Logic, Epistemology, and the Unity of Science 47

Raffaele Pisano
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Murray Peake

Essay *on Machines in General* (1786)

Text, Translations and Commentaries. Lazare Carnot's Mechanics—Volume 1

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Raffaele Pisano
IEMN, Lille University
Villeneuve D'Ascq Cedex, France

Jennifer Coopersmith
Adjunct Lecturer La Trobe University
Bendigo, VIC, Australia

Murray Peake
Ille-et-Vilaine, France

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Preface

It is never easy to conceive and to realize a vast editorial project. This volume represents the first successful step in exactly such a broad editorial project. It presents a faithful English translation of Lazare Carnot's *Essai sur les machines en général* (1786), enriched by a long and accurate *Introduction* and by a detailed technical and linguistic apparatus of *End Notes*. The *Introduction* draws a very good picture of the epoch in which Lazare Carnot lived and worked, including his engagement both as a scientist and as an important politician. The authors reconstruct Carnot's cultural milieu with great care and offer a translation of Carnot's *Essay* on the machines. I congratulate the authors on their excellent work!

This book and its research programme is to be interpreted as the natural continuation of the masterly work *Lazare and Sadi Carnot. A Scientific and Filial Relationship* (Springer, 2014, 2nd ed.) by Charles C. Gillispie and Raffaele Pisano.

The ambitious editorial research enterprise I signalled at the beginning of this Preface, of which the *Essai sur les machines en general* is the first volume, consists of the analysis, translation, and commentary of Lazare Carnot's three Mechanical works. The other two essays whose publication is anticipated by Springer are the *Principes fondamentaux de l'équilibre et du mouvement* (1803) and *Géométrie de position* (1803).

It is a pleasure to observe and to emphasise that all the possible difficulties of such an extensive editorial programme have been overcome in the best possible manner. In particular, the authors have been able to render the eighteenth-century French in modern English without any scientific ambiguity and with great precision. The authors often add—in square brackets—explicative terms, which are useful for a precise reading of the text. Finally, the *End Notes* clarify all aspects of Carnot's scientific work, in reference to both mechanical and mathematical issues. It also seems appropriate to me to stress the high quality of both the scientific and the historical apparatuses of this book, which helps the reader to follow Lazare Carnot's Mechanics.

I also commend to the reader the new insights it offers regarding the relations between pure and applied science and the links between mechanics, mathematics, and engineering. The conceptual, empirical, and methodological aspects of Carnot's works are appropriately underlined by the authors in the *Introduction* and in the *End Notes*.

I am confident that this research project, including the other two forthcoming volumes, can be considered a milestone for the diffusion and comprehension of Lazare Carnot's science.

Paolo Bussotti
University of Udine, Italy

The original version of the book was revised: The Introduction in the Frontmatter has been reissued as the first chapter of the book. The correction to the book is available at https://doi.org/10.1007/978-3-030-44385-6_5

Acknowledgments

We express our gratitude to the directors and staff members of libraries and archives that we met; we express our profound appreciation for their collaboration. Special thanks to distinguished scholar and friend Paolo Bussotti (University of Udine, Italy) for his accurate *Preface* and suggestion.

We are particularly grateful to Monsieur Dr. Gaetan Carnot, member of Carnot's family and Founding Member and Executive Committee Member of *Fondation Carnot*, who was so generous for again removing (as already done for Lazare and Sadi Carnot, 2014 by Gillispie and Pisano) all restrictions and authorizing us to publish portraits, from the original and special collection of Carnot's family. The images are conserved in France at *Académie François Bourdon, Le Creusot—Archives Lazare Carnot*. We acknowledge the kind permission and rights to use the images, particularly of the *Essai sur les machines en général* (1786), *Gallica National French Library* (BnF), *Archives et patrimoine historique de l'Académie des sciences, Paris* (France), *Académie François Bourdon, Le Creusot—Archives Lazare Carnot* (France; in particular M. François-Yves Julien), *Collections archives de la bibliothèque de l'École polytechnique de Palaiseau* (Essonne, France; in particular M. Olivier Azzola). We warmly acknowledge M. Thierry et Mme Caroline Carnot for the extraordinary opportunity to visit (RP) private documents and manuscripts of Carnot's Family archived at their Château de Presles, South of Paris. We address our gratitude to Mme Sylvie Carnot for all

information concerning her private Lazare Carnot's Nolay Archives. We thank M. Jean Le Bret, member of Carnot's family who gave to one of us (RP) copies of Lazare Carnot's Ascending (1719–1489) and Descendants (1753–2020) Genealogies and Mme Pascale Cordier, another member of Carnot's family to have made accessible her private Lazare and Sadi Carnot's family documents. We are grateful to M. Alain Stouvenel (BDFF—*Base de Données de Films Français avec Images*) for sending us (RP) a rare documentary film on *Lazare Carnot ou Le glaive de la Révolution* (Antenne 2 by Jean–Francois Delassus, January 2nd, 1978).

