

The Life and Science of LÉON FOUCAULT

The Man Who Proved the Earth Rotates

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Chapter 1

Introduction

Henri Sainte-Claire Deville leaned back in his heavy academician's chair, sick with emotion. It was a grim Monday afternoon, a grey March day, so different from the carefree warmth of his childhood days as a colonial in the Caribbean.¹ There he sat, amid the wood-panelled splendour of the elegantly proportioned chamber where he and his fellow members of the exalted Académie des Sciences were holding their regular weekly meeting. The damp vapours rising from the River Seine flowing silently a hundred metres away, and the sharp bite of the watery west wind would normally have found a chilly echo in the uncertain light of the flickering candles, which the Académie, in its stolid perversity, continued to use to illuminate its deliberations, even though this was the year 1868. But the 49-year-old chemist was hot. The chamber was packed. The public had read the newspapers and had turned up in force. People were standing in the aisles. Sainte-Claire Deville held no illusions: they had come to enjoy a cock fight, and he was one of the cocks. It was only a small comfort to know that the spectators were mostly on his side, as were the newspapers and magazines. In an epoch when any opinion might be wrapped in a cocoon of polite words, there had been no misunderstanding the full meaning when *Les Mondes* had reported of the previous week's meeting that:

In a solemn and sorrowful voice, M. Henri Sainte-Claire Deville read out an eloquent protest made in the name of M. Léon Foucault and his friends. It was an outcry against the admittedly indirect accusations from which M. Le Verrier had felt himself unable to spare [M. Foucault].²

There had been a religious silence then. The public benches had been empty, and, unaware of what was in store, the odious Le Verrier had been absent. This week, the Imperial Senator and Director of the Paris Observatory was present, and as soon as the Permanent Secretary had finished reading out the correspondence, he had jumped up and been given the floor. Le Verrier had just boomed out that Sainte-Claire Deville's intervention had said 'nothing new, was unnecessary', adding, preposterously, that it was 'absolutely unjust'.



Fig. 1.1. The prominent dome to the right of this 1860s engraving of Paris is part of the Institut National, which included the Académie des Sciences as one of its constituent academies. The Institut marked the northern limit of the Latin Quarter on the left bank of the River Seine. The bridge in the foreground is the Pont du Carousel; behind it is the Pont des Arts. The imposing building on the left is part of the Palais des Tuileries. The rectangular, box-like boat moored in the left foreground is a floating wash house.

‘What does he know?’ thought Sainte-Claire Deville, his anger flaring. ‘Foucault – my dear, good, *quaint* friend Foucault – is hardly cold in his grave after a prolonged and difficult death. *I* was his confidant, *I* know what troubles he suffered at the hands of the unspeakable Director of the infernal Observatory, but here is the dictator himself claiming they always enjoyed the most cordial relations.’

Le Verrier had prepared his remarks on paper, and it was obvious he was approaching their end. Eyes everywhere were turning to Sainte-Claire Deville. He swung his weight forward in his seat, readying himself to get up. ‘Can I contain myself?’ he wondered, ‘I must stick to my written text.’ The candles flickered. The busts and statues looked down impassively. ‘M. Sainte-Claire Deville has the floor,’ the Chairman announced.

* * *

‘No man is an island,’ sang the poet. We cannot hope to understand who this Foucault was, the significance of his achievements, and why his friends were so incensed, without also understanding his world and its preoccupations. This world was mid-nineteenth century France and will be foreign to many readers, so let us set the scene with some historical background.

The Ancien régime

Let us begin in the seventeenth century with Louis XIV, the *roi soleil*, or Sun King, whose court was characterized by lavish entertainments and sumptuous pleasures. Behind the throne of this absolute and initially debauched monarch was an active and intelligent finance minister, Jean-Baptiste Colbert (1619–83). Colbert saw that the basis of power was wealth, and that the basis of wealth was production. He endeavoured to advance national and regal wealth

