

THE ECOLE NORMALE AND THE
EDUCATION OF THE SCIENTIFIC
ELITE IN 19TH-CENTURY FRANCE,
WITH A STUDY OF THE *ANNALES
SCIENTIFIQUES DE L'ENS*

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It has long been noticed that the roles played by both the Ecole Normale Supérieure and the Ecole Polytechnique (hereafter ENS and EP respectively) in French science changed markedly during the 19th century. As the former rose from humble origins to a prominent position among French scientific institutions, the latter, which in 1820 occupied a lone position in European science, by 1900 had become an educational center for elite civil servants and military officers.

With the aim of improving our understanding of that change, this paper studies three different questions. First of all, it provides some quantitative evidence germane to the shifting roles played by both institutions. Secondly, it makes an attempt to supplement Craig Zwerling's account of the emergence of the ENS as a leading scientific institution (1). Finally, it studies the scientific journal bearing the ENS's name.

The quantitative evidence gathered so far suggests the decades 1830-

40 and 1870-80 as the periods in which significant changes took place in the number of scientists coming out of the two schools. The period 1800-1835 was dominated by the Ecole Polytechnique. From 1835 to 1875 the ENS and the EP competed to provide French society with scientists. From 1875 to the end of the century the ENS predominated.

Throughout the period 1840-1870 (but excluding the short interval 1852-56) scientific education at the ENS appears to have exhibited an essentially steady process of growth and consolidation in which Pasteur's role as assessed by Zwerling has to be strongly qualified. Furthermore, it deserves to be emphasized that the elitist character and tiny dimensions of the ENS and the specific role of secondary education in 19th century France allowed the ideas of reform of higher scientific education present in the French university since the 1830s to be implemented in this institution.

Finally, my study of the *Annales scientifiques de l'Ecole normale supérieure* highlights two major changes concerning scientific journals in the last third of the 19th century: their specialization with reference to scientific disciplines and their differentiation with reference to the eminence of the people publishing in them.

Methodological remark

The figures and diagrams in section 1 rest on Table 1 of the Appendix. In elaborating Table 1, the *Dictionary of Scientific Biography* (hereafter DSB) not only was the main source of information about 19th century French scientists but was also taken to be a reliable catalogue of the individuals who played a role of any consequence in 19th century French science. Admittedly, this is, for an arguable assumption DSB's preface contains a warning against use of the *Dictionary* as a source for statistical purposes. In cataloguing scientific contributions one meets difficulties which are to a large extent intrinsically insurmountable. Scientific characters and achievements are hard, not to say impossible, to rank in a complete order; the more so when minor ones are compared each other. Furthermore the size of the catalogue is an independent variable which will always determine how many of these minor characters are to be cited. These features certainly disqualify the DSB as a source from which to derive *absolute* quantitative information about the scientific life of a given society. Nonetheless, the fact remains that the information embodied in the DSB represents to a large extent how historians of science today

understand who was who in 19th-century science. Moreover, for the purpose of comparing the weight of ENS-educated to EP-educated people it can be expected that a consistent criterion—even if a flawed one—has presided over the selection of individuals and, therefore, the relative weight of both populations may be approximated by assuming DSB's list of 19th century French scientists to be a nearly representative sample.

1. *An attempt at periodization*

Figure 1 compares the number of French scientists cited in the DSB who entered at the Ecole Normale and the Ecole Polytechnique in each decade throughout the 19th century. While the increase in the number of *normaliens* is steady, the numbers of *polytechniciens* experience sharp variations in conformity with a general pattern of decrease.

The existence of three differentiated periods can be discerned. During the first third of the century the predominance of the EP was unchallenged. Almost the converse is true during the last quarter, although Polytechnique's contribution was not so marginal here as Normale's was in 1800-1835 (2). In the middle period from the 1830's to the 1870's, competition would be the best word to describe their contributions. This general outline is highlighted by figure 2, which compares the number of scientists educated at Normale and Polytechnique throughout the century. The irregular patterns of variation that N' and P' exhibit fit roughly with the pattern followed by the whole population of scientists, F. A. striking feature of these figures is the coincidence of three «valleys» of the F-values with the revolutionary periods 1826-30, 1846-50, and 1866-70.

Two other quantitative variables which patterns of variation suggest as a meaningful periodization the one here proposed are the number of scientific licences and doctorates granted by the Sorbonne between 1811 and 1885 (see Figure 3). The patterns of variation of both variables are clearly very similar although their absolute numbers are not. A central period, from the early 1830s to the early 1870s, is clearly separated from the preceding and following periods by sharp increases in both the number of licences and of doctorates.

The relative positions of the ENS and the EP as education centers for French scientists should be qualified by taking three factors into account: the different size of their student populations, the quality of the scientists trained there, and the differences in the educational background provided by each institution.

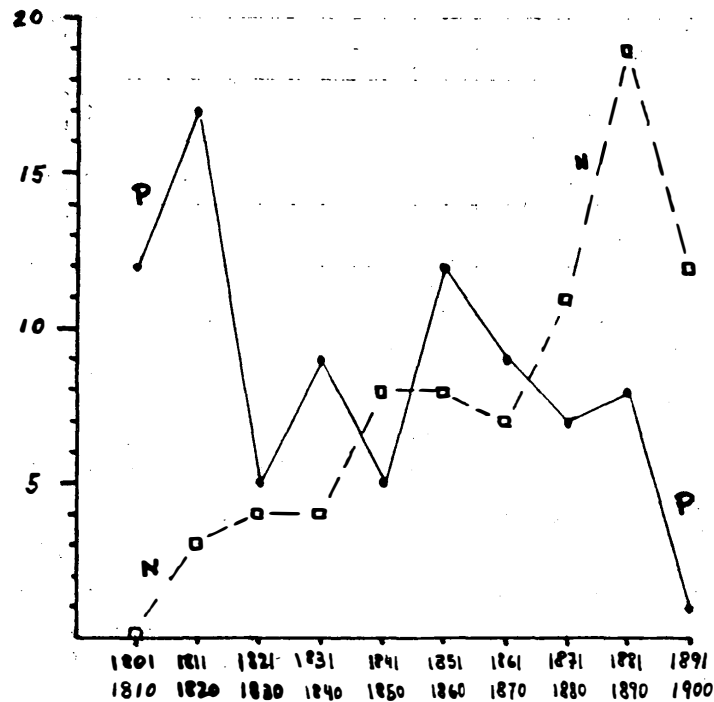


Figure 1

Normaliens (N) and Polytechniciens (P) who entered school between 1801-10, 1811-20, etc. (from figures in Table 1, Appendix).