We thank *Springer Nature* for its kind authorisation to allow us to adapt some pages of the *Lazare and Sadi Carnot. A Scientific and Filial Relationship* (Gillispie and Pisano 2014). We thank all referees for their valuable remarks, which have been of great help. We express gratitude to Dr. Julie Robarts (Melbourne University, Australia) for her observations of English language; eventual remaining English mistakes are up to us. The English proofreading funding was kindly supported by IEMN, Lille University—UMR CNRS 8520, France. Thank you!

Finally, of great importance, we address our acknowledgments to Shahid Rahman and Christi Jongepier–Lue, respectively, Springer Editor-in-Chief book Series and Springer Associate Editor for their fine work and positive reception of our project on the *Essay on Machines in General (1786) Text, Translation and Commentaries. Lazare Carnot's Mechanics—Volume 1.*

The Authors
November 2019

Remarks For the Reader

This book, entitled *Essay on Machines in General* (*Essai sur les machines en général*, 1786), is the first volume of a three-volume set, a unique and major project on the works of Lazare Carnot, *Lazare Carnot's Mechanics: Text, Translations and Commentaries* (expected 2018–2022). The other two volumes are: *Fundamental Principles of Equilibrium and Motion* (*Principes fondamentaux de l'équilibre et du mouvement*, 1803) and *Geometry of Position* (*Géométrie de position*, 1803), also to be published by Springer.

The research for this major project dates back to the end of the 1990s and was carried out by Raffaele Pisano, then also in collaboration with Charles Coulston Gillispie (1918–2015). This research project is devoted to history and historical epistemology of science, integrating history and epistemology of scientific methods and combining epistemological and historical approaches to clearly identify significant historical hypotheses. Therefore bibliographical references, the relationships between physics–mathematics and physics–geometry, and the role played by science in context are strongly stressed.

These volumes (this one and the others cited above, prior to publication) are critical translations, motivated by an important goal: to valorise and spread the name and works of the scientist, Lazare Carnot, to an Anglophone audience.

In this first volume, the translation was mainly carried out by Jennifer Coopersmith and Murray Peake, and the critical commentaries were mainly produced by Raffaele Pisano. The edition used for our critical English translation of the *Essai sur les machines en général* (1786) is archived at the *Archives et patrimoine historique de l 'Académie des sciences, Paris, France BNF* and displayed by National French Library (BnF) website Gallica. An official permission was asked and obtained. The full notice, adapted from BnF (cfr. Gallica website), is:

> Title: Essai sur les machines en général . Par M . Carnot,… Nouvelle édition
> Author: Carnot, Lazare (1753–1823).
> Publisher: impr. de Defay (Dijon) | Nyon l'aîné (Paris)
> Publication date: 1786
> Format: 107 p.; in-8
> Rights: public domain
> Identifier: ark:/12148/bpt6k65435732
> Source: Bibliothèque nationale de France, département Sciences et techniques, 8-V-11886
> Relationship: http://catalogue.bnf.fr/ark:/12148/cb30197796
> Date of online availability: 2013, 31st July

The aim has been to keep to the character of the original *Essai sur les machines en général* (1786) but also to make it easy to understand for the modern reader.

With regard to the first aim, we do not simplify, modernize, or in any other way correct the ideas within the *Essai sur les machines en general*. With regard to the second aim, language explanation and critical comments are reported in footnotes and endnotes, respectively. We have sometimes broken up very long sentences into shorter sentences or changed the word-order. Also, on occasion, extra words have been added for continuity of phrasing or to add a short in-text explanation or to give an alternative modern term. These additions are always in square brackets and in situ. (It should always be clear from the context whether we have to do with continuity or explanation.)

We have corrected obvious printers' errors and indicated this in a footnote. We also use footnotes to draw attention to corrections applied from the *Errata*. We remark that this *Errata* does not appear in the BnF edition that we used for our critical translation. On the contrary, this *Errata* appears in several digital editions (e.g., see Google books). It appears that some editions added this *Errata*. We also note that Lazare Carnot Mathematical Works (1797) does not include this *Errata*. For completeness we decided to use the *Errata* from one of these digital editions (Google, public domain). We warmly thank Google digital books and its cited source as University of Lausanne (Cfr. Google books website).

