Robert Fox
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I

Scientific Enterprise and the Patronage of Research in France 1800-70

In the mid-1860s French scientists came, quite suddenly, to see the state of scientific research in their country as a national scandal. In 1868, in *Le budget de la science*, Louis Pasteur wrote passionately of the " suffering " and " penury " of the deprived community for which he considered himself a spokesman.[1] With no financial support for their experiments and with access to only the most rudimentary laboratory facilities, the scientists of France were like soldiers without arms, sacrificing health and personal fortune in their dedication to research. The remedy, for Pasteur, was clear: the financial provision for research laboratories—" temples of the future, of wealth, and well-being "[2]—had, quite simply, to be drastically increased. In all this Pasteur was by no means alone. Indeed, his criticism was only one product of a campaign of protest and often harsh recrimination which involved nearly all of the country's leading scientists, as well as many other intellectuals, and which culminated in the remarkable meeting of the Académie des sciences on 6 March, 1871, just five weeks after the end of the Franco-Prussian war, at which member after member, including Henri Sainte-Claire Deville, Jean-Baptiste Dumas, and Charles Hermite, rose to speak bitterly of the parlous state of French science.[3]

In nearly all the complaints of the 1860s there was a strong common theme: admiration for the successes of the German research schools and the peculiarly German ideals of *Wissenschaft* and university-based research united the scientists of France and their sympathisers,[4] as it united so

[1] Pasteur, Louis, *Le budget de la science* (Paris: Gauthier-Villars, 1868), p. 5.

[2] *Ibid.*, p. 4.

[3] *Comptes rendus hebdomadaires des séances de l'Académie des Sciences*, LXXII (1871), pp. 231–239 and 261–269.

[4] See, for example, Renan, Ernest, " L'instruction supérieure en France. Son histoire et son avenir ", *Revue des deux mondes*, 2e période, LI (1864), especially pp. 80 and 86–89. Although my subsequent references are to the article as it appeared in the *Revue des deux mondes*, it may also be consulted in Psichari, Henriette (ed.), *Oeuvres complètes de Ernest Renan*, 10 vols. (Paris: Calmann-Lévy, 1947–1961), Vol. I, pp. 69–97. Admiration for Germany is also evident in Pouchet, Georges, " L'enseignement supérieur des sciences en Allemagne ", *Revue des deux mondes*, 2e période, LXXXIII (1869), especially pp. 442–443, and Papillon, Fernand, " Les laboratoires en France et à l'étranger ", *ibid.*, 2e période, XCIV (1871), especially pp. 596–600 and 605–606. There were frequent references to the success of German science in the statements made at the Académie des sciences on 6 March, 1871. See also Pasteur, L., *op. cit.*, p. 4, and Pasteur's article of 1871 in the Lyons newspaper *Salut public*, of which passages are reproduced in Vallery-Radot, René, *La vie de Pasteur* (Paris: Hachette, 1900), pp. 278–280. For a more general study of French attitudes towards German science, see Paul, Harry W., *The Sorcerer's Apprentice: The French Scientist's Image of German Science 1840–1919* (Gainesville: University of Florida Press, 1972).

many of the educational reformers of Britain at precisely the same time.[5] French studies of German practices in scientific research and education abounded in this period, and, almost without exception, they took the form of eulogies. This was true equally of the abundant periodical literature[6] and of more formal reports, such as those on German medical education by Sigismond Jaccoud and Paul Lorain, published in 1864 and 1868 respectively,[7] and that of Adolphe Wurtz on German university laboratories, published in 1870.[8]

In support of their view that greatly increased financial support for their work was urgently needed, the French scientists had ample evidence. Learned papers, books, and highly trained students flowed in abundance from the research schools of universities like Giessen, Berlin, Heidelberg, Göttingen, and Bonn, and in some cases had been doing so for over 20 years. Although the point was rarely conceded by the protesting scientists, the excellence of German science had even been recognised, albeit slowly and with great caution, in certain government circles. It was at the request of the Minister of Education, Gustave Rouland, that Jaccoud undertook his investigation of the German medical faculties in 1863,[9] and from 1863 to 1869 the Ministry of Education was headed by Victor Duruy, a man who had imbibed a lasting admiration for German scholarship through his own historical research and, more particularly, through his youthful contact with Jules Michelet, his professor at the École normale in the early 1830s.[10] Not surprisingly, it was Duruy who, in 1868, commissioned the report by Wurtz,[11] which was perhaps the most telling of all the indictments of the conditions for laboratory research in France.

Now it could be objected that the statements of such men as Pasteur and Wurtz are not reliable evidence since, like most French scientists in the late 1860s, they had a strong personal interest in encouraging government intervention in science on a large scale and they were quite openly

[5] See, for example, Huxley, Thomas Henry, " A Liberal Education; and where to find it " (1868), in his *Lay Sermons, Addresses and Reviews* (London: Macmillan, 1895), pp. 43–44; Arnold, Matthew, *Schools and Universities on the Continent* (London: Macmillan, 1868), pp. 222–232; Playfair, Lyon, *On Teaching Universities and Examining Boards* (Edinburgh: Edmonston and Douglas, 1872), pp. 23–24 and 30–31; and, on Mark Pattison's conversion to German ideas of the university, Sparrow, John, *Mark Pattison and the Idea of a University* (Cambridge: Cambridge University Press, 1967), pp. 105–149.

[6] See, for example, Renan, Ernest, *op. cit.*, pp. 80 and 86–89; Pouchet, George, *op. cit.*, pp. 442–443; and Papillon, Fernand, *op. cit.*, pp. 596–600 and 605–606.

[7] Jaccoud, Sigismond, *De l'organisation des facultés de médecine en Allemagne* (Paris: Delahaye, 1864), and Lorain, Paul, *De la réforme des études médicales par les laboratoires* (Paris: J. Bonaventure, 1868).

[8] Wurtz, Charles Adolphe, *Les hautes études pratiques dans les universités allemandes* (Paris: Imprimerie Impériale, 1870).

[9] Jaccoud, S., *op. cit.*, *passim.*

[10] On Michelet's admiration for Germany, which was shared in the 1820s and 1830s by Romantics like Victor Hugo, Gérard de Nerval, and Jean Jacques Ampère, see Monod, Gabriel, *La vie et la pensée de Jules Michelet 1798–1852*, 2 vols. (Paris: Champion, 1923), Vol. I, pp. 145–169. Duruy most handsomely acknowledged his debt to Michelet in a letter of 22 April, 1884, probably to Monod, reproduced in Monod, G., *op. cit.*, Vol. I, p. 257.

[11] Wurtz, C. A., *op. cit.*, pp. 1 and 3.

involved in polemical activity to that end.[12] However, in this paper I shall not question the opinion, shared by Pasteur, Wurtz, and the great majority of their fellow scientists, that on the eve of the Franco-Prussian war the provision for laboratory research in France was lamentable by the contemporary standards in German universities. What I shall question, with special reference to the physical sciences—though it is difficult to treat them in isolation—is whether the commonly drawn contrast between the apparently flourishing state of scientific research under Napoleon and its condition in the 1860s can be explained in terms of government attitudes, in the way that both Pasteur and Wurtz, for example, suggested.[13] I shall argue that even during the First Empire, governmental patronage of science was rarely enlightened and only intermittently generous and that the indifference which was complained of so bitterly in the 1860s, far from being something new, had in reality been characteristic of the attitudes of governments throughout the century. Of course, the degree of indifference varied. For example, the governments of the Second Empire—especially while Duruy was Minister of Education— were more responsive to the needs of scientific research than were those of the restored Bourbons. But even when nineteenth-century French governments did act as the patrons of research, they normally did so in response to external pressures, such as the personal approaches that were made to Napoleon III by Claude Bernard and Henri Sainte-Claire Deville,[14] and they acted on their own initiative only on the rare occasions when a piece of research promised a solution to some urgent problem.[15]

So the task, as I see it, is to ascertain why from the 1820s the demands made on governments and the institutions of science were so slight, whereas before 1815 men of high intellectual and social standing, like the mathematician and physicist Pierre Simon de Laplace and the chemist Claude Louis Berthollet, were content to devote themselves to research and to the far from easy task of acquiring good facilities both for their own work and for that of their disciples. With this as my problem, I shall pay special attention to certain attitudes towards research which

[12] I discuss the difficulties encountered by Pasteur and Wurtz in their personal research later in this paper. In the late 1860s Pasteur, as administrator and director of scientific studies at the École normale, was trying to promote research there and to free the institution from its traditional preoccupation with teaching. Wurtz was engaged on the investigation of research facilities in German universities; see Wurtz, C. A., *op. cit.*

[13] See Pasteur's contribution to the *Salut public*, quoted in Vallery-Radot, R., *op. cit.*, p. 279, and Wurtz, C. A., *op. cit.*, pp. 6 and 12–13.

[14] See Olmsted, James Montrose Duncan and Olmsted, E. H., *Claude Bernard and the Experimental Method in Medicine* (London, New York, and Toronto: Abelard-Schuman, 1952), pp. 126–127, and Liard, Louis, *L'enseignement supérieur en France 1789–1889*, 2 vols. (Paris: Armand Colin, 1888–1894), Vol. II, p. 273. On the campaign by a group of scientists including Bernard, Victor Regnault, and Jean-Baptiste Dumas, which led to the appointment of Marcellin Berthelot to the newly established posts at the Collège de France, first as a lecturer in 1863, then as a professor of organic chemistry in 1865, see Velluz, Léon, *Vie de Berthelot* (Paris: Plon, 1964), pp. 63–69.

[15] Two such occasions, referred to later in this paper, occurred when Dulong and, later, Regnault were commissioned to perform research concerned with the operation of steam-engines.

came to be held by French scientists during the second quarter of the nineteenth century. Although I do not claim that these new attitudes were alone responsible for France's loss of the supremacy in scientific research which she enjoyed in Europe during the early years of the nineteenth century, I do believe that they contributed greatly, and in a way which has not been recognised before, to the French failure to respond to the growing German challenge of the 1830s and 1840s. In so far as my paper directs attention to the attitudes of scientists themselves, and assigns to their paymasters a more passive role than is customary, I hope that it will also serve a more general purpose in pointing to the importance of personal motivation in nineteenth-century French science. For it is my belief that it was individual initiative, rather than government sponsorship, which brought French science its successes early in the century, and it was the lack of such initiative which brought French science to its unhappy state during the Second Empire.

Individual Initiative and Public Patronage under Napoleon

The excellence of French science in the age of Napoleon has rarely been doubted.[16] It was an age in which not only Laplace and Berthollet but also Jean-Baptiste Biot, Siméon Denis Poisson, Étienne Malus, Joseph Louis Gay-Lussac, Louis Jacques Thenard, Georges Cuvier, Joseph Fourier, and Jean-Baptiste Delambre, as well as members of an older generation like Gaspard Monge, Lazare Carnot, and Antoine François de Fourcroy, were all at the height of their powers. It was an age of great discoveries, notably Gay-Lussac's law of combining volumes and Malus's discovery of the polarisation of light, and of major experimental investigations like the work of Gay-Lussac and Thenard on chlorine and the alkali metals and the study of the specific heats of gases undertaken by Delaroche and Bérard for the Institut's prize competition of 1812. Among the books published were the first four volumes of Laplace's *Traité de mécanique céleste* (1799–1805) and Berthollet's *Essai de statique chimique* (1803); and the many distinguished contributions which appeared in the journals of the period included all Malus's writings on mathematical physics and some of the most important of the papers of Laplace, Biot, and Poisson.

For these successes Napoleon himself has received much credit. He was eulogised in his own lifetime, most fulsomely perhaps in the reports on the state of science which Delambre and Cuvier presented to the Emperor

[16] However, for a particularly unfavourable view of Napoleonic science see [Moll, Gerrit], *On the Alleged Decline of Science in England. By a Foreigner* (London: T. and T. Boosey, 1831), pp. 6–7, 10–16, 18–19, and 21–33; also Moll's letters to Michael Faraday, dated 24 December, 1830, and 13 November, 1831, in Williams, L. Pearce (ed.), *The Selected Correspondence of Michael Faraday*, 2 vols. (Cambridge: Cambridge University Press, 1971), Vol. I, pp. 187–189 and 204–208. For more recent criticism of Napoleonic science see Williams, L. P., " Science, Education and Napoleon I ", *Isis*, XLVII (1956), pp. 369–382, and Hahn, Roger, *The Anatomy of a Scientific Institution. The Paris Academy of Sciences, 1666–1803* (Berkeley, Los Angeles, and London: University of California Press, 1971), pp. 310–312.

in 1808,[17] and later, in 1830, both Babbage and Brewster portrayed him as a model patron.[18] By his own membership of the First Class of the Institute (he was elected to the mechanics section in 1797), the personal favour which he showed to scientists, his provision of prizes for work in voltaic electricity, his encouragement of industry, and his celebrated gift of a huge electric pile for research at the École polytechnique, he gave some justification for these favourable opinions.[19] But, even when he was granting favours, considerations of utility or national prestige were never far from Napoleon's mind.[20] And, in any case, Napoleonic science was not entirely the creation of Napoleon himself, as critics such as the Dutch observer Gerrit Moll, professor of physics at Utrecht, were quick to point out.[21] Most of the young men who distinguished themselves at the Institute or in the circle of Laplace and Berthollet were products of the École polytechnique, created in 1794 some five years before Napoleon became First Consul; and other scientific institutions, such as the École des ponts et chaussées, the Écoles des mines, the Muséum d'histoire naturelle, and the First Class of the Institut, were relics of the Ancien Régime.[22] Moreover, when Napoleon did introduce measures relevant to science they showed little sympathy for science as an intellectual activity. For example, when in 1804 he subjected the École polytechnique to a military regime, he did so with complete disregard for the interests of science and for the protests of Monge, Berthollet, and Fourcroy.[23] The decision that henceforth students should wear uniform and live in barracks was in itself not too harmful, although the increasingly military tone may well have affected recruitment[24]; but the drastic reduction in the financial provision for research and laboratories was a measure of striking insensi-

[17] Delambre, Jean-Baptiste Jean, *Rapport historique sur les progrès des sciences mathématiques depuis 1789, et sur leur état actuel* (Paris: Imprimerie Impériale, 1810), especially pp. 1–3 and 40–42, and Cuvier, Jean L. N. F., *Rapport historique sur les progrès des sciences naturelles . . .* (Paris: Imprimerie Impériale, 1810), especially pp. 389–394. Both reports were commissioned by Napoleon himself.

[18] Babbage, Charles, *Reflections on the Decline of Science in England and on Some of its Causes* (London: B. Fellowes and J. Booth, 1830), p. 26, and [Brewster, David], "Decline of science in England", *Quarterly Review*, XLIII (1830), pp. 315–316.

[19] On Napoleon's scientific interests and his contributions as a patron of science, see Crosland, Maurice P., *The Society of Arcueil. A View of French Science at the Time of Napoleon I* (London: Heinemann, 1967), pp. 4–55.

[20] It is particularly difficult to see his patronage of electrical research as anything but an attempt to gain for France some of the prestige that the work of Volta and Davy had earned for Italian and English science.

[21] Moll, G., *op. cit.*, pp. 18–19. The large measure of continuity between eighteenth-century Science and the science of the First Empire has been pointed out more recently in Ben-David, Joseph, "The Rise and Decline of France as a Scientific Centre", *Minerva*, VIII, 2 (April 1970), pp. 160–179, especially pp. 165–172.

[22] However, the Muséum d'histoire naturelle (previously the Jardin du Roi) and the First Class of the Institut (previously the Académie royale des sciences) had been reorganised and renamed in 1793 and 1795 respectively.

[23] Pinet, Gaston, *Histoire de l'École polytechnique* (Paris: Baudry, 1887), pp. 48–55.

[24] The possible effect on recruitment is suggested by L. P. Williams, "Science, education and Napoleon I" . . . pp. 372–373. However, on some entrants to the École polytechnique who were attracted by the prospect of a military career, see Crosland, M. P., *op. cit.*, pp. 83–87. A more serious impediment to recruitment after 1804 was the withdrawal of the grant to students and the imposition of a charge of 800 francs per annum.

tivity,[25] and it set the tone for the remaining years of the Empire, in which the interests of science at the École polytechnique, the Institut, and, from 1808, in the newly founded Imperial University were consistently made subservient to practical demands.[26]

In short, there was a darker side of French science under Napoleon. Against the brilliance of many of the young *polytechniciens* of the early years, like Biot, Poisson, Dulong, Arago, and Petit, we have to set the fact that they achieved their distinction in physics despite the poor teaching in the subject which they received as students under Jean Henri Hassenfratz, who was a thoroughly incompetent professor of physics from 1794 to 1815.[27] And in admiring the extraordinarily high quality of the winning entries in the Institut's prize competitions, especially those of 1807 (by Fourier), 1809 (by Malus), and 1812 (by Delaroche and Bérard), we should not overlook the crisis of 1809 when two meetings of the First Class of the Institut had to be abandoned because of a lack of communications.[28]

Had French science depended solely on the patronage of Napoleon or on the provision made in the institutions of science, it is difficult to see how it could have flourished as it did during the First Empire. Hence, if we are to account for its successes, I believe we must look not to official or government patronage but rather to the personal motives of the individual scientists. In particular, as far as the physical sciences are concerned, we must look to Laplace and Berthollet, the two men who dominated French physics and chemistry throughout the years of Napoleon's rule. For in my opinion the source of most of the achievements for which Napoleonic science is justly celebrated lies in the ambition of these two men in pursuit of a joint programme of work, which they conceived as the fulfilment of a research tradition the origins of which lie in the Newtonian science of the eighteenth century. In an almost literal sense, they sought to be the Newtons of their age and they planned their research to this end.

I shall summarise what I call the "Laplacian" programme very briefly.[29] The goal which Laplace and Berthollet set themselves was the explanation

[25] See Hahn, R., *op. cit.*, p. 311.

[26] See Williams, L. P., "Science, education and Napoleon I". . . . pp. 376–379, and Crosland, M. P., *op. cit.*, pp. 40–45 and 155–158. On the wretched state of the science faculties in the Napoleonic university see Liard, L., *op. cit.*, Vol. II, pp. 105–124 and 136–138. Examining for the *licence* and *baccalauréat* and, to a lesser extent, teaching, were seen as the proper functions of the faculties of science and of letters. Research had no place in them.

[27] See Fox, Robert, *The Caloric Theory of Gases from Lavoisier to Regnault* (Oxford: Clarendon Press, 1971), pp. 231–232; also Arago's recollections of Hassenfratz in his "Histoire de ma jeunesse", in *Oeuvres complètes de François Arago*, 17 vols. (Paris: Gide; and Leipzig: Weigel, 1854–1862), Vol. I, pp. 12–13.

[28] Crosland, M. P., *op. cit.*, pp. 158–161, and Hahn, R., *op. cit.*, pp. 306–307.

[29] I have given more detailed accounts of the programme elsewhere, and full references for the summary which follow may be found in these other sources. See Fox, Robert, "The Laplacian Programme for Physics", *Boletin de la Academia Nacional de Ciencias de la Republica Argentina*, XLVIII (1970), pp. 429–437, and "The Rise and Fall of Laplacian Physics", *Historical Studies in the Physical Sciences*, IV (in press).

of all physical and chemical phenomena in terms of attractive and repulsive forces which they assumed to exist between the particles of matter, whether the matter in question was that of ordinary ponderable substances or one of the imponderable fluids of heat, light, electricity, or magnetism. In his earlier writings, such as the *Exposition du système du monde* (1796),[30] Laplace gave only a hint of what by 1809 had become an explicit research programme.[31] However, there is little doubt that the programme was conceived clearly enough by 1805. In that year, encouraged no doubt by the support he had gained in Berthollet's writings on chemical affinity,[32] he devoted lengthy sections of the fourth volume of the *Mécanique céleste* to mathematical treatments of optical refraction and capillary action in terms of the short-range attractive forces first postulated by Newton.[33] And after 1805 most of his own researches, and those of the disciples who worked with him and Berthollet in Berthollet's private laboratory at Arcueil, were directed to the fulfilment of the programme.

The willingness of Laplace and Berthollet to spend so much of their admittedly considerable senatorial income in order to provide research facilities at Arcueil is the most obvious mark of their dedication to the programme.[34] But it is equally revealing to observe the way in which they used their influence in manipulating for their own ends facilities which were not directly under their control. They secured their disciples' leisure and freedom for research by placing them in teaching and other posts at various institutions in Paris[35]; and at the Institut they achieved a dual purpose by proposing subjects for the annual prize competitions which would yield

[30] In this book Laplace looked forward to the time when not only optical refraction and capillary action (already treated in the Laplacian manner by eighteenth-century Newtonians) but also the cohesion of bodies, their crystalline properties, and even chemical reactions, would be explained in terms of the attractive forces exerted by the ultimate particles of matter. See Laplace, P. S., *Exposition du système du monde*, 2 vols. (Paris: Imprimerie du Cercle-Social, an IV [1796]), Vol. II, pp. 196–198.

[31] The programme is stated in Laplace, P. S., "Mémoire sur les mouvemens de la lumière dans les milieux diaphanes", *Mémoires de la classe des sciences mathématiques et scientifiques de l'Institut de France*, X (1809), pp. 329 and 338.

[32] Berthollet's writings on chemical affinity include his *Recherches sur les lois de l'affinité* (Paris: Baudouin, an IX [1801]), as well as the *Essai de statique chimique*, 2 vols. (Paris: Firmin Didot, an XI [1803]).

[33] Laplace, P. S., *Traité de mécanique céleste*, 5 vols. (Paris: Duprat; Courcier; Bachelier, 1799–1825), Vol. IV (1805), pp. 231–281. Two separately paginated supplements, added in 1806 and 1807, contained his theory of capillary action.

[34] On the incomes of Berthollet and Laplace, which exceeded 50,000 francs annually during the First Empire, see Crosland, M. P., *op. cit.*, pp. 69–74. The incomes should be compared with the 6,000 francs paid to the permanent secretaries of the First Class of the Institut and to professors at the École polytechnique. According to a letter to Macvey Napier, cited in Morrell, J. B., "Science and Scottish University Reform: Edinburgh in 1826", *The British Journal for the History of Science*, VI (1972–1973), p. 51, John Leslie was impressed to find Berthollet and Laplace with annual incomes of between £5,000 and £6,000 each when he visited Paris in 1814. At the current rate of exchange, this suggests incomes in each case of well over 100,000 francs per annum. On the income of Berthollet after the Bourbon Restoration, see Crosland, M. P., *op. cit.*, pp. 398–401.

[35] For example, the influence of Laplace helped Biot, Arago, and Poisson to obtain appointments at the Bureau des longitudes. And, to varying extents, the backing of Arcueil furthered the careers of Thenard, Gay-Lussac, Poisson, Arago, and Malus at the École polytechnique, of Biot at the Collège de France, and of Dulong at the École normale. See Crosland, M. P., *op. cit.*, pp. 190–221.

both success, and a prize of 3,000 francs, for one of their protégés, and an answer to some problem raised by their programme. Malus was someone who benefited in an obvious way from patronage of this kind, for it seems certain that the prize competition for a mathematical study of double refraction was set, in December 1807, not only in the hope that Laplace's earlier treatment of refraction would be extended to embrace double refraction as well, but also with Malus specifically in mind. Predictably Malus, who treated the problem in the classic Laplacian manner, won the prize[36]; so, in 1812, did Delaroche and Bérard, whose experiments on the specific heats of gases, performed at Arcueil, upheld the position favoured by Laplace on a technical issue in the caloric theory.[37]

By the end of the First Empire, Laplacian physics (though arguably not Berthollet's chemistry) was, to all appearances, in an unassailable position. It had stimulated work of outstanding quality; its principles, most notably the theories of imponderable fluids, were taught as standard doctrine in science courses at all levels; and its exponents dominated not only teaching but also research. Yet, however remote such a possibility may have appeared early in 1815, change sufficiently drastic to overthrow both the content and the structure of Napoleonic physical science was imminent.

The Restoration

There is abundant evidence that in the years immediately after the downfall of Napoleon French cultural life underwent a radical change. François Guizot, Edgar Quinet, and Alphonse de Lamartine, among others, all convey the feeling of exhilaration and intellectual liberation which was so common in the period, despite the sinister activities of the Congrégation, and which led to so many brilliant achievements in literature and the arts. For Guizot the Restoration came like spring after a long, hard winter,[38] while Quinet, in retrospect, described the Empire as an intellectual "desert".[39]

Not surprisingly, most men of science did not react to the Restoration with quite the unbridled joy which so many of their literary contemporaries displayed. For example, they could scarcely accept Lamartine's view of mathematics as the shackles which had bound human thought under Napoleon but which were now, to his relief, broken.[40] However, Lamartine

[36] The prize-winning paper was "Théorie de la double réfraction" *Mémoires présentés à l'Institut . . . par divers savans . . . Sciences mathématiques et physiques*, II (1811), pp. 303–508.

[37] Their entry was published as "Mémoire sur la détermination de la chaleur spécifique des différens gaz", *Annales de chimie et de physique*, LXXXV (1813), pp. 72–110 and 113–182. On the 1812 competition see Fox, R., *Caloric Theory of Gases. . . .* pp. 131–150.

[38] See Bertier de Sauvigny, Guillaume André de, *La restauration*, new ed. (Paris: Flammarion, 1955), p. 328.

[39] Quinet, Edgar, *Histoire de mes idées. Autobiographie*, 7th ed. (Paris: Hachette, 1895), Vol. XV of the *Oeuvres complètes d'Edgar Quinet*, p. 241.

[40] Lamartine, Alphonse M. L. de P. de, *Des destinées de la poésie* (1834), in *Oeuvres complètes de Lamartine publiées et inédites*, 41 vols. (Paris: Chez l'auteur, 1860–1866), Vol. I, pp. 30–32.

was correct in perceiving that a cultural change had taken place, and, by winning the love of the attractive wife of the aged physicist, J. A. C. Charles, and making her the beloved Elvire of the *Méditations*,[41] he symbolised the nature of the change in a curiously appropriate way. Science could no longer command the special respect which it had enjoyed under Napoleon, and success in the literary salons, on the stage or political platform, or in the revived political press, rather than at the laboratory bench, became increasingly the typical ambition of gifted young men. It was entirely characteristic of this period, and symptomatic of a considerable " generation gap ", that two such important young literary figures as Victor Hugo and Quinet should have turned to literature in the first years of the Restoration after being destined for the École polytechnique by their fathers.[42]

Yet Lamartine overstated his case, for, despite a certain loss of prestige, the Restoration did little harm to science. Some politically suspect scientists, it is true, became the victims of reaction. But while Monge, Guyton de Morveau, Lazare Carnot, J. N. P. Hachette, Louis Poinsot, and Louis Benjamin Francoeur were punished for their earlier services to the revolution and Napoleon by being removed from positions in teaching or in the Académie des sciences, the majority of scientists reconciled themselves without difficulty to the monarchy,[43] and the institutions of science were left to function much as they had done in the last years of the Empire. In fact, when changes did occur, they were usually for the better, as at the École polytechnique, where demilitarisation and the replacement of the former Jacobin Hassenfratz by Petit stimulated a (temporary) rise in academic standards.[44] But in all too many cases the opportunity for change was missed and the weaknesses of Napoleonic science were perpetuated. This was especially unfortunate in the case of the faculties, which at the Restoration were ripe for reorganisation. The harm done by their isolation from one another, and by their financial impoverishment, was fully recognised by Royer-Collard and Guizot as they worked for the strengthening of higher education in the provinces during the 11 months of the First Restoration. But the resulting legislation of 17 February, 1815, which would have created, in place of the monolithic Imperial University, 17 regional universities, each consisting of a group of faculties and possessing a large measure of independence in administration and teaching, was never

[41] On this episode see, for example, Bertrand, Louis, *Lamartine* (Paris: Arthème Fayard, 1940), pp. 170–172.

[42] See, in addition to the standard biographical sources, Quinet, E., *op. cit.*, pp. 208–216, 225–232, and 239–247.

[43] None, except perhaps Cuvier, did so more easily than Laplace. However, his adoption of the prevailing illiberal attitudes was to do him great harm, as I point out later in this section.

[44] On demilitarisation, which was revoked in 1830, see Pinet, G., *op. cit.*, pp. 93–103 and 421–430. The replacement of Hassenfratz is discussed in Fox, R., *Caloric Theory of Gases* . . . pp. 231–232.

put into effect.[45] For by 1 March Napoleon had landed at Fréjus, and by the time the Hundred Days were over the faculties were fortunate to survive in any form at all. The new bill of 15 August, 1815, merely confirmed the old imperial structure,[46] and the faculties resumed their modest roles as examining bodies and as the purveyors of low-level instruction—roles which they were to fulfil for the rest of the century.

So in many respects continuity rather than change characterised the transition from the Empire to the Restoration, as far as science was concerned. But I believe that in some less obvious ways the decade 1815–1825 did mark a turning-point. In the history of scientific thought, as in so many intellectual activities, these were years of great change, years in which science shared some of the upheavals that are more commonly associated with the emergence of the new Romantic movement in literature, music, and art. There were challenges to established beliefs in medicine and mathematics[47]; and in the physical sciences, between 1815 and 1820, the Laplacian programme came to be discredited in the eyes of all but a few increasingly isolated diehards, headed by Laplace himself and the most loyal of his disciples, Poisson.[48]

The discrediting of the Laplacian orthodoxy, and of Berthollet's chemistry, have a special and obvious importance for our understanding of French science during the Restoration. From the point of view of the " internal " history of science, the best known casualty of the anti-Laplacian movement of 1815–20 was the corpuscular theory of light, which Augustin Fresnel, with the backing of François Arago, ruthlessly undermined in his celebrated early papers on diffraction and double refraction. But scarcely less important were the attacks on the material theory of heat—the caloric theory—by Alexis Thérèse Petit and Pierre Louis Dūlong, and the rapid acceptance of the chemical atomic theory, which implied clearly the rejection of Berthollet's chemistry of affinities and molecular forces. However, for the purposes of this paper, it is more important to see the turning away from Laplace and his school as one aspect of the decline of

[45] Liard, L., *op. cit.*, Vol. II, pp. 125–136 and 181–183. Guizot's preference was for no more than four regional universities, though he fully shared Royer-Collard's desire for decentralisation.

[46] However, some strengthening was attempted by the closure of 17 faculties of letters and three science faculties, at Besançon, Lyons, and Metz. See Liard, L., *op. cit.*, Vol. II, pp. 136–138.

[47] On medicine see Ackerknecht, Erwin H., *Medicine at the Paris Hospital 1794–1848* (Baltimore: Johns Hopkins University Press, 1967), pp. 61–80. On the declining influence of Lagrange and the rise of Fourier see Grattan-Guinness, Ivor, *The Development of the Foundations of Mathematical Analysis from Euler to Riemann* (Cambridge, Mass., and London: MIT Press, 1970), pp. 1–45, and the same author's *Joseph Fourier 1768–1830. A Survey of his Life and Work based on a Critical Edition of his Monograph on the Propagation of Heat, presented to the Institut de France in 1807* (Cambridge, Mass., and London: MIT Press, 1972), pp. 441–490.

[48] For much fuller studies of the discrediting of Laplacian physics and Berthollet's chemistry, see Fox, R., *Caloric Theory of Gases*. . . . pp. 227–248 and 270–280, and my papers " The Laplacian Programme for Physics ", pp. 435–436, and " The Rise and Fall of Laplacian Physics ". Full references for the account which follows will be found in these sources.

Arcueil as a source of influence and patronage. For during the first half of the nineteenth century there was no change in the course and style of French scientific research more drastic than that which accompanied this decline.

From 1815, when advancing age and a diminished income were impeding the activity of Berthollet,[49] little research was performed at Arcueil. And Laplace, with his programme discredited on scientific grounds and his personal standing, especially in the eyes of younger scientists, adversely affected by his pliability on political matters and his illiberal views—notably on the freedom of the press—found it increasingly difficult to exert his old influence.[50] Power quickly passed into the hands of a new anti-Laplacian generation with Fresnel, Arago, Dulong, and Petit as its leading members and with Joseph Fourier as its detached though sympathetic elder statesman. By 1816, Laplacian influence in the leading scientific journal, the *Annales de chimie et de physique*, was greatly reduced when Arago was made one of the two joint editors (with Gay-Lussac [51]), and at the École polytechnique and the Société philomathique the critics of Laplace and his school became rapidly more powerful. At the Académie des sciences also the Laplacians lost control, the decisive event there being the victory of Fourier over Biot, who was still loyal to Laplace, in the election of 1822 for the post of permanent secretary for the mathematical sciences. From that point the science of Laplace was doomed, as Biot himself acknowledged by holding aloof from the scientific community of Paris until the 1830s.

Of course, the decline of a research school is not in itself remarkable. But what is remarkable and significant in this case, and in need of explanation, is the fact that there emerged no school to take the place of the school at Arcueil. In attempting to explain this, I shall continue to pay special attention not to official policies towards science, which changed little after the Restoration, but rather to the attitudes of individual scientists. In particular, I shall try to show how the interests of scientists under the Bourbon and Orléans monarchies were diverted by their adoption of a mode of life incompatible with a deep commitment to research.

The New Style of Science

When Amaury, the hero of Sainte-Beuve's novel *Volupté*, returned about 1820 to a France that he had not seen for some three years, he

[49] By February 1816, Berthollet's income was reduced to 24,000 francs. See Crosland, M. P., *op. cit.*, pp. 398–401.

[50] Laplace's growing unpopularity is well conveyed by the critical comments in the articles on him in Rabbe, Alphonse, *et al.* (eds.), *Biographie universelle et portative des contemporains*, 5 vols. (Paris: Levrault, 1834), Vol. III, pp. 151–153, and Hoefer, Johann Christian Ferdinand, *Nouvelle biographie générale*, 46 vols. (Paris: Firmin Didot, 1855–66), Vol. XXIX, cols. 533–534.

[51] Although he was not prominent in the revolt against the ideas of Berthollet and Laplace, Gay-Lussac was decidedly sympathetic to the new theories, especially to Fresnel's wave theory of light.

observed with astonishment the change which had come over French life. He wrote:

> What struck me most when I first returned from America . . . was that, after the Empire and the excess of military force which had been prevalent in that period, people had gone over to excess in words, to a wasteful and elaborate use of declamation, imagery, and promises, and to an equally blind confidence in these new weapons.[52]

In pointing to the new fashion for declamation and the consequent striving for oratorical effect, Sainte-Beuve was making an observation of characteristic astuteness which complements the recollections of Lamartine, Guizot, and Quinet referred to in the previous section. That he was correct in identifying a new spirit abroad in France in the early years of the Restoration is apparent in the flowering of political oratory, which continued throughout the reigns of Louis XVIII and Charles X, with such brilliant debaters as the Comte de Villèle, Royer-Collard, and Benjamin Constant dominating the Chamber of Deputies,[53] and the point is supported also by the success of the many religious preachers of the period.[54] But the correctness of Sainte-Beuve's observation cannot be better illustrated than by the ability of Victor Cousin, Guizot, and Villemain to attract such huge and admiring crowds to their lectures at the Sorbonne on, respectively, philosophy, history, and French literature,[55] and we may be sure that Sainte-Beuve himself knew of the scenes of enthusiasm with which these three men were received, especially by the young. Increasingly, success in higher education came to be measured by success at the lectern, rather than in research and scholarship, and Cousin, Guizot, and Villemain were only the most brilliant of numerous teachers in the faculties and other institutions who aspired to popular acclaim as lecturers. Some of these teachers were scarcely less charismatic than Cousin, Guizot, and Villemain themselves; and this was true even of lecturers in science, who in this respect have not received the attention they deserve.

In science, as in other subjects, success was more readily achieved in Paris, with its large educated public, than in the provinces, where audiences for lectures in the faculties, when they could be assembled at all, were

[52] Sainte-Beuve, Charles Augustin, *Volupté*, 2 vols. (Paris: Eugène Renduel, 1834), Vol. II, p. 285.

[53] This flowering of political oratory, which men of the stature of Guizot and Thiers maintained throughout the Orléans monarchy, though with somewhat diminished brilliance, has been widely recognised. For a contemporary study, see "Timon" [L. M. de La Haye, vicomte de Cormenin], *Etudes sur les orateurs parlementaires* (Paris: La Nouvelle Minerve, 1836).

[54] However, in this case it should be noted, first, that the abbé de Frayssinous, who was perhaps the most successful preacher under the restored Bourbons, had already had a considerable following at Saint-Sulpice during the First Empire, and, secondly, that the finest achievements in nineteenth-century religious oratory belong to a later period, from the mid-1830s, when Ravignan, Dupanloup, and, most brilliant of all, Lacordaire enjoyed their greatest renown.

[55] On these lectures, see Johnson, Douglas, *Guizot: Aspects of French History 1787–1874* (London: Routledge & Kegan Paul, 1963), pp. 118–119 and 121–122.

commonly sparse and nearly always ill-informed [56]; even modest successes, like that of Pasteur, who had audiences of 250 at the faculty of science in Lille in the 1850s,[57] were unusual. Of course, some lecturers, like the gauche and inarticulate Ampère, were incapable of attracting a large audience even in the most favourable circumstances, in Paris or anywhere else.[58] But Thenard, Biot, and Gay-Lussac, for example, were so successful at the Sorbonne that the young Charles de Rémusat, whose educational background at the Lycée Napoléon had been almost exclusively linguistic and philosophical, attended their lectures, in preference to those of Cousin and Villemain, shortly after the Restoration.[59] By comparison with Villemain's lectures, which he regarded as no more than an " entertainment ", Thenard's exposition of chemistry was enthralling. As Thenard spoke, according to Rémusat, " It seemed . . . as though the veil of nature was being raised before my eyes. I felt that I was gazing for the first time on a world in which, until then, I had lived as though surrounded by magical mysteries or rather by senseless prodigies." [60]

Dumas was another attractive lecturer who, when Pasteur attended his lectures in the 1840s, regularly had audiences of between 700 and 800, or even 1,000, at the Sorbonne.[61] And even a less celebrated figure like the physicist C. S. M. Pouillet was able to attract an audience of over 800 when he performed some experiments of Faraday, presumably his demonstration of electromagnetic induction, at the Sorbonne in 1832.[62]

The new style of declamatory science was most evident in the faculties, where audiences could be won, and to a large extent had to be won, by the attractiveness of the lecturer. Although payment in the faculties was

[56] On the audiences in the provincial faculties, see Liard, L., *op. cit.*, Vol. II, pp. 136–138 and 276–282. The problems of teaching in a provincial faculty are well illustrated by the experiences of Antoine Augustin Cournot, a conscientious and able teacher who in 1834 began lecturing at the faculty of science in Lyons. Although a large audience was present for the first month of the course—apparently attracted by the novelty of the newly founded faculty—attendance had fallen to about a dozen by the end of the year; see Cournot, Antoine Augustin, *Souvenirs (1760–1860)*, ed. Botinelli, E. P. (Paris: Hachette, 1913), p. 156. Victor Duruy's report of 1868 on higher education suggests that in the 1860s the composition of the audiences in the science faculties was a somewhat greater problem than their size. For example, in 1865 only 94 out of the 2,232 who attended lectures in the country's 16 science faculties were registered students; the remainder were for the most part casual students whose commitment to serious study was slight. See *Ministère de l'Instruction Publique. Statistique de l'enseignement supérieur. 1865–1868* (Paris: Imprimerie Impériale, 1868), pp. xxxii–xxxiii.

[57] See Pasteur's letter to his father, 19 December, 1855, in Vallery-Radot, Pasteur, *Pasteur. Correspondance 1840–1895*, 4 vols. (Paris: Flammarion, 1940–1951), Vol. I, pp. 383–384.

[58] On Ampère's difficulties as a lecturer see Launay, Louis de, *Le grand Ampère* (Paris: Perrin, 1925), pp. 189–191.

[59] Rémusat, Charles François Marie de, *Mémoires de ma vie*, 3 vols. (Paris: Plon, 1958–1960), Vol. I, pp. 241–244.

[60] *Ibid.*, Vol. I, p. 242.

[61] See Pasteur, Louis, " Souvenirs intimes ", *Le centenaire de l'École normale 1795–1895* (Paris: Hachette, 1895), p. 478, and the letter from Pasteur to his parents, 9 December, 1842, in Vallery-Radot, P., *Pasteur. Correspondance* . . . Vol. I, p. 81. It was some years later that Pasteur reported that audiences of over 1,000 were normal; see the letter to his father, 25 February, 1854, *ibid.*, Vol. I, p. 328.

[62] See the letter from J. N. P. Hachette to Michael Faraday, 9 July 1832, in Williams, L. P., *Selected Correspondence*. . . . Vol. I, p. 229.

not determined by the size of the audience, as it was in many European universities at this time, notably in Germany and Scotland,[63] self-esteem and the successes of their literary and political contemporaries seem to have provided the scientists with a sufficient incentive to attract the *grand public*. Trivialisation of the subject-matter was a constant danger, and scientific lectures in the faculties came to be criticised for the low level at which they were pitched.[64] Such exceptions as the lectures of Dumas at the Sorbonne, which had sufficient intellectual content to stimulate the interests of Pasteur and Sainte-Claire Deville in chemistry,[65] were rare. But well prepared popular lectures were preferable to many given in the institutions devoted to preparation for a professional qualification. At the École polytechnique, for instance, where syllabuses between the 1820s and 1850s showed a remarkable degree of inflexibility and disregard for new ideas and discoveries,[66] the quality of the teaching appears to have deteriorated markedly. In the early 1820s Biot, who had known the École polytechnique in its great days, wrote of it " descending every day to a state of uniform mediocrity, which engenders neither resistance nor noise " [67]; and 10 years later he wrote of the suspicion of intellectual activity which had been apparent in government policies since the beginning of the century and which had been manifested, to the serious detriment of science, both in the closure of the *écoles centrales* (now replaced by the more classically oriented *lycées*) and in the increasingly mundane and specialised character of the studies at the École polytechnique.[68] It is true

[63] However, the number of registered students was one factor that determined the *éventuel*, paid in addition to the basic salary to professors in the faculties; see *Statistique de l'enseignement supérieur* . . . pp. 342–343. On the class-fee system in German and Scottish universities see Paulsen, Friedrich, *The German Universities: Their Character and Historical Development*, trans. Perry, W. D. (New York: Macmillan, 1895), pp. 136–140, and Morrell, J. B., *op. cit.*, pp. 48–56. In the opinion of Biot, who was generally critical of the state of science in France at the time, it was one of the strengths of the French system that professors were not paid directly by their students; see his review of Babbage's *Reflections on the Decline of Science in England*, in the *Journal des savants* (January, 1831), p. 46. However, this advantage seems scarcely to have diminished the French lecturers' concern to impress their audiences.

[64] Renan, E., *op. cit.*, pp. 81–86, and Monod, Gabriel, *De la possibilité d'une réforme de l'enseignement supérieur* (Paris: Ernest Leroux, 1876), pp. 26–27. Renan was critical not only of the faculties but also of other institutions, such as the Collège de France and the Muséum d'histoire naturelle, which (unlike the École polytechnique, for example) were not concerned with giving a professional training.

[65] On these lectures see the comments of Désiré Gernez and Pasteur in *Le centenaire de l'École normale*, *op. cit.*, pp. 408 and 458.

[66] For example, it was only after 1850 that references to " electric fluid " disappeared from the annually published syllabuses of the École polytechnique. See Fox, R., " The rise and fall of Laplacian physics" . . . f.n. 142.

[67] Letter from Biot to Thomas Chalmers, *c.* 1822, in Hanna, William, *Memoirs of the Life and Writings of Thomas Chalmers, D.D. LL.D.*, 4 vols. (Edinburgh and London: Thomas Constable, 1849–1852), Vol. II, p. 15.

[68] See his review of Babbage's *Reflections*, in the *Journal des savants* (January 1831), p. 47. The specialised nature of the education at the École polytechnique was also complained of by Théodore Olivier in his *Mémoires de géométrie descriptive, théorique et appliquée* (Paris: Carillan-Goeury and Dalmont, 1851), pp. vi–xviii, though with a somewhat different thrust. Olivier's complaint was that ever since the reorganisation of the École in 1816, under the influence of Laplace, Poisson, and Cauchy, there had been an undue preoccupation with abstract mathematics, in particular with algebra, to the detriment of education in both technical subjects and the experimental sciences.

that such criticisms appear to have had little effect on recruitment, for the careers open to *polytechniciens* were, then as now, attractive ones [69]; but its continuing effectiveness in the training of professional engineers, and in the consolidation of a social and intellectual elite,[70] cannot obscure the fact that the École polytechnique had declined as a centre of innovation both in teaching and research by the middle of the century.

A growing preoccupation with the wider audiences for science, at the expense of dedication to original research, is apparent also at the Académie des sciences. Indeed, it was one of the most serious charges directed against Arago in a virulent attack by the Italian-born mathematician, Guglielmo Libri, in 1840, that, in the 10 years since his election as a permanent secretary of the Académie, Arago had consistently sacrificed accuracy and content in the interests of oratorical effect, especially in his official *éloges* of deceased members.[71] Moreover, he had aggravated the fault and had led other academicians to seek public acclaim by encouraging the publication of the weekly *Comptes rendus* of the activities of the Académie, which began to appear in 1835.[72] Biot, a member of the older generation accustomed to closed sessions to which visitors were admitted only by special invitation and whose activities were surrounded by an air of secrecy, viewed the new publication with equal distaste, and he too protested—as bitterly as he had done some years earlier when representatives of the press began to be admitted to meetings.[73] Yet Biot and Libri were not surprised by the new publicity which was accorded to the Académie and sought by Arago; both men saw it simply as part of the vulgarity that had come to afflict French science. In fact, the scientists who were so criticised by Biot and Libri were simply following the dominant style of French intellectual activity between the Empires, a style which had its most glittering successes in the rise of the Romantic movement in literature and the arts but which, as we have seen, could readily be adapted to the needs of science, at least of science in its popular form.

[69] On the continuing demand for places at the École polytechnique, see Artz, Frederick Binkerd, *The Development of Technical Education in France, 1500–1850* (Cambridge, Mass., and London: MIT Press, 1966), pp. 232–233.

[70] I use the word "consolidation" here since the great majority of students at the École polytechnique between 1815 and 1848 were the sons of men who had been successful in military or administrative careers or in the professions, while fewer than 1 in 7 were the sons of businessmen and industrialists, and scarcely any came from the *classes populaires*. See Daumard, Adeline, "Les élèves de l'École polytechnique de 1815 à 1848", *Revue d'histoire moderne et contemporaine*, V (1958), pp. 226–234.

[71] [Libri, Guglielmo B.I.T.], "Lettres à un Américain sur l'état des sciences en France. I. L'Institut", *Revue des deux mondes*, 4th ser., XXI (1840), pp. 802–807. Arago was also criticised in this article for his oratorical performances in his lectures at the Observatory in Paris. It is interesting that these lectures by Arago, with those of Cuvier at the Muséum d'histoire naturelle and the Collège de France, were the very ones which had so enthralled the duchesse de Duras some 20 years earlier; see Villemain, A. F., *Souvenirs contemporains d'histoire et de littérature*, 2 vols. (Paris: Didier, 1854–1855), Vol. I, pp. 467–468.

[72] Libri, G. B. I. T., *op. cit.*, p. 795.

[73] See his comments in the *Journal des savants* for February 1837 (pp. 78–84) and November 1842 (pp. 642–661), reproduced in Biot, Jean-Baptiste, *Mélanges scientifiques et littéraires*, 3 vols. (Paris: Michel Lévy, 1858), Vol. II, pp. 257–292.

The activities of the Restoration salons provide further evidence of the extent to which the scientists of the day followed the prevailing cultural pattern. Although the evidence now available is less than conclusive, there seems little doubt that scientists became increasingly prominent in salon society after 1815. Of course, science had been by no means a stranger in the salons of earlier periods. In the eighteenth-century salons, such works as Buffon's *Histoire naturelle* had been much discussed, and the cabinets of natural curiosities and the private laboratories of that period had probably done as much to sustain polite conversation as to promote serious research.[74] During the First Empire, too, science had not been ignored in cultivated society; it was under Napoleon, for example, that the house of Madame de Rumford, the widow of Lavoisier and the unhappy wife of Count Rumford, became a fashionable centre for gatherings of men and women in Paris with scientific interests.[75] But it was as clear to the leading scientists of the Empire as it had been in the eighteenth century that the salons could never serve science in the way that they patently served the interests of politics and literature; and it is remarkable, therefore, that after 1815, at a time when the dependence of scientific research on expensive laboratory facilities grew rapidly, so many leading men of French science were apparently beguiled by the resurgence of salon activity which followed the Restoration. Cuvier's weekly soirées were perhaps the most celebrated,[76] and it seems that no one was more assiduous than he and Alexander von Humboldt in attending the salons of others.[77] But, between the Empires, Cuvier and Humboldt were by no means the only scientists who were prominent in the Parisian salons; Maine de Biran, Baron Férussac, and Jean-Baptiste Dumas [78] were all at the centre of regular gatherings, and many others, including Arago, Fourier, and the engineer G. J. Christian, were active in salon society. Although the "scientific" groups never acquired the renown of, say, Charles Nodier's brilliant gathering of early Romantics at the Arsenal,[79] just as Madame de

[74] Taton, René (ed.), *Enseignement et diffusion des sciences en France au XVIIIe siècle* (Paris: Hermann, 1964), pp. 619–712.

[75] For a first-hand account of Madame de Rumford's salon see Rémusat, C. F. M. de, *op. cit.*, Vol. I, pp. 174–175.

[76] Cuvier's salon is particularly well described in the correspondence of the young Charles Lyell. See, for example, Lyell's letters of July and August 1823, February 1829, and October 1830, in Lyell, Katherine Mary, *Life, Letters and Journals of Sir Charles Lyell, Bart.*, 2 vols. (London: John Murray, 1881), Vol. I, pp. 125–128, 134–140, 248–251, and 306–307.

[77] Cuvier appears to have excelled in the salons and was a special favourite of the duchesse de Duras, at whose salon he mixed freely with ambassadors, men of government, and courtiers. Humboldt ("as indefatigable in society as in science", as Villemain put it) was also much admired at the Duras salon, as he was at the salon of Madame de Montcalm, sister of the duc de Richelieu; see Villemain, A. F., *op. cit.*, Vol. I, pp. 465–467 and 477.

[78] On the circles of these three, see, respectively, Gouhier, Henri (ed.), *Maine de Biran. Journal*, 3 vols. (Neuchâtel: Éditions de la Baconnière, 1954–1957); Lyell, K. M., *op. cit.*, Vol. I, p. 303; and Vallery-Radot, P., *Pasteur. Correspondance . . .* Vol. I, p. 152.

[79] On Nodier's salon, see, for example, Salomon, Michel, *Charles Nodier et le groupe romantique d'après des documents inédits* (Paris: Perrin, 1908), pp. 116–224.

Rumford's circle never matched Madame de Récamier's, they were by no means ephemeral and were attractive to many men of distinction, like Cousin, Guizot, and Royer-Collard—who had no specialist interest in science.

It was clearly in their non-specialist character that the weaknesses of these groups, as centres of creative scientific activity, lay. At Cuvier's salon, discussion in the 1820s ranged over politics and such topics as Scott's latest novel and the Marquis Las Cases's account of Napoleon on St. Helena, while science was largely ignored [80]; and we know that Humboldt, like Cuvier, was quite as ready to discuss politics or the arts as science.[81] So even if the " scientific " salons of the 1820s, 1830s, and 1840s did not offer such fripperies as dancing and cards, as Nodier's and certain others did, they were still very different from the small, select gatherings which had met, for the purposes of serious discussion and corporate research, in Berthollet's house at Arcueil. Although most of the discussion in the Restoration salons has naturally passed unrecorded, there is no evidence that they stimulated research or that they were ever intended to do so.

Of course, the public character of so much Restoration science was not harmful in every respect. Substantial, well delivered lectures could benefit science by arousing the interest of able young men; the influence of Dumas's lectures on Pasteur and Sainte-Claire Deville, already referred to, is a good illustration. And the discussion of science in polite society, among literary men, philosophers, and politicians, helped to create a broad, popular interest of which there is much evidence in Balzac's *Comédie humaine* and in the novels of Stendahl.[82] But such benefits were slight, for generally the large lecture theatre and the non-specialist salon were not conducive to a deep commitment to research. The wit and rhetorical skills which they fostered had had no place at Arcueil, just as they had no place in the chemical laboratory which Liebig founded at Giessen in 1824 or in the other German university laboratories for which Giessen served as a model.

Penury and Indifference

In the quest for recognition by the lay public, it was serious research which suffered most. If we accept that a new, public style of science did

[80] It was Cuvier himself who set the tone in this respect: " Not a word could I get on natural history " was Lyell's complaint in 1829, and in the following year Cuvier was persuaded to discuss fossil anatomy only because he was " not in spirits about political affairs ". See Lyell's letters to his sister and to Gideon Mantell, 23 February, 1829, and 10 October, 1830, in Lyell, K. M., *op. cit.*, Vol. I, 249 and 307. See Villemain, A. F., *op. cit.*, p. 467, on the breadth of Cuvier's conversation in the salons.

[81] Villemain, A. F., *op. cit.*, Vol. I, pp. 465–466 and 477.

[82] The scientific basis for the structure and conception of the *Comédie humaine* is described explicitly in Balzac's general preface to the series (dated July 1842), in *Oeuvres complètes de Honoré de Balzac*, 40 vols. (Paris: Louis Conard, 1926–1963), Vol. I, pp. xxv–xxxviii. Stendahl's science has been the subject of a detailed study by Jean Théodoridès; see his *Stendahl du côté de la science* (Aran: Éditions du Grand Chêne, 1972).

emerge after 1815, it is certainly not surprising that French scientists until the mid-1860s were generally so content with conditions for research which we now recognise to have been quite inadequate, when judged by the standards of the research facilities available in so many German universities by the middle of the century. Yet the paucity of public complaints [83] should not be allowed to obscure the fact that, at least until the 1850s, there was almost no institutional provision in France either for the personal work of professors or for that of advanced students wishing to perform research under their supervision. The situation was well summarised by Pasteur's assistant E. Duclaux. Referring to conditions which he observed at the École normale but which would have been found in virtually any institution of higher education about the middle of the century, he wrote:

> . . . the professors had at their disposal only the premises and funds allocated to their chair. No private laboratory; nothing resembling what today we should call a research laboratory. When they wanted to work, they exercised their wits; they skimped on the essentials in order to have something left over; they set themselves up as best they could in the quiet corner of a lecture room, always ready to clear away their apparatus at lecture times.[84]

In reading this account, it should be borne in mind that, from the time the École normale moved from the Collège du Plessis to its new premises in the rue d'Ulm in 1847, the laboratories there were considered to be the best available anywhere in France.[85] The teaching laboratories were comparatively spacious, and from 1851, when he arrived there from Besançon to take the chair of chemistry, Sainte-Claire Deville worked hard for an improvement in the facilities for the research of professors.[86] But even the energetic Deville had very modest success, and it was not until 1866 that he acquired the only laboratory which, according to Fernand Papillon, could even remotely be compared with those in the German universities.[87]

In the other institutions of Paris conditions for research were even less favourable than those at the École normale. The " little closet, a few metres square " at the Collège de France, where François Magendie performed his great physiological researches between 1830 and 1855, was not only unsuitable for the purposes of research, it was also damp and unhealthy, so much so that even the rats found it difficult to survive! There, if anywhere, Claude Bernard's description of French laboratories as

[83] I stress " public " here, since certain individuals, among them Pasteur, did complain privately about their conditions before the 1860s. See, for example, Pasteur's letters of 20 January, 1851, to the Minister of Education, and 12 and 14 December, 1854, to the dean of the faculty of science in Strasbourg and the Minister of Education respectively, in Vallery-Radot, P., *Pasteur. Correspondance . . .* Vol. I, pp. 217–218 and 351–355. On some other complaints dating from as early as the 1830s, see Paul, H. W., *op. cit.*, pp. 5–7. Despite this evidence, the fact remains that the complaints only became widespread, public, and concerted in the mid-1860s.

[84] Duclaux, E., " Le laboratoire de M. Pasteur ", in *Le centenaire de l'École normale . . .* p. 458.

[85] Papillon, F., *op. cit.*, pp. 601–602.

[86] On the difficulties and achievements of Deville at the École normale see Gay, Jules, *Henri Sainte-Claire Deville. Sa vie et ses travaux* (Paris: Gauthier-Villars, 1889), pp. 10–16.

[87] Papillon, F., *op. cit.*, pp. 601–602.

" the graves " of scientists had a special relevance.[88] Yet it was in this very same laboratory that Bernard himself worked, first as assistant to Magendie and then, from 1855, as his successor as professor of medicine.[89] The facilities for the important work in organic chemistry which Marcellin Berthelot performed in the " insignificant " laboratories of the École de pharmacie were equally unsatisfactory.[90] And nowhere was the scandal greater than at the ancient and revered Sorbonne. There the inadequacy of the buildings was acknowledged by the laying of the foundation stone for new premises to house all the faculties in 1855, but, in the absence of the necessary funds, it was only in 1895 that the science faculty was eventually able to move from the cramped quarters in the old Sorbonne which it had occupied since 1821.[91] In the old buildings, facilities for laboratory work had been derisory, and the establishment of modest new laboratories for physics, physiology, and chemistry in the late 1860s did little to improve conditions which were almost as bad for teaching as for research. From 1874 to 1881, as professor of organic chemistry, Adolphe Wurtz still had to prepare all his demonstration apparatus in the École de médecine and then transport it to the Sorbonne for his lectures, and it was only in 1881 that he was given a small room, vacated through the death of Deville, for the preparation of his demonstrations.[92]

Such experiences, together with accounts of Flourens's miserable *cabanon* at the Jardin des plantes and of laboratories at the École polytechnique which, even by 1871, had not changed since the days of Gay-Lussac's early triumphs some 50 years earlier,[93] all confirm that Pasteur was almost literally correct when he wrote, in 1868, that the educational budget did not contain one penny allocated for laboratory research.[94] In such circumstances the question of taking in students scarcely arose, although Wurtz, who was far more aware than most Frenchmen of the effectiveness of the German traditions of research, did seek to copy the German model in the 1850s and 1860s by accepting pupils in his far from spacious laboratory at the École de médecine.[95]

[88] *Ibid.*, p. 60, and Pasteur, L., *Le budget de la science . . .* p. 6. In support of Bernard's claim, Pasteur asserted that the professor of chemistry in the science faculty at Lyons, Amant Bineau, had died prematurely because of the conditions in the " cellar " which served as his laboratory; *ibid.*, p. 7.

[89] However, as a result of his personal approach to Napoleon III, Bernard was able to effect some improvement in his conditions.

[90] Papillon, F., *op. cit.*, p. 601.

[91] On the facilities at the Sorbonne, *ibid.*, pp. 601 and 604; Pasteur, L., *Le budget de la science . . .* p. 6; Caullery, Maurice, " La Faculté des Sciences ", in Durkheim, Émile, *et al.*, *La vie universitaire à Paris* (Paris: Armand Colin, 1918), pp. 51–55.

[92] Friedel, Charles, " Notice sur la vie et les travaux de Charles-Adolphe Wurtz ", *Bulletin de la Société chimique de Paris*, new ser., XLIII (1885), p. xx. I am grateful to my colleague, Dr. J. H. Brooke, for drawing my attention to this article.

[93] Papillon, F., *op. cit.*, p. 602.

[94] Pasteur, L., *Le budget de la science. . . .* p. 8.

[95] Friedel, C., *op. cit.*, pp. xii–xvii. Wurtz's standards and style of work, like Gerhardt's and Regnault's, were coloured by his experiences in Liebig's laboratory at Giessen, where he was a pupil in the 1840s.

If the facilities for research were poor in Paris, they were better, at least in the case of certain laboratories, than those available in the provinces, where the science faculties had failed utterly to become centres of learning. Indeed, during the Bourbon and Orléans monarchies their condition even deteriorated, and this despite the fact that they never lacked influential friends who wished to see them strengthened academically. For example, Paul-François Dubois, the joint founder of *Le Globe*, deputy for Loire-Inférieure, and from 1840 to 1850 director of the École normale, argued strongly for vigorous and adequately endowed provincial universities in the report on the budget for education which was presented in the Chamber of Deputies in 1836,[96] while in his eight months as Minister of Education in 1840 Victor Cousin set about grouping the isolated faculties into a small number of well financed universities in the main provincial centres.[97] But Dubois's views, like Guizot's 20 years before and Jean-Baptiste Dumas's during the Second Empire,[98] were not heeded, and by the time he left office Cousin had done no more than obtain the permission of the Chamber of Deputies to establish the new science faculty which he needed at Rennes for his proposed Breton university. So it was the very different philosophy of such extreme exponents of decentralisation as Villemain and Salvandy that prevailed from 1815 and ensured that faculties remained isolated from one another and poorly equipped until Liard's reorganisation of 1896.[99]

The situation was only aggravated by the creation of several new faculties in the 1830s and 1840s.[100] By the time Victor Duruy began his investigation in 1865, the state of the provincial faculties, whether of law, medicine, letters, theology, or science, was for the most part deplorable. Well housed science faculties, such as those at Caen, Nancy, and Clermont-Ferrand, were exceptions; elsewhere cramped and unhealthy conditions in poorly adapted premises were normal, and such laboratories as did exist were inadequate.[101] There was little money for the purchase of equipment and books [102] and no provision whatsoever for the private research of profes-

[96] Liard, L., *op. cit.*, Vol. II, pp. 183–185 and 190.

[97] For Cousin's own account, see his " Huit mois au Ministère de l'Instruction Publique ". *Revue des deux mondes*, 4th ser., XXV (1841), pp. 387–390. For a statement of his educational philosophy, see his comments in the *Revue de Paris*, XXX (1831), pp. 184–185.

[98] On Guizot see Liard, L., *op. cit.*, Vol. II, pp. 125–136 and 181–183, and my comment in f.n. 45. On Dumas, see Rohr, Jean, *Victor Duruy, ministre de Napoléon III. Essai sur la politique de l'instruction publique au temps de l'Empire libéral* (Paris: Pichon and Durand-Auzias, 1967), pp. 90–91.

[99] Liard, L., *op. cit.*, Vol. II, pp. 188–199.

[100] *Ibid.*, Vol. II, pp. 188–189. Three of the new faculties, at Lyons, Bordeaux, and Besançon, were science faculties, bringing the total to 10 by 1848. The new faculties were created largely to meet the growing need for examiners for the *baccalauréat*; *ibid.*, Vol. II, pp. 190–199.

[101] *Ibid.*, Vol. II, pp. 271–276, and *Statistique de l'enseignement supérieur. . . .* pp. 15–17, 56–59, and 416–429. On Duruy's investigation and his findings see also Rohr, J., *op. cit.*, pp. 90–109.

[102] Provincial science faculties had no more than 1,800 francs annually to cover expenses incurred in teaching and research. Often there were no funds at all for the purchase of books.

sors. Intellectual stagnation was a natural corollary of this material neglect, and it is not surprising that such a gifted and ambitious young man as Charles Gerhardt, whose education and family background in Strasbourg had brought him into close contact with Germany and who had known the delights of working with Liebig at Giessen, was so dissatisfied with the research facilities available to him as a professor at Montpellier in the 1840s.[103]

When conditions in the institutions were so bad, interest in research was not easily stimulated. But, unlike so many critics in the 1860s, I believe that the poor conditions should not be seen as a primary cause of France's modest record in research about the middle of the century. Rather they were a symptom of the indifference of French scientists themselves, who, as I have already observed, were so rarely moved to protest, at least publicly. In some cases the complacency of the French scientists took a positive form. A. J. Balard, who held chairs of chemistry successively at the École normale and the Collège de France between the 1830s and the 1870s, took a real pride in the handicaps under which he worked. And Marcellin Berthelot, while admitting the great difficulties encountered in undertaking serious research in France, declared his preference for the French system at the time of a visit to Heidelberg in 1858. In his view, the advantages of well endowed laboratories and *Lehrfreiheit* were outweighed by the low income of the *Privatdozenten* and the heavy burden of routine laboratory teaching imposed on German professors.[104] Both Berthelot and, in his less distinguished way, Balard showed by their own research that the French system could be made to work. But, unfortunately, these two men had a commitment greater than that of many of their contemporaries, who, far from being dedicated to research, seem to have been ever-ready to assume responsibilities which took them away from their laboratories.

Some of the activities which lured French scientists from research between the Empires were academic. Especially for teachers in the provincial faculties, with meagre basic salaries of 4,000 francs per annum and few serious students, examining was attractive as a source of additional income; paid at the rate of 5 and later 7 francs for each candidate in the *baccalauréat*, one week of examining could yield over 300 francs.[105] In

[103] Grimaux, Édouard and Gerhardt, Charles, *Charles Gerhardt. Sa vie, son oeuvre, sa correspondance 1816–1856* (Paris: Masson, 1900), pp. 13–29, 55–57, 59–61, and 93–94.

[104] See his letter to Renan, quoted in Velluz, L., *op. cit.*, pp. 45–46. Berthelot remained cautious in his criticism of the facilities for science in France, even after the campaign of protest in the 1860s (in which he did not participate) and the military defeat of 1870–1871. As late as 1882 he wrote to Michel Bréal: " Granted, it serves some purpose to stress, with the Chambers and the public, the condition of German professors, in order to improve that of French professors. But we should not be deceived by this comparison, in which the deficiencies of our own system are contrasted with the outstanding aspects of that of our neighbours ". The passage from the letter to Bréal is quoted in Paul, H. W., *op. cit.*, p. 10.

[105] Prost, Antoine, *L'enseignement en France 1800–1967* (Paris: Armand Colin, 1968), p. 227. Another supplement to the basic salary was the *éventuel*, a sum determined by the budget of the faculty in question and the number of registered students. Since the number of such students in science faculties was low—especially when compared with student numbers in the faculties of law—the *éventuel* was small, exceeding 2,000 francs in only three of the country's 16 science faculties in 1865. In none of the 11 law faculties of France was the *éventuel* less than 2,150 francs. See *Statistique de l'enseignement supérieur* . . . pp. 342–343.

Paris, an even greater snare was *cumul*. Although it had been common enough under Napoleon I,[106] *cumul* seems to have been practised even more extensively after the Restoration, in science as in other disciplines. Of the great scientific *cumulards* the best known was perhaps Dumas, who had teaching duties at the Athénée, the École centrale des arts et manufactures, the Sorbonne, the École polytechnique, the École de médecine, and the Collège de France—though admittedly not *all* at the same time. But even Dumas, who excelled in the multiplicity of the responsibilities which he accepted, was not without his rivals; indeed, there were very few of his contemporaries in science who did not hold at least two teaching posts.[107] In doing so they not only jeopardised their research but also, as we can see from complaints that were made against them, did much harm to the career prospects of younger men.[108]

Dumas's career is especially interesting, for his decision to abandon science for politics in the exciting days of 1848 points to another, non-academic outlet for the talents of scientists. Like *cumul*, politics and public life in general had been attractive to French scientists and mathematicians before 1815; during the First Empire Monge, Chaptal, Fourcroy, and, for six unhappy weeks, Laplace had held government posts. But from the 1820s, as political activity grew in interest and intensity, scientists, like Ampère and Biot, who did not take positions in politics or in academic or government administration, became increasingly uncommon, and instances of successful scientists who sacrificed their research for public life, like Arago, Thenard, and Gay-Lussac, were correspondingly more frequent.

The diversion of interest from research in France would not have been

[106] At this time young family men, like Biot and Dulong, would have found it difficult to live on the income from only one post. On the *cumul* of scientists during the First Empire, see Crosland, M. P., *op. cit.*, pp. 224–226.

[107] See, in addition to the usual biographical sources, Crosland, M. P., *op. cit.*, pp. 226–231. Gay-Lussac, who was particularly enterprising, acted as industrial consultant as well as taking on a wide range of teaching duties. The combined salaries of Thenard, who defended the system of *cumul* against the attacks of Gerhardt in 1848, came to 30,000 francs p.a. for a few years. This sum far exceeded the 13,000–14,000 francs which, according to Thenard, a successful academic *cumulard* might expect to earn between his mid-thirties and his fifties. It is clear from his reply to Gerhardt that Thenard considered *cumul* to be normal and proper, given that salaries in teaching compared most unfavourably with the salaries of 15,000–18,000 francs which were commonly paid in government administration; see Thenard, Paul, *Un grand Français. Le chimiste Thenard* (Dijon: Jobard: 1950), pp. 206–209.

[108] Indignation against *cumul* seems to have reached a peak in 1848, when a petition on the subject was presented to the provisional government by a group of scientists and doctors. No one protested more vigorously than Charles Gerhardt, who saw *cumul* as the chief cause of his failure to obtain a teaching post in Paris; see Grimaux, E. and Gerhardt, C., *op. cit.*, pp. 172–179. As the naturalist Quatrefages observed, an unfortunate consequence of *cumul* was that appointments to the most important chairs tended to be made rather late in life; see Quatrefages de Bréau, Jean Louis Armand de, " De l'enseignement scientifique en France ", *Revue des deux mondes*, 5th ser., XXII (1848), pp. 501–502.

so remarkable and damaging had it not become widespread just at a time, in the 1830s and 1840s, when research in the German universities was beginning to flourish. And how ironical this was, for the German achievements owed much to French science. For example, no one did more to publicise the case for experimental research and exact science in a Germany dominated by *Naturphilosophie* than did Alexander von Humboldt, whose observations were based almost entirely on his experiences as one of the most prominent members of the Arcueil circle during the First Empire.[109] It was through working in Gay-Lussac's laboratory in 1824 that Liebig was inspired by the ideal of exact experimental science for which he provided such a favourable institutional setting at Giessen.[110] But, as research became increasingly integrated in education in the German universities,[111] the French maintained their rigid distinction between the conveying of established truths and the acquisition of new knowledge, and, at least in the institutions for higher education in science, largely ignored the latter. While French lecturers strove for oratorical effect, German professors developed the severe style of which Ernest Renan and George Pouchet thought so highly.[112] And even when the effectiveness of German research and research schools was beyond dispute and when students throughout Europe were flocking to the German universities, the French remained unimpressed—so much so that, of the 169 matriculated students who came from outside Germany to work in Liebig's laboratory at Giessen between 1829 and 1850, only 22 came from France, and of these no fewer than 14 came from Alsace, where German influences were unusually strong.[113] Frenchmen willing to express admiration for German research and scholarship, in the way that Victor Cousin did as a result of the tours in Germany and Holland which he made after the Restoration, were decidedly in a minority until the 1860s.[114]

Awareness of Governmental Neglect

The complacency of the French lasted far into the Second Empire, until, almost without warning, in the mid-1860s, public complaints about the

[109] See Crosland, M. P., *op. cit.*, pp. 104–113.

[110] On the importance of Liebig's French experiences for his later work, see the autobiographical passage quoted in Merz, John Theodore, *A History of European Thought in the Nineteenth Century*, 4 vols. (Edinburgh and London: Blackwood, 1896–1914), Vol. I, pp. 190–191.

[111] See, on this process, Paulsen, F., *op. cit.*, pp. 79–88.

[112] See Renan, E., *op. cit.*, p. 83 and Pouchet, G., *op. cit.*, pp. 443–446.

[113] Wankmüller, Armin, "Ausländische Studierende der Pharmazie und Chemie bei Liebig in Giessen", *Tübinger Apothekengeschichtliche Abhandlungen*, Heft 15 (Stuttgart, 1966), pp. 8–9 and 11–16. I am indebted to Dr. W. H. Brock for this reference.

[114] For Cousin's view of German university life see his "Lettres à M. le comte de Montalivet, Ministre de l'Instruction Publique et des Cultes, sur l'état de l'instruction publique en Allemagne", *Revue de Paris*, XXIX (1831), pp. 15–37, 74–107, and 209–240; *ibid.*, XX (1831), pp. 101–117 and 164–186; also the later versions of these articles, published as *Rapport sur l'état de l'instruction publique dans quelques pays de l'Allemagne, et particulièrement en Prusse* (Paris: Levrault, 1833); 3rd edn., 2 vols. (Paris: Pitois-Levrault, 1840). This form of admiration for scholarship and research and the institutions which fostered them should not be confused with the Romantic interest in German literature and philosophy which was common at this time.

state of the country's science became both frequent and bitter. The complaints were nearly always presented in the form of an explicit and unfavourable comparison with Germany, and this is not surprising since by that time the French had had occasion to reflect not only on the effectiveness of German higher education, but also on the growing political and military power of Prussia, especially after her crushing victory over Austria in 1866. In such circumstances, it was natural that the case for a greater provision for scientific research should normally be argued with reference to the national interest. Renan's much-quoted assertion that it was the science of Germany which had triumphed at Sadowa was probably in the minds of many of the critics,[115] and after the tragedy of the Franco-Prussian war both Sainte-Claire Deville and Pasteur put at least some of the blame for France's defeat on her neglect of science.[116]

The long-standing lack of government support for research was most frequently blamed in the late 1860s, and there can be no denying that the complaints had substance. For although French governments had not neglected research entirely—the Bureau des longitudes is a good example of an official research institution—the motives for official sponsorship had always been, understandably, utilitarian.[117] For instance, the only special research projects in physics to be financed by government funds between 1815 and 1870 were the two investigations of the properties of steam and gases which Dulong, between 1823 and 1829, and Regnault, between 1840 and 1870, were commissioned to conduct.[118] In both cases the patronage was lavish enough to allow the performance of experiments other than those that were asked for, and results of some theoretical importance were obtained.[119] But the purpose was clearly and explicitly to provide information that could be put to immediate use, whether (as in the case of Dulong's investigation) it was in order to enhance the safety of steam-engines, or (as in the case of Regnault's) it was to increase their efficiency.

[115] Wurtz, for example, argued strongly for the connection between the intellectual attainments of a nation and its political and military strength. See Wurtz, C. A., *op. cit.*, pp. 12–13.

[116] For Deville's comment, see *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, LXXII (1871), pp. 237–238. For Pasteur's, see Vallery-Radot, R., *La vie de Pasteur . . .* pp. 277–280.

[117] Research institutions which failed to show their usefulness in the way that the Bureau did were, by comparison, sadly neglected. The Muséum d'histoire naturelle, where a state of extreme delapidation was exposed by a government committee of enquiry in 1858–1859, is a good illustration of this; see Du Camp, Maxime, "Les écoles à Paris", *Revue des deux mondes*, 2e période, CIII (1873), pp. 823–825. Although an enquiry in 1863 had confirmed the findings of the earlier committee, showing that the gardens, specimens, and live animals were still in a deplorable condition, there had been little improvement by 1872, when Du Camp made his critical observations.

[118] On this research see Fox, R., *Caloric Theory of Gases. . . .* pp. 249–250 and 297–303.

[119] Regnault was even able to take in students at his laboratory in the Collège de France. See *Mémoires de l'Académie des sciences*, XXVI (1862), p. ix. The young William Thomson worked there in 1845.

If cases of government intervention in support of research were few between 1815 and 1870, the reason was that science so rarely appeared to be useful. But also science appeared to do little harm, and when, very occasionally, measures unfavourable to science were taken, they were the result of short-term political considerations rather than of a consistently hostile policy. This was certainly true of the discrediting of mathematicians and scientists that took place immediately after the Bourbon Restoration, for science at that time was all too easily charged with being a product of the revolutionary and Napoleonic periods.[120] Indeed, the elite of scientific apprentices, the *polytechniciens*, had aroused the justified suspicion of royalist sympathisers by fighting ardently in the defence of Paris in 1814 and by rallying joyfully to Napoleon during the Hundred Days.[121] So it was only to be expected that after the Restoration science would suffer and that scientists would be scrutinised with special care.

By the 1820s, a much greater threat to the political and religious ideals of the Restoration seemed to lie in the eclectic philosophy of Cousin and in the prevailing anti-clericalism of the teachers in secondary and higher education.[122] As lay and clerical officials recognised the new threat, so the radical associations of science began to be forgotten. It is entirely characteristic of these changing attitudes that the government and the newly created Grand Master of the University, Monseigneur Frayssinous, demonstrated their suspicion of subversive intellectual activity by closing the École normale in 1822, while the specialist institutions of science went almost unscathed.[123] To a government concerned to maintain loyalty to the Bourbons and the church, science appeared neutral, and, once the early years of the Restoration were past, it appears to have lost its neutrality only when it became involved in movements for popular education, which in the 1820s aroused as much fear among the legitimists of France as they did among the Tories of Britain.[124]

Of the targets for suspicion of this kind, the most obvious was the Conservatoire des arts et métiers, founded in 1794 as an industrial museum

[120] I have already referred to some of the scientists and mathematicians of the Restoration who lost their positions in teaching and the Académie des sciences for political reasons.

[121] Pinet, G., *op. cit.*, pp. 73–92.

[122] On the conflicts between the administrators and the predominantly liberal, anti-clerical teaching body—among whom, in Paris, at least, the *normaliens* were the most influential, see Gerbod, Paul, " La vie universitaire à Paris sous la Restauration de 1820 à 1830 ", *Revue d'histoire moderne et contemporaine*, XIII (1966), pp. 5–48. The suspension of Cousin from his chair at the Sorbonne between 1820 and 1828 was characteristic of this period, as was the determination with which the church gained control of the new *agrégation* in philosophy in 1825.

[123] On this closure, which lasted until the École normale was re-opened in 1826 as the École préparatoire, see Liard, L., *op. cit.*, Vol. II, pp. 164–166, and *Le centenaire de l'École normale* . . . pp. 222–228. The only purely scientific institution to suffer at this time was the École de médicine in Paris, where courses were suspended for several months in March 1822; see Liard, L., *op. cit.*, Vol. II, pp. 162–163.

[124] On the fear of the Mechanics' Institutes in England, see Cardwell, Donald S. L., *The Organisation of Science in England*, 2nd edn. (London: Heinemann, 1972), pp. 41–42, and the anonymous attempt to allay the fears of "A Country Gentleman ", in the *Edinburgh Review*, XLV (1826–1827), pp. 189–199.

but far more important since 1819 as an institution offering part-time education in technological subjects to working men. Because of its concern with technology and industry, the Conservatoire had liberal and Saint-Simonian associations of which none of the reactionary governments of the 1820s could possibly approve. Suspicion was greatly heightened by the fact that, as far as its teaching function was concerned, it was the creation of the same Charles Dupin who, almost alone, had defended Lazare Carnot when Carnot was exiled from France shortly after the downfall of Napoleon[125] and who, especially during the ministry of the duc de Richelieu (1815–1818), had done so much to arouse the hostility of ministers, in whose eyes his brilliant, first-hand investigation of the industrial, commercial, and military strength of Britain was subversive and unpatriotic.[126] The professors of the Conservatoire included not only Dupin but also Jean-Baptiste Say, professor of industrial economy and, like Dupin, no friend of reactionary governments.[127] They were therefore unusually vulnerable to official censure and they were perhaps fortunate to suffer no more than mild harassment by the police and a withdrawal of permission to give their lectures in the evenings.[128] But the important point is that the motives for the harsh treatment of the Conservatoire were political and only incidentally concerned with science itself.

So after the Restoration science proceeded against a background of government indifference rather than of special favour or hostility. Modest provision was made for what government officials regarded as essential needs, which were invariably those of the unambitious teacher rather than those of the research scientist aspiring to an international reputation. It is understandable that the twenty-one-year-old Pasteur, fresh from Besançon, was impressed by the facilities available to him as a student at the École

[125] On this episode, see Lacaine, A. Victor and Laurent, H. Charles, *Biographies et nécrologies des hommes marquants du XIXe siècle*, 7 vols. (Paris: À la Direction, 1844–1850), Vol. IV, p. 279, and Bertrand, Joseph, *Éloges académiques* (Paris: Hachette, 1890), pp. 234–236. Dupin's sympathy for those who suffered at the Restoration was demonstrated also by his *Essai historique sur les services et les travaux scientifiques de Gaspard Monge* (Paris: Bachelier, 1819), in which he championed Monge, his teacher at the École polytechnique from 1801 to 1803.

[126] On Dupin's tours of Britain and the official impediments to his work that he encountered in France, see especially Lacaine, A. V. and Laurent, H. C., *op. cit.*, Vol. IV, pp. 280–284. Although Dupin had sought permission to visit Britain since the fall of the Empire, it was only in the summer of 1816 that permission was granted. For some three years thereafter Dupin was suspect, and his earliest published accounts of his observations, notably his *Mémoires sur la marine et les ponts et chaussées de France et d'Angleterre* (Paris: Bachelier, 1818), were temporarily withdrawn from naval and military libraries. It was, significantly, during the ministry of the mildly liberal duc de Decazes that the Conservatoire began to offer lectures. A study of the Conservatoire's early years which pays special attention to the political background is my article " Education for a New Age: the Conservatoire des arts et métiers, 1815–1830 ", in Cardwell, Donald S. L. (ed.), *University of Manchester Institute of Science and Technology. Commemorative Essays, 1824–1974* (Manchester: Manchester University Press, to appear in 1974).

[127] On the police surveillance of Say and Dupin, who were both considered to be extremely suspect, see Dreyfus, Ferdinand, *Un philanthrope d'autrefois. La Rochefoucauld-Liancourt 1747–1827* (Paris: Plon, 1903), pp. 415–416.

[128] On the difficulties of the Conservatoire, see Dupin, F. P. Charles, *Forces productives et commerciales de la France*, 2 vols. (Paris: Bachelier, 1827), Vol. II, pp. 232–233, and Fox, R., " Education for a New Age . . .".

normale in 1843 [129]—but it is equally understandable that, by 1851, when he was teaching in the science faculty at Strasbourg (generally considered to have been the best of the provincial science faculties in the nineteenth century), he felt greatly constrained by an annual budget for chemistry of between 1,300 and 1,400 francs, of which 400 francs went immediately to pay the laboratory assistant.[130] At Strasbourg, as elsewhere, there was no provision for research.

It is important to stress that poor conditions and lack of encouragement did not make research impossible. The teaching load was not intolerable in any of the institutions of higher education, although the practice of *cumul* could easily make it appear so [131]; C. M. Despretz, for many years professor of physics at the lycée Henri IV in Paris, showed that serious research could even be undertaken by professors in *lycées*. In all such work, however, strong individual initiative and dedication were indispensable, and, especially for teachers in the faculties, it was always tempting to abandon laboratory work, which brought no monetary reward and often little prestige or advancement, in favour of extra teaching or examining, which was at least lucrative.[132] In these circumstances, it was only to be expected that those who excelled in research were often men who possessed not only exceptional personal ambition and ability but also private means. Claude Bernard, good entrepreneur that he was, gained his support first by contracting a judicious marriage and later by making a personal approach to Napoleon III.[133] More often the source of finance was a man's own family, as in the cases of Berthelot, Sainte-Claire Deville, and Hippolyte Fizeau, all of whom had fathers able to support them for some years in their important early researches.[134]

Those who were less fortunate had to finance their research from their earned incomes, and when we consider the personal sacrifice which this

[129] See his letter of 11 November, 1843, to his parents, in Vallery-Radot, P., *Pasteur. Correspondance . . .* Vol. I, pp. 92–93.

[130] See his letter of 20 January, 1851, to the Minister of Education (Parieu), *ibid.*, Vol. I, pp. 217–218.

[131] Dulong was someone who suffered in this way. See Fox, R., *Caloric Theory of Gases . . .* pp. 255–256.

[132] In Quatrefages de Bréau, J. L. A. de, *op. cit.*, pp. 500–501, it is stated that the temptation was especially great in the provincial science faculties, where professorial incomes were normally lower than in the faculties of law or medicine. Certainly law and medicine provided more opportunities for extra-mural earnings, but Duruy's enquiry of 1865 showed that the incomes of professors in the provincial faculties of law, medicine, science, and letters did not differ greatly, nearly all of them lying between 5,000 and 7,000 francs; see *Statistique de l'ensiegnement supérieur . . .* pp. 342–343.

[133] Olmsted, J. M. D. and Olmsted, E. H., *op. cit.*, pp. 46–47 and 126–127.

[134] On Berthelot's background, see the article on him, by M. P. Crosland, in Gillispie, Charles Coulston (ed.), *Dictionary of Scientific Biography* (New York: Charles Scribner's Sons, 1970 in progress), Vol. II, p. 63. On Sainte-Claire Deville, see Gernez's comments in *Le centenaire de l'École normale . . .* p. 409. In his early work Fizeau was supported by his father, a professor at the École de médecine in Paris. Although he performed some of his most important work at the Paris Observatory, he never held a permanent full-time post and he continued to finance most of his research privately throughout his life. See Cornu, Marie Alfred, "Notice sur l'oeuvre scientifique de H. Fizeau", *Annuaire pour l'an 1898, publié par le Bureau des longitudes* (Paris: 1898), especially pp. C.2–3.

entailed, French achievements in research between the 1820s and 1860s seem remarkable. One unidentified foreign visitor to a Parisian laboratory about the middle of the century wrote: "I used to respect your work; it appeared great. Now that I know the material resources at your disposal, I wonder at it." [135] In the great majority of French laboratories admiration would have been fully justified. Nowhere was this truer than in the private laboratory in the rue Cuvier where Dumas performed the research which did so much to establish the science of organic chemistry in the 1830s and 1840s, and where from 1832 to 1848 he offered one of the few courses of laboratory instruction available in France between the Empires.[136] Other private laboratories, such as those of J. B. J. D. Boussingault, Fizeau, J. T. Pelouze, Léon Foucault (in his own residence in the rue d'Assas), and the physiologist E. J. Marey (in the attic of an abandoned theatre), were generally more modest,[137] and, since they offered no systematic courses of instruction, students were very rarely admitted to them. The difficulties of the young Thomas Andrews, professor of chemistry at Queen's College, Belfast, from 1849 to 1879, whose vain search for a course of laboratory instruction in chemistry ended in Paris only when he made a personal contact with Dumas,[138] would have been all too common for a visitor to France about 1830.

Thus by the middle of the century scientific research was by no means flourishing in France—a fact which was especially evident in the physical sciences, where the development of thermodynamics, the kinetic theory of gases, and electro-magnetism was proceeding in the almost total absence of French contributions. However, without the enterprise and dedication of a few individuals like Dumas, Pasteur, and Wurtz, the situation would certainly have been very much worse. Naturally this leads us to the question why those who did perform serious research at this time made the sacrifices which were necessary in order to do so. The most pressing motive, at least for younger men, seems to have been the desire for professional advancement, usually in the form of an appointment to one of the famous and comparatively lucrative teaching posts in Paris. As ambitious men like Pasteur knew well, the preoccupation with teaching in the institutions for higher education in no way diminished the importance of research as a means of demonstrating one's competence to an appointing committee. The mere desire for renown in the national and international scientific community was another incentive which might have been expected to weigh heavily, but, in keeping with my analysis of the new style of science after

[135] Quoted in Pasteur, L., *Le budget de la science. . . .* p. 10, and Papillon, F., *op. cit.*, p. 609.

[136] Wurtz was among those who worked in Dumas's laboratory in the 1840s. On him and other students who attended about the same time, see Friedel, C., *op. cit.*, p. ix.

[137] See Papillon, F., *op. cit.*, pp. 594, 604 and 607.

[138] *The Scientific Papers of the late Thomas Andrews, M.D., F.R.S.* (London: Macmillan, 1889), pp. xi-xii. Dumas had only one other pupil, an American, in his laboratory at the time.

the Restoration, I see it as one of the saddest aspects of nineteenth-century French science that this particular incentive was of slight importance. As the chief evidence for this, I would point once again to the frequency with which scientists like Arago, Gay-Lussac, Thenard, Dumas, Berthelot, and Joseph Bertrand achieved eminence by their record in research but then, rather than building a research school in the German manner, used their eminence in a second career unrelated to research or, in many cases, even to science.

I believe, then, that there can be no doubt concerning the great importance of the determination and initiative of a few individuals in nineteenth-century French science. The point is reinforced if we examine developments in scientific and technological education after the Restoration, for these were no less dependent on private enterprise than was research. For example, at the Conservatoire des arts et métiers the appointment of three professors and the establishment of courses of public lectures in 1819 followed an approach by Charles Dupin to the duc Decazes.[139] Similarly the founding of the École centrale des arts et manufactures and the Association polytechnique in 1829 and 1830 resulted from the activities of small groups of, respectively, capitalists and graduates of the École polytechnique.[140] Even the government reforms of the 1860s, notably the founding of the research-oriented École pratique des hautes études in 1868, could never have come about but for the personal convictions of Victor Duruy, whose policies as Minister of Education from 1863 to 1869 reflected his whole-hearted support for the scientists' demands for improved research facilities.[141]

By the time he left the Ministry, Duruy had gone some way towards fulfilling his self-imposed task of providing government support for research on a totally new scale. The Sorbonne, for example, had new laboratories for physics, chemistry, and physiology, all established with Duruy's backing,[142] and the École pratique des hautes études, although no more than an administrative union of teachers and existing facilities for research, did at least strengthen the claims of laboratories and their users in the struggle for resources. But even while the energetic Duruy was minister, his schemes were always hindered by the lack of funds, and the disasters which followed in 1870–1871 so inhibited reform after his departure from the Ministry that many of the complaints of the 1860s, especially those concerning the faculties, continued to be voiced throughout the rest of the

[139] On the establishment of lectures at the Conservatoire see, for example, *Ministère de l'Éducation Nationale. Cent-cinquante ans de haut enseignement technique au Conservatoire national des arts et métiers* (Paris: Conservatoire national des arts et métiers, 1970), p. 21.

[140] See Comberousse, Charles de, *Histoire de l'École centrale des arts et manufactures depuis sa fondation jusqu'à ce jour* (Paris: Gauthier-Villars, 1879), pp. 10–36, and *Histoire de l'Association polytechnique et du développement de l'instruction populaire en France* (Paris: Imprimerie et Librairie Centrales des Chemins de Fer, 1880), pp. 33–40.

[141] On Duruy's role in the founding of the École pratique see Liard, L., *op. cit.*, Vol. II, pp. 286–295, and Rohr, J., *op. cit.*, pp. 116–121.

[142] Papillon, F., *op. cit.*, pp. 596, 601, 604, and 607.

century. It is perhaps not surprising that Gabriel Monod should have still been complaining bitterly of the state of the faculties in the 1870s, in particular of their isolation from one another and the popular nature of their teaching;[143] but what is striking and significant is that 30 years later the historian Ferdinand Lot could still describe the faculties, now reorganised into 15 universities, in a way which suggests that there had been little improvement in their condition, either materially or intellectually.[144]

Even in the early 1900s, it seems, the need for the individual scientist to create his own opportunities in the face of financial deprivation and an almost total absence of official encouragement was scarcely diminished.

Conclusion

In this paper I have examined the way in which an ideal of corporate, planned research first flourished, in Napoleonic France, and was then abandoned in the 50 years following the overthrow of Napoleon. I have tried to show that France's successes in scientific research under Napoleon and her comparative quiescence from the 1820s cannot be explained adequately in terms of either the generosity or the parsimony of government sponsorship. Of course, government initiative in, say, the 1840s, when the superiority of the facilities in German laboratories was becoming so very marked, would have been of great benefit, and it is tempting to censure successive ministers of education for their failure to act. But why should a government have taken such an initiative at that time? Even in Germany governments made their provision for research largely in response to external pressure, such as Liebig for one never ceased to exert[145]; the same was true *a fortiori* in Britain, where the individualist tradition in scholarship was strongest.[146] What France by contrast patently lacked was a scientific community ready to assert its demands persistently and publicly on behalf of science.

Since I believe that the role of individual initiative has not received the attention it deserves from historians of French science, I have discussed in some detail the highly personal motives which led Laplace and Berthollet to act as patrons in the way they did. Clearly their success as patrons owed

[143] Monod, G., *De la possibilité d'une réforme de l'enseignement supérieur, passim.*

[144] Lot, Ferdinand, *De la situation faite à l'enseignement supérieur en France*, 2 vols. (Paris: Cahiers de la Quinzaine, 1906). Similarly in his *Les hautes études pratiques dans les universités d'Allemagne et d'Autriche* (Paris: Masson, 1882), pp. 1–3, Wurtz wrote of a number of laudable projects, such as the rebuilding of the science faculties in Lyons and Bordeaux, but he made it clear that, with the notable exception of the enlargement of the faculty of medicine in Paris, little progress had been made since his earlier report in 1870.

[145] The importance of Liebig's enterprise is brought out well in Morrell, J. B., "The Chemist-Breeders: the Research Schools of Liebig and Thomas Thomson", *Ambix*, XIX (1972), pp. 1–46.

[146] See Morrell, J. B., "Individualism and the Structure of British Science in 1830", *Historical Studies in the Physical Sciences*, III (1971), pp. 183–204.

a great deal to facilities which were dependent on government funds. But for the training at the École polytechnique, where would they have obtained the supply of recruits for their school? And without the financial support and prospects of good careers which came of victory in the competitions of the Académie, how could they have hoped to engage gifted young men in long and expensive research? Yet, for all this, I believe that the achievements of Laplace and Berthollet, though obviously dependent upon the facilities which were available under Napoleon, owed far more to the skill and determination with which the facilities were utilised. The importance of individual initiative becomes still clearer when we make the comparison with the years after the collapse of the Arcueil school. In these years, despite a large measure of institutional continuity with the period before 1815, there were no schools of research in France, no one willing to take on the mantle of the masters of Arcueil.[147]

In attempting to explain this striking contrast I have paid special attention to a change in the style of French intellectual life after the Restoration. In my view, this change, above all else, was responsible for the ease with which the interests of even established scientists were diverted to popular lecturing and public life and for the preoccupation with teaching and success in examinations, such as the highly esteemed *agrégation*, which characterised institutions which might otherwise have become centres of research.[148] In putting this case I do not claim to have considered every possible cause of the decline of the research ideal in France. How, for example, are we to gauge the effect of the premature deaths of such men as Petit, in 1820, and Fresnel, in 1827, who might conceivably have filled the gap left by the great Napoleonic patrons? And what importance should be attached to the size of personal fortunes? Certainly incomes had some effect, at least on the style of patronage, for after the Restoration, when an annual income of 30,000 francs was exceptional and could only be earned at the expense of time for personal research, and when in any case laboratory research was becoming more costly and complex, it was out of the question for any French scientist privately to offer facilities which

[147] There were still, of course, traditions of research, notably in the work of Gabriel Lamé and J. M. C. Duhamel, which owed much to Fourier. And such "elder statesmen" of French science as Fourier, Ampère, and Arago continued to help younger men. The mathematician C. F. Sturm, for example, was greatly helped in his career through influence of this kind; see Speziali, Pierre, *Charles-François Sturm (1803–1855). Documents inédits* (Paris: Palais de la découverte, 1964). But the unity and close supervision that were characteristic of the Arcueil school were absent.

[148] For Renan, the École normale and the *agrégation* were the chief culprits in diverting the attentions of France's intellectual elite from original research. *Agrégés*, educated by "lengthy exercises in the skills of rhetoric", dominated secondary and higher education both in administration and teaching, and between 1821 and 1842 well over one third of all the *agrégés* were also *normaliens*. See Renan, Ernest, *op. cit.*, pp. 84–86, and Gerbod, Paul, *La condition universitaire en France au XIXe siècle* (Paris: Presses Universitaires de France, 1965), pp. 62–64. For Lot, writing in 1906, the *agrégation* was the "intellectual scourge" of France, which both discouraged research and failed to select those who would become the best teachers; see Lot, F., *op. cit.*, Vol. II, pp. 148 and 162–166.

were even remotely comparable with those which Berthollet and Laplace had offered at Arcueil.[149]

Perhaps also we should take an internalist view and consider the possibility that the eminence of such men as Fourier, Cauchy, Navier, and Lamé in mathematical physics diverted attention to mathematical problems and made laboratory research and its shortcomings appear unimportant.[150] A lack of enthusiasm for research may also have been one unhappy consequence of the centralisation of French higher education, which gave no encouragement to the invigorating spirit of rivalry which was so strong in the German universities.[151] And, finally, we might consider the effect of secondary education, which between the Empires was dominated by an abiding preoccupation with the classics, to the undoubted detriment of science.[152] At the very least, the classical bias of the *lycées* probably contributed to a diversion of able students from science and hence to a weakening of the scientific community.[153]

Even if my characterisation of the public, rhetorical style of post-Restoration science, with its accompanying attitudes towards research, is accepted, how are we to explain the readiness of French scientists to adopt this style when attitudes in Germany were so different? Perhaps, on this point, Renan gave as good an explanation as we can ever hope to have when he stated that it was simply a question of national characteristics, a consequence of "the peculiar character of the French mind."[154]

[149] For a comparison of post-Restoration incomes with those of Berthollet and Laplace see footnotes 34, 49, and 107.

[150] Théodore Olivier certainly believed that a growing concern for mathematics harmed experimental science at the École polytechnique after 1816. Olivier, Théodore, *op. cit.*, pp. vi–xviii.

[151] The centralisation of French science was much criticised about 1870, not only in France but also abroad. See, for example, Playfair, L., *op. cit.*, pp. 7–11. Some of the harmful effects of centralisation are discussed in Ben-David, J., *op. cit.*, pp. 174–179, and in the same author's "Scientific Productivity and Academic Organization in Nineteenth Century Medicine", *American Sociological Review*, XXV (1960), pp. 828–843.

[152] The harmful effects of the classical bias in secondary education were stressed in Dumas, Jean-Baptiste André, *et al.*, *Ministère de l'Instruction Publique. Rapport sur l'enseignement scientifique dans les colléges, les écoles intermédiaires et les écoles primaires* (Paris: P. Dupont, 1847).

[153] In this respect the effect was probably similar to that which the Romantic movement is sometimes thought to have had. On the latter, see Herivel, J. W., "Aspects of French Theoretical Physics in the Nineteenth Century", *The British Journal for the History of Science*, III (1966–1967), pp. 116–118.

[154] Renan, E., *op. cit.*, p. 84.