The number of students entering both schools was for most of the century subject to yearly variations depending on administrative needs. Until 1833 the number of science students entering the ENS oscillated between 5 and 12, with an average of 8.6 for the years 1826 to 1833 inclusive. From 1834 to 1878 the number was never under 10 or above 19, with a single exception (3), and the average was 13.4.

From 1879 until 1887 there was a fixed number of 20 science students entering the ENS. From 1888 to 1894 the number varied annually around an average of 17.1 (4). Compared with those fairly small numbers, the EP admitted a yearly average of 200 students between 1830 and 1880 (5).

It is hard to compare the quality of scientists coming out of both

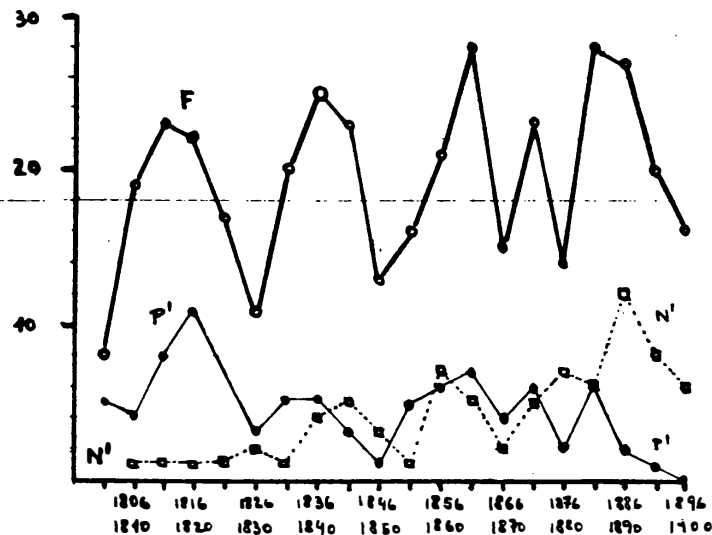


Figure 2

French scientists (F), Normaliens (N'), and Polytechniciens (P') cited in the DSB who were 20 years old between 1801-05, 1806-10, etc. (from figures in Table 1, Appendix).

institutions throughout the century. However, it is possible to give a loose characterization. The first period 1800-ca. 1835 shows an overwhelming superiority for the EP. Galois is almost the only name of any consequence which the ENS can oppose to the famous figures coming out of the EP. But the exception of the Galois case is in itself symptomatic of how far the ENS was from the standard educational path of the scientific elite in that period. In the middle years, from the late 1830s to the 1870s, the EP kept its preeminence in mathematics and allied disciplines. But in the same period important experimental scientists began to come from the ENS laboratories. Poincaré (1873) (6) was the last major figure who came out of the EP in the 19th century, and from the 1870s the ENS took the lead even in mathematics and mathematical physics. Duhem (1882), Cartan (1888), Borel (1889) and Lebesgue (1897) are instances of the Normale's preeminence in that traditional EP stronghold.

Students at the EP were not exposed at all to natural history and related topics (7), and people educated at the ENS were therefore able to contribute to a much broader range of subjects than EP people. Never-

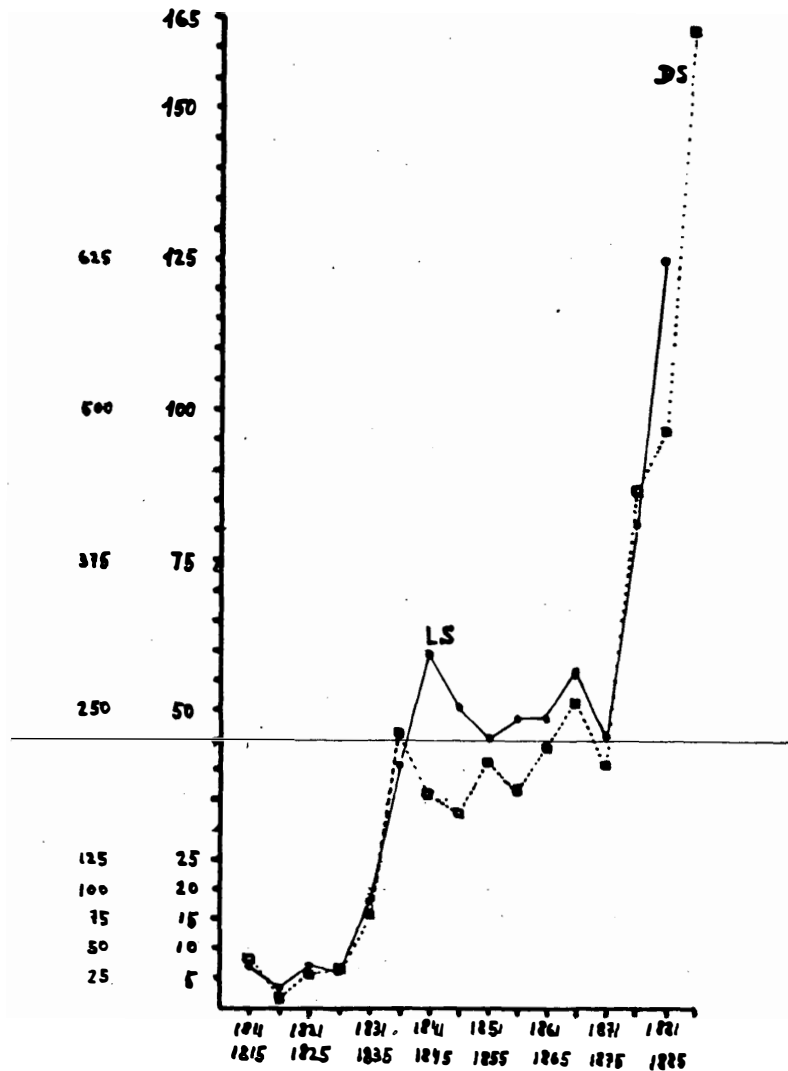


Figure 3

Number of degrees granted by the Paris *Faculté* of Science (from figures in Table 1, Appendix). LS = licence in science, DS = doctorate in science. To read the number of licences the value of every subdivision of the vertical axis should be taken as 25. To read the number of doctorates, as 5.