The layout is such that the translated pages always keep in step with the original manuscript, the French always having an odd page number and the English an even number. In so far as English has a smaller word-count than French, the translated pages are shorter than the French original. However, in displaying the mathematical relations most clearly, sometimes more spacing has been used than in the original.

The reader should be aware that Lazare Carnot's *Essai sur les machines en général* was written some seventy years before the physical concept of "energy" had been discovered and therefore before the term *energy* had entered the physics lexicon. Other physics terms such as *force, action, percussion, soliciting force, moment of activity, puissance*, and so on, have changed or firmed-up their meaning or fallen into disuse. These terms are left in place but, where necessary, the modern term is given in square brackets straight afterwards, or explained in a footnote or endnote. Two terms deserve special mention. One is *hard*, the other is *weight*. Carnot usually uses the property hard, of a body, to mean that the body is deformable but not elastic (like a lump of putty, the body may change its shape but it does not rebound). The term *plastic* is used to convey this meaning. Carnot sometimes uses the term *weight* to mean, loosely speaking, some mass or body, and other times to mean the force exerted on a mass due to gravity. In this case we write *force-weight* and explain in an endnote. Further remarks and commentaries on terminology may

be found in *Lazare and Sadi Carnot. A Filial and Scientific Relationship* (Springer, 2014) by Charles Coulston Gillispie and Raffaele Pisano.

As well as terminology, some symbols have changed their use or fallen into disuse. According to Florian Cajori (1859–1930) in his *A History of Mathematical Notations* (1928–1929), the Lazare Carnot years were a time of transition during which the integral sign was used both for integration and for summation. We have continued to use the integral sign, $\int$, except where there is no infinitesimal quantity (dt, ds, etc.). In these cases, the integral sign, $\int$, is replaced by the summation sign, $\sum$. One other symbol to note is the eighteenth-century sign for the French *livre tournois*, ℔, a French unit of currency, used by Carnot to mean a pound weight. We have translated this as lb and added a footnote. There exists one previous translation into English, the work of 1808, published in instalments by Alexander Tilloch in *The Philosophical Magazine*:

> Carnot L (1808a) Essai sur les machines en général (Part I) In: Philosophical Magazine: comprehending the various branches of science, the liberal and fine arts, agriculture, manufactures, and commerce. Tilloch A (ed). Vol. XXX. Murray J, London, pp. 8–15; pp. 154–158; pp. 207–221; pp. 310–320. Very interesting are the avant-titre page of the book where a portrait from the original of Lazare Carnot is published and a short biography/comment of Lazare Carnot written by the editor (pp. 370–371).
>
> Carnot L (1808b) Essai sur les machines en général (Part II). In: Philosophical Magazine: comprehending the various branches of science, the liberal and fine arts, agriculture, manufactures, and commerce. Tilloch A (ed). Vol. XXXI. Murray J, London, pp. 28–36; pp. 136–144, pp. 220–228; pp. 295–305.
>
> Carnot L (1808c) Essai sur les machines en général (Part III). In: Philosophical Magazine: comprehending the various branches of science, the liberal and fine arts, agriculture, manufactures, and commerce. Tilloch A (ed). Vol. XXXII. Murray J, London, pp. 124–130.

Our present work is an utterly original translation, more modern in style, and benefits from more than a hundred years of advance in science over the earlier translation and remarkable research on the subject (Gillispie 70s–90s; Drago and Pisano 90s–2000s; Gillispie

and Pisano 2014; Pisano since 2000s–etc. See also endnotes and references sections below). It also differs from this earlier translation in certain particulars: (1) We have used $\int$, and $\sum$, as appropriate, in place of *S*, (2) We have translated fils as threads rather than as wires, (3) We have incorporated Carnot's own *Errata*.

This volume has been independently blind-peer refereed.

The Authors
November 2019

About the Authors

Prof. Dr. Raffaele Pisano HDR (Italy, 1970) is a Physicist and Full Professor at the IEMN CNRS-Lille University, Lille, France. His fields of research | teaching are: History of Physics, History of Physics-Mathematics/Theoretical Physics, History of Applied Sciences and Technology, Historical Epistemology of Science, Comparative and Intellectual History, NoS | History of Science and Teaching. Since 2017, he is elected President of the Inter-Divisional Teaching Commission(DLMPST/IUHPST/DHST).

