



Charles Coulston Gillispie  
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# Lazare and Sadi Carnot

A Scientific and Filial Relationship

*2nd Edition*

# Lazare and Sadi Carnot: A Scientific and Filial Relationship

# HISTORY OF MECHANISM AND MACHINE SCIENCE

Volume 19

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Charles Coulston Gillispie • Raffaele Pisano

# Lazare and Sadi Carnot

A Scientific and Filial Relationship

Second Edition

 Springer

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# Foreword

Les talents écartent l'ennui, chassent le vice, et sèment la vie de fleurs:  
puissance, richesse, vous n'offrez point ces avantages!

(Legend of a lithograph depicting the spirit of enlightened industry and belonging to a great–great granddaughter of Lazare Carnot)

The first part of this compendium consists of slightly revised excerpts from my monograph, *Lazare Carnot Savant*, published in 1971 (Gillispie 1971). The preface to that book, which is based partly on access to the Carnot family archives, explains how it came to be written, and makes the necessary acknowledgments. It contains a short section on the more famous work of Sadi Carnot, whose *Réflexions sur la puissance du feu et sur les machines propres à développer cette puissance* is generally regarded as the origin of the science of thermodynamics (Carnot 1824). It appeared to me that Sadi Carnot's analysis may be read as an application of his father's invention of the science of machines to heat engines.

I have suggested as much in what follows. My colleague and co–author, Raffaele Pisano, has independently devoted much more intensive study to the work of Sadi Carnot and its influence. It seemed to both of us that it would be well to publish, or in my case to republish, our findings. Both father and son were trained as engineers, Sadi at the newly founded *École polytechnique*. They had no idea that their work would develop into the physics of work and energy. So it came about, however, and that is the reason for including an account of it in a series devoted to the role of engineering mechanics.

The major portion of *Lazare Carnot Savant* is here included. We are not reprinting the appendices, which are reproductions of Carnot's unpublished papers discussed in Chapter 3, Parts A and B, nor the essay on the unpublished mathematical theory of the infinite contributed to my book by my late colleague, A.P. Youshkevitch, which has little to do with engineering mechanics. Princeton University Press has generously granted the necessary permission, for which I am extremely grateful.

Princeton, USA

Charles Coulston Gillispie



# Preface

This extraordinary book on two outstanding French engineers and scientists has been written by two authors who combined their efforts to that end in a very fruitful way. The result is based on deep historical, epistemological, and methodological insights that shed completely new light on the scientific and filial relationship between the famous politician, mathematician, and engineer Lazare Nicolas Marguerit Carnot (1753–1823) and his son Nicolas Léonard Sadi Carnot (1796–1832) who was also trained as an engineer at the newly founded *École polytechnique de Paris*.

While Lazare Carnot wrote on machines and adapted the science of mechanics to the science of machines, his son elaborated a general, abstract, thermodynamical theory. Insofar the purpose of Gillispie and Pisano is not to recount the history of mechanics, but to identify the points of entry of Lazare Carnot’s engineering science into mechanics (p. 100). The authors are well aware that the analogy between fluid flow and heat flow has often been discussed in the research literature in order to characterize the influence of Lazare’s work upon Sadi’s (p. 18).

Yet, the authors make a much wider claim for the continuity between the works of the two Carnots. They would like to show that Sadi Carnot’s *Réflexions sur le puissance motrice du feu* published after his father’s death “may properly be read not only as the foundation of thermodynamics, but also as the culmination of a methodologically and conceptually coherent series” of Lazare Carnot’s essays on the science of machines (p. 15).

How can such a strong claim be demonstrated? Gillispie and Pisano study and compare the different steps of Lazare Carnot’s thinking about mechanics, of his writings, and compare them with Sadi Carnot’s *Réflexions* which can be taken for the foundation stone in the science of thermodynamics (p. 77).

To that end they identify those elements of the arguments that were derived from the work of the father. They amply and clearly explain their methods and methodology as well and include even a whole chapter (Chap. 6) that deals with such general issues like historical methodology, interpretation, and scientific theory.

Their key notion is historical epistemology which is based on the use of logical-historical categories. The authors adopt them in order to investigate Sadi Carnot’s scientific thought. They are interested in *effective history* that is history relying on

the fundamental choices made by scientists who influenced the interpretation of history by means of crucial choices (p. 156).

Their leading questions read: What is the theoretical organization in the two Carnots? On what principles is it based? In order to answer to these two questions they study the history of science by means of a logical investigation (p. 191). Thus they are able to demonstrate that Sadi Carnot's reasonings with double negative sentences (DNS) are based on non-classical logic. The authors' list in the appendix comprehends 65 such sentences. Their sequence may synthetically express the entire development of Sadi Carnot's scientific thought (p. 205).

Gillispie and Pisano convincingly conclude that Sadi Carnot's "theory has to be qualified as a logical theory because the double negative sentences illustrate for the first time a very detailed structure of Sadi Carnot's arguments, adequately representing Carnot's original scientific thought" (p. 211). But the two authors go even further by explaining that the origin of the idea of the cycle was the analogy with the electric circuit in Alessandro Volta's battery. Hence Lazare Carnot, not Sadi, first had the idea of the cycle of heat machines (p. 234).

The fruitfulness of Gillispie's and Pisano's approach becomes again obvious when they apply the method of historical epistemology to the mathematical footnote in Sadi Carnot's *Réflexions* which combines epistemological and historical approaches to identify significant historical hypotheses (p. 257). The authors claim that Lazare Carnot's synthetic method is present in Sadi Carnot's theory paying particular attention to Sadi Carnot's reasoning process (p. 279). Their hope is certainly justified that their approach can contribute to clarify the birth and development of Sadi Carnot's theory and the historical knowledge of thermodynamics.