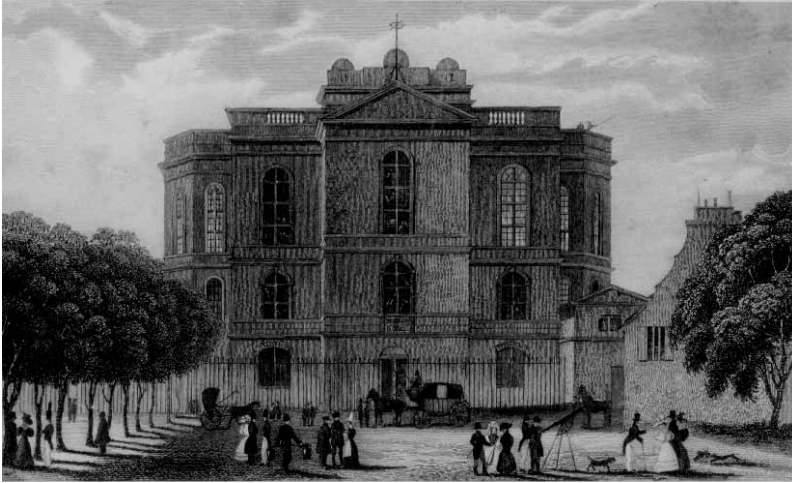


Fig. 1.2. Paris Observatory in the 1840s, viewed from the north. When completed in 1672 it was outside Paris and enjoyed an open horizon. The architect was Claude Perrault, brother of the fairy-tale teller; his building is more grand than practical.

with sound, forward-looking accounting, and via the promotion of industry, transport and trade. Among the numerous institutions founded through his influence were the Académie Royale des Sciences, or Royal Academy of Sciences, in 1666,³ and the Observatoire de Paris, or Paris Observatory, in 1667.⁴ The Academy was founded with the practical aim of applying science to industry in order to improve manufacturing and increase exports. No utilitarian goal constrained the Observatory, however, where the astronomers were free to study whatever they wished.

The Academy initially found lodgings near the Louvre, but the Observatory needed purpose-built quarters (Fig. 1.2). The Italian-born Jean-Dominique Cassini stamped his mark on the early Observatory.⁵

The French Revolution

The causes of the French Revolution in 1789 have been debated at length. The absolutism of the Bourbon kings and the inflexible grip of the nobility on its privileges had produced widespread discontent amongst the middle classes who were the mainspring of economic production. The eighteenth-century enlightenment advanced the supremacy of reason against the inequality and injustice of established authority and institutions. The scorn of superstition and passionate belief in the benefits of science and reason were most notably expressed in the seventeen volumes of the *Encyclopédie*, or Encyclopedia, published between 1751 and 1765; its attempted suppression epitomized the rigidity of the ruling classes. In 1789 May, social unrest combined with urgent financial problems to persuade Louis XVI to summon the *États généraux*, or States-General. This advisory body of the church, the nobility, and city corpo-

rations (in effect, the middle classes) was traditionally summoned to rubber-stamp controversial royal policy, but had not met for over 150 years. The King and nobles lost control; and the *États généraux* transformed itself into the *Assemblée Nationale Constituante*, or National Constitutional Assembly, intent on reform. The fortress-prison of the Bastille in eastern Paris, emblematic of the old order and its injustices, was stormed on July 14.

The National Assembly tried to create a constitutional monarchy, but war with Austria and the King's attempted flight and efforts to mobilize foreign military support in 1792 led to more radical policies. A Republic was declared and the King was guillotined, but Revolutionary government was unstable as different factions vied for power. By the standards of modern terror, the French Revolution was comparatively bloodless, but scientists executed included the chemist Antoine Lavoisier and several astronomers (Fig. 1.3).

For the Revolution, the *Académie Royale des Sciences* was a suspect institution and was abolished in 1793 along with all other learned academies, literary societies, universities and medical schools. Suppression was short lived, however, and two years later the *Académie des Sciences* was resurrected as one of five academies forming the newly created *Institut National*, or National Institute (now the *Institut de France*, visible in Fig. 1.1). Other academies included the *Académie Française*, devoted to literature, and the *Académie des Beaux-Arts*, dedicated to fine art. Amongst institutions created by the Revolution, the so-called *grandes écoles* (literally, major schools) were set up to provide and develop technical services and knowledge, as well as to train the administrators, scientists and engineers that the new order required. These institutions included the *École Normale Supérieure*, set up to educate an intellectual élite who would go on to propagate technical knowledge and the spirit of enlightenment as secondary and tertiary teachers throughout France; the *École des Mines*, for mining; and the *Conservatoire des Arts et Métiers*, established to act as a repository of scientific and industrial devices, to encourage technical innovation, and to spread scientific, technical and industrial know-how. There were also some older institutions. The *École des Ponts et Chaussées* (bridges and carriageways), set up to train civil engineers, dated from 1747. But the pick of the Revolutionary institutions was the *École Polytechnique*, founded for instruction in science and engineering, and which during the first half of the nineteenth century was a world leader in scientific research, most notably in mathematics and mechanics. Entry to the *grandes écoles* was by competitive examination and provided a route for young men of intelligence, but little wealth, to rise in the new, meritocratic France.

