War Cultures in Postwar French Mathematics: A Critique of the Bourbaki and Forman Theses

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Introduction: Recovering the Absent War

In 1919, George Sarton wrote: "The war has helped us to understand more clearly that science can be used to sinister purposes, as well as good ones. (...) [S]cience must be tempered by humanity, and the best way of doing this is to explain its organic development, and also to show all that was really great, beautiful, and noble in these civilizations of the old, all that our conceited scientists and inventors have too often forgotten and disdained."[1]

Could it be that history of science, as we know it, emerged as a result of the First World War? In the intellectual effervescence that followed the conflict, the young founder of *Isis*, who had been forced to flee his native Belgium after it was occupied by the German Reich, started to promote a "new humanism" according to which the history of science would epitomize the history of human thought, civilization, and progress. As Sarton wrote already in 1916, science, in particular, made "for peace more than anything else in the world."[2] Since that time, the ambitions of the history of science shifted many times and in various directions. But, despite incontrovertible evidences provided by historians of the Second World War, of the Cold War and, to a lesser extent, of the early modern period, the tendency to see war as an unnatural deviation from the mainstream path of scientific development has remained strong.

As a historian of the mathematical sciences interested by the effect war experiences had on the lives and works of mathematicians and scientists (and as someone whose chief concerns have mostly remained outside of the history of quantum mechanics in Germany), I have always found the Forman thesis especially inspirational in a way that is markedly different from the usual contexts in which it is discussed (modern physics and/or Weimar Germany). By claiming that German mathematicians and physicists rejected causality and embraced a certain form of modernity as a result of their adapting to a hostile intellectual environment that was clearly shaped by contemporary international politics, Paul Forman suggested that the ways in which scientists sought to be actors in wider cultural spheres could impact their scientific activities. In particular, it seemed to me to address the question raised at least

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[1] G. Sarton, "War and Civilization," *Isis* 2 (1919), 315–321, on 319.

[2] Quoted by Tore Frängsmyr, "Pioneer George Sarton Inspired Swedish History of Science," *Uppsala Newsletter — History of Science* 38 (2006), 1. See G. Sarton, "The New Humanism," *Isis* 6 (1924), 9–42 and *The History of Science and the New Humanism*(New York Henry Holt and Co., 1931); on Sarton, see Arnold Thackray and Robert K. Merton, "On Discipline Building: The Paradoxes of George Sarton," *Isis* 63 (1972), 472–95, and David Aubin and Patrice Bret, "Introduction," in *Le Sabre et l'éprouvette: l'invention d'une science de guerre, 1914-1939*, ed. Aubin and Bret (Paris: Agnès Viénot, "14-18 Aujourd'hui," 2003).

implicitly by Sarton: that is, to put it bluntly, is there any sense to try and discuss the impact of World War I on science?

One may reasonably ask whether in such general terms the question can even make sense. Although this is not an aspect of Forman's famous paper that is usually put forward, "Weimar Culture" can indeed be read as arguing that the First World War had a tremendous effect on theoretical physics.[3] After all, why would an event that has left its indelible imprint on the history of the twentieth century, a conflict characterized by its participants and every one that followed as a "scientific war,"[4] not be as absolutely determining for the history of science as it was for the history of cinema, fashion, or work? As I shall discuss below, historians of science had little wish to attribute to the period of WWI more than changes in the institutional organization of science. Forman was one of the first historians to challenge that view, but, as I will explain below, I believe he actually ended up reinforcing the view that war activities did not properly belong to mainstream history of science.[5]

The history of French mathematics in the interwar period provides another instance where theses about the impact of the First World War on the content of a scientific discipline have been advanced. In this case, claims however were roughly contrary to Forman's. The "Bourbaki thesis," as I shall dub it, provided a handy explanation for anti-modern trends in postwar French mathematics.[6] Contrary to the Forman thesis, the Bourbaki thesis was held, not by radical historians, but by the central figures of their discipline trying retrospectively to reflect on the way they had achieved prominence. But here again, the argument, which was roughly based on simple demographics, skirted any consideration of wartime activities.

