory. He argued implicitly throughout the *Cours* that his depiction of positive physics was not only philosophically justified, but historically accurate as well, deducible through the proper analysis of the history of the subject. Comte's own connections with the French mathematical physics community, both institutional (graduate of École polytechnique, mathematics tutor for École polytechnique students), and personal (friend of French scientists, occasional writer on mathematical topics) lend some credence to this claim. Comte was in a position to know about science, both with regard to its history and to its contemporary practice. His use of actual physical theories and sciences as models for the positivist program suggests not only that Comte was aware of developments in contemporary science, but that he drew inspiration for his philosophical speculations from them. Otherwise, the correspondence

70) *Cours*, vol. 1, pp. 24-25.

71) *Cours*, vol. 2, p. 563 below.

between philosophy and history would have been simply too fortuitous. The very favorable response to Comte's philosophy in a review appearing in the highly influential and very respectable *Edinburgh Review* of 1838 indicates that others shared Comte's perceptions of the nature and direction of scientific progress. Not only did the reviewer agree with Comte's general philosophical program,⁷²⁾ but praised his historical accounts of mathematics, astronomy, and physics for their accuracy and sagacity.⁷³⁾

This is not meant to imply that Comte was "correct" in considering the history of physics as the progressive embodiment of positivism. But it does indicate that the historical perceptions that Comte had of contemporary physics, or at least of its major developments, were both reasonable and not uncommon. Comte was keenly aware of the scientific currents and fashioned an account of positive physics that was consonant with many of them. Utilitarian, anti-metaphysical, predictive, verifiable, and mathematical theories lodged in experimental specialities, therefore, were not just philosophical creations for Comte, but reflections of practice as it actually was.

There is yet a fourth way in which Comte's personal interests corresponded with his account of positive physics. From the earliest days of his formal education, at the lycée in Montpellier, Comte exhibited both a great talent for and a great interest in mathematics.⁷⁴⁾ This interest grew during his time at the École polytechnique into a desire to comprehend all sciences.⁷⁵⁾ There Comte learned the intricacies of higher mathematics and their connections with physics and chemistry from some of the luminaries of French science.⁷⁶⁾ Comte's frequent mention in his early letters of these individuals and their courses, always with enthusiasm and reverence, indicates clearly his strong interest in science and the role of the École in enhancing that interest.⁷⁷⁾

In addition to furthering his love for science in general and mathematics in particular however, the École polytechnique also taught Comte something quite different; it taught him to identify himself as a *polytechnicien*, a member of a self-consciously elite corps composed of the ablest young bourgeois in France.⁷⁸⁾ The emphasis on "corps" is crucial to the definition of a *polytechnicien*. The students at the École polytechnique received not just scientific

72) See "Cours de Philosophie Positive" in *The Edinburgh Review*, (1838), vol. 67, 136 : 271 – 308, especially pp. 280 – 281.

73) See, for example, *ibid.*, pp. 292, 305.

74) See Gouhier, *op. cit.*, vol. 1, p. 68.

75) Comte entered Ecole polytechnique in October, 1814 and left with the expulsion of his class in April, 1816 for general lack of discipline and disloyalty to the King. On entrance, he was ranked fourth in his class, and after the first year, as the result of disciplinary infractions, eighth. (See Gouhier, *op. cit.*, vol. 1, pp. 270, 276.)

76) These luminaries included Poinot, Arago, Thénard, Petit, and Poisson. (See *Correspondance*, pp. 3, 6.)

77) For example, in a letter to Valat in 1815 Comte wrote "these two courses are excellent: the chemistry one is taught by the celebrated Thénard, and the physics one by Petit, both former students at the Ecole." *Correspondance*, p. 6.

78) As Comte wrote in 1815 to his friend Valat, "you would not believe what good spirit reigns among the students of the Ecole; the most perfect union exists among us." *Correspondance*, p. 6. See also John H. Weiss, "Bridges and Barriers: Narrowing Access and Changing Structure in the French Engineering Profession, 1800 – 1850" (Unpublished MS), p. 32.

training, but military training as well; they were prepared to become engineering officers in the French army and managers in the state corporations.⁷⁹⁾ These military/managerial values, inculcated through the complete control that the École had over the lives of its cadets,⁸⁰⁾ included emphasis on hierarchy, discipline, and patriotism.⁸¹⁾ Comte's own early letters reflect the École's infatuation with order and unvarying regimen. His description of a typical day at the school included mention of the precise hours at which stipulated activities were to be performed and of a schedule that dictated an activity for virtually every hour of the waking day.⁸²⁾

A *polytechnicien*, however, was more than simply a disciplined soldier; he was also an engineer, or at least an engineer-to-be. The graduates of the École polytechnique, Shinn has demonstrated, went overwhelmingly into civilian or military engineering careers.⁸³⁾ Comte himself states explicitly in an early letter that he had intended to enter the public service, an intention frustrated by the expulsion of his class in 1816.⁸⁴⁾ What expectations would Comte have faced as an engineer in the making? As John Weiss's study of French engineering demonstrates, in addition to the need to master the basic technical skills, an engineer was "led to expect responsibility for supervising and planning tasks involving large sums, large groups of men, and considerable political difficulties from local interests" and to perceive himself as a member of a large and well-delineated professional hierarchy.⁸⁵⁾