Desiring to 'make our shipping flower' and to develop navigation and trade, the Revolution founded a *Bureau des Longitudes* (Board of Longitude). The Bureau was to be in charge of the Republic's astronomy, a discipline which the Revolution felt had already produced so many benefits: it had chased



Fig. 1.3. Jean Sylvain Bailly, astronomer and Mayor of Paris, guillotined on the Champ de Mars in 1793. Other astronomers amongst the Revolution's twelve thousand or so victims were J. B. G. Bochard de Saron and Johan Wilhelm Wallot.⁶

away superstition, and it had provided theoretical foundations for geography and navigation, even though the means of determining longitude at sea were still imperfect. The Bureau was equipped with a staff and a budget and given charge of the Paris and other observatories, such as the naval ones at Brest and Toulon.⁷

The Revolution introduced a uniform system of weights and measures to promote trade, but the metric system was slow to take root. In his newspaper articles, Foucault often used pints, feet, leagues, pounds and toises, and his pendulums were engineered in inches and lines.

Napoléon I

The political disorder of the Revolution ended in 1799 with a *coup d'état* by Napoléon Bonaparte and conspirators. A Corsican by birth, Bonaparte had won prestige by leading a brilliant military campaign in Italy with decisive victories over the Austrians, and from an expedition aimed to strike at Britain's wealth by occupying Egypt and closing the route to India. Although the Egyptian expedition had been thwarted when Nelson sank the French fleet, it had had the merit of audacity. Bonaparte's new constitution was apparently liberal, but in fact gave him the bulk of power as First Consul, elected for ten years. During the next few years he set about his long-lasting reform of the legal system, the church, education and the administration of the French state. In 1804, with the pope reduced to the rank of a spectator, he crowned himself Emperor of the French. Already at war with Britain, he set about dominating continental Europe. Initial success was followed by ruin, and in 1814 he abdicated. He returned after a short exile in Elba, but defeat at the battle of Waterloo ended his reign after only one hundred days.

Napoléon had intellectual aspirations and hoped that France would be the seat of all future science. While in Cairo he founded a local Institut d'Égypte, modelled on the Institut National. He famously said that:

To divide the night between a pretty woman and a starry sky, and to spend the day working on one's observations and calculations, seems to me to be heaven on earth. Of all the sciences, astronomy is the one which has been most useful to reason and commerce. Astronomy particularly has need of long-distance communications and the Republic of Learning...⁸

The Marquis de Laplace (Fig. 1.4), pre-eminent at the time in French physics, sent the first two volumes of his *Mécanique céleste*, or Celestial Mechanics, to Napoléon, who with wit responded, 'The first six months which I can spare will be employed in reading it.'⁹ Napoléon re-established the universities, with the doctorate as their highest degree. The university in Paris was the Sorbonne, with origins dating back to the thirteenth century.



Fig. 1.4. Pierre Simon Laplace (1749–1827), the pre-eminent French physicist at the end of the eighteenth and beginning of the nineteenth centuries, but a man of ungenerous character.

The Restoration

The Bourbon restoration brought Louis XVI's brothers to the throne: first Louis XVIII; and then Charles X in 1824. Foucault was born in 1819, midway through Louis XVIII's reign. Charles X's claim to rule by divine right and his suppression of liberties provoked the 'July Revolution' in 1830 and his abdication after five days of bitter street fighting in Paris. His elected successor, Louis-Philippe, possessed astonishing republican, royalist *and* liberal credentials. Foucault lived his formative years and early adulthood under this 'citizen king's' rule. But during this reign political corruption, judicial malpractice and a restricted parliamentary franchise united liberals and extremists in calls for reform. In 1848 February, riots caused Louis-Philippe to flee to England. One legacy of his reign, however, was the re-establishment of the Collège de France. Unlike the universities or *grandes écoles*, the Collège de France offered and offers no degrees or diplomas. The professors taught as they saw fit in classes open to all.