Comparing Lazare and Sadi Carnot's theories of the efficiency of a machine, they conclude that "neither theory is based on axioms, but on the program of scientifically resolving a crucial problem that in the minds of the lay people of the time coincided with metaphysics" (p. 370).

Gillispie and Pisano have written a really remarkable book that reveals an impressing knowledge of the huge amount of original and modern publications regarding history and philosophy of science. They always help the reader not to lose track of things by adding summaries, illustrations, and by compiling their arguments or those of their heroes in long lists. In spite of all similarities they have proved between father and son they do not overlook a crucial difference between them. Sadi Carnot's work was deep in a way that his father's was not: It founded the science of thermodynamics (p. 86).

Berlin, Germany

Eberhard Knobloch

# Acknowledgments

The genesis of such a difficult and lengthy book has deep roots, and the final result has been a long time in the making. When the research and production of a work of this nature is carried out over a significant period of time, many friends and scholars become contributors to both the research and the writing process. I owe gratitude to many such people and will never manage to thank them all appropriately.

My own early research on Lazare and Sadi Carnot began with a lengthy dissertation on Sadi Carnot's logic and mathematics which I wrote while on the faculty of physics at the University of Naples "Federico II", in my native city. Since appearance of this specialized historical and scientific work, many additional papers have been written by me and by others, on Sadi Carnot alone and on the two Carnots jointly, often in collaboration with my adviser Antonino Drago, the first Italian historian since the 1980s–1990s to recognize the importance of studying the two Carnots jointly as a unique program of scientific research in Italy. Therefore, my first acknowledgments are to him.

Of course, this crucial first book to include both of the Carnots would not have been possible, first without Charles Gillispie's approval and vast, indispensable works on Lazare Carnot, and second without all of Robert Fox's historical details and profound research on Sadi Carnot. These are two definitive, worldwide recognized, masters of the history of science and, as well, friends and colleagues of mine. I feel very privileged to have known and to have worked with them.

A special acknowledgment goes out to my friend and historian, Eberhard Knobloch, President of the *International Academy of the History of Science* who generously accepted to write his insightful and very much appreciated *Preface*. I also thank him for his cultural and persuasive and constant, encouragement. A particular acknowledgement and appreciation goes to the *European Society for the History of Science's* congresses for promoting the history of science in its broadest sense and contacts between scholars and institutions across Europe, and all the world. It gave me the possibility to know and exchange several elements of interest of history of science, mechanics and thermodynamics. Thus I have naturally incurred many debts.

I have to thank the *Centre Française Vietè – épistémologies, histoire des sciences et des techniques* and his head, Stéphane Tirard, University of Nantes, where I was welcomed to spend my post–doctoral tenure research for a correlated project on the history of thermodynamics.

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# Chapter 1

## Biographical Sketch of Lazare Carnot

Known to French history as the “Organizer of Victory” in the wars of the Revolution, and to engineering mechanics for the principle of continuity in the transmission of power, Lazare–Nicolas–Marguerite Carnot (1753–1823) remains one of the very few men of science and of politics whose career in each domain deserves serious attention on its own merits. His father, Claude, lawyer and notary, was among the considerable bourgeois of the small Burgundian town of Nolay, west of Beaune and thus on the opposite side of the ridge from the superb vineyards of the Côte-d’Or. Members of the family still own the ancestral home. Carnot’s most notable descendants have been his elder son Nicolas–Léonard Sadi (1796–1832), a principal founder of the science of thermodynamics, and the latter’s nephew, also called Sadi, President of the French Republic from 1887 until his assassination in 1894. A minor versifier himself, Lazare named his heir after a Persian poet whose work he admired in translation. His younger son, Hippolyte (1801–1888), wrote the first biography, a source of major importance for the personal details of his father’s life.<sup>1</sup> Carnot had his early education in the Oratorian Collège (a school) at Autun. Thereafter his father enrolled him in a tutoring school in Paris, which specialized in preparing candidates for the entrance examinations to the service schools that trained cadets for the Navy, the Artillery, and the Royal Corps of Engineers. Strong in technique and low in prestige, the Corps of Engineers was the only branch of military service in which a commoner might hold a commission. On completing the normal course of 2 years, Carnot graduated from its school at Mézières at the age of 20 in 1773. Gaspard Monge teacher of mathematics and physics, was then at the height of his influence over the cadets.<sup>2</sup>

---

<sup>1</sup>It is an exemplary work of family piety, written for the edification of Carnot’s descendants, *Mémoires sur Carnot par son fils* (Carnot 1861–1863). The standard biography is *Le grand Carnot* by Marcel Reinhard (Reinhard). (The 2nd edition, 1994, also includes preface by Charles Coulston Gillispie).

<sup>2</sup>On Mézières, see *L’École royale du génie de Mézières* by René Taton (1964a, pp 559–615).

Although Carnot's handling of problems always bore the mark of the engineer he became, it does not appear that he was one of Monge's favorite pupils. There was little mention of the one by the other whereas Monge's disciples were given to fulsome tributes. Nor is it recorded that Monge took the slightest interest in Carnot's writings on mathematics or mechanics or did anything to secure them a hearing. Some further inference may be permitted from their differences in temperament: Monge's that of a pedagogue and mathematician who, when he involved himself in public affairs, proved to be theoretical, emotional, incapable of decision, deficient in judgment, and inattentive to detail; Carnot's that of an engineer, eminently practical, able in conception and execution, and capable of the deeper consistency that inheres in judging of circumstance and practicality rather than asserting moral absolutes. Carnot's approach to mathematics and mechanics was more concerned with operations and fundamentals than that of Monge. Its actual mathematical yield was much less while its significance for the physics of work and energy was much greater.