In an important book published first in 1998, cultural historians of the Great War Stéphane Audouin-Rouzeau and Annette Becker insisted on a paradoxical fact about the postwar. Total war had required a tremendous level of commitment in warring nation. Widespread consent was supported by millenarianist hopes giving rise to a true "crusade myth." Traces of the war, however, were later forcefully rejected.[7] Forgetting was part of a culture of mourning that played out very differently, but not incommensurably so, in defeated and victorious nations. By confining changes forced upon science by the First World War to its social organization or ideology, I contend, we may be perpetuating contemporary scientists' wishes to forget. In order to account for deep changes in the representation and practice of science in the interwar

[3] Paul Forman, "Weimar Culture, Causality, and Quantum Theory, 1918–1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment," *Historical Studies in the Physical Sciences* 3 (1971), 1–115.

[4] There is no room to discuss here what this meant to contemporaries, how the perception was formed, and whether its was felt in the same way in various countries. Let me just recall that H.G. Wells' famous letter tro the *Times*; Robert Millikan who saw the First World War as providing "A New Opportunity in Science," *Science* 50 (1919), 285–297 ; the science chronicler of the *Revue des deux mondes*, the astronomer Charles Nordmann's comment about on Painlevé's parliamentary report that led to the creation of a ministry of inventions: "It is the first time I am aware of that, in a governmental document, science is officially allowed to play a role in affairs of the state. [C'est la première fois à ma connaissance que, dans un document gouvernemental on admet officiellement la science à jouer un rôle dans les affaires de l'État.]" Charles Nordmann, "Science et guerre," *Revue des deux mondes* 30 (1915), 698–708.

[5] Later work by Forman had considerable importance in altering that view; see esp. *National Military Establishments and the Advancement of Science and Technology: Studies in Twentieth-Century History*, ed. Paul Forman and Jose M. Sánchez-Ron (Boston-Dordrecht: Kluwer Academic Publishers, 1996).

[6] See Herbert Mehrtens, *Moderne, Sprache, Mathematik: Eine Geschichte des Streits um die Grundlagen der Disziplin und des Subjekts formeler Systeme* (Frankfurt: Surkamp, 1990).

[7] Stéphane Audoin-Rouzeau and Annette Becker *14-18, retrouver la* guerre (Paris: Gallimard, 1998), 17; trans. *14-18: Understanding the War* (But title varies slightly from printing to printing).

period, I want to argue that we historians of science cannot go on avoiding the war, but on the contrary we too need to "recover" it.

Forman and World War I

When Forman's seminal article was written, the First World War was in the process of being taken on by historians of science in a major way. Dan Kevles, Roy MacLeod, Thom Hughes, or Spencer Weart, as well as Forman himself, just to name a few, started to identify the Great War as a key episode in the development of powerful scientific communities.[8] With the hindsight of World War II and of the Cold War, and in a context of countercultural denunciations of war cultures in the sciences, historians documented the ways in which various forms of scientific mobilization, hastily put together between 1914 and 1918, formed the matrix for a future, deeper reorganization and growth of a scientific apparatus that was to be put in the service of the State, and of the military especially. Further studies along those lines have been useful in underscoring the privileged position scientists then carved for themselves as the primary interlocutors of general staffs for all matters regarding inventions and technological innovations.[9] The Great War thus appeared as both the root and the imperfect pre-figuration of forms of big science to become dominant only in the 1940s and 1950s.

But contrary to what was being exhibited about latter conflicts, history of science studies dealing with the First World War by and large confined its impact on postwar science to its institutional or—sometimes—ideological aspects. In so doing, historians were echoing assessments widespread among contemporary scientists who saw in World War I a series of "lessons" to be drawn for future mobilization, but without much impact on the content of science. The American physicist George K. Burgess was typical in assessing in 1919 that, while hundreds if not thousands of new applications of known principles were due to war work, one would be hard pressed to name even two or three new principles developed because of the war.[10] Suman Seth has likewise shown that some German physicists shared the feeling that war was a pause in normal scientific activities. As Karl Herzfeld noted in a letter to Sommerfeld in 1916, "the general business [of physics] is naturally less intensive than in

[8] Paul Forman, "The Financial Support and Political Alignment of Physicists in Weimar Germany," *Minerva* (1974) 39–66; Daniel Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, Mass.: Harvard Univ. Press, 1995), first publ. 1978 but announced by several papers; Roy MacLeod and E. Kay Andrews, "Scientific Advice in the War at Sea 1915-1917: The Board of Invention and Research," *Journal of Contemporary History*, 6 (1971), 3–40; Thomas P. Hughes, *Elmer Sperry: Inventor and Engineer* (Baltimore: Johns Hopkins Univ. Press, 1977); Spencer Weart, *Scientists in power* (Cambridge, Mass. : Harvard University Press, 1979). For a review of this type of work, see also Guy Hartcup, *The War of Invention: Scientific Development, 1914-18* (London: Brassey's Defence Publ., 1988).