theless, two additional facts have to be taken into consideration. First, *polytechniciens* following their studies at the Ecole des Mines were able to contribute —as some did— to Geology. Secondly, the practical organization of the ENS curriculum and its pattern of examinations were strongly biased against natural sciences. Not until 1869 was the *agrégation* in natural sciences created (8). Up to that year, whoever was interested in the licence in natural sciences was allowed to take the examination at the end of his third year. But now the third year was the one in which to prepare the *agrégation* —either on mathematics or in physical sciences. Even though the latter included topics in natural history, the emphasis lay strongly in experimental physics and chemistry. Probably the more significant factor that gave students at the ENS a broader scientific scope than their EP counterparts was the broadened definition of chemistry—one large enough to open areas on the border with natural history.

If weighted in relative terms, therefore, the ENS fared fairly well from 1840 on. Because the number of its science students was small compared with that of the EP, and because the advantages linked to the educational background did not stem from institutional limitations, we can conclude that its significance as a center of scientific education deserves to be upgraded.

2. *The shaping of the scientific education at the ENS*

The ENS gained a new role in French science in part because the Ecole Polytechnique abandoned its prominent position in training teachers of higher education—a fact that Pasteur repeated again and again as an argument for improving scientific education in the university and in the ENS (9). That EP graduates were no longer interested in higher education can be easily shown. The number of *polytechniciens* engaging in teaching careers peaked in the period 1816-1820 with 48 individuals—they represented 11.4 per cent of all the polytechnicians coming out of the school during those years. Now in the early 1850s the number had shrunk to 3 individuals, a mere 1 per cent (10).

The foregoing figures highlight one of the most interesting facts about science in 19th century France. The quality of the EP's instruction remained excellent (11) and its reputation was likely to be ever higher. The affair of Gaston Darboux—to be described below—illustrates how much more prestigious the Ecole Polytechnique was than the Ecole Normale early in the 1860s. And we know that in the 1870s the EP still was attracting

the best prepared students. In 1877, for instance, it was necessary to go down to the student ranked 35th in the ENS entrance examination to be able to fill up the first 15 places (having been also accepted by the EP, the other 20 students choosed to become polytechnicians) (12). Thus in the second half of the 19th century the Ecole Polytechnique came to play a distorting role on the French scientific stage. The best endowed, most prestigious center for scientific education, it attracted most of the best students coming out from secondary education only to provide them with offices and social roles where, in all probability, they would not make any scientific contribution, nor would anyone expect them to do so.

Terry Shinn has convincingly linked the evolution of the Ecole Polytechnique to the increasing power wielded by the polytechnician elite (13). Whatever the reasons for the decline of the EP as a nursery of scientists, the fact remains that something had to replace it, and nothing was in a better position than the Ecole Normale.

Pasteur's personal action and Pasteur's laboratory were certainly instrumental in raising the ENS to a prominent scientific position. He was appointed director of scientific studies in 1857 and kept this position until 1867. His role in bringing about reforms in the scientific section of the ENS has been analyzed elsewhere (14) and I will not insist on it. Nonetheless, in what follows I shall suggest that an exaggerated emphasis has been laid on Pasteur as an agent of a far-sighted administration (15).

A 20th century scholar might have singled out two major drawbacks to the ENS move towards a prominent position as a center of education for the scientific elite. A very real one was economic hardship. A teaching position at the Ecole Normale was not tremendously attractive from the standpoint of economic reward. Its *maîtres* earned significantly less than the professors at the EP or at the Sorbonne at least until 1880 (16). Bertrand and Hermite are examples of professors leaving the school when they could get higher paying positions. Pasteur unsuccessfully asked for more professors, for improvements in faculty's salaries so that he could hire big names, and unsuccessfully asked for the creation of a scientific journal from at least 1859 on (17). His correspondence, furthermore, contains evidence about how little the administration was concerned with financially supporting Pasteur's scientific work in the school during the late 1850s and early 1860s (18).

The second obstacle to overcome —more apparent than real— was the formal definition of the ENS as a center of education for high-school teachers. Indeed it has been argued that the success of the ENS in taking over the EP's role hinged upon the opening of a new pattern of professional

career for *normaliens*. The new pattern, research-oriented instead of *lycée*-oriented, allowed *normaliens* interested in scientific research to avoid both preparing for the *agrégation* and spending years doing secondary teaching. Pasteur, according to this account, was instrumental in implementing the new pattern: «The years between 1857 and 1867 were the crucial ones in which the new research-oriented career became established among *normaliens*. (19).

As a matter of fact, secondary education, as it was understood in 19th century France, would not be opposed to university education any more than undergraduate and graduate studies conflict today. Differences between baccalaureate and licence were not marked. Some *Lycées* had special courses preparing for the *grandes écoles* examinations. The level was comparable to, if no higher than, that of many Faculty courses. A *Lycée* might have better laboratories than a provincial Faculty. As a rule, therefore, throughout as least the 1880s a position in a Parisian *Lycée* was always more coveted than one in a provincial *Faculté*. Indeed Smith has shown that there was no significant change in the percentage of *normaliens* fulfilling secondary education tasks until after 1920 (20). Furthermore, there was no contradiction in training both secondary teachers and would-be scientists in Pasteur's thought or in Bersot's —the director from 1870 to 1880. Pasteur was particularly opposed to examinations offering direct entrance to university teaching positions. The elite issuing from the ENS, in his opinion, had to be a leaven for the bulk of secondary teachers. The university had to choose its professors among those individuals in the *Lycées* who had proved to be the most gifted for original research (21).