Carnot's professional life in the 16 years prior to the Revolution did not on the whole prove stimulating. On leaving Mézières with the rank of lieutenant, he entered on a sequence of garrison duties, first at Calais, and then successively at Le Havre, Béthune, Arras, and Aire. Only in Aire did he find cultivated company. There, in the 1780s, he was admitted to the predominantly literary Society of Rosati, a group of beaux esprits famous for having counted Carnot and Maximilien Robespierre among their members rather than for any lasting contribution to letters. Carnot's training did, however, serve him in good stead in several instances. The fortifications of the port of Calais were being rehabilitated during his tour of duty there. He was detached from Le Havre for 3 years of duty on the harbor under construction at Cherbourg, the most considerable and elaborate engineering works undertaken by the military and naval establishment in the latter part of the century. In these and other, lesser assignments he made the reputation of a sound, reliable, and enterprising young officer. His personnel file contains a series of recommendations by his superiors.

Nevertheless, the life was not one to engage the full talent or fulfill the ambition of an able and talented man. In a memoir of 1776, Charles Augustin Coulomb (1736–1806) a fellow engineer and in science a far more famous one, took occasion to testify to its limitations. "After graduating from Mézières a studious young man who would withstand the boredom and monotony of his work had no choice except to cultivate some branch of science or literature that was entirely independent of his professional duty."<sup>3</sup> Later on, Carnot described himself as having been "neglected, lonely, absent-minded, preoccupied, what was called a 'philosophe,' or in other words sort of an odd type."<sup>4</sup> Such was his sense of himself during the years between his graduation from Mézières in 1773 and 1784, when he won a competition set by the Academy of Dijon for an essay on Vauban. In the perspective of his later military

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<sup>3</sup>It is quoted by Stewart Gillmor in *Coulomb and the Evolution of Physics and Engineering in Eighteenth-Century France* (Gillmor 1971, Appendix B).

<sup>4</sup>In the Hyppolyte's wording (Carnot 1861–1863, I, p 93).

and political career, the *Éloge de Vauban* (1784) appears, naturally enough given the subject and the discussion that ensued, to be its opening episode.<sup>5</sup>

Although no detailed account of Carnot's studies during the preceding interval is possible, the individuality of his scientific work is such that he must have been occupying it with a self-education in mechanics and mathematics that carried him far beyond the text-book level of the curriculum of Mézières. It must have been in the isolation of garrison life that Carnot set himself to reading and re-reading d'Alembert, Bossut, Bêlidor Euler's mechanics, and Daniel Bernoulli's hydrodynamics. His early work bespeaks an auto-didactic familiarity. He had no access to the scientific milieu of Paris. He spent his frequent and lengthy leaves at home in Nolay and in Dijon. While he was at Calais his father sent the younger brother, Claude-Marie-Feulint (1755–1836) to reside with him and to be tutored by Lazare in the mathematics and mechanics for the entrance examinations at Mézières.<sup>6</sup> Feulint succeeded on the first try.

What is more substantial, Carnot's earliest publication was not the *Éloge de Vauban* of 1784, but *Essai sur les machines en général* of 1783. We analyze that work in detail in the next chapter. It contains in principle all that Carnot actually contributed to mechanics, while also constituting the starting point of the French engineering tradition in the science of machines. From documents in the Archives of the Academy of sciences in Paris, in those of the German Academy of Sciences in Berlin, and in those of the Carnot family in their house at Nolay, it is possible to fix with precision the occasions for Carnot's earliest formal composition in the literature of mechanics and mathematics.

Even like the *Éloge de Vauban*, those writings were elicited by competitions set by learned societies. He composed two early drafts of the *Essai sur les machines en général*, the first completed in March 1778 while at Cherbourg and the second in July 1780 at Béthune. The Academy announced the competition in April 1777 for the year 1779 and then adjourned it to 1781 since the judges found none of the initial entries to be worthy of an award. On the second round a memoir by Coulomb won the prize while Carnot's was accorded Honorable Mention. The contents and their conformity to the Academy's desiderata will be discussed in the next chapter, following analysis of the *Essai sur les machines en général* itself.<sup>7</sup> As for Carnot's complementary interests in the foundations of mathematics, his *Réflexions sur la métaphysique du calcul infinitésimal* (1797) grew out of a memoir that he submitted to the *Royal Prussian Academy of Sciences* in 1785.<sup>8</sup>

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<sup>5</sup>The prize was first offered in 1783, but in the absence of worthy entries, the competition was adjourned to 1784. For the details see both *Le grand Carnot* and *Mémoires sur Carnot par son fils* (Reinhard, I, pp 76–86; Carnot H, pp 99–117).

<sup>6</sup>On that see the arguments presented by Hyppolite (Carnot H, I, pp 94–95).

<sup>7</sup>Below, Chapter 2.