[9] From a vast literature, let me cite: Michael Pattison, "Scientists, Inventors, and the Military in Britain, 1915-19: The Munitions Inventions Department," *Social Studies of Science*, 13 (1983), 521–68; Yves Roussel, "Histoire d'une politique des inventions, 1887-1918," *Cahiers pour l'histoire du CNRS*, 3 (1989), 19–57; Jeffrey Allan Johnson, *The Kaiser's Chemists: Science and Modernization in Imperial Germany* (Chapel Hill: Univ. of North Carolina Press, 1990); Andrew Hull, "War of Words: The Public Science of the British Scientific Community and the Origins of the Department of Scientific and Industrial Research, 1914-16," *British Journal for the History of Science* 32 (1991), 461–82; Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880-1945," *Isis*, 86 (1995), 194–221; D. Aubin, "La guerre du froid, la défaite de l'inventeur: bombes à oxygène liquide et production d'hélium," in *Le Sabre et l'éprouvette*, 105–116; Gabriel Galvez-Behar, "Le savant, l'inventeur et le politique: le rôle du sous-secrétariat d'État aux inventions durant la première guerre mondiale," *Vingtième siècle* 85 (2005), 103–117.

[10] George K. Burgess, "Science and the After-War Period," *Scientific Monthly* 8 (1919), 97–108, on 98. On the "lessons of war," see, e.g., Charles Moureu, *La Chimie et la guerre. Science et avenir* (Paris: Masson, 1920).

LA DÉFENSE NATIONALE
et les Inventeurs

Un savant est chargé d'une direction spéciale

M. Painlevé a été nommé, tout à la fois, ministre de l'instruction publique et ministre des inventions intéressant la défense nationale. Grand maître de l'Université, il a pris la direction des services de l'enseignement au lendemain de la constitution du nouveau ministère. Il a, hier, organisé le nouveau service qui lui a été confié, et il a placé à sa tête M. Emile Borel, sous-directeur de l'École normale supérieure, professeur à la Faculté des sciences.

M. Borel a fait campagne comme sous-lieutenant d'artillerie territoriale. Sa brillante conduite lui a valu une citation à

M. EMILE BOREL

peacetimes, because a great proportion of physicists are either busy in the field or with works for the military."[11]

Another case in point might be the French mathematician Émile Borel, recently brought to the fore by Hélène Gispert. In the secret report he wrote to support Borel's candidacy to the Academy of Sciences in 1919, Paul Painlevé added the following sentence to the previous report he had written in 1912: "The mathematical work of Monsieur Borel having been interrupted by the war, I only need to add to my 1912 report a few words in relation to the 18-months period from January 1913 to July 1914." Yet, as the minister who had appointed Borel as the head of the "*service des inventions*," Painlevé probably was the person susceptible to be most aware of Borel's important wartime activities (figure).[12]

Yet, as any reader of Forman's knows well, contemporaries were divided about the "lessons" one was to draw from the experiences of World War I.[13] While some scientists bracketed their war experience, others considered that this was the dawn of a new age, the "scientific and industrial age," according to the chemist Charles Moureu who had taken a large part in the war gas production, or a "New World of Science," as an American book published in 1920 proclaimed in its title.[14] Many of those who had taken part in the formidable technoscientific or industrial mobilization (scientists, engineers, inventors, industrialists, or military personnel) marvelled at the number of great realizations made possible during the war. The war confirmed the scientific nature of the modern world, and the need to infuse its values and techniques throughout society.

Of course, we must not see both views as mutually exclusive: as the case of Borel who played major roles in the postwar reorganization of science in France eloquently shows, war can be both a break in what one considered to be one's properly scientific activity and, at the same time, a means allowing the emergence of new social structures for science policy. In this

[11] Karl Herzfeld to Arnold Sommerfeld, 14 Nov. 1916 DM NL 089 (059); quoted by Suman Seth.

[12] Minister of Education and Inventions [*ministre de l'instruction publique et des inventions intéressant la défense nationale*] in 1915, Painlevé put Borel at the head of a large Service des Inventions where he worked in particular on improving range table and developing sound ranging techniques for locating enemy artillery pieces. Note that Borel concurred with Painlevé, writing in support of his own candidacy to the Academy: "Depuis cette date [August 1914] les applications dont j'ai eu à m'occuper diffèrent trop de mes travaux du temps de paix pour qu'il y ait lieu de les mentionner ici." On this, see Hélène Gispert, "1900-1930 Mathematical France: Identifying Breaks and Continuities," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

[13] Paul Forman, "Scientific Internationalism and the Weimar Physicists: The Ideology and Its Manipulation in Germany after World War I," *Isis* 64 (1973), 151–180.