Thus a *polytechnicien* was an individual well-versed in science and mathematics, and socialized into an appreciation for hierarchy, order, discipline, and management. His education emphasized theory and the order which such theory could create out of the detailed and chaotic phenomena of nature. In all of these respects this background was clearly correlated with Comte's account of positive physics. The order and harmony that Comte stressed in his definition of utility reflects the emphasis on order and management of the *polytechnicien* and of the engineer. The insistence on predictability and verifiability are consonant with an engineer's or military officer's concern with phenomena that can be perceived, not simply conceived. More generally, the graduated hierarchy into which Comte placed the sciences and the overwhelming emphasis on science within his broad conception of positivity were consonant with the social values of the *polytechnicien*. Even Comte's separation of theory from practice and his own interest primarily in the more theoretical aspects of science were visible in the education of the *polytechnicien*, in which a student was taught theory by the Ecole polytechnique and applications by the École de Ponts et Chaussées or some other post-

79) As Terry Shinn has noted, this meant that "the Ecole polytechnique would be profoundly marked, between 1804 and 1814, by this exaltation of military values, which would dominate its history throughout the nineteenth century." Terry Shinn, *L'Ecole Polytechnique, 1794 - 1914*, Paris: Presses de la Fondation Nationale des Sciences Politiques, 1980. p. 24.

80) *Ibid.*, p. 25.

81) *Ibid.*, pp. 25 - 26.

82) *Correspondance*, p. 5.

83) See Shinn, *op. cit.*, p. 36.

84) *Correspondance*, p. 13.

85) Weiss, *op. cit.*, p. 33.

Polytechnique training program.⁸⁶⁾

Thus, in a variety of ways Comte's description of positive physics was quite closely correlated with his personal interests and with environmental influences. Although it is impossible to demonstrate that such interests and influences, in and of themselves, caused his account of positivity to take the form that it did, the degree of correspondence between the two is highly suggestive. It seems clear that in important ways Comte's philosophical program reflects his interest in and allegiances to the French physical science community. Three of the factors most important in shaping Comte's account of positivism, his decision to search for a permanent position within the mathematical and physical science branch of the academic bureaucracy, his interest in the contemporary practice of physics, and the combination of his native mathematical ability with his education at École polytechnique, were forces shaping the entire first generation of post-1800 French physicists. Regardless, therefore, of whether Comte's philosophical system was thereby emblematic of the entire physical science community's approach to physics, it is clear that it was partially a product of that community, as much as Fourier's theory of heat or Ampère's theory of electromagnetism.

Thus Comte's emphasis on mathematics, experimentation, prediction, and verification was one reaction that a French intellectual could have had to the forces molding early nineteenth century French physics. It may even be reasonable to claim that what many contemporary physicists were doing with physical phenomena was little different from what Comte was doing with philosophical notions — demanding that the chaos be brought into order by tying theory over more tightly to observable fact.

Appendix I

Comte — A Brief Chronology

1798	Born January 9, in Montpellier
1809-1814	Attended lycée in Montpellier
1814-1816	Attended Ecole polytechnique
1816	Comte's class at Polytechnique expelled
1817-1824	Worked with Saint-Simon
1819	First letter indicating outline of Comte's positive system
1821	<i>Mémoire sur le calcul des variations</i>
1822	<i>Plan des travaux scientifiques nécessaire pour réorganiser la société</i>
1824	Final break with Saint-Simon
1826	First group of lectures on positivism First nervous breakdown
1829	Second set of lectures on positive philosophy; audience included Fourier, Blainville, Poinso, Navier, Broussais, Esquirol
1830	First volume of <i>Cours de philosophie positive</i> published

86) In fact, contemporary engineers and Comte were similar in yet one other way. Shinn has noted that French engineers were engaged in the pursuit of social position through their scientific knowledge. The same, of course, can easily be said of Comte. See Shinn, *op. cit.*, p. 198.

	Fourier died
1832	Comte named <i>répétiteur</i> (tutor) in analysis and rational mechanics for Ecole polytechnique
1835	Second volume of <i>Cours</i> published
1837	Named <i>examineur</i> for Polytechnique under patronage of Dulong
1842	Sixth and final volume of <i>Cours</i> published
1848	Comte establishes Société Positive to promulgate Cult of Humanity
1851 - 1854	<i>System de politique positive</i> published; describes religion of humanity
1857	Comte died on September 5 in Paris

Appendix II

Table 1

Individuals Mentioned in the Physics Chapters of the *Cours* 5 or More Times

<i>Name</i>	<i>Number of Times</i>
Fourier	53
Newton	22
Ampère	18
Coulomb	15
Galileo	13
Descartes	12
Archimedes	10
Huygens	9
Chaldni	8
Laplace	7
Euler	7
Oersted	6
Stevin	6
Duhamel	6
Savart	6
Sauveur	6
Dalton	5