<sup>8</sup>A facsimile of that entry is printed as *Appendix A* in the present author's *Lazare Carnot Savant* (Gillispie 1971). That book also contains an essay *Lazare Carnot and the Competition of the Berlin Academy in 1786 on the Mathematical Theory of the Infinite* (Ivi, pp 149–168) by my esteemed

Just prior to his recognition for the *Éloge de Vauban*, Carnot made one more attempt to win the approbation of the Academy of Sciences. On 17 January 1784 he sent in a “Lettre sur les Aérostats” in response to its invitation to interested parties to communicate reflections inspired by the first human flight. On 5 June 1783 Joseph and Étienne Montgolfier had created a sensation by sending a balloon filled with heated air soaring to a height of 6,000 ft above the town of Annonay.<sup>9</sup> Their feat and its elaborate repetitions in Paris raised the engineering problems of locomotion and stability of flight. The studies evoked were by no means all sterile. A memoir by Jean-Baptiste Meusnier de la Place contains the principle that much later governed adjustment of specific gravity of a submarine in accordance with its depth.<sup>10</sup> Carnot addressed himself rather to the problem of a “dirigeable” and proposed a scheme for a propeller to be powered by a motion of systole and diastole created in the balloon by the dissipation and restoration of heat, a sort of jellyfish effect. The notion was visionary enough. What excites interest in retrospect is his discussion of heat, fluids, and the potential awaiting the steam engine. “Notice by the way, gentlemen”, he wrote “how much labor will be saved in factories when the mechanism of heat is better understood.” And further, “The engine powered by heat provides a very powerful motive principle and the principle can as easily be adapted to moving blades and wheels as to beams and pistons” (Carnot H, I, p 185). Throughout his life, indeed, Carnot maintained a lively interest in the work of mechanical invention, rather in point of principle, criticism, and appreciation, however, than of participation. He does not appear to have been gifted with practical inventiveness himself.

Only with his military writings did Carnot win attention. Biographers and historians interested in Carnot as wartime leader and Member of the Committee of Public Safety have naturally looked in these for clues to what their author would become.<sup>11</sup> In good philosophic vein Carnot invoked the example of Vauban to convey his own enlightened sentiments about natural equality in men of merit and inequities in the social order. The central thrust of the essay was strategic. It celebrated, in the declamatory style thought appropriate for ceremonial occasions, the complements of geometry and enlightenment that impelled Vauban, the founder of professional military engineering, to conceive that the purpose of warfare should be defense of civilization rather than destruction of the enemy.

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colleague, the late A. P. Youshkevitch of the Moscow Institute for the History of Science and Technology.

<sup>9</sup>On that one can consult *The Montgolfier Brothers and the Invention of Aviation* (Gillispie 1983).

<sup>10</sup>*Mémoire sur l'équilibre des machines aérostatiques* (3 December, 1783). On that see: Meusnier de la Place (1783). Gaston Darboux published this paper in his *Mémoires et travaux de Meusnier relatifs à l'aérostation* (Darboux). See also, *The Montgolfier Brothers and the Invention of Aviation* (Gillispie 1983, pp 100–101).

<sup>11</sup>The Academy of Dijon, embarrassed by its experience with its most famous laureate, Jean-Jacques Rousseau, thereafter took care to edit the texts it crowned before publication. As published Carnot's *Éloge de Vauban* was a toned down version of what he had delivered. Its original tenor has been plausibly reconstructed by G. Duthuron (Duthuron, pp 152–165).

Historians have sometimes waxed a little wry at Carnot's expense for having celebrated, when a young Turk, the humanitarian warfare of position, and then, when actually in charge of waging a war, for having put into effect the contrary strategy of mobility, mass, offensive, and conquest. What must be remembered is the difference in circumstances. In the 1780s Carnot was a young engineering officer writing out of the specialist tradition of his corps and upholding its mission in the design and construction of formal works of siege craft and defensive fortification. Doing so required him to contend against the renewed emphasis of the combat arms on gallantry, movement, and command under fire. Chivalric pretensions were the line officers' part in the aristocratic resurgence. In power during the Revolution, however, Carnot did not dispose of the disciplined, technically trained, professional, and careful forces that such a conservative strategy presupposed. His troops were untrained levies, some under arms out of patriotism, and some because of conscription. Patriotic soldiers furnished a commander with dash and conscripted soldiers with mass. Both sorts were altogether different from the armies of Louis XIV and the eighteenth century.

The unexpectedness of what happened to persons swept along in the ineluctability of what happened to society always enhances the historical drama of the French Revolution. There is no need to follow Carnot's political career in detail. It will suffice to evoke it as the context, the disproportionately important context, in which recognition for scientific originality came the way of a no longer young engineering officer suffering increasing frustration over the seemingly dead end of his career as a military engineer and the neglect accorded to his scientific work. The earliest phase, that of the Constituent Assembly, saw that pattern relieved through the new facility of expressing grievances openly and advocating change. At the outset Carnot did not think to go beyond professional matters. That the army must be reformed to secure promotion in accordance with merit rather than noble birth; that equity and dignity must be accorded to the Corps of Engineers; that the Engineers and the Artillery, the two "learned branches (*armes savantes*)", should be amalgamated into a single, scientifically trained corps, headed by an elective council rather than an authoritarian commander; that warfare itself was to be limited and humanized by a combination of firepower with fortification – these were ideas shared by many of Carnot's colleagues. His advocacy was distinguished in its imperative tone and further in that like many of his countrymen, though few professional colleagues, he went over the heads of his superiors and addressed his reclamations not to the War Office, but directly to the National Assembly.<sup>12</sup>

The way to politics itself opened out of Carnot's reassignment to duty in the North, specifically to Aire in the region of Calais, where he and his younger brother, Feulint, had put down roots among the interests and sympathies of the locality. There he followed for a time in the way smoothed by Feulint's readier congeniality.