[14] Charles Moureu, *La Chimie et la guerre. Science et avenir* (Paris: Masson, 1920), 376; and Robert M. Yerkes, ed., *A New World of Science: Its Development during the War* (New York: The Century Co., 1920).

perspective, I have found "Weimar Culture" to be especially stimulating. Forman was one of the few historians to suggest that the period of the First World War might have had an appreciable effect not only on the organization of science, but also on some of its basic principles.[15] And what effect: acausality, quantum mechanics, and so on!

A closer look at Forman's "Weimar Culture" however reveals a paradox. The paper indeed seems to hinge on an absence, war being by and large occulted by the author. Hermann Weyl's whole year of military service in the German Army near Saarbrücken, his release at the request of the Swiss Government in May 1916, and his taking refuge to neutral Zürich are all left without mention.[16] Similarly, Forman does not think worth discussing the fact that Richard von Mises (figure) was intensely involved with aviation throughout the period: as technical advisor to the nationalistically and militaristically informed "Prinz-Heinrich-Flug" race in 1913-14, as one of the first to be awarded a pilot's licence from the German "Nationalflugspende" in 1914, as an officer of the Austrian air force during the war who served actively, who was involved in the conception of the first "Grossflugzeug" (600 horsepower airplane), and whose lectures about flight theory (*Fluglehre*) to Austrian officers were published in 1918 and went through several editions (the English translation being still in print).[17] In Forman's article, there is no mention of fighting. Defense work in which scientists might have been involved is nowhere even brought up. There is no acknowledgement and much less discussion that many of the physicists or mathematicians he discusses might have suffered the loss of relatives or students.

[15] Another example might be Robert M. Friedman, "Constrituting the Polar Front," *Isis* 73 (1982), 343–362.
[16] Norbert Schappacher, " Selflimitation & Holism in Mathematics: The example of Hermann Weyl and World War I," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.
[17] Reinhart Siegmund-Schultze, "Richard von Mises (1883-1953) as an organizer, propagandist, teacher, practitioner, engineer, textbook author, and theorist of aviation before and during World War I," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

When Forman actually pays attention to the war, it appears as the last glitter of a golden age, now irredeemably lost. This was a time when scientists could share sentiments with "the rest of the German public" (p. 8). Indeed, they might have been even more optimistic than most and feel "*self*-confidence and *self*-satisfaction due to their contributions to Germany's military success and to their anticipation of a postwar political environment highly favourable to the prosperity and progress of their disciplines" (p. 8; original italics). It is important to notice that the few wartime scientists' speeches quoted by Forman as expression of this confidence are all dated from the last months of the war. Felix Klein mapped out a glorious and harmonious future where government money seals the alliance struck between the university and the military (p. 9). Wilhelm Wien reaffirmed the old view according to which physics was rooted in empiricism rather idealism and constantly reinforced, and was reinforced, by technology (p. 41-43). Forman even attributes an episodic "wartime mind" to Oswald Spengler's *Decline of the West*, "as, for example, in its positive valuation of technology" (p. 30). If cracks in this monolith of self-assurance are to be found in Forman's article, they point to a rather peaceful willingness to open up discussion regarding troubling questions about the nature of truth in physics and logic (Hermann Weyl, p. 52, 76-78) or of causality (Prussian Academy of Sciences, p. 70).

Rhetorically, the war thus seems to function in the article as a straw man: the height of an era of positivistic self-confidence in support of which few arguments are provided, nicely standing in contrast to a period of intellectual malaise that had produced the countless expressions of self-doubt so strikingly excavated by Forman. War appears as a sketchy "cultural environment" to be contrasted with Weimar culture. So, rather than admitting that Forman's article hinges on an absence, one might be tempted to reaffirm that it is concerned precisely with what it announces to be dealing with—"Weimer Culture"—and that it deals with war only in so far as the Weimar Republic, both as regime and cultural environment, can be said to have emerged from the Great War and the collapse of the German Army.