It has been said above that no institution was better placed to take the lead of the EP than the ENS. There were at least three features of the Ecole Normale which played a crucial role in its transformation from a *pépinière de professeurs*, as it was called in the 1840s (22), into a *pépinière de savants*, as Pasteur liked to call it. For one thing, it was the institution that received the best students from among those who wished to commit themselves to a university career. Secondly, it subjected them to a regime of strong internal competition and hard work. Already in the late 1830s, Alexander Bache, a U.S. citizen reporting on European education institutions, remarked on the damage that overwork did to the health of the ENS students (23). From 1834 to 1848 the Ecole Normale, which was ordinarily tuition-free, stimulated students' performance by charging those ranked low half the cost of their education. Beyond that, a student's rank

was paramount in assuring him a good (or bad) position when leaving the school.

Finally, the students were given effective instruction. The state of education in the *Facultés* of science was certainly bad. It lacked appropriate facilities and the university, as a whole, was exam-degree oriented. Already by the late 1830s there were voices demanding reforms and suggesting sensible ideas. It has been said that the Ecole Normale, in the 1860s, was a kind of experimental field where the reforms that were to improve the *Facultés* were tried out (24). That is also true for the 1840s. In 1837 Dumas —the chemist Pasteur called *maître* all through his life— wrote a report to the Ministry on behalf of the Sorbonne's Faculty of science. The Faculty asked for libraries, for laboratories to teach and to do research, for assistants, and for new chairs (25). In 1846 Dumas sent a new report for the Ministry. He called for the same reforms, emphasizing even more strongly the need to give up class-room teaching and to adopt laboratory instruction. There are two interesting novelties in that report vis-à-vis the one of 1837. *Facultés* should not have auditors filling up the amphitheaters. They needed students of whom a certain level of work and knowledge could be asked and who in return were to insist on good courses and good teaching. In his 1846 report Dumas acknowledged not only the leading role the ENS —along with the EP— was playing in the reform of scientific education, but the right they had to occupy a privileged place (26). That was not the case in 1837: «En un mot, il s'agit d'assurer la perpétuité de l'enseignement des sciences, chose nouvelle, mais dont on conçoit la haute importance dans l'état de notre civilisation. Ce rôle appartient de droit à la Faculté de Paris.»

By 1840 the organization of both sections, science and letters, of the ENS took on the general configuration that they still had by 1880 and that, to a large extent, persisted till the end of the century (27). Science students were supposed to have passed the licence both in mathematics and in physics by the end of the second year. That meant being examined in differential and integral calculus and in chemistry by the end of the first year, and in mechanics and physics by the end of the second. The third year was spent preparing the *agrégation*, either in mathematics or in physical and natural sciences. Also in the last year the students spent between 2 and 6 weeks practicing teaching in a Lycée.

At least in theory, the scientific education given in the school relied heavily on courses at the Sorbonne. In practice, however, the courses taken there appear to have been a nuisance more than anything else. In Pasteur's 1858 proposal to improve the ENS, he complained about an

arrangement which amounted to a waste of student's time. Many of the courses at the *Faculté* were too shallow or too specific to prepare for a licence examination. A self-sufficient school was the ideal solution, in Pasteur's opinion (28).

That was not to be the case. In the early 1870s, the mathematician Appell still attended the Sorbonne's course on infinitesimal analysis and on chemistry when a first year student (29). Third year students could freely follow courses at the Sorbonne or at the Collège de France, though they only had a limited number of hours to do so. The first and second-year curriculums, which did not substantially change from about 1840 to about 1870, included 6 lectures, and 6 conferences, and laboratory sessions at the school. The conferences —seminars we would call them— were classes intended to discuss or reexamine the magistral lecture or to develop aspects in detail. The fact that originally all the teaching at the school was of that kind was at the origin of the teacher's title, *maitre de conférences*. Conferences were generally recognized to be an essential part of the teaching given at the ENS (30). Since its establishment in the tailor-made building in the rue d'Ulm in 1847, good material facilities for scientific instruction —laboratories and a library— were available. The ENS, therefore, appears to have embodied and practised the reformed scientific education that many were demanding in all the Faculties of science.

The disciplinary norms that regulated student life were tough. Until the late 1860s no books and journals other than those strictly needed for instruction were allowed. Recreational passes were limited to Sundays, plus one additional afternoon from 1848 on. Reveille was at 5:00 in the morning (6:00 from the late 1860s on). Searches of the students' desks were not unknown (31).

The last factor that I shall single out among those shaping the ENS as a leading intellectual center is the strong elitism pervading generally the policy of the French administration towards the Ecole Normale. Its relevance stems from the fact that it legitimated the exclusive character and small dimensions of the school. Again and again we read that the school, which always was small, had to be kept small —that this was the key to its success. Already in the 1840s it was clear that the school needed to enroll a larger number of students if it was to yield enough professors to the growing secondary education. In spite of its director's opinion, the school remained small (32). In 1887 Greard could not be more explicit: Since the level of the candidates is very good, we could accept more students in the school, but should not do so because «l'Ecole Normale est destinée à former une élite, et une élite ne peut se former que dans le

commerce étroit, presque intime, d'un nombre sévèrement limité d'intelligences distinguées avec les maîtres qui les dirigent» (33).

3. *The Annales Scientifiques of the ENS 1864-1893*

Finances

Already in the summer of 1859 Pasteur wished to publish a scientific journal bearing the name of the Ecole Normale. He proposed his idea to the Ministry and asked for its official patronage (34). The Ministry was not very generous in its financial support. In 1864, when the *Annales scientifiques de l'Ecole Normale Supérieure, publiées sous les auspices du Ministre de l'instruction publique, par M. L. Pasteur...* eventually started publication, it cost neither the Ministry nor the school anything. The publisher of the journal —Mallet-Bachelier first, his successor Gauthier-Villards later on— assumed the cost of publication in return for a contract that a fixed number of copies be bought by the Ministry (35).