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<sup>12</sup>*Réclamation adressée à l'Assemblée nationale contre le régime oppressif sous lequel est gouverné le Corps Royal du Génie . . .* A manuscript copy is preserved in the family archives at Nolay. On these matters, see *Le grand Carnot* by Reinhard (Reinhard, Chapters 11–12, I, pp 148–176).

Lazare Carnot followed Feulint personally and married into the same family. He did so politically and ran alongside his brother as candidates for election as deputies to the Legislative Assembly in September 1791. Feulint had taken part in various councils and deputations to the Constituent Assembly. Better known in the region, he was elected to the first seat on the second ballot. Lazare Carnot for his part had joined the Society of Friends of the Constitution in his garrison town of Aire and had been its president for a time. That was his only political activity prior to his election. He won the ninth seat, also on the second ballot. That so limited a political experience as Feulint's and Lazare's should suffice for election as representatives of the people will be less surprising when it is recalled that the outgoing Constituent Assembly had stipulated, unwisely in the judgment of most historians, that none of its members might be reelected. The French people having had no voice in their own affairs, there were in 1791 no communities in which significant political experience might have been attained. In Reinhard's view, Carnot, now married into a substantial family, entered upon his legislative duties in a much calmer spirit than had been his at the outset of the Revolution in 1789. Already struck down were the aristocracy and the impediments to promotion and dignity that had engendered the angers of his youth. Like the majority of deputies he supposed the Revolution to be over and looked forward to participating in the regime of a constitutional monarchy that would ensue. He can have had no thought of wielding power in posts of the highest responsibility.

He came to do so because the new regime, in which men of his kind, the qualified and able bourgeoisie, could feel at ease was anything but stable. In reality the Revolution had only begun when the Legislative Assembly convened in October 1791. In its further course Carnot's professional military competence in harness with his engineer's ability to improvise arrangements and organize procedures proved to be great advantages, both to him and to the nation. The critical faults in the political structure made his qualities relevant. Throughout the first 6 months of his legislative career the untrustworthiness of the king and many of his ministers dissipated the credibility of combining monarchy with constitutionalism and confirmed Carnot in a kind of latent republicanism. Thereafter, following the declaration of war in April 1792, instigated by the Girondist faction with a view to exhibiting the duplicity of the crown, the unreliability of the leadership of the army and the reverses of the opening campaigns put at a premium the services of any patriotic deputy with military competence.

Lazare Carnot's actual political interventions in the Assembly were maladroit. He was never a notable orator. Still, knowing how he conducted himself in the pressures soon to be upon him, the historian can understand how it was that his traits made themselves felt in the heightened sensibility of those intense and febrile days when the French monarchy was proving its caducity, and no one dared plan openly for what might take its place. Nothing was then observed more narrowly than character. Men took one another's measure, and Carnot's began to come through. His contemporaries felt the intelligence, the probity, and the sense of reality that proved adequate to judging of the rightness of republicanism (for he was never a democrat, and never in rapport with the demagogues and idolaters of humanity); the

instinct for concentrating on the job at hand; the fund of toughness about what he could not help (the Terror later and the guillotine) so long as it did not touch him in his own pride; the selflessness about material interests in a man alert in defense of his dignity; the passion to prevail with the right answer; and the unwillingness to compromise his own principles combined with some insensitivity to those of others that might conflict.

His biographer alludes to a mathematical dogmatism in Carnot's spirit.<sup>13</sup> It may not be necessary to read his character that way. On the whole he was a critical thinker about mathematics, but not a notable mathematician. His scientific work was at the opposite pole from dogmatism. It may be preferable to attribute the rigidity in him to a fundamental decency, manifest in the stands he took, in which he appears in retrospect the more sympathetic for a certain maladroitness, his fervor not always suited to the matter, but well suited to the times. His brother's reluctant behavior in contrast gradually revealed a man of the old dispensation insufficiently tempered by an occasional opportunism. Judging of events with a surer instinct, Lazare Carnot moved to the left and the Republic. Originally the less popular of the brothers, only he was returned to the Convention from the Pas-de-Calais in September 1792 following the overthrow of the Monarchy and the dissolution of the Legislative Assembly at the hands of the city of Paris in its rising of 10 August.

Among the hundreds of deputies to the Convention, Lazare Carnot was the one who most effectively improvised the function of the Representative on Mission by means of which the sovereignty of the people was exercised in specific actions throughout the mass of the nation. The substitution of the Republic for the Monarchy was the act in the first instance of the city of Paris. Other municipalities, provincial administrations, civil servants, officers of the army and navy, in short the agencies and agents of government – all that remained in the inertial grip of routine procedures of the Old Regime when the personnel was not, as much of it was and especially so in the armed forces, actively or potentially disposed to Counter-Revolution at home or to treating with the enemy abroad or to both these oppositions now constituting treason. Into such situations of anarchy, confusion, or active disaffection in the winter of 1792 and into the summer of 1793 would come sometimes one, though usually two or three, of the deputies to the Convention, Representatives of the People, dressed in blue waistcoats with brass buttons, red, white, and blue sashes, and felt hats decorated with tricolor feathers. To them was delegated *carte-blanche* the sovereign authority of the People, and in them was incarnated for the time being its revolutionary will. They might suspend local officials and replace them with others; they might set up special tribunals and sit as judges; they might exercise eminent domain over property, fix prices; and requisition whatever transport, enterprise, livestock, foodstuffs, or supplies were required for military purposes; when on mission to the armed forces, they might supersede commanders and overrule or countermand orders. They might do whatever they thought necessary.

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<sup>13</sup>The argument is well treated by Marcel Reinhard in his *Le grand Carnot* (Reinhard, I, p 187).

Thus on the morrow of 10 August 1792 the National Assembly designated commissioners to apprise the several armies that the Republic had supplanted the monarchy and to secure their allegiance to the regime. Lazare Carnot, Claude–Antoine Prieur de la Côte–d’Or and Anne–Pierre Coustard were dispatched to the Army of the Rhine. Carnot was the chief of mission. They arrived in Phalsbourg on the 14th, summoned the acting commander, the former duc de Biron et de Lauzun, together with his staff and immediate subordinates, and required them on the spot to reply one after the other to the question: “Do you purely and simply accept the decrees of the National Assembly, YES or NO?”

All accepted except one, whom they immediately relieved of duty. Thereupon they moved among the rank and file from one unit to the next explaining the portent of events in Paris, staged a triumphal entry into Strasbourg as embodiments of the sovereign Republic, outmaneuvered the mayor, a constitutional monarchist, purged the local administration of persons of his persuasion, replaced a number of suspect officials throughout Alsace, entered into diplomatic relations with the Swiss on problems of the scrambled border, and returned triumphantly to Paris on 4 September to assure the Assembly that the Army of the Rhine was trusty and the eastern Departments loyal to the Republic (Reinhard, Chapter 18, I, pp 254–287).

Between Carnot’s election to the Convention a few weeks later and his entry into the Committee of Public Safety in August 1793 he was much absent from Paris in the discharge of further missions: to the Army of the Pyrenees when Spain entered the war; to the Pas–de–Calais and the North when the initial conquest of the Austrian Netherlands (i.e. Belgium) turned into confusion and defeat; to the Army of the North when its commander, Dumouriez, deserted to the Austrians, taking captive with him the Minister of War and several members of the Convention. At that humiliating nadir of military misfortune Carnot overrode Dumouriez’s demoralized successor and organized the defense himself.

His actions were no less firm in politics. He voted the execution of Louis XVI. He moved the decree to annex Belgium and Monaco. He proposed the conscription of all men between 20 and 25 (“every citizen is born a soldier”). Those measures were consistent with the principle that he proposed for the basis of the Declaration of Rights: that the “safety of the people is the supreme law.” Carnot’s was a tough republican will, and his reputation that of a reliable, not to say a ruthless, patriot when in the late summer of alarm, defeat, civil war, and treason he was called upon by the more politically minded men constituting the great Committee of Public Safety to join its membership together with a younger Burgundian and fellow engineer, Prieur de la Côte– d’Or.

The historical vision of the French Revolution tends to be dominated by the climactic events of the Year II of the Republic, which is to say the autumn, winter, spring, and early summer of 1793–1794 prior to the overthrow of Robespierre on 9 Thermidor (27 July, 1794) and termination of the Jacobin Terror as an instrument of government associated with his spirit and dominant influence. Those months were dramatic ones from any standpoint, and not least Carnot’s. Barely 2 years previously he had been a captain of engineers relieved that the way to promotion was finally

open, settling into family life, and resigned to the imminent approach of middle age. Now he found himself called to membership in the body of 12 men who were ruling France and determining the destiny of the Revolution.

The Committee of Public Safety was like no government that had ever existed. Originating in early 1793 to exercise the Convention's general supervision, first over the War Office, and then over all ministries, it rapidly came to supersede them and to take executive power into its own hands. Everything about it was anomalous except its energy. All powerful in action, it existed only at the will of the Convention, which renewed its mandate monthly and only for a month. Implementing its decrees through the Jacobin Club of Paris and the network of Jacobin clubs throughout France, it both controlled and depended upon what was in effect a one-party political system. By its own definition this government was merely provisional, "revolutionary until the peace". With no precedents, it evolved its own procedures. Its responsibility was collective. Any or several members signed and validated decrees for the whole, working round the clock behind the doors of their council room in the Tuileries, sometimes two or three of them at a time, sometimes five or six, never the whole 12. Some were off on mission to the armed forces or to some point where counter-revolution threatened or revolution needed their firm guidance. Their creation was the *levée-en-masse*, which mobilized the French people into the first incarnation of a modern nation in arms beating back its enemies, overrunning its frontiers, and destroying the assent of history to the old order in Europe.

At home the Committee destroyed dissent. Its instruments were the Revolutionary Tribunal and the guillotine. No survivor involved in the application of that Terror could ever after escape either the inner necessity to shift the responsibility from his conscience elsewhere or the external necessity to justify himself when public reaction set in after Thermidor. The purposes of the present monograph does not require reaching a moral judgment on Carnot's part in the Terror, whether it was one of application or acquiescence. Several things may be said, however. On the one hand his ruthlessness is not to be gainsaid. He encouraged Louis Turreau, deputy on mission in the rebellious Vendée, to put down counter-revolution and "exterminate the brigands to the last man". He signed the decree ordering that the city of Lyons should be brought into line, "torch in hand and bayonets fixed". Toulon, also in rebellion, was to be burned to the ground by red hot cannon balls.<sup>14</sup>

On the other hand there is justice in the view, originating with Hippolyte if not with Carnot himself, that dissociates him from the zealotry of Robespierre, Saint-Just, and Couthon, who would have made of the Revolution a moral crusade for the regeneration of humanity, and woe in the Republic of Virtue to whoever faltered or fell short. He is to be distinguished too from those other colleagues who appear to

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<sup>14</sup>On that see *Le grand Carnot* by Reinhard (Reinhard, II, pp 86–87). On the governance of the Committee of Public Safety, see *Twelve Who Ruled: the Committee of Public Safety during the Terror* by Robert R. Palmer (Palmer).

have been adventurers and malcontents rather than crusaders in a great cause: Collot d'Herbois, a paranoid and unsuccessful actor; Billaud-Varenne, an unscrupulous drifter and would-be lawyer; Hérault de Sechelles a renegade aristocrat; Barère the wily politician who ever sought to please. It was not in the company of such as these, fanatics, sadists, or demagogues, that Carnot was with his own kind, but rather in that of Prieur de la Côte-d'Or and Prieur de la Marne, one an engineer and one a lawyer (they were unrelated); Jeanbon Saint-André a Protestant, sometime pastor, and ship's captain; and Robert Lindet careful, industrious, and the senior member in point of age.

Carnot concentrated on supreme direction of the war, with Prieur de la Côte-d'Or's assistance with respect to ordnance, supply, materiel, weaponry, and the revolutionary production of saltpetre and gunpowder. He began by reorganizing the armies and their command in the autumn and winter of 1793-1794. His also was the strategy of a three-pronged offensive into Belgium in the spring of 1794. Thereby the French armies passed over into the attack that they sustained against all of Europe for the better part of 20 years. Robespierre, who had no head for military matters, avoided the responsibility of signing the Committee's decrees concerning prosecution of the war, just as Carnot tended to eschew those concerning matters of police and revolutionary justice (Reinhard, II, p 89). War and Terror were intimately related, however. Military security was invoked at the time, and has often been accepted by historians, as justification for the strong hand of the Terror. What is more to the present point, it was certainly military success in the spring of 1794 that rendered the Terror unnecessary and finally intolerable to a people no longer fearful of foreign invasion and in a position instead to export despotic interference in ordinary life from its territory to that occupied by its armies.

Therein lay the reason that after 9 Thermidor Carnot alone among his erstwhile colleagues remained in office, albeit not continuously, under the Convention and into the regime of the Directory that ensued in 1795. "Carnot organized the victory", cried an anonymous voice from the floor of the Convention when at a tumultuous session of that expiring body on 20 May 1795 he was under attack as an erstwhile terrorist (Reinhard, II, p 158). Fearful of despotism, the framers of the Constitution of the Directory placed the executive power in the collective hands of five men to be elected by the upper house of the legislature upon nomination by the lower. In November 1795 Carnot was elected a Director. During the nearly 2 years he held office, he was the leading figure of that precarious regime, ill fated in the absence of a stable, sturdy center by the irreconcilability of surviving radicalism on the left and reviving royalism on the right.

In the early days the threat from the left seemed the more dangerous. Carnot took charge of putting down with a very heavy hand a rising called Conspiracy of the Equals, led by an obscure journalist, one François-Émile Babeuf. Regrouping the armies after the disarray of Thermidor, and directing them across the Alps, he seemed at first to handle military administration with his old sure touch. The sword he chose turned out to have two edges. His was the decision to vest command of the Army of Italy in the youthful General Napoleon Bonaparte, with whom Carnot conducted a correspondence that for a short while bore the appearance of

exchanges between patron and protégé, mentor and pupil, Aristotle and Alexander. This time, however, instead of saving the Republic, the success of its military strategy doomed it.

Carnot was driven from office 2 years before that dénouement. In the spring of 1797, the legislative elections resulted in a royalist resurgence. Unwilling to accept the undoing of the Revolution, the factions of the left prepared to reject the verdict of the polls and to purge the two assemblies of their reactionary members. Their coup occurred on 18 Fructidor (4 September 1797). Carnot was persuaded that the Constitution could not be preserved by violating its provisions and refused to lend himself to that maneuver. Warned that his fellow Directors planned his arrest, he escaped from his quarters in the Luxembourg, went into hiding for a few weeks, and then fled into Switzerland. So ended the political career in which, though never holding power alone, he shared in the supreme power for a longer period, August 1793 until September 1797, than any revolutionary statesman prior to Napoleon Bonaparte and longer too than any minister of State had done throughout the reign of Louis XVI. At few periods in modern French history would four almost uninterrupted years of power seem short.

Thereupon, turning 50 years of age, Carnot resumed the studies in mechanics and mathematics that he had begun with the ambitions of a young engineer in the Old Regime. After the strenuous life of a national leader he reengaged his interest in technical studies with every appearance of enhanced enthusiasm. Mechanics and politics shared nothing in content. Nevertheless, given the historical juncture, the two aspects of Carnot's life were not different in the qualities required of him. The activism animating the nascent profession of engineering was congruent with the activism animating the large political affirmations of the Revolution. In the great world of politics, men acted on the belief that by taking charge of their own affairs they could add to their stature. In the special world of engineering the practices on which men acted in building and working contained problems that were brought into the house of science, where they alimented analytical mechanics and helped turn it into modern physical science.

Carnot had written one major book, *Réflexions sur la métaphysique du calcul infinitésimal* (Carnot 1797), before his entry into government and perhaps prior to the Revolution. Like the *Théorie des machines en général* he developed it out of a memoir he had submitted in 1785 to an academic prize competition, this one set by the Prussian Academy of Sciences, Arts, and Letters in Berlin. The subject was the theory of mathematical infinity. His remaining technical books followed very rapidly on his retirement from government: *Lettre au citoyen Bossut contenant des vues nouvelles sur la trigonométrie* (Carnot 1800a); *De la corrélation des figures de géométrie* (Carnot 1801); the revision of *Essai sur les machines en général* (Carnot [1783] 1786) under the title *Principes de l'équilibre et du mouvement* (1803a); the book he considered his major work, *Géométrie de position* (1803b); and *Mémoire sur la rélation qui existe entre les distances respectives de cinq points quelconques pris dans l'espace, suivi d'un essai sur la théorie des transversales* (Carnot 1806b).

The newly founded Institut de France constituted the forum in which Carnot led a professional life throughout the Napoleonic regime. Embedded in the very

constitution of the Directory, the Institute replaced the *Académie des sciences*, which had been suppressed as a privileged body in August 1793. Like the Academy before it, the First (or scientific) Class of the Institute fulfilled two functions. On the one hand it saw to the advancement of Science by publishing its memoirs and endorsing publication of worthy treatises submitted to the judgment of its committees. On the other hand it advised government departments and the public on technological matters by examining the design and merit of new machines, industrial processes, and agricultural methods submitted by inventors and entrepreneurs in hopes of a patent, premium, or subsidy. Throughout the Eighteenth Century in the great days of the old Academy, its leading members esteemed the former of these functions and regarded the latter with ill-concealed impatience. Something of that differential was no doubt inherent in the value structure of the science of the Enlightenment. It would oversimplify and exaggerate matters to say that the utilitarian and humanitarian emphasis of the Revolution transvalued those values. Nevertheless, the Institute did devote a larger share of its attention to applied science and engineering.

There was, in short, a displacement toward engineering; or perhaps it would be more accurate to say that engineering problems occupied a larger share of the attention and respect of scientists. Such was certainly Carnot's preference. He came into the Institute from that world and was at ease in it as he probably would not have been in the company of the old Academy. The effect of the Revolution was to legitimate and accelerate this shift, not to cause it. Once his own treatises just mentioned were published (which had no immediate effect in science proper whatever their significance for its later course), Carnot devoted his time, energy, and interest to many commissions of the Institute charged with examining the merits of many of the numerous mechanical inventions that attest to the fertility of French technical imagination in the early Nineteenth Century.

These tasks were no mere desultory hobbies of retirement. In an average year Carnot would sit on 12 or 15 such commissions, some on machine technology, some on military technology, some on mathematics. Carnot would frequently be charged with framing the report. A number of these reports amounted to memoirs reviewing the whole state of a subject. In reporting on a notational scheme for descriptive algebra, for example, Carnot summarized the development of "analysis situ" (now called topology) from its invention by Leibniz through the contributions of Euler and d'Alembert to his own applications of algebra to geometry.

Normally, however, Carnot scrutinized inventions of a more practical sort. He was a member of the Commission that Robert Fulton invited to watch his steamboat mount the Seine in the summer of 1804. Even more intriguing was an internal combustion motor called the *Pyréolophore* by its inventors, the brothers Claude and Joseph Niépce, of whom the latter was known later for his invention of the tintype and association with Daguerre in the development of photography. The Niépce motor, said Carnot in an enthusiastic report (1806), was the first device ever imagined for drawing motive power from the expansive force of heated air. It presented the advantage over the steam engine that all the fuel was employed to produce the expansion that went into the motive force. In 1809 Lazare Carnot reported to the Institute on another heat engine invented by a prolific inventor

called Cagniard de Latour. As in the Niépce motor the expansive agent was air but employed in a much subtler manner. The fundamental notion was to pipe atmospherically cool air into the bottom of a bath of heated water and to draw power from its thermal expansion on rising.<sup>15</sup> These devices have in common with the ideal heat engine later imagined by Sadi Carnot that they draw motive power from the expansibility common, not just to steam, but to all gases. That feature renders them more interesting as probable intermediaries between the work of father and son than are certain other, perhaps equally ingenious inventions on which Carnot framed reports, notably a force pump operated by air compression, invented by a certain Lingois; a number of hydraulic machines constructed and operated by a prominent industrialist, Mannoury–Ectot; and a memoir of 1814 by Dupin on the stability of floating bodies.

Such were Carnot's occupations during the decade from 1804 to 1814 when he was in his 50s and his two children were boys. He never abandoned his interests in military strategy nor his role as a defender of the Revolution. He wished to help defend the country amid the crumbling of the Napoleonic system and offered his services to Napoleon at the moment when the catastrophic retreat from Moscow reached the Rhine. In those desperate circumstances, Napoleon appointed him Governor of Antwerp. Carnot commanded the defense. It was the only direct command in his career, and he maintained French control even after Napoleon's first abdication. He then accommodated himself to the initial return of the Bourbons and even addressed a memoir to Louis XVIII counseling him about the aspects of the previous quarter century that the king must needs respect in order to preserve his throne. Nevertheless, Carnot rallied to Napoleon upon the return from Elba and took the Ministry of the Interior during the Hundred Days.

That act, rather than having voted for the execution of Louis XVI, exhibited the consistency of the old revolutionary and was not forgiven by a monarchy that had had to be restored twice. His wife having died and Sadi Carnot having graduated from the *École polytechnique*, Carnot took the younger son, Hippolyte, into exile. Forbidden the Rhineland because of its proximity to France, he and Hippolyte settled in Magdeburg. There Carnot corresponded with German colleagues, published a few volumes of mediocre verse, and brought up Hippolyte, who became a Saint-Simonian.

There on 2 August 1823 Lazare Carnot died.

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<sup>15</sup>For detail on these and other devices inspected by Carnot, see *Lazare Carnot Savant* (Gillispie 1971, Chapter 1, pp 27–29, notes 47–54). On the Cagniard engine, see *Sadi Carnot and the Cagniard Engine* by Thomas S. Kuhn (1961, pp 567–574).