Dr. Jennifer Coopersmith is a physicist, philosopher, and writer of general physics books. Adjunct Lecturer, University of La Trobe, Bendigo, VIC, Australia.

Murray Peake is a retired Information Technology consultant now living in Brittany.

Contents

Chapter 1
Introduction

Lazare Carnot, *l'organisateur de la victoire*

This is the first research volume, in translation and with English commentary, of the Springer French editions of three remarkable works of Lazare Nicolas Marguérite Carnot: *Essai sur les machines en general* (Carnot [1783] 1786). The other two pre-print volumes are: *Principes fondamentaux de l'équilibre et du mouvement* (Carnot 1803a) and *Géométrie de position* (Carnot 1803b). For Lazare Carnot's biography, we direct the reader to the main recent authorities' works (Gillispie and Pisano 2014; Dhombres and Dhombres 1997, Gillispie 1971; Gillispie and Youschkevitch 1979, 1982; Dupre 1892). In agreement with Master Charles Coulston Gillispie (1918–2015):

> There is no difficulty in understanding why the scientific community should have ignored Carnot's *Essai sur les machines en général* […] in the 1780's. His book does not read like the rational mechanics of the eighteenth century. It had long since become normal to compose treatises of mechanics addressed to a professional public in the language of mathematical analysis; though Carnot reasoned no less rigorously than did contemporary mathematical argument, he conducted the discussion verbally, conceived the mathematical expressions he did employ in a geometric or trigonometric rather than algebraic spirit, and usually went on to explain in words what the formulas contained. The genre was apparently of an altogether lower order than that of d'Alembert and Lagrange or Euler and the Bernoulli family. Judging by the style alone, prolix and naive,

R. Pisano et al., *Essay* on Machines in General *(1786)*, Logic, Epistemology, and the Unity of Science 47, https://doi.org/10.1007/978-3-030-44385-6_4

> a contemporary reader might easily have supposed the book to be among the many negligible writings that retailed merely elementary mechanics under one pretext or another. Yet, the essay, despite its title, could never have served the purpose of a practical manual for designing or employing actual machinery. (Gillispie and Pisano 2014, pp. 15–16)

The following introductory research presents Lazare Carnot as military man, politician and scientist on one side, and his mechanics, particularly his *Essai sur les machines en général* in context, on the other.

1.1 Lazare Nicolas Marguérite Carnot (1753–1823)

Lazare Nicolas Marguérite Carnot (Nolay, France, 1753 May 13th—Magdeburg, Prussia [Germany] 1823 August 2nd) was also called *L'Organisateur de la Victoire* and *Le Grand Carnot*, due to the services he rendered to politics during the French revolution, in the army as a general (i.e., the battle of *Wattignies La Victoire*) and scientist (physics, mathematics, geometry, fortifications and mechanical machines). Despite the dominant Newtonian and Lagrangian mechanics, and taking into account his political background, Carnot's works are of great importance to both the history of physics and the history of mathematics (Chamay 1984–1985; Gillispie and Pisano 2014).[1]

Son of Claude Carnot (1719–1797) *Notaire Royal/avocat au parlement de Bourgogne* and Marguerite Pothier (1726–1788), Lazare Carnot was born in Nolay, a village in the current Côte-d'Or

[1] Some paragraphs of the second part of this introduction are an adaptation theoretical advancement from Gillispie and Pisano 2014, pp. 16–23; pp. 353–356; pp. 376–380. Necessary parts are quoted from them as a self-citation. We thank *Rights and Permissions Springer Nature* for its kind authorisation. See also: *A Development of the Principle of Virtual Laws and its Conceptual Framework in Mechanics as Fundamental Relationship between Physics and Mathematics* (Pisano 2017) and *Reading Science, Technology and Education: A Tradition Dating back to Science into the History and Historiography* (Pisano, Anakkar et al. 2017) both published by Transversal (see also Pisano and Capecchi 2015). We show appreciation and thankful to these notable publishers–journals. As we already remarked in the *Acknowledgments* section, we also express gratitude to *Gallica–National French Library* (BnF), *Archives et patrimoine historique de l'Académie des sciences, Paris* (France), *Académie François Bourdon, Le Creusot – Archives Lazare Carnot* (France), *Collections archives de la bibliothèque de l'École polytechnique de Palaiseau* (Essonne, France). An infinite and particular gratitude is addressed to *Monsieur Gaetan Carnot, member of Carnot's family*, for his kind permission to use the images.

department in eastern France. He began his studies in humanities and philosophy at the Collège d'Autun. Then, under the *Societas Presbyterorum a Santo Sulpitio (Society of the Priests of Saint Sulpice)* he focused on theology, logic and mathematics. Thanks to these scientific studies and the meeting with Duke Louis–Marie–Victor d'Aumont de Rochebaron (1632–1704), a French Army officer and Marquis de Nolay, he undertook his military and scientific education (Reinhard 1950–1952).

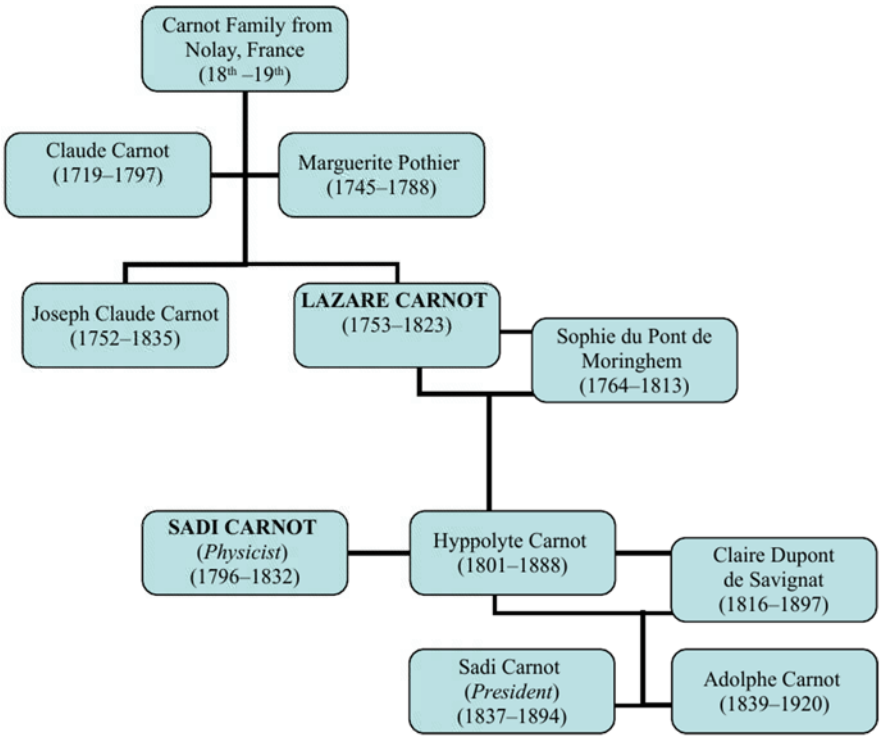
In 1771, Carnot was accepted by *École royale du génie de Mézières* and appointed as a second lieutenant (1773) where he improved his education in mechanics, technical drawing and, geography. One of his professors was Gaspard Monge (1746–1818; Monge 1799). Some years before, in 1764, Louis–Alexandre Berthier (1753–1815) was also accepted at the *École royale du génie de Mézières*. By the age of twenty Carnot had graduated from the school as first lieutenant, after also attending Louis Joseph (1736–1818) Prince of Condé's engineer corps. During this period, physics, mathematics, engineering and military fortifications were his main interdisciplinary fields within military strategic (geometric) defence. Typical of Carnot's designs for fortresses in the tradition of Vauban is a loop-holed wall, built as the *channel of a fortification*, now called the Carnot wall.

Parallel to science, politics also absorbed Carnot's life: he became one of the first delegates (1791) of the new *Assemblée législative (Legislative Assembly)*. He was also elected (1791) member of the *Comité de l'Instruction Publique (Committee of Public Instruction)*. It was a committee—part of the *Legislative Assembly*—established to reorganize the French education system in this period. Carnot suggested interesting reforms to both the teaching and public education systems that were not implemented. The ferociously combative environment and social instability were not favorable preconditions for new, advanced, ideas.

In Salperwick (North of France) on 1791, May 17th Lazare Carnot married (with a dowry of 30,000 books) Jacqueline Sophie du Pont

(Dupont) also de Lierdt (1764–1813) from Moringhem (North of France). They had two sons: Nicolas Léonard Sadi Carnot (1796–1832), physician/engineer founder of the thermodynamics, and Hippolyte Carnot (1801–1888), an important French political leader. The latter was born in Saint–Omer (North of France) not far from Lille.

The following Diagram 1.1 shows ancestry and descendants of Lazare Carnot from Nolay (France) branch. For our aims it is limited to 1719–1920 (Fig. 1.1):



Diagr. 1.1 Extract of Lazare Carnot family from Nolay (France): 1719–1920. We thank M. Jean Le Bret, member of Carnot's family who gave us (RP) copies of Lazare Carnot's Ascendant (1719–1489) and Descendant (1753–2020) Genealogies

Fig. 1.1 « Le Comte Carnot, membre de l'Institut Royal de France (section Sciences physique et mathématiques—Mécanique) (s. d.) ». *Plate from the original portrait conserved at Académie François Bourdon, Le Creusot—Archives Lazare Carnot. Very kindly authorization by Monsieur Gaetan Carnot, member of Carnot's family*

At the end of 1770s Carnot was busy completing his *Essai sur les machines en general* for his first (lost) edition of 1783 (Fig. 1.11). At the beginning of the 1780s he also participated in a competition organised by the *Académie des sciences*. He wrote two unpublished memoirs: *Mémoire sur la théorie des machines pour concourir au prix de 1779 proposé par l'Académie royale des sciences de Paris* (Carnot 1778 [9]; Fig. 1.9; hereafter 1779) and *Mémoire sur la théorie des machines pour concourir au prix que l'Académie royale des sciences de Paris doit adjuger en 1781*(Carnot 1780[1]; Fig. 1.9; hereafter 1780).

This was also a successful period of important appointments in his military career. He became *capitaine au corps royal du génie* (1783), then in rapid succession *lieutenant–colonel, colonel, général de brigade* and *général de division* (1784; the same year he wrote his famous *Éloge de M. le Maréchal de Vauban*; Cfr. Duthuron 1940).

In 1787 he was an official member of *Académie de Dijon*.

In 1792, the *Legislative Assembly* (1791, 1st October to 1792, 20th September) concluded its activity. From the 22nd of September 1792 to the 2nd of November 1795 the *Convention national* (*National Convention*) governed France, and Carnot was elected the *43rd President of the National Convention* (1794; see Fig. 1.3). He demonstrated his military prowess, for example, participating in a military mission (1792, Bayonne) to improve the current defensive systems against Spanish attacks. One year after, a significant political event was his vote in favour of the death sentence of King Louis XVI (1754–1793).

In 1793 Carnot was elected member of the *Comité de salut public (Committee of Public Safety)* a new committee established by *National Convention*. He was also charged as one of the *Ministers of War* (Culp 1914). He achieved several military victories through the implementation of his singular defensive strategies, especially against the prevailing methods of European armies. Among others, these included a unique massive army, that is the organization of military forces capable of fighting a total war, achieving the neutrality of

Prussia, and interrupting communications with Austria and England. Essentially, it consisted of a substantial army divided by units, which rapidly attacked from the flanks rather than head on. Carnot also saw to—in his capacity of *Minister of War*—several emergencies, such as the scarcity of munitions (due to the lack of saltpetre[2] and copper) and other technical needs. He successfully organized the army and *ad hoc* strategies, including the Northern front, battle of Wattignies, 1793, 15–16 October and came to be known at this time as the Organizer of Victory (Fig. 1.2).

In Arras—North of France, not far from Lille—Lazare Carnot met Maximilien François Marie Isidore de Robespierre (1758–1794). The two officers were both members of the *Société des Rosati d'Arras*, a literary society established in 1778, 12th June. Carnot enrolled in the society in 1786, Robespierre in 1787. The society was essentially inspired by Jean de la Fontaine (1621–1695), Guillaume Amfrye de Chaulieu (1639–1720) and Jean de la Chapelles' (1651–1723) writings. Later on, in the 1790s, especially in the course of Carnot's roles at the *National Convention*, the tension between them became extreme: anti-Prussian Robespierre and anti-English Carnot; and also in regard to Jacobin politics. We should remark that Carnot had shown no opposition to the *la Terreur* until he, and other of his colleagues of the *National Convention*, arrested (1794, 27th July) Robespierre and his twenty-one associates and condemned them to capital punishment by beheading (1794, 28th July).

In 1794, Gaspard Monge, Jacques–Elie Lamblardie (1747–1797) and Lazare Carnot founded the *École centrale des travaux publics*. In 1795 this institution was renamed the *École Polytechnique*, as it is still known (Fig. 1.3).

[2] *Potassium nitrate* (KNO_3) is a nitrogen-containing compound. The niter (from nitrogen as a source) exists in nature as a mineral. Generally, it is referred to as saltpeter or saltpetre.

In 1795 Napoléon Bonaparte (1769–1821) was general in-chief of the *Armée d'Italie* (Army of Italy) located on the Italian border. Due to his political disagreement with Paul–François vicomte de Barras' (1755–1829) reactionary ideas, in the same year, Carnot left the *Comité de salut public*. On 1795, April 11th Lazare Carnot became (1795–1797) one of the five directors of the *Directoire (Directory)*. The latter governed France until 1799. He supported Napoléon's initiatives; he was the only one of the *Directory* to do so (Dhombres and Dhombres 1997; Hicks). The life of this *Directorate* was not easy, due to the several cultural and political differences between the members.

In 1796 (April 30th) Carnot was elected president of *Directory*; on June 1st, his first son, Nicolas Léonard Sadi, was born (Figs. 1.4 and 1.5). His presidency ended on 1796, 29th July.

Sadi Carnot is the father and "inventeur de la Thermodynamique" as noted in the History of *École polytechnique* (Callot 1980, p. 390). In 1824, one year after Lazare Carnot's death, Sadi Carnot's only published work appeared: *Réflexions sur la puissance motrice du feu* (Carnot 1824 [1824], 1978; Girard 1824, Gondinet 1833; Challey 1971; Costabel 1976). He wrote another two (unpublished) manuscripts. The first is *Notes sur les mathématiques, la physique et autres sujets* (Carnot 1878b, pp. 89–102; see also Carnot 1878a; Robelin 1832; Rosenfeld 1941; Rumford 1798). The manuscript is conserved in the archives of the *Académie des science–Archives et patrimoine historique de l'Académie des sciences*, Paris (Gillispie and Pisano 2014). Sadi Carnot wrote crucial details about early ideas on the law of conservation (Gillispie and Pisano 2014).[3] The second manuscript is *Recherche d'une formule propre à représenter la puissance motrice de la vapeur d'eau* (Carnot 1978, pp. 223–234; Cfr. Clément 1819a,b, 1970). In this work, Sadi Carnot indicated a mathematical expression for motive power applicable to heat machines *en*

[3]Recent studies (Pisano's works; Gillispie and Pisano 2014) remarked on some differences between the 1824 edition and the 1878 a manuscript given to the *Académie des sciences* (Carnot 1878a). The manuscripts edited by Gauthier–Villars (Carnot 1878b) are not always reproduced in their entirety. To consult Sadi Carnot's complete manuscripts see Pisano's works; Gillispie and Pisano 2014; see also Carnot 1978, 1986, masterfully edited by Robert Fox.

Fig. 1.2 « Lazare Carnot à Wattignies: portrait à cheval en uniforme de commissaire aux armées par R. Desvarreux (1909) ». *Plate from the original portrait conserved at Académie François Bourdon, Le Creusot—Archives Lazare Carnot. Very kindly authorization by Monsieur Gaetan Carnot, member of Carnot's family*

Fig. 1.3 « Lazare Carnot annonce à la tribune de la Convention la prise de Condé, nouvelle reçue par le télégramme Chape en 1794, gravure (s. d.) ». *Plate from the original portrait conserved at Académie François Bourdon, Le Creusot – Archives Lazare Carnot. Very kindly authorization by Monsieur Gaetan Carnot, member of Carnot's family*

général. This work is very connected to the filial and scientific relationships between Lazare and Sadi on a common scientific project (Gillispie and Pisano 2014), concerning the study of the efficiency of mechanical and heat machines; the project originally belonged to Lazare (*ibidem*). The manuscript was found in 1966 (Gabbey and Herivel 1966). It was presumably written between November 1819 and March 1827 (Gillispie and Pisano 2014): decisive evidence still is lacking to determine the precise date. Generally speaking, it was written before Carnot's publication of 1824 (Gillispie in Gillispie and Pisano 2014, Chap. 3, ft. 42) and after April 1823 (Fox in Carnot 1986, p. 168).[4]

In 1797 (September 4th) three members of the *Directory*—with military support from Charles Pierre–François Augereau (1757–1816)—staged a *coup d'état* called the *Coup of 18 Fructidor*–Year V. They were Paul–François de Barras, Jean–François Rewbell (1747–1807) and Louis–Marie de la Révellière–Lépeaux (1753–1824). Lazare Carnot was removed and obliged to seek protection in Switzerland (Geneva). In this period, he wrote *Réflexions sur la métaphysique du calcul infinitésimal* (Carnot 1797a), in order to explain and justify the role of the mathematics used in the previous *Essai sur les machines en général* (Carnot [1783] 1786).

In 1799 Carnot came back to France and was appointed (1800 April 2nd) by Napoléon as *Minister of War*. He was in charge until October 8th, which included the events of the *Battle of Marengo* (1800 June 14th). Two years later, he did not support *Napoléon's Consular powers for life and descent heritage*: he voted against this proposal. This also was the period of *Principes fondamentaux de l'équilibre et du mouvement* (Carnot 1803a) and *Géométrie de position* (Carnot 1803b).

Between 1800 and 1806 Lazare Carnot devoted himself to the geometry inspired by earlier mechanical and mathematical works, such as

[4]Charles Gillispie argued (*Ibidem*) the role played by the concepts of reversibility and incompleteness and completeness of a cycle. Robert Fox (Carnot 1986, pp. 168–169) argued his "tentative inclination to suppose" (Carnot 1986, p. 169) suggesting a date between November 1819 (when Clément lectured as a professor at *Conservatoire des arts et métiers* in Paris) and 8 March 1827, when the latter acknowledged a "distinguished mathematician" (Carnot 1986, p. 167) for information which added to his lecture. However, whether the composition of the unpublished manuscript was elaborated before or after (or during: Pisano) the composition of *Réflexions sur la puissance motrice du feu* is still an outstanding question that requires resolution.

those on equilibrium, analysis and gemotery . He wrote four masterpieces (Carnot 1800, 1801, 1803a, 1806).

In 1800 Carnot addressed a remarkable letter to Charles Bossut (1730–1814) in which new results and intellectual standpoints in geometry, particularly in trigonometry (Carnot 1800, pp. 401–421; Cfr. Bossut 1800a, b) were presented.

In 1801 he wrote *De la corrélation des figures de géométrie* (Carnot 1801), and his second son, Lazare Hippolyte, was born (Saint–Omer, April 6th). In this book he presented several of Euclid's theorems and various forms of a theorem, later called as *Carnot's theorem*,[5] or *the law of cosines* (cfr. Carnot 1801, § 220, pp. 162–164). This remarkable theorem (Lagrange 1813, p. 406) which referred to the triangle—such as the generalisation of Menelaus from Alexandria (ca. 70–140; Chemla 1998, 1990)—was also presented in the *Géométrie de la position* (Carnot 1803b, p. 168; p. 291; pp. 436–437), where it is fully derived and written in the modern forms. As such, the latter is considered to complement the previous *De la corrélation des figures de géométrie* (Carnot 1801). Another important work on the subject was *Mémoire sur la Relation 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).

Lazare second's son Hippolyte Carnot had an excellent political career: *Député* (1839–1849; 1850–1851; 1871–1875), *membre du Corps législatif* (1864–1869), *Ministre de l'instruction publique* (1848) and *Sénateur inamovible* (1875–) and wrote several works on politics and on teaching.

[5] As an extension of Pythagoras's theorem for the case of triangles, it concerns the lengths of the sides of a triangle to the cosine of one of its angles. It is—in some manner—also attributed to al–Biruni (ca. 973–1048), al–Kash (ca. 1380–1429) and François Viète (1540–1603); Bonaventura Cavalieri also presented it and its complete proof in *Trigonometria plana, et sphaerica, linearis and Logarithmica* (Cavalieri 1643; see also 1635). It is also possible to find it in the Euclid's *Elements*, Proposition 13, Book II (see also Proposition 12). The *théorème japonais de Carnot* is a theorem presented in *Géométrie de position* (Carnot 1803a, p. 168) related to the proof of the *Japanese theorem for concyclic polygons*. Lagrange appreciated this theorem very much (Lagrange 1813, pp. 406–407). On the contrary, Cauchy was very critical of the theorem: "In the various treatises of mechanics it is taught that live forces are lost every time bodies undergo a sudden change in velocity, and that this loss of live force is the sum of the live forces due to the velocities that are lost. But this proposition, which has been named Carnot's theorem, is evidently inexact as is the demonstration on which it purportedly rests. (Cauchy 1829, p. 116).

Fig. 1.4 « Lazare Carnot en uniforme de membre du Directoire exécutif (s. d) ». *Plate from the original portrait conserved at Académie François Bourdon, Le Creusot—Archives Lazare Carnot.Very kindly authorization by Monsieur Gaetan Carnot, member of Carnot's family*

Fig. 1.5 Sadi en uniforme de polytechnicien en 1813, reproduction d'après Boilly (s. d). ». *Plate from the original portrait conserved at Académie François Bourdon, Le Creusot—Archives Lazare Carnot. Very kindly authorization by Monsieur Gaetan Carnot, member of Carnot's family*