Another hint at Forman's unwillingness to let war penetrate his argumentation is provided by his insistence on the suddenness of change in his account, his use of religious metaphors here being quite revealing. While he insists on at least two occasions (p. 67 and 70) that issues of acausality and determinism in the precise form they took in the postwar discourse seemed unrecorded in German academic life before the Armistice, Forman repeatedly emphasized the abruptness ("within a year of the end of the war" [p. 16]) with which scientists gave in to the "hostile environment"—or "convert" to the new faith. This is not without recalling then trendy ideas about Gelstalt switches, paradigm changes, or epistemic breaks, although Forman, sticking to religious metaphors, is careful not to multiply his use of loaded language. "The quasi-religious conversion to acausality […] became a famous example in the German physical community during the summer and fall of 1921. As if swept up in a great awakening, one physicist after another strode before a general academic audience to renounce the satanic doctrine of causality" (p. 80). By emphasizing the suddenness of the conversion, Forman thus radically severs his analyses of the early Weimar period from any inkling at understanding wartime thought.

Nevertheless, I want to say that we are not mistaken in seeing war as playing an important role in Forman's argument. Indeed, war is represented as a tunnel at the end of which underground trends were now allowed to blossom. The cultural movements discussed by Forman (*Lebesphilosophie*, neoromanticism, antipositivism, belief in acausality) are "intellectual currents, whose sources lay in the prewar period, but which welled up

immediately following Germany's defeat, continued to dominate the intellectual milieu in the mid-1920's as in the first years of the Weimar Republic" (p. 18). Only in the "radically rearranged scale of values ascendant in [its] aftermath of Germany's defeat" (p. 6), those undercurrents could forcefully emerge. Buried by the discipline, hopes, and requirements of war, a persisting "subterranean acausality current" (p. 67n) was allowed to spring out and become mainstream in German culture only after the Armistice.[18]

Forman most clearly expressed the reason for which prewar marginal beliefs could take the center stage in the postwar when he approvingly quotes Arnold Sommerfeld: "The belief in a rational world order was shaken by the way the war ended and the peace dictat."[19] Forman therefore attributes to the *end* of the war, and not to the war itself, all responsibility for the cultural changes he wishes to account for. It was the irrationality of defeat, and not the absurdity of trench warfare, that induced some people to relinquish earlier faith in rationality and determinism and to embrace acausality. The rhetorical power of the reference to an absence becomes obvious. War happened outside of science. The effect it has on science can only be mediated by cultural critics such as Spengler. Ultimately, war, here too, has been bracketed.

The Bourbaki Thesis

To discuss the specific ways in which German mathematicians and physicists experienced the war and how this might have been played out in subsequent years would clearly be going beyond what I think I am capable of speak about, especially in front of an audience as this one. Instead, I would like to shift foci to other experiences which have given rise to another classic thesis about war effects on science—in this case, mathematics in France. Again, it is a rather surprising and controversial thesis; not least because it was formulated by mathematicians whose view of history was aggressively internalist.[20] Although I am fully aware that if historiography has shown one thing since the early 1970s it surely is that war experiences varied greatly not only from one nation to the other but also depending on the scientific domain in which one was involved, I believe that to draw such comparison might be useful, if only to make certain questions more explicit.

Bourbaki is famously the penname adopted by a group of young French mathematicians intent on reestablishing their discipline on the most general, abstract, and rigorous foundations. Never perhaps has a student prank had such impact in the history of mathematics. Charles Denis Sauter Bourbaki was a French general who fought in the Franco-Prussian war in 1870–71. A hoax lecture given by students at the École normale supérieure to the entering class in 1923 culminated with a "Bourbaki theorem." On 10 December 1934, a group of mathematicians, many of whom had taken part in that lecture, as either audience or pranksters, met in a Parisian café. Agreeing that analysis textbooks available in French (such as Édouard Goursat's *Cours d'analyse*) were outdated, they decided to write collectively a book to replace them. Having been in touch with modern German mathematics, especially at David Hilbert's Göttingen, influenced in particular by Barteel van der Waerden's *Moderne*

[18] This is not the place to discuss what such assertion might mean exactly. One may here simply accept Forman's stated intent and try to suspend judgment as to just how hard it might be to implement it convincingly: "To fully characterize an intellectual atmosphere one must specify not merely the likes and dislikes, the sympathies and antipathies, but also the mood, the morale, the accepted view of the contemporary cultural situation, and the common notion of what that situation demanded, or where it must lead" (p. 26).

[19] A. Sommerfeld, "Über kosmische Strahlung," *Südd. Mon athefte* 24 (1927), