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The Rise and Decline of France as a Scientific Centre

THE shift of the scientific centre from England to France which occurred during the second half of the eighteenth century did not establish a very pronounced French superiority. France was the centre of the scientific world, but for England it was only a slightly more successful competitor, and no more than a senior partner in a common intellectual enterprise. During the first three decades of the nineteenth century, however, French scientific supremacy became much more unequivocally established.[1] In spite of the brilliance of some British scientists such as Dalton, Davy, Faraday and Young, neither in Britain nor anywhere else were there first-rate scientists covering all the then existing fields of science. Only in France, or more precisely in Paris, were all fields of science pursued at an advanced level.[2]

This systematic coverage of all the sciences in a single centre has been interpreted as the first instance of organised professional science in contrast with the amateur pattern of the seventeenth and eighteenth centuries. This view would seem to be supported by the existence of a few institutions of scientific higher education in France which were more advanced than those in other countries. But it is difficult to make this interpretation consistent with the fact that French scientific leadership came to an end about 1830–40. Had this really been the first instance of organised professional science, then the scientific supremacy of France should have

1 In the 26 five-year periods between 1771 and 1900, Britain made more discoveries in heat, light, magnetism and electricity than France or Germany in eight. Germany made most discoveries in these fields in 11, while France led the other two countries in six of the five-year periods. (France and England were equal, and ahead of Germany, in the half-decade from 1811 to 1815.) Of the eight half-decades of British superiority, seven of them fall between 1771 and 1810, of the 11 half-decades of German superiority, 10 fall between 1851 and 1900 when Germany led in every five-year period. France's periods of supremacy lay between 1815 and 1830, with a renewal of supremacy between 1841 and 1850. See Rainoff, T. J., " Wave-like Fluctuations of Creative Productivity in the Development of West European Physics in the Eighteenth and Nineteenth Centuries ", *Isis*, XII, 2 (May, 1929), tables 4–6, pp. 311–313. In physiology, between 1800 and 1924, France led in a number of original contributions in four out of the five half-decades until 1824. After that Germany led in every half-yearly period until the end of the period. A similar calculation of numbers of discoveries in medical sciences by decades between 1800 and 1926 shows France leading from 1800 to 1829, and Germany taking the lead thereafter in every decade until 1910 when the lead passed to the United States. See Zloczower, A., " Analysis of the Social Conditions of Scientific Productivity in 19th Century Germany " (unpublished M.A. dissertation, Hebrew University of Jerusalem), based on Rothschuh, K. E., *Entwicklungsgeschichte physiologischer Probleme in Tabellenform* (Munich: Urban & Schwarzenberg, 1952), and Ben-David, J., " Scientific Productivity and Academic Organisation ", American Sociological Review, XXV, 6 (December, 1960), p. 830.

2 See Crosland, Maurice, *The Society of Arcueil: A View of French Science at the Time of Napoleon I* (London: Heinemann, 1967).

lasted longer than three decades. The professionalisation of science yields its best results in the second or third generation.

I believe that the great upsurge of French science following the Revolution was only indirectly related to the new institutions of higher education established between 1794–1800, and that those institutions did not constitute a beginning of organised professional science. They were rather the culmination of eighteenth century patterns of scientific work. I suggest furthermore that the upsurge was due to the re-emergence and reinforcement under Napoleon and the Restoration of the same constellation of social forces which furthered the growth of science during the last decades of the *ancien régime*, and which was temporarily disrupted under the Revolution. This interpretation is consistent with the exact duration of the upsurge and the paradoxical onset of the decline in the 1830s when a liberal regime finally made the "institutionalisation" of scientific values in France possible.

The first part of this paper is an attempt to substantiate this interpretation. The second part attempts to explore the structure and the working of French science during the rest of the nineteenth and twentieth centuries. The main purpose of this will be to see why, in spite of its numerous parallels with the British system, French science has been relatively ineffective in responding to the challenge of organised scientific research which emerged in Germany about the middle of the nineteenth century and was subsequently further developed in the United States.

The Importance of Scientism in the Advancement of Science

The pressure during the Revolution for the establishment of new scientific-educational institutions and regular careers for scientists, scholars and philosophers was primarily a product of demands by scientistic philosophers and other intellectuals rather than of demands by expert scientists.

The scientistic movement in French intellectual opinion consisted from its very onset of persons with practical interests in politics and economics. Their principal aim in using science as a model in political and economic affairs was to provide objective, "scientific" proof of the necessity for changes which they desired, and which they could not or would not support by traditional arguments. They were often careless and superficial in their thinking. There was a great deal of confusion about the meaning of scientific laws when applied to human action, and much confusion between statements of fact and judgements of value. This confusion persisted throughout the eighteenth and nineteenth centuries in much of the philosophical thought about man and society.[3]

Nonetheless, until the second half of the eighteenth century the philosophers did not raise the question as to whether there were methods other

[3] See Gillispie, Charles C., *The Edge of Objectivity: An Essay in the History of Scientific Ideas* (Princeton University Press, 1960), pp. 151–157.

than empirical science to arrive at truth through efforts of human intellect. Explicitly or implicitly, they accepted Newtonian natural science and Baconian intellectual strategy as the only available methods, short of revelation, of attaining significant and objectively valid knowledge. Their purpose was to explore what these methods and knowledge consisted of and to apply the conclusions to morals, politics and economics.

In the eighteenth century Britain was the only large country where people could propagate change and reform without the danger of persecution. Furthermore, the intellectuals in Britain were an integral part of what can be described as the upper middle class. They were often wealthy and well-connected, and many earned their incomes from ecclesiastical or governmental positions, or independent professional work. They were not politicians themselves, but they usually had direct access to political leaders and often acted as their advisers. It is not surprising that they had first-hand and practical knowledge of politics, economics and legislation and that their views were rarely revolutionary or utopian. The way they tried to apply science to the practical problems of society was not dissimilar to the way in which the great inventors of the age went about applying the scientific approach to the building of machinery or the treatment of illness. They were well aware of the complexity as well as the specificity of the problems with which they dealt and did not try to deduce suggestions for social reform from first principles. Even a man like Bentham who was inclined by temperament to reason from first principles was driven to a great deal of practical social gadgeteering.[4]

Germany was almost at the other end of the scale, as it was a country (or rather an area comprising several countries) where change was legitimate only if initiated by the ruler and where intellectuals (except some foreigners) had no access to policy-making. Hence there was little incentive to treat political and economic questions in the same manner as in Britain and France. France, finally, was somewhere in between. The place of the intellectual in French society was similar to that in England. The outstanding ones among them were members of the upper middle class and had excellent contacts with the ruling circles. At the same time, however, France was in many ways ruled in an even more traditional manner than Prussia and other German lands. Religious pluralism was not officially tolerated, invidious distinctions of status and rank were officially bolstered, and attempts at social reforms had to stop short at sacrosanct traditional prerogatives.[5]

Another aspect of the situation was the degree of social consensus concerning the legitimacy of change. In Britain, social heterogeneity and social change were generally accepted, and even those who considered these things as evils were resigned to living with them. In Germany,

[4] See Letwin, S.R., *The Pursuit of Certainty* (Cambridge University Press, 1965), pp. 176–188.

[5] Smith, P., *A History of Modern Culture,* Volume II, *The Enlightenment 1681–1776* (New York: Collier, 1962), pp. 485–490.

change and heterogeneity were only acceptable to a few, although these few had often disproportionate influence in ruling circles. In France, however, society was much more evenly divided between those who favoured and those who opposed change, and the balance of power between the two factions was much more delicate than anywhere else. Since the church and the official educational establishment in general (with very few exceptions, such as the *Collège de France* and in part, the academies) were monopolised by the traditional sector, the clash between progressives and traditionals was particularly violent in matters of education and religion.

The effect which this situation had on political thought in France has been described by Tocqueville, who believed that since ideas about society were not put to the test, there was no way to judge their effects. The ideas, therefore, became increasingly abstract and doctrinaire.[6] This was his interpretation of the situation in France in the period before the Revolution. Furthermore, since the intellectuals realised, or at least believed, that they could not change anything, the purpose of their writings was to make a striking intellectual impression and to stir opinion.

This tendency was further reinforced and channelled in a new direction by the invidious distinction conferred upon natural scientists by the same governments who persecuted and despised other intellectuals, including the supporters of the scientistic movements (merchants, technologists and upper grade artisans). As a result, there was ambivalence towards science even among the groups which had originally been its most ardent supporters. On the one hand, these groups were still interested in the establishment of a freer society; change and improvement through social reform was still the aim of these philosophers as well as of their scientistically-minded public. Science, which seemed to be integral to these reforms, continued to be an important symbol for them. On the other hand, however, they wanted a type of science in which they could participate, and which would be relevant to their aspirations.[7]

This situation led to a questioning of the very validity of Newtonian science as a model for the logic of inquiry. Attention turned to contents and methods of cognition which were not assimilable to science as it was conceived at that time. For example, Diderot chose to play up chemistry and biology against mathematical physics as the model for sciences, and Rousseau pointed out the inadequacy of science for the description of the moral experience of man, and suggested a new intuitive conception of nature as the only valid way to true understanding.

The questions raised by Diderot and Rousseau were all valid and were as implicit in the state of natural and social science as those raised by Locke and Hume. In this sense they emerged out of immanent intellectual

[6] See Tocqueville, Alexis de, *L'ancien régime* (Oxford: Basil Blackwell, 1937), pp. 147–157.

[7] See Gillispie, Charles C., *op. cit.*, pp. 178–201.

developments. Indeed the problem Diderot raised, the handling of complex structures, became the central achievement of organic chemistry, biology and electromagnetism in the nineteenth century. The inadequacy of eighteenth century science in explaining problems successfully handled by technology was epitomised in the discovery of the steam engine.[8]

The same is true of the problems raised by Rousseau. The basis of validity of moral values in secular societies and the place of creative intuition in the scheme of scientific method have been basic questions to which the social sciences have returned time and again since then. Speculations about the moral consensus of modern societies eventually led to the foundation of modern sociology by Weber and Durkheim.[9] The place of intuition and metaphysics in scientific discovery remains an intensely debated question among philosophers even today.[10]

The long-term effects of this development were very significant. Parallel with an empiricist social science which tended to select problems amenable to empirical investigation and to leave the basic metaphysical questions for ceremonial occasions (as happened in Britain), there emerged in France a tradition of raising basic philosophical questions with little regard for their practical consequences or empirically demonstrable solutions. The raising of basic issues, however justified they are in principle, only contributes to knowledge on rare occasions and is usually avoided by "normal science".[11] The British social philosophers of the eighteenth century behaved in this respect like "normal scientists". Even when, like Hume, they raised fundamental problems, these were never carried to the extreme where they became abstract doctrines which questioned the validity of all moral order and rational search for social reform.[12] In France speculation was carried to just such extremes. Even if this was not the intention of the philosophers, their ideas could easily be used in political or ideological rhetoric for attacking the very foundations of political and moral order.[13]

What interests me here is not the validity of these questions, but the effects of raising them. Implicit in this development was the rise of new intellectual movements which were secular and ascientific (or potentially even anti-scientific), accepting neither the discipline of religious orthodoxy nor that of scientific method.

8 *Ibid.*, pp. 173, 184–192.

9 See Parsons, Talcott, *The Structure of Social Action* (New York: McGraw-Hill, 1937), pp. 307–324; Aron, Raymond, *Main Currents in Sociological Thought*, Volume I (New York: Basic Books, 1965), pp. 89–91, 198–202, and Volume II (New York: Basic Books, 1967), pp. 11–23.

10 See Kuhn, Thomas S., *The Structure of Scientific Revolutions* (Chicago University Press, 1963), pp. 84–90.

11 *Ibid.*, pp. 35–36, 76–79.

12 See Halévy, Elie, *The Growth of Philosophic Radicalism* (Boston: The Beacon Press, 1955), pp. 11–13; as has been pointed out, this was true even of the most doctrinaire of all British philosophers, Bentham.

13 See Crocker, Lester G., *An Age of Crisis: Man and the World in 18th Century French Thought* (Baltimore: Johns Hopkins Press, 1959), pp. 9–106, 461–473.

These, however, were not the immediate consequences. Diderot and Rousseau belonged to the Enlightenment and the short-term effect of their ideas was to make men more optimistic about their own intellectual and moral capacities. This implied a loosening of discipline and the sense of responsibility in philosophical and even in scientific thought, but not, however, a rejection of natural science as the model of intellectual inquiry nor the rejection of the political and educational ideals of the scientistic movement. The combination of the loosening of intellectual discipline with adherence to the goals of scientism turned the latter into a popular movement.[14] Thus the frustration of the political and social goals of the scientistic movement led to the taking up of philosophical themes for the sake of literary accomplishment rather than with a view to providing solutions for practical problems. This in turn popularised the scientistic movement and generated a great intellectual ferment, as manifested in the foundation all over France of local academies, literary circles and clubs eagerly discussing science, social and economic problems and philosophy.

The popularisation of scientific and philosophical interest reversed the trend towards greater separation between expert science and the scientistic movement to which I have already referred. The popular discussion of science insisted that science be socially, technologically and politically "relevant". Although this demand for "relevance" contained seeds of potential anti-scientism and more than potential scientific quackery (such as the famous case of Marat), it also implied admiration for science and a willingness to support it and use it as widely as possible.

The intellectuals became completely alienated from the official educational establishment, especially from the Sorbonne, controlled by the church (and, in the appropriate faculties, by the medical and legal guilds). As a rule they were also opposed to the Roman Catholic Church. Those participating in the new current of intellectual activity felt persecuted although they were not actually suppressed by the official intellectual establishment. They considered the powers and the official privileges of the institutions and the intellectuals who staffed them as completely illegitimate.[15]

Revolutionary and Napoleonic Reforms of Intellectual Institutions

Following the devastation caused by the Terror, a new educational and scientific structure was created and the secular intellectuals acceded to the intellectual monopolies previously exercised by the clergy. It was this, and not the internal requirements of science, which led to the emergence of new educational organisations and government offices providing careers for secular intellectuals, including scientists. The scientistic outlook of the intellectual movement and its high regard for science set the structure

[14] See Mornet, D., *Les origines intellectuelles de la révolution française 1715–1787* (Paris: Armand Colin, 1934), pp. 35–95, 125–127.

[15] *Ibid.*, pp. 129–134, 150, 177, 270–281.

of the system. At the top of the system were a number of *grandes écoles* (including some established under the *ancien régime*), designed to train personnel for government service and higher (including the upper levels of secondary) education. The most famous of these were: the *Ecole polytechnique*, for the training of army officers and higher civil servants; the *Ecole normale*, designed to create a new body of professors for the upper levels of education which after a number of changes comprised both the *lycées* and the faculties (the universities in the accustomed sense had been abolished in 1793 and were only nominally reestablished in 1896, so that every faculty constituted a separate institution); and the *Ecole de médecine*, for the training of the army medical corps.

These educational establishments had, by the standards of the times, excellent laboratory facilities and were complemented by the *Institut*, the *Musée d'histoire naturelle* and the *Observatoire* which were purely research (or in the case of the *Institut* research and honorific) establishments.[16] But they did not represent any new conceptions either in teaching or in the organisation of research. Specialised schools for advanced training for the various professions were favoured by the "enlightened" absolutist regimes and had already existed before the Revolution (*e.g.*, the *Ecole des ponts et chaussées*). Even elite institutions of a purely scientific nature such as the *Collège de France* and the *Musée d'histoire naturelle* assumed their dominant character before the Revolution.[17] The *Collège de France* became an even more distinguished institution, where all fields of science and scholarship were pursued at the most advanced scientific level in a spirit of academic freedom; the spirit of free inquiry was also introduced into some of the new specialised schools, such as the *Ecole polytechnique*, which were ostensibly for the training of professional practitioners.[18]

The Position of Research in the New Institutional System

Only the "central schools" of sciences and letters, designed to replace the *collèges* which had been abolished in 1793, represented a new educational experiment qualitatively different from anything which had existed before. Although intended to be higher secondary institutions, they were in many respects the first attempt to establish a modern university.[19] Had these schools been maintained, they might have led to the emergence of regular careers in research and to modes of organised research such as

[16] See Newman, Charles, *The Evolution of Medical Education in the Nineteenth Century* (London: Oxford University Press, 1957), p. 48, and Crosland, Maurice, *op. cit.*, pp. 190–231.

[17] See Lavisse, Ernest, *Histoire de France Illustrée*, Volume IX (Paris: Librairie Hachette, 1929), pp. 301–304, and Taton, René (ed.), *A General History of the Sciences*, Volume III, *Science in the 19th Century* (London: Thames and Hudson, 1964), pp. 259–440, 511–615.

[18] See Gillispie, Charles C., *op. cit.*, pp. 176–178.

[19] See Liard, Louis, *L'enseignement supérieur*, Volume II (Paris: Armand Colin, 1894), pp. 1–18, and Lefebvre, Georges, *The French Revolution: From 1793 to 1799* (London: Routledge & Kegan Paul, 1964), pp. 290–292.

eventually developed in Germany. But the experiment was soon abandoned. The specialised schools, although now more numerous and of a higher standard than before, perpetuated the eighteenth century patterns of the scientific role and scientific work. Their teachers were supposed either to train students preparing to take special examinations and enter particular careers, or to lecture freely to an undifferentiated audience. Neither of these activities entailed the transfer of the locus of research to the institutions in question or the involvement of the student in the teacher's research. Although the majority of scientists now became teachers, research continued to be a private activity, as it was before the Revolution when scientists earned their living from a variety of sources. Teaching was a partial sinecure which provided an opportunity to engage in research; it was not regarded as having anything more to do with research than that. Other partial sinecures, such as certain civil service appointments, were acceptable alternatives.[20] As far as research was concerned, the amateur pattern still prevailed.

The inner isolation of research from teaching continued because there was no intellectual or economic incentive to overcome it. As has been pointed out, had the central schools been maintained there might have arisen a demand for a combination of the teaching and research roles, but as things were there were good arguments against such a combination.

In seventeenth and eighteenth century Britain and France, humanistic studies were not included in the conception of science. The question as to the extent to which the scientific method should be applied to humanistic studies became an important issue in these countries only during the nineteenth century under the influence of German scholarship.[21] This is not to say that French scholars in these fields in the early nineteenth century were not as outstanding as any. In some fields, such as oriental studies, Paris was indeed the world centre.[22] But it was accepted that the humanistic subjects had important aesthetic and moral aspects which distinguished them from science. The importance of these aspects to education was never denied. On the other hand, natural science and the scientistic social sciences were supposed to have practical applications for technology, economy and government which the humanistic subjects did not possess. Thus the overlap between the function of the humanities and the newer scientific fields was only partial, and there was no awareness that all these different fields might be optimally pursued within a single organisation by persons who adopted similar methods of investigation and instruction and considered themselves to be members of the same profession.

20 See Crosland, Maurice, *op. cit.*, pp. 1–5, 70, 151–179.

21 See Clark, Terry N., "Institutionalization of Innovations in Higher Education: Social Research in France, 1850–1914" (Ph.D. dissertation submitted to the faculty of political science, Columbia University, 1966), pp. 319–321.

22 See Liard, Louis, *op. cit.*, pp. 172–173.

This explains why the capture of the uppermost reaches of the educational system and parts of the civil service by scientists, and, prior to the Napoleonic empire, by scientistic philosophers, did not lead to a complete "scientisation" of the educational system, such as occurred eventually in Germany. In this latter country, even the humanities came to be taught both at the higher and at the secondary level in a scientific way based on systematic philology.

While every scientist and philosopher in the revolutionary period was convinced that education needed thoroughgoing reform, and especially a great infusion of scientific content, there was no sense that there was anything wrong with scientific research. French scientists did better than any others within the existing individualistic pattern of private laboratories. There was no demand or wish to change this pattern and shift the locus of research to the educational establishments. Thus, while the revolutionary period can justly be seen as the beginning of scientific-educational policy, it was not the beginning of a deliberate science policy.

The distinction between education (imbued with science) and research was also apparent from the attitude towards academic freedom. The apparent lack of this freedom in the nineteenth century French system has often been noted. Nonetheless, French research workers were as aware as others of the importance of scientific freedom, and there is no evidence of any interference with the freedom of research. Education, however, was a different matter. French scientists and scientistic philosophers were insistent on removing church control from the school system, but they were not interested in eliminating the direct control of the state—which had its own non-scientific interest in the creation of a loyal citizenry—or in dictating to educationists in non-scientific fields how to go about their jobs. In fact, they saw strict state control of education as a necessary safeguard against the resurgence of church control.

There was no reason for the scientists to object to the state control of education, since they themselves were prominent in the civil service and especially in educational administration.[23] The educational reformers looked forward to the creation of a society where science and technology were to play a leading role. They envisaged a state where economic production and social welfare would attain new heights as a result of the contributions to research and discovery of a brilliant corps of scientific and technological leaders and the work of a prosperous and patriotic citizenry.[24] Teaching science was, therefore, only one of the many tasks assigned to scientists, and was not to be their exclusive domain. The freedom of the scientists was ensured by the privacy of research. All that was needed for this were some private means and a few public facilities

[23] For the importance of scientists in the late revolutionary period and under Napoleon see Crosland, Maurice, *op. cit.*, pp. 1–5, 70, 151–179.

[24] See Merz, John Theodore, *A History of European Thought in the Nineteenth Century*, Volume I (New York: Dover Publications, 1965), pp. 110–111, 149–156.

for competent scientists. This was adequately taken care of by the eighteenth century pattern which was greatly augmented in scale by the new opportunities.

Why French Science Flourished in the First Third of the Century

The Napoleonic policies further reinforced the eighteenth century pattern. The discontinuation of the central schools and the reestablishment of traditional syllabi in primary and secondary and in part of higher education abolished the only potential source of change. But none of the Napoleonic policies caused any harm to expert science, nor did they reverse the trend of increasingly using the services of scientists for a variety of functions. The spirit of high-grade science prevailed in some of the *grandes écoles* and in a few faculties.[25] The links of the leading scientists with the political elite, which began on a very small scale during the last decades of the *ancien régime*, were considerably extended. Scientists as a class, and not just a few privileged ones, became part of the official elite during the last years of the Revolution and they maintained this status under Napoleon. Berthollet, Cuvier, Laplace and others were given important positions in government and/or were trusted advisers to the emperor. The increasing autocracy of the empire and the reactionary policies of the Restoration perhaps reduced the actual influence of the scientists, but not their potential influence since they remained members of the elite.[26]

TABLE I

Types of Career of French Scientists Born During the Eighteenth Century

Born	Traditional [a]	Modern [b]	Traditional to modern [c]	Unknown
1745 or before	31	8	10	0
1746–55	14	3	9	1
1756–69	5	5	8	1
1770–89	6	34	2	2

SOURCE: Histories of science and biographies of scientists.

[a] Traditional: priests, lawyers, physicians, industrialists, engineers, proprietors, army officers, civil servants whose work was unconnected with education.

[b] Modern: teachers, research workers and civil servants connected with education.

[c] Traditional to modern: those who switched over from one type of career to another.

[25] See Liard, Louis, *op. cit.*, pp. 57–124.

[26] See Crosland, Maurice, *op. cit.*, pp. 4–5, 20–26, 42.

This opening-up of new opportunities for scientists is evident from a survey of the occupations of scientists before and after the Revolution. Before 1789, the majority of scientists were wealthy men (noblemen, physicians, etc.) who financed their scientific work from their own resources. Even Lavoisier, who was as close to being a career scientist as anyone could be at that time, had to maintain himself as a tax farmer, and could devote to his scientific work only one whole day a week; the other days were divided between research and business.[27]

After 1796 it is difficult to find any scientist in France who did not have a position either in higher education or in the educational civil service (or occasionally in some other civil service position, presumably granted to him for his scientific achievements).

Thus the reasons for the dissatisfaction with the educational and general intellectual monopolies of the clergy disappeared. This fact was not changed by the Napoleonic reaction against the revolutionary reforms. Scientists certainly had no reason to feel that they were prevented by traditional status privileges or ecclesiastical monopolies from using their talents and reaping the social benefits due to them.[28]

Even the moral problem of acquiescence in the new situation was less severe than it may appear. The situation which inspired the educational reforms of the late revolutionary period had passed. In a closed class society where power, honour and economic means were allocated to organised estates, the immediate goal of all "modern" intellectuals had to be the replacement of the existing intellectual estate (the church and the university corporations) by themselves. With the abolition of the estates, however, the whole perspective changed. At the very point when the scientistic movement obtained the educational monopoly, this monopoly lost its value as a means of ensuring dignity and resources for scientists and philosophers. Now that the whole society was open to them, education became a much less important issue.

Finally, the scientists were not alone in abandoning the educational ideas of the Revolution. The great intellectual ferment embracing broad classes of society preceding the Revolution had abated. The autocratic educational policies of Napoleon were probably not much different than they would have been under a system of *laissez faire*, except that in the latter case there might have been more experimentation and more variety. There was probably as little popular sympathy for the continuation of the scientistic trend in education as for the continuation of the general revolutionary upheavals.[29]

Similarly, there was little enthusiasm for the continuation of the educational utopia of Condorcet which would have created opportunities for higher education at the most advanced level for everyone capable of

[27] See Gillispie, Charles C., *op. cit.*, p. 215.
[28] See Lefebvre, Georges, *op. cit.*, p. 305.
[29] See Gerbod, Paul, *La condition universitaire en France au XIX^e siècle* (Paris: Presses Universitaires, 1965), pp. 78–81.

benefiting from it intellectually. It was not easy to find competent teachers and students for the central schools all over the country. And there was no interest in force-feeding the educational system so that it might serve as a mechanism for the equalisation of social status. Having attained the abolition of legally defined estates, few Frenchmen were interested in meddling further with the class system.[30]

The end result of the revolutionary and Napoleonic reforms was, therefore, an enhancement of eighteenth century patterns and conceptions of scientific work. The peak of the organisational system consisted of the *Institut* and the *grandes écoles* which were all pre-revolutionary structures. Furthermore, the new *grandes écoles* no longer had to contend with the privileged, non-scientific universities. Those had been abolished and the faculties which came in their stead were less privileged than the *grandes écoles*. Finally, some of the faculties also taught science, and science teaching was also introduced into secondary education.[31]

The great flowering of French science between 1800–30 was, therefore, not the result of any new ideas or practices about scientific training and research, or about the uses of science. It was rather the result of increased support for science, and probably increased enthusiasm for it in the eighteenth century manner. These were generated by the same conditions which had existed before the Revolution. The excesses and the upheavals of the latter created a reaction against political and educational reforms and ideological preoccupations. At the same time, however, the classes supporting the scientistic movement became much stronger. Successive French governments, even if reactionary, had to reckon with them and conciliate them. This was the same constellation as that which prevailed under the Restoration in Great Britain and during the last decades of the *ancien régime*, but with the balance further tilted in favour of science.

This spirit was reflected in the way research was supported. Some of the *grandes écoles* were given lavish facilities. This, however, was not done with a view to creating public facilities for the systematic training of future research workers, but rather as a public gesture in favour of science. The evidence for this is that there was no policy for keeping the facilities up to date, or for developing them in accordance with the changing requirements of science and the numbers of students who were to be trained.[32]

Nevertheless, in a few cases the new facilities were effectively used for the purpose of training relatively large numbers of students, and in any case they provided increased opportunities for research as well as for the acquisition of scientific knowledge, especially as the motivation to study science and excel in it was high. Hence the opportunities were taken advantage of by the older scientists who survived the Revolution, as well as by the generation which grew up during the Revolution. The

30 See Lefebvre, George, *op. cit.*, pp. 291–309.

31 See Liard, Louis, *op. cit.*, pp. 119–124, for the state of higher education following the Napoleonic reforms.

32 See *ibid.*, pp. 209–218.

meeting of these two generations was, therefore, an extremely fruitful one, and the transition between them resulted in a great rise in the level of scientific activity.[33]

Stagnation and Decline after 1830

This leads to the explanation of the stagnation and subsequent relative decline of scientific activity in France during the 1830s and the 1840s. After the Napoleonic period the situation of science in the class structure of French society became similar to that prevailing in England. Science was now "institutionalised" in the sense that scientists, and after the brief interval of suppression scientistic intellectuals as well, could aspire to all the honours and influence they might have wished for. It was possible to use science and to apply it as widely as possible, and any success in this respect was greeted by social approval.

Once, therefore, the opportunities provided by the abortive reforms of the 1790s were exploited, there was no more drive to change the educational and scientific systems. When the Napoleonic era and the Restoration came to an end, there was an opportunity to resume the work of the Revolution in educational reform. But the attempts to do this were thwarted by the priority given to political considerations over scientific and educational interests.[34] As in England after the Glorious Revolution, in France the "institutionalisation" of science led to a relative decline of scientific enthusiasm. Once the opportunities opened up by the revolutionary changes were exploited, there was a deflection of interest to social reform, social philosophy (Fourier, Saint-Simon, Comte) and technological activity.

Thus, by the 1830s, science had lost the symbolic glamour which it had possessed in the eighteenth century and which had been further enhanced during the first decades of the nineteenth century. France was a society which offered many other attractive opportunities. A young man whose talents allowed him to choose between science and more practical interests in 1780 would probably have tried his luck at science first.[35] By 1840, he would probably have been drawn more to practical politics, business, industry or perhaps creative writing.[36] All these allowed him as much freedom as science, and an equal or superior income.

33 See Crosland, Maurice, *op. cit.*, pp. 97–146.

34 The idea of animating the faculties and making them autonomous was put forward by Guizot and Cousin, but it was dropped for fear that any loosening of state control over the conferment of academic grades might be used by the church for the strengthening of its own system of education. This apprehension was enough to thwart the reforms since there was no noticeable demand for a higher level of scientific and scholarly education. See Liard, Louis, *op. cit.*, pp. 179–199, 215–217.

35 Marat was a good example of the attraction which science held for an ambitious young man whose talents were journalistic and political prior to the Revolution; see Gottschalk, Louis R., *Jean-Paul Marat: A Study in Radicalism* (New York: Greenberg, 1927), pp. 8–31.

36 See Liard, Louis, *op. cit.*, pp. 211–222, for an account of the relative lack of interest in science and scholarship and the abandonment of academic careers for careers in politics during the 1840s. The small attraction that science held after the Napoleonic reforms which lasted until 1880 can be seen from the very small number of diplomas in

Thus scientific growth settled down to a pattern similar to the English one. Creative scientists were not produced or trained by any particular part of the educational or scientific system. They were either individuals with a strong sense of personal calling and of exceptional genius, or members of families with a strong tradition of scientific interest and perhaps hereditary talent, who sought out their teachers at the Sorbonne, the *Collège de France*, the *Ecole normale*, or wherever they happened to be.

Accordingly, the development of French science up to about 1830–40 can be explained as a function of the degree of " institutionalisation " of scientific values. The support for it was generated by a belief in a pragmatic and " progressive " social order. Where this belief was not shared by politically and economically important groups of the population, there was on the whole little science. Where it was so supported, the volume of scientific activity varied according to the degree of the realisation of the general social aspirations of the groups supporting science (*i.e.*, the scientistic movement). In the British as well as the French case, the peak of the support for science (including, apparently, personal motivation, as well as the establishment of official scientific institutions) was reached during the lull following violent revolutions, just before the liberal reforms demanded by the scientistic movements were firmly established. During these transitional periods revulsion from the violence and anarchy of revolutions temporarily halted the push for the realisation of the broader aims of the movement, as well as the preoccupation of many of its adherents with philosophical (or, in the English case, theological) and educational problems, thus centring attention on science. The flattening out of the growth in scientific enthusiasm began in both cases with the relatively peaceful establishment of liberal regimes and the dispersion of intellectual interest in political, economic and technological concerns. Now that change was possible and legitimate in every sphere of life, there was no more reason to concentrate innovative talent and interest on science alone.

This explains the apparent paradox that the return to liberalism in 1830 did not bring in its wake a return to the scientific enthusiasm and educational reforms of the revolutionary period. But it does not explain the subsequent course of French scientific growth. Towards the middle of the century the conditons of this growth changed. It ceased to be exclusively determined by the preferences of the intellectual community

science granted by French faculties. Only in the decade 1861–70 did the yearly average surpass the 100 mark; prior to that the average was considerably less. Thus the total output of science graduates from all the French faculties was probably less during this period than the output of the one engineering school, the *Ecole centrale des arts et manufactures*, which graduated some 3,000 engineers between 1832–70, an average of approximately 75 a year. See Prost, Antoine, *L'Enseignement en France 1800–1967* (Paris: Armand Colin, 1968), pp. 243, 302. For the widespread initiative—much of it private—in technical and technological education during the first half of the nineteenth century in France, see Artz, F. B., *The Development of Higher Technical Education in France* (Cambridge, Mass.: The MIT Press, 1966), pp. 212–268.

and its supporters; to an increasing degree it came to depend on the organisation of higher education and research. Such conditions emerged first in Germany and presented a challenge to the older scientific countries, such as Britain and France. It is difficult to understand the relative inability of the French system to respond to this challenge which became increasingly evident in the 1840s. In France, as in England, science was by and large accepted as an intrinsically worth-while pursuit, as well as a generalised tool of social amelioration. The resources at its disposal early in the century were superior to those existing in England. How then can we explain the fact that English science, when faced with growing German and later American superiority, could reform itself promptly and effectively, and as a result enter a period of steady growth, while the French response occurred later and did not lead to uninterrupted growth?

This problem cannot be solved by the scheme of analysis which has been applied so far. The explanation is not to be sought in the interests of wider social groups in science or in a scientistic philosophy (which were similar in France and England), but in the peculiar characteristics of French scientific organisation.

The outstanding feature of this organisation and of French bureaucracy in general was centralisation. Whether as a result of age-long absolutistic traditions, or because of the basic rift in French society between those who welcomed the Revolution and those who never accepted its legitimacy, the French civil service never renounced its prerogatives of control over every aspect of social life.

This had a variety of debilitating effects. In order to maintain its control, the government preferred to establish schools and institutions with very specific purposes. Science, however, was rapidly changing, so that what was an adequate organisation in 1820 was likely to be out of date 20 years later. To keep pace with developments, scientific organisation should have been constantly adapted to new situations. But it was difficult to change organisations which had narrowly defined purposes without the use of coercion. Furthermore, the more centralised a system, the greater the likelihood that even relatively minor changes in the existing state of affairs would have unexpected political or administrative repercussions. Under such circumstances, it was preferable to create new institutions rather than to try to change existing ones. In order not to hurt vested interests and also for reasons of bureaucratic convenience, these again had to be " special purpose " institutions.

The Ecole Pratique des Hautes Etudes

The way in which this system limited the effect of even the most imaginative innovations can be seen from the case of the *Ecole pratique des hautes études* established in 1868. This can be considered as the first experiment in postgraduate training. Its purpose was to organise courses, seminars

and laboratory instruction conducted in a completely free manner by the outstanding research workers in Paris, irrespective of their affiliation to one of the faculties or *grandes écoles*. Through this device all the outstanding but scattered and fragmented scientific talents were pooled for the purpose of advanced training for research. The conception was more advanced than anything that existed in Germany or elsewhere at that time, since nowhere else did there exist a specialised scheme for the training of research workers.

There is little doubt that this institution made an immense contribution to the training of scientists and scholars. Having, however, been conceived from the very outset as a complement to existing institutions, its potentialities for development were greatly limited. At the time of its establishment, the *Ecole pratique* was denied the power to grant degrees. In the long run the lack of this power in the only institution designed to train research workers at an advanced level delayed the correction of one of the most anomalous features in the French academic career, namely, the requirement that aspirants to such a career should pass an examination (the *agrégation*) rather than prepare an advanced piece of research.

The long-term disadvantages arising from the absence of students properly " belonging " to the *Ecole pratique* were paralleled by the absence of a teaching staff exclusively or preponderantly identified with the school. This reduced the incentive for initiating changes and innovations in its structure. It also restricted opportunities for cooperation or even significant intellectual interchange between members of the teaching staff.

Inflexibility as a Result of Centralisation

This institutional inflexibility was reinforced by assigning the *Ecole pratique* a special function to supplement those performed by other institutions.[37] Had the situation been such as to allow competition among a number of institutions, its example might well have spread more widely in France. In the United States, and to some extent even in Britain, any successful innovation in higher education was bound to be imitated and reproduced in several institutions. The competition which thus arose stimulated further changes and innovations. The centralised French system, where each institution had a special and rigorously delimited function, produced exactly the opposite results. The success of a single institution made it " unnecessary " to duplicate a function already so well taken care of.[38] Thus academic anomalies were permitted and indeed forced to survive.

Of course, the avoidance of " unnecessary overlap " and " duplication ",

[37] See Liard, Louis, *op. cit.*, pp. 294–295, and Guerlac, H. E., " Science and French National Strength ", in Earle, E. M. (ed.), *Modern France* (Princeton University Press, 1951), pp. 86–88.

[38] See Zeldin, Theodore, " Higher Education in France, 1848–1940 ", *Journal of Contemporary History*, II, 3 (July, 1967), pp. 77–78.

and the use as far as possible of existing resources and manpower, are highly reasonable administrative principles. But their application resulted in France in the continuation of a vicious circle in which pioneering institutions established by enlightened administrations were too narrowly based and too rigidly fitted into the whole structure to be able to influence the system, or to adapt themselves when the need for adaptation eventually arose. Even where they were able to maintain high scientific standards, they were incapable of the initiative and rapid expansion which characterised similar institutions elsewhere.

One way of changing this situation might have been to resort to private enterprise and to establish institutions which could compete with the official ones. This kind of initiative was effective in Britain in coaxing the old universities into reforms during the nineteenth century. But the governmental monopoly of higher education and science in France was too strong and too comprehensive to allow private initiative the necessary scope which would have enabled it to compete effectively.[39] Such institutions as the *Ecole centrale des arts et manufactures* (established in 1829) or the various private study groups and schools in other fields including the social sciences, or even the famous and highly successful Pasteur Institute, remained specialised and isolated efforts, complementing the existing establishments rather than exerting pressure on them.[40]

This situation where initiative in organisational change was frustrated or thwarted by a centralised system which made each particular organisation a negligible quantity was responsible for the often criticised individualism, fragmentation and conservatism of French scientific efforts. Since it was virtually hopeless to try to change anything in the system as a whole or in the structure of individual institutions through concerted action by those immediately concerned, the best strategy for the individual scientist was to pursue his own ends " egotistically ". He worked as an individual and tried to further his own purposes. The individualistic isolation of scientists from each other provided a parallel to similar phenomena generated by the French political and bureaucratic systems in civic affairs and in many work situations.[41]

This state of affairs imprinted on French science a distinctive characteristic. During the second half of the nineteenth century, scientific work started growing in scale, and came to be based increasingly on cooperation and division of labour. Scientists in different fields and in

39 The centralisation of the system has prevented even the most able people from thinking in terms of individual institutions. Even such an outstanding politician of science as Victor Duruy was convinced that the system as a whole was sound and needed only more support for research. See Liard, Louis, *op. cit.*, pp. 287–288.

40 See Prost, Antoine, *op. cit.*, pp. 302–305, and Guerlac, H. E., *op. cit.*, p. 88.

41 See Crozier, Michel, *The Bureaucratic Phenomenon* (University of Chicago Press, 1963), pp. 214–220; for a detailed description of the problem in relation to science, see Zeldin, Theodore, *op. cit.*, pp. 67–68, and Gilpin, R., *France in the Age of the Scientific State* (Princeton University Press, 1968), pp. 107–108.

different institutions came to regard themselves increasingly as members of professional communities pursuing common purposes and defending common interests. In France this development was greatly inhibited by the structure described above. This probably had a directly detrimental effect on the quality of scientific work. In addition, it contributed to the relative isolation of French scientists from the international scientific community of which they had been the centre early in the nineteenth century (*i.e.*, at the time when scientists everywhere worked as isolated individuals). Elsewhere scientists started forming " schools " and working in groups. In France, with few exceptions, they went on working as individuals, training their successors as personal apprentices or not training any successors at all.

The Conditions of Reform in France

Under these conditions, changes in French scientific organisation occurred in a different way from in the other scientifically important countries. In the latter, changes were instigated either by the competitive initiative of various independent universities and other institutions, or by the pressures and policies of scientific elites acting as the representatives either of the scientific community as a whole (*e.g.*, the Royal Society in England), or of formal and informal associations of scientists and scientific institutions, as in the United States. In France, innovations occurred not as the result of horizontal combinations of scientists or scientific institutions, but of vertical combinations of individual scientific entrepreneurs or scientific cliques—usually identified with political tendencies—on the one hand, and individual administrators and politicians on the other. To such a short-lived constellation was due the foundation of the *Ecole pratique des hautes études* by Victor Duruy during the last years of the Second Empire. Only rarely did these situations last long enough to leave time for the fulfilment of programmes of comprehensive reform. Such a relatively long period did occur between 1879 and 1902. A representative group of scholars and scientists led by the historian Ernest Lavisse and the chemist Berthelot (the latter also served as Minister of Education in 1886–87), supported by Alfred Dumont and Louis Liard (directors of higher education from 1879–84 and 1884–1902 respectively), tried to reform the French faculties on the model of the German universities. Although they did not succeed in this, they expanded the whole system very considerably—the number of professors in France increased from 503 in 1880 to 1,048 in 1909 and then remained nearly static until the 1930s—and they raised its standards.[42] The university structure established by these reforms remained virtually unchanged until 1968.

During the period from 1879 to 1902, and then again in the 1930s under

[42] See Guerlac, H. E., *op. cit.*, pp. 83, 88–105, and Prost, Antoine, *op. cit.*, pp. 223–224, 234.

the *Front populaire* government and after the Second World War (the *Centre national de la recherche scientifique* was established in 1936 and subsequently expanded) French science policy was conducted somewhat similarly to British science policy. It was inspired by a fairly representative informal elite of scientists and intellectuals and carried out by sympathetic governments. But France, unlike Britain, possessed no organisational infrastructure for this movement. The influential scientists were individuals who had mutually congenial outlooks in a situation in which general political trends were favourable to science. These were periods in which there was a greater than usual consensus of a liberal-socialist tone, infused with scientism and favourable to science. But there were no central bodies such as the Royal Society and the Athenaeum where a common point of view could be formed and promulgated and no universities which commanded deep institutional loyalty; nor did France possess an intermediary body such as the University Grants Committee which could consolidate these elite groups beyond the duration of politically favourable periods. The French scientistic elites were always politically tinged; cooperation within them always involved some tension and was unstable. As soon as the politically favourable constellation passed, as a result of a change of government, or perhaps even of a mere change of ministers or directors of higher education, the elite group was in danger of dissolving into political factions which used the various scientific institutions as a base for individual or clique activities rather than acting in the interests of the scientific community as a whole.[43]

Under these conditions, such continuity of action as existed has been ensured neither by the continuity of an elite, nor by the continuity of independent scientific organisations. The stability of the system—like that of many other things in France—has rested primarily on the central bureaucracy. Between this bureaucracy and the individual scientist there have been no significant intermediary organisations, only shifting cliques. As a result, the system has been ill-suited for ventures involving flexibility and cooperation. It has only been possible to devise within it a variety of strategies ensuring careers, and some, but rarely sufficient, means for research.

It is in this manner that I explain the relative inefficiency of the French system, as compared to the British, in keeping pace with scientific centres in Germany and the United States. The inability to compete successfully is not a result of any lack of motivation to excel in science. This motivation has been institutionalised in French society and it has brought forth brilliant scientists as well as imaginative policies to further science. But because of their dependence on passing political constellations, the policies

[43] This apparently happened as a result of the Dreyfus affair which polarised political passion; see Clark, Terry N., *op. cit.*: the general instability of conditions comes through clearly in Zeldin, Theodore, *op. cit.*, pp. 53–80, 69–80, and in Gilpin, R., *op. cit.*, pp. 112–123.

designed to improve French scientific research and training have had little continuity. Moreover, the absence of independent scientific organisations commanding the loyalty of scientists and encouraging their cooperation has inhibited the growth of up-to-date patterns of scientific work. Both the dependence of the system on the vicissitudes of politics and its organisational rigidity derive from its centralised bureaucratic organisation.