François Arago

At this point it is appropriate to introduce François Arago (Fig. 1.5), who was Director of the Paris Observatory from 1843 until his death in 1853. He was born in 1786 at Estagel in the Roussillon, adjacent to the Spanish border, and



Fig. 1.5. François Arago (1786–1853): astronomer, physicist, politician, Permanent Secretary of the Académie des Sciences and Director of the Paris Observatory.

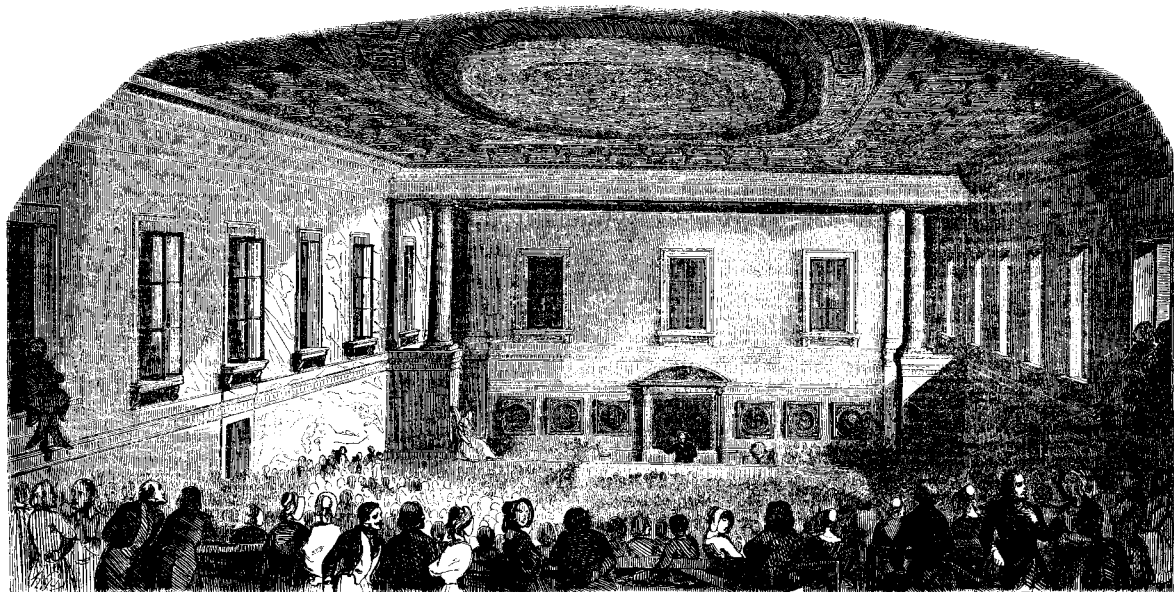


Fig. 1.6. Was Foucault among the audience represented in this engraving of one of Arago's public astronomy lectures? The purpose-built lecture theatre at the Observatory could hold 800 people.

spent his adolescent years in Perpignan, where his father was treasurer of the mint. He entered the École Polytechnique with ambitions for a military career. Soon, however, his staunchly republican views collided with political authority. Bonaparte as First Consul was preparing his transformation to Emperor. Arago was among those at the École who refused to sign a petition urging this change. Bonaparte resolved to dismiss these student republicans, but on seeing a list of their names and marks, with Arago first in his year, he sighed, 'One can't send down the top student. Oh, if only he'd been at the bottom.'¹⁰

Arago's mathematical prowess was such that within two years he was offered a post at the Paris Observatory to work on the refraction of light by the Earth's atmosphere with Jean-Baptiste Biot (1774–1862). Triangulation of the Paris meridian was required, supposedly for the practical implementation of the metric-system metre as one ten-millionth of the distance from pole to equator, but really for investigation of the Earth's flattening.¹¹ The meridian had already been surveyed from Dunkirk to Barcelona. Early in 1806, Arago and Biot left for Spain to extend the triangulation to the Balearic Islands. The heroic enterprise was completed, but Arago's return to France was obstructed by French military involvement in Spain in 1808. After several escapes and imprisonments, attempted poisoning, capture by pirates, and two passages through Algiers, Arago regained French shores in 1809 July.¹² Two months later, he was elected to the Académie des Sciences,¹³ more in recognition of the romance of his exploits than for any fundamental contribution to science. In the 1810s his scientific work was mostly in optics and in later

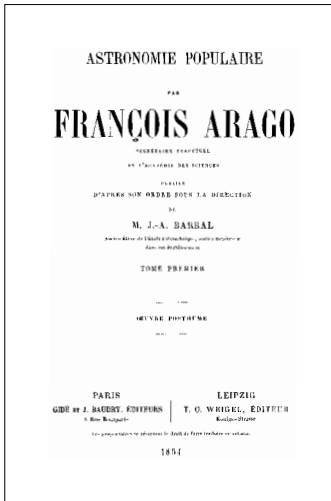


Fig. 1.7. In his final years, Arago dictated his astronomy lectures to his niece, Lucie Laugier, foreseeing that they would provide substantial royalties for his heirs.¹⁸ They were published posthumously in four volumes.

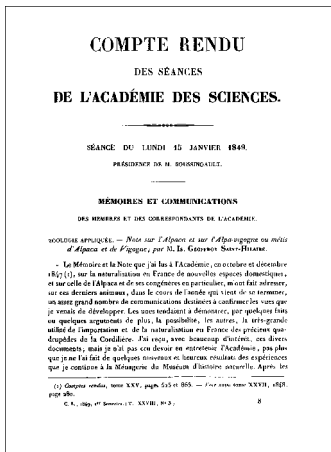


Fig. 1.8. Founded by Arago, the *Comptes rendus* reported the Academy's weekly meetings.

chapters we shall discover some of the rôle he played in the development of the transverse wave theory of light.

In the 1820s Arago's interest turned to electromagnetism. In 1830 he was made one of the two Permanent Secretaries of the Academy, where he was able to wield considerable influence. As one commentator noted, 'The President [of the Academy] is only a man of straw, whilst the secretaries direct everything and are omnipotent: they are the true masters of the house.'¹⁴

Foucault later wrote:

Arago was one of the first to realize that science would not prosper in the depths of laboratories, that it would wither even in the solitude of Academies, and that after having given the world steam power, railways and the electric telegraph, science still needed to be talked about, even by the uneducated.¹⁵

Beginning in 1812, Arago delivered public lectures on astronomy, as required by the Act that had established the Bureau des Longitudes. They were exceptionally successful, and from 1841 until the last series in 1846 they were delivered in a 'spacious, elegant and practical' lecture theatre which had been specially constructed for the purpose at the Paris Observatory (Fig. 1.6).¹⁶ The lectures were published posthumously, entitled *Astronomie Populaire* (Popular Astronomy, Fig. 1.7).

While approved members of the public had been allowed to attend the Monday meetings of the Academy from 1809, Arago admitted everyone who cared to turn up, and also the press. In 1835 he founded the *Comptes rendus*, or weekly printed reports of these meetings, which over time were a great influence in standardizing forms of scientific presentation (Fig. 1.8).

The rise of astrophysics – or physical astronomy, as it was also called – is often associated with the introduction of spectral analysis into astronomy following the clear formulation of empirical laws for the absorption and emission of radiation in 1859 by Gustav Kirchhoff in Heidelberg. But 'Arago introduced physics into astronomy', as a later director of the Paris Observatory noted.¹⁷ Previously astronomers had been chiefly concerned with the movements of the stars and planets, seeking to explain them in their minutest details by Newton's laws of gravitation and motion. Arago used photometry and polarimetry to try to fathom the physical nature of celestial bodies, and showed, for example, that the Sun's surface was not solid but gaseous.

Drawn into politics by his younger brothers, Arago was elected *député* (representative) for the Pyrénées-Orientales and then for the 12th *arrondissement* (or district) of Paris after the 1830 revolution.¹⁹ His politics were left-wing and republican, but he believed in public order and moderate change. He was a member of the provisional government in the newly declared Second Republic in 1848. In this capacity he promoted and signed the decrees abolishing slavery in the French colonies and flogging in the navy. We shall see in

Chapter 6 that Foucault welcomed this government favourable to the middle classes and peasant proprietors.

Napoléon III

The Second Republic was short lived. Attempts to disperse the unemployed from Paris into the provinces resulted in a workers' revolt in 1848 June and a brief civil war conducted with relentless cruelty. The upshot of these 'June Days' was a general desire for strong government, which a few months later translated into the election to the French Presidency of Prince Louis-Napoléon Bonaparte. This unusual man was the nephew of Napoléon I and had been raised abroad. He entertained no doubt but that his Napoleonic destiny was to rule France. In 1836 he had crossed the border into Strasbourg and in 1840 he had landed in Boulogne, in both cases expecting to foment rebellion among the troops and be swept to power. His reward in 1840 was imprisonment in the Château of Ham, in northern France, until his escape six years later disguised as a workman. Louis-Napoléon was no common prisoner, however. While in Ham he found occasion to sire two illegitimate children and to study science (Fig. 1.9). Napoléon I had said that had he his life to live again, he would have thrown himself into the study of the exact sciences.²⁰ As we shall see, his nephew maintained this interest in science and later supported Foucault, Pasteur and others in their scientific endeavours.

Three years after his election as Prince-President, Louis-Napoléon overthrew democratic government in a *coup d'état* during the night preceding 1851 December 2. The *coup d'état* was legitimized in a massively favourable plebiscite, as was the restoration of the Empire a year later and Louis-Napoléon's enthronement as the Emperor Napoléon III.²²

The Second Empire is a considerable embarrassment in France even today. Perhaps this is because it is difficult to believe that a free people should have voted for a hereditary head of state, perhaps it is because of the perceived dishonour with which the Empire ultimately disintegrated – through a hopeless war against the Prussians cleverly provoked by Bismarck, ending in military defeat at Sedan in 1870. But the two decades over which the Second Empire endured were an extraordinary time. Louis-Napoléon has variously been described as 'strange and enigmatic', an 'amiable adventurer',²³ or, most memorably, as 'Napoléon le Petit' (Napoléon the Small) by Victor Hugo, one of his regime's most vociferous exiles. Yet Louis-Napoléon's heartfelt desire was for progress and to improve the lot of the masses while maintaining social order and stability, aspirations outlined in his book *De l'extinction du paupérisme* (On the elimination of poverty). As Emperor, he built workers' villages and tried to introduce free, compulsory primary education. Despite numerous military adventures, his general aim was for a more just and less volatile commu-



Fig. 1.9. Louis-Napoléon Bonaparte (1808–73), the future Emperor Napoléon III, studying electricity in his prison laboratory at Ham in the 1840s. In a report to the Academy he complained that his readings were perturbed by the iron bars around the windows.²¹

nity of nations based on the self-determination of peoples; and he was sickened by the sufferings of war. His reign was a period of enormous technical, industrial and commercial expansion, albeit accompanied by high-level corruption. It was also a time of gaiety, crinoline and fêtes. The energetic could attend one of Paris's numerous *bals*, or public dances; one of the most famous, the Jardin Bullier, was located only 500 metres from the Observatory. Foreign visitors to Paris eyed the *grisettes* – young unmarried women of no particular fortune earning a modest living in the city and keen to enjoy themselves, which, unhindered by middle-class conventions, they did. Paris is the splendid city it is, in part because of Second-Empire replacement of dank and narrow streets by light and airy boulevards, and the installation of proper drains. The Expositions Universelles of 1855 and 1867 were showcases for France's agricultural and industrial strength and associated prosperity and modernity. Foucault died in 1868. The last twenty years of his life were essentially those of the Second Empire, and he was one of the Empire's best known and most popular savants.

The state of technology

The mid-nineteenth century was the daybreak of the technological manner in which we now live. In 1846 a Parisian newspaper, *Le National*, listed the great industrial innovations of the previous half-century: the improvement of underwater cements; the application of the steam engine to sea and land transport; the application of electricity to electroplating and telegraphy; and the discovery of the daguerreotype. The daguerreotype and electroplating feature in Chapters 3 and 4, but the other innovations contributed to the nineteenth-century's rapidly improving communications. Rivers were crossed with stronger bridges and viaducts built using better hydraulic mortars. The first railway from Paris was completed in 1837 and ran some twenty kilometres to Saint-Germain-en-Laye. It was soon followed by two competing lines to Versailles – and the first serious French railway accident – and then, in 1843, by railways to the much more distant Orléans and Rouen. By 1870, the network had extended to some 22 000 km. The Alps were pierced by tunnels at Semmering and Mont-Cenis; the sea-route to India was halved when the Suez Canal opened in 1869. From 1845 onwards, the movable paddles of optical telegraphs read from a distance through a telescope were replaced by electric wires able to transmit signals over far greater distances. Improved sanitation and nutrition reduced disease while surgery was revolutionized by anaesthesia and later by asepsis. The output of agricultural and manufactured goods grew with mechanization and the chemical industry flowered. To Foucault's obvious delight, science and industrialization were making the world a materially better place.