Financial difficulties beset the *Annales* for most of its early life. In the summer of 1866, in a letter to the minister, Pasteur proposed to increase the number of copies subscribed (only 30) by requiring all the provincial *Facultés* and important *Lycées* to buy copies. Thereby the publisher would be able to increase the number of pages of the journal and the large number of papers Pasteur had been receiving could be published» (36). Pasteur's proposal appears to have failed since by the time he stepped aside as director of the *Annales* in 1871, the administration was again asked to buy 50 instead of only 30 copies of the journal (37). Indeed, the arrangement with the publisher was not without problems. Apparently he played a more important role than expected concerning editorial policies. «Je pourrais citer des travaux d'un rare mérite qui auraient fait le plus grand honneur à nos *Annales* et que l'éditeur a écarté, soit pour leur longueur, soit pour le prix élevé d'impression de certaines planches ou figures.» While denouncing the intrusion, Pasteur was pointing to an increased subscription as a way to reach an honorable accord (38).

Financial problems prevented publication in 1871. They were temporarily overcome by the personal involvement and forceful dedication of Sainte-Claire Deville, the new director from 1871 on. Deville started asking friends and acquaintances to subscribe for the journal. Even if that worked for a while, the journal was soon in trouble again. Deville then accepted as the last way out a personal allocation of 2000 francs included in the

budget as *séours à un savant pauvre*. Not until around 1880 was the journal's viability ensured by the administration (39).

Motivations

Along with the generic significance that any scientific journal has, I think it can be argued that the *Annales* played a specific role in winning a new reputation for the scientific undertakings carried on inside the university. After his 3-year tenure as dean of the science *Faculté* at Lille, Pasteur was familiar with the kind of expectations raised by scientific training in the provincial *Facultés*. He was acquainted too with the fact that their new scientific courses could easily turn into vocational technical training (40).

To get an idea of what the university's and the ENS's reputation was like, we can look at the journals on the occasion of Gaston Darboux's choice of the ENS after winning the first position in the entrance examination of both the Normale and the Polytechnique (41). A distinguished journalist took the occasion to exercise his sarcasm. The action of Darboux—who, according to the ENS's head, was a young man «d'un rare savoir et de la plus haute espérance»—was termed an «accident singulier». After pointing out that it was well known «ce que deviennent depuis dix ans dans l'Université les gens d'un rare savoir et de la plus haute espérance», he criticized the fact that many distinguished *normaliens* abandoned educational careers (42).

In 1863, two articles prompted the minister to ask Pasteur for a written answer upholding the good name of the scientific training provided by the university (43). Attacks against university institutions on the grounds of their uselessness for practical (i.e. industrial and economical) purposes were usually coupled with another kind of accusation. These institutions, profiting from their institutional power and because of their general incompetence, stifled useful initiatives and discoveries stemming from «free» scientists. Those are topics which make up the bulk of a book like Yves Guyot's *L'inventeur* (1867). The opposition between «official» and «free» science was particularly evident in the polemical articles about spontaneous generation (44).

Pasteur was altogether identified with the reforming spirit which in 1854 set up 8 provincial scientific *Facultés*, introduced in their teaching laboratory work and new disciplines and courses, and, in 1855, set up a research laboratory in the ENS. The *Annales* was to publicize the new life

enjoyed by science inside the university and particularly inside the Ecole Normale. «L'Ecole Normale, et avec elle l'Université, marqueraient leur place dans le mouvement scientifique», said Pasteur in 1859 to justify the creation of the journal. It was almost a necessary consequence of the clearly defined goal of transforming the university in one of the high scientific institutions of France. «Les mémoires des professeurs sortis de l'Ecole Normale vont enrichir des recueils étrangers à l'Université, et la gloire commune dispersée ne s'offre aux yeux de personne dans son unité et sa force... L'esprit de corps, ... nous est inconnu. Nos traditions n'existent pas, il n'y a jamais eu moyen de les fixer» (45). The *Annales* were to be a landmark highlighting the ENS and the university and publicizing their new roles on the French scientific stage.

Directors and editorial boards

In its 19th century period the *Annales* was published in 3 different series by 4 directors.

Seven volumes in quarto (the format was to remain the same) of some 360 papers each made up the first series. It spans the interval from 1864 to 1870. Less than a month after asking for retirement from his chair at the Sorbonne on the grounds of failing health, Pasteur also resigned the direction of the *Annales* on the same grounds. That was in October 1871, the year in which the journal did not appear because of financial problem (46).

The journal had an editorial board including, along with Pasteur, 9 *maîtres de conférences* in the scientific disciplines. The board remained almost unchanged throughout the first series and was always composed of individuals actually teaching at the school (47).

This feature disappeared in the second and subsequent series. The second one, from 1871 to 1883, appeared in 12 volumes of some 550 pages each, a size which the volumes kept in average up to the end of the century. Deville was its director until he died in 1881. He was replaced by another chemist, Debray, also *maître de conférences* at the school by the time he took over the direction. In spite of the heading «Comité de rédaction composé des maîtres des conférences scientifiques», which remained on the opening page of every volumen up to at least 1893, the names listed there included along with those of almost all the actual professors at the school those of some former ones. The editorial boards more and more contained professors no longer teaching at the school and they

soon outnumbered the school's *maîtres* (48). Also, a list of professors of natural sciences was always included in spite of the complete absence of natural history articles from the beginning of the third series on.

As we shall see, while the first and second series roughly shared an editorial policy concerning the interdisciplinary character of the journal, the third series markedly diverged from it. Debray was the director of the *Annales* until his death, in 1888, although he was not professor at the school since 1885. His successor the mathematician Hermite—who held the position up to 1900—no longer was someone teaching at the school. The patterns of changes in the direction and the editorial board suggest thus a drift towards a journal only nominally linked to the ENS by the 1890s.

Content

The *Annales* included only scientific articles. There was no section for reviewing books or journals, nor any place for announcements or communications. Between 1883 and 1888 it changed from being an interdisciplinary journal to a journal of mathematics and mathematical physics.

To describe the general structure of its content and its variations I classify the articles into the following categories: mathematics (M), mathematical physics (MPh), experimental articles (E), observational and physical astronomy (PhA), natural history (NH), and other (O). Mathematical physics also includes mathematical astronomy and celestial mechanics. E includes all the papers concerning chemistry and experimental physics; articles whose status between MPh and E was unclear, were classified as E articles. O includes 4 articles for the 29 volumes perused: Vernet's obituary, one paper on meteorology and two papers on technology.

The hardest delimitation problems lie between the E and NH categories. As a rule I included in NH the articles primarily dealing with taxonomy or descriptions of natural specimens, and in E those whose main goal is to study chemical processes—such as fermentations. Thus, most of the articles by Pasteur or his disciples published in the first series fall into the E category. The same holds for the article «Analyse immédiate des minéraux» (49) the object of which was to establish chemical methods for the analysis of minerals. The single NH article of the first series is Duclaux's on silk worms (50). By the same token, Pasteur's studies on silk-worms, Van Tieghem's on germination and Chamberland's on microscopic orga-

nisms, all of them in the second series, have been classified as NH articles. Apart from those mentioned, most of the NH papers in the second series are accounts of fossil or geological formations. The E category includes a single paper dealing with no laboratory work at all, Deville's «La théorie atomique et la loi des proportions multiples» (51).

This is a highly arbitrary classification and there are problems in allocating articles to each category. The choice of categories certainly fails to convey information about the wide range of different fields dealt with in the *Annales*. Nonetheless, it has the virtue of avoiding major problems of classifications while highlighting the most significant features of the evolution of the *Annales's* content.

Table I shows the changing size of the different categories throughout the 29 volumes of the period considered. The change in the character of the journal taking place between 1884 and 1888 is a good hint about the moment in which the growing size of publication made interdisciplinary journals obsolete. It also hints at the actual limits of specialization in the late years of the 19th century and, particularly, stresses the relationship between mathematics and mathematical physics.

TABLE I

Number of articles in the ANNALES, 1864-1893

	<i>1st series</i>	<i>2nd series</i>		<i>3d series</i>	
	1864-70	1872-77	1878-83	1884-88	1889-93
M	47.2 (35)	32.5 (26)	67.1 (47)	77.4 (65)	81.7 (58)
MPh	18.9 (14)	17.5 (14)	10.0 (7)	14.3 (12)	16.9 (12)
E	25.7 (19)	31.3 (25)	15.7 (11)	8.3 (7)	1.4 (1)
PhA	4.1 (3)	5.0 (4)	2.9 (2)	—	—
NH	1.4 (1)	11.3 (9)	4.3 (3)	—	—
O	2.7 (2)	2.5 (2)	—	—	—
Total	100 (74)	100 (80)	100 (70)	100 (84)	100 (71)

A most interesting feature of Table 1 (52) is the minor, almost marginal, role accorded to NH articles. Their virtually complete absence in the first series could be accounted for by the secondary place natural history was given in the ENS's curriculum. Yet only a slight increase in their number took place after 1869, even though there were regular students preparing the *agrégation* in natural sciences.

Two classics were reprinted in the *Annales*: Carnot's *Reflexions sur la puissance motrice du feu* and Gay Lussac's *Mémoire sur la combinaison des substances gazeuses les unes avec les autres*. It also made an effort to publicize foreign papers judged to be important. In the middle ground between these two kinds of articles lie the letters by Jacobi about elliptical functions written about 1830. With the single exception of an article by Kirchoff on mathematical physics, all the foreign contributions concerned mathematics. Foremost among them, Klein's *Program of Erlangen*, Kronecker's short papers on elliptical functions, Weierstrass's paper on analytical functions and Beltrami's essay of interpretation of non-Euclidean geometry. Other foreign contributors were Markoff, Kapteyn, Hurwitz, Cesaro, Brioschi and Lipschitz.

Noticeably enough, not a single English contribution appeared. Interestingly too, not a single reference to Darwin's theory can be found in the journal.

The *Annales* also published some papers which turned out to be classics soon after their publication. That was the case with Pasteur's work on the fermentation of wine, Mascart's on the ultra-violet spectrum, Lamy's on thallium, and Darboux's on orthogonal surfaces, all of them in the first series. In subsequent years it published significant papers by Darboux, Picard and Duhem, among others.

In order to supplement this qualitative assessment, let us look at the number of authors of scientific relevance who published in the journal and to the number of articles they wrote in it. Taking citation in the DSB as a criterion for significance, the first and second series were not markedly different in this respect. 30.2 per cent of authors, writing 37.8 per cent of the articles of the first series, are cited in the DSB. For the second series the figures are 30.1 and 36.0 respectively. A small improvement took place for the third series: 36.8 per cent of the authors and 48.4 per cent of the articles are the corresponding numbers (53).

Comparing journals

An interesting comparison can be made among the three leading French mathematical journals, the *Annales*, the *Journal de Mathématiques pures et appliquées*, and the *Journal de l'Ecole Polytechnique*. As Table II shows, between the 1860s and the 1880s the relationships among the journals significantly changed. From a situation of slight differentiation we get, 20 years later, a very marked hierarchy in which the *Journal de Mathématiques* occupied a towering position. It had become a journal able by itself to assure a mathematician's reputation. Besides the more important French mathematicians, the big names of German mathematics —Klein, Hilbert, Sylow, Weierstrass— appeared in it. (Interestingly enough, no English name either in mathematics or in mathematical physics appears in any of the volumes perused, with the single exception of a paper by Cayley in 1862 in the *Journal des Mathématiques*.) The difference in rank between the *Journal de l'Ecole Polytechnique* and the *Annales* would appear still larger by looking to the quality of the authors writing in them. The authors publishing in the *Annales* were of more significance generally.

TABLE II

The *Annales* compared to the *Journal de Mathématiques*
and the *Journal de l'Ecole Polytechnique*

	1860-70 (a)	1885-89	
	1	2	3
Journal des Mathématiques	49.2	91.3	96.7
Annales scientifiques	30.2	44.4	54.9
Journal de l'E. Polytech.	31.6	33.3	33.3

1. Percentage of authors who are cited in the DSB.

2. *Ibid.*

3. Percentage of articles written by authors in 2.

(a) For the *Annales* the figure correspond to the years 1864-70. For the *Journal des Mathématiques*, to 1860-69. For the *Journal de l'Ecole Polytechnique*, to 1861-70.

This hierarchy of journals would appear marked and more diversified if two additional periodicals of national character were taken into account:

the *Bulletin de la Société Mathématique de France* and the *Bulletin des sciences mathématiques et astronomiques*, both starting publication early in the 1870s. The *Bulletin de la Société* included news and announcements coming from the *Société* but it was mostly a mathematics journal, clearly the 4th in our ranking. The *Bulletin des sciences mathématiques*, on the other hand, focused almost entirely on reviews and bibliographical information, its section on foreign and domestic journals being particularly large and thorough.

For the *Journal des Mathématiques* the changes illustrated by Table II were accompanied by changes in the format of the articles and in the range of its content. In the 1860s it included articles on technology, rapports and shorts analysis of books, and it could even publish a whole book in instalments. Articles could be of almost any length and their scope almost of any range. Liouville, for instance, could sign 38 different «articles» in a single volume, most of them dealing with particular cases of the same general problem (54). For the *Journal de l'Ecole Polytechnique* the only noticeable change was its regular yearly publication (55).

Thus, by the 1880s periodicity, the format of the articles and the range of their content had reached a standard form. I think we can conclude, then, that between the 1860s and the 1880s a significant transformation of the scientific periodicals gave them many of the features which would characterize them in the 20th century.

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NOTES

(1) In his «Emergence of the Ecole Normale Supérieure as a centre of scientific education in the nineteenth century».

(2) It must be remembered, however, that the ENS only started to work regularly in 1810-11.

(3) In 1851 entered 8 science students.

- (4) Source: *Centenaire*, p. 673-90.
- (5) From Shinn's *L'Ecole Polytechnique*, p. 49. According to Marielle's *Répertoire*, the average for the period 1794-1853 was 134 (unnumbered sheet titled «Tableau des entrées et sorties annuelles des élèves de 1794 a 1853»).
- (6) A date in parenthesis following a name gives the year of a student promotion, i.e. the year in which he was given entrance to the school.
- (7) See the *programmes* of the EP for the years 1828 and 1847.
- (8) *Centenaire*, p. 436.
- (9) *Oeuvres*, VII, p. 193, 206-7 and 217.
- (10) See Table 3, Appendix.
- (11) See Pasteur, *Oeuvres*, VII, p. 207 and 217. For a somewhat contrary view see Shinn's *Ecole Polytechnique*, p. 47-8.
- (12) Greard's *Education*, p. 66.
- (13) See his *Ecole*, chapters III and IV, *passim*.
- (14) In Zwerling's «Emergence», p. 41-50.
- (15) See Zwerling's «Emergence», p. 41-50, *passim*, especially p. 44-45. Weisz's *Modern Universities*, p. 203, assumes Zwerling's account.
- (16) See Pasteur, p. 162, Ocagne, p. 345 and Charton, p. 471. In 1880 Sorbonne's professors earned 15000 fr. while ENS's *mâîtres* earned 10000 fr.
- (17) *Oeuvres*, p. 151-4.
- (18) *Correspondence*, II, see letters in p. 59, 76, 86, 89, 298 for Pasteur begging money to run his laboratory. See letter in p. 76 for Pasteur getting an assistant appointed in 1860.
- (19) Zwerling's «Emergence», p. 36-44; the quotation comes from p. 41.
- (20) Smith's *Ecole Normale*, p. 51.
- (21) *Oeuvres*, VII, p. 157. See Bersot, p. 345 and 354.
- (22) Charton (1842), p. 526.
- (23) *Report*, p. 448.
- (24) See Zwerling's «Emergence», p. 36.
- (25) Extraits des proces-verbaux des deliberations de la Faculté des sciences, 15 Novembre 1837, in Greard's *Education*, p. 236-55.
- (26) Extrait des proces-verbaux... 18 Septembre 1846, in Greard, p. 256-70.
- (27) This account relies in Paul Dupuy's «Resumé de l'histoire de l'Ecole Normale», in *Centenaire*, p. 211-52. For the laws and *arrêts* setting up the reorganization of the late 1830s, see p. 235-38.
- (28) «Notes sur les modifications à apporter à l'enseignement des sciences...», in *Oeuvres*, VII, p. 151-3.
- (29) Appell, *Souvenirs d'un Alsacien*, p. 158.
- (30) Melon, *Enseignement supérieur*, p. 33, Bersot, *Etudes*, p. 376. For detailed curriculums, see Dupuy, p. 257, Ladd's *Ecole Normale*, p. 53.
- (31) See Jeannin, *Ecole*, p. 59-80, *passim*. Pasteur won a reputation as an extremely rigorous director and was associated to some more or less important disciplinary conflicts. See Lavis's article and Thomas's *Saint Beuve*, chapter 3.
- (32) Gerbord, *Dubois*, p. 222, 226.
- (33) Greard, p. 66. For other instances of the same see Bersot, p. 376 and the article on Fustel de Coulanges in *Centenaire*.
- (34) Pasteur, *Oeuvres*, VIII, p. 172.
- (35) *Ibid*, p. 175, 178-9.
- (36) *Correspondence*, II, p. 266-7.

- (37) Pasteur, *Oeuvres*, VII, p. 178-9.
- (38) *Ibid*, p. 179.
- (39) From D. Gernez's article in *Centenaire*, p. 472-3.
- (40) See his compte-rendus for the academic years 1854-55 and 1855-56 as dean at Lille, *Oeuvres*, VII, p. 132-46. He did not fail to remark that while the cours on applied mechanics ended gathering no more «qu'une douzaine d'auditeurs sérieux» (p. 141), the cours on French literature (a complementary cours making up the new diplôme in applied science) «a même produit à Lille une impression vive; il a reuni constamment l'élite de la société et le nombre des auditeurs s'est soustenu au chiffre élevé de 200 personnes environ» (p. 143-4).
- (41) Pasteur played a key role in winning over Darboux for the ENS, according to Picard, «Gaston Darboux», p. 80. The very fact that Darboux's preference for the Normale reached the press stresses the differences in public standing enjoyed by both schools at that time.
- (42) Picard, «Gaston Darboux», p. 81-2.
- (43) The minister's letter to the head of the ENS and Pasteur's note in answer to his request are in *Oeuvres*, VII, p. 187-90.
- (44) See for instance Pasteur's letter to *L'opinion nationale* in *Correspondence*, II, p. 170.
- (45) *Oeuvres*, VII, p. 172-3.
- (46) *Correspondence*, II, p. 551, *Oeuvres*, VII, p. 177-9. Pasteur suffered a brain attack in 1868.
- (47) The *comité de redaction* is listed in the opening page of each volume. In 1864 it included Briot, Hermite and Puiseux (mathematics), Verdet (physics), Deville (chemistry) and Delesse, Des Cloizeaus, Lacaze-Duthiers and Valenciennes.
- (48) For instance, volume 4 (1875) lists, under «Sciences Mathématiques» Bertrand, Bonnet, Bouquet (X), Bourget, Briot (X), Darboux (X), Hermite and Puiseux; under «Sciences Physiques» Balard, Bertin (X), Friedel (X), Gernez, Deville (X) and Troost (X); and under «Sciences Naturelles» Delafosse, Delesse (X), Des Cloizeaus, De Lacaze-Duthiers, Pasteur, Perrier (X) and Van Tieghem (X). People with (X)-marked names were professors in that year.
- (49) 1 ser, 1 (1864): 81-112.
- (50) «Recherches sur la respiration et l'asphyxie de la graine de vers à soie», 6 (1869): 85-110.
- (51) 2 ser, 5 (1876): 199-205.
- (52) Numbers in parentheses are absolute numbers of articles.
- (53) The absolute numbers from which the percentages stem are given in Table 2, Appendix.
- (54) Liouville was particularly fond of this kind of article. The *Journal's* volumes for the years 1860 to 1864 included 22, 35, 38, 38 and 27 articles, respectively, by Liouville. This is the reason why the number of articles for the period 1860-70 has been left aside in Table II.
- (55) In the 10 years period 1861-70, for instance, only 6 volumes came out.

APPENDIX

TABLE 1

	<i>N</i>	<i>P</i>	<i>F</i>	<i>N'</i>	<i>P'</i>	<i>LS</i>	<i>DS</i>	<i>DP</i>
1801-05	—	8	8	—	5	—	—	—
1806-10	0	4	19	1	4	—	—	—
1811-15	3	12	23	1	8	36	8	5
1816-20	0	5	22	1	11	14	2	3
1821-25	1	1	17	1	1	36	6	2
1826-30	3	4	11	2	3	30	7	17
1831-35	0	4	20	1	5	89	16	14
1836-40	4	5	25	4	5	209	47	13
1841-45	4	3	23	5	3	298	36	17
1846-50	4	2	13	3	1	254	33	15
1851-55	1	5	16	1	5	226	42	9
1856-60	7	7	21	7	6	242	37	15
1861-65	5	4	28	5	7	240	44	21
1866-70	2	5	15	2	4	285	52	15
1871-75	6	5	23	5	6	228	41	8
1876-80	5	2	14	7	2	407	87	17
1881-85	9	7	28	6	6	625	97	7
1886-90	10	1	27	12	2	—	163	2
1891-95	9	1	20	8	1	—	—	—
1896-1900	3	0	16	6	—	—	—	—

N = Number of French scientist quoted in the DSB who entered the ENS between 1801-05, 1806-10, etc.

P = *Ibid.* at the EP.

F = Number of French scientists cited in the DSB who were 20 years old between 1801-05, etc.

N' = Id. id. and who were educated ant the ENS.

P' = Id. id. at the EP.

LS = Number of licence-es-sciences granted by the Sorbonne.

DS = Number of scientific doctorates granted by the Sorbonne.

DP = Id. id. by the provincial *Facultés* of sciences.

Sources:

Data in columns *N*, *P*, *F*, *N'* and *P'* come basically from the DSB. Students's lists included in *Le Centenaire de L'Ecole Normale* and in Marielle's and Leprieur's *Repertoire* have been used to supplement information. I was not able to find out the entrance's year for a very few scientists

who entered Polytechnique after 1864; I consistently assumed they entered in their 20th year. LS comes from the tables in Greard's *Education*, p. 285-9. DS and DP are my elaboration after Maire's *Catalogue*. There are slight variations between figures in DS and the ones provided by Greard. These differences may be accounted for by the difficulties on cataloguing mentioned by Maire in his Preface. The differences are never significant for statistical purposes with the single exception of the period 1881-85 in which Greard reports 86 and Maire 97 scientific doctorates.

TABLE 2
Authors and articles in the ANNALES

	A	B	C	D	E	F
1st serie 1864-70	43	13	74	28	30.2	37.8
2nd serie 1872-83	93	28	150	54	30.1	36.0
3d serie 1884-93	76	28	155	75	36.8	48.4

A = Number of different authors in the *Annales*

B = Number of authors in A cited in the DSB.

C = Number of articles written by authors in A.

D = Number of articles written by authors in B.

E = Percentatge of B over A

F = Percentatge of D over C

Sources: My elaboration.

TABLE 3
Polytechniciens adopting teaching careers

	A	B	C
1794-95	7	100	7.0
1796-1800	38	650	5.8
1801-05	52	609	8.5
1806-10	28	792	3.5

	A	B	C
1811-15	46	861	5.3
1816-20	48	422	11.4
1821-25	15	442	3.4
1826-30	13	612	2.1
1831-35	39	739	5.3
1836-40	28	718	3.9
1841-45	19	777	2.4
1846-50	11	670	1.6
1851-53	3	296	1.0

Source: Marielle's Répertoire

1854-55	1	—	—
1856-60	3	—	—
1861-63	0	—	—

Source: Leprieur's Répertoire

A = Number of Polytechniciens who adopted teaching careers.

B = Number of Polytechniciens who came out of the school

C = Percentatge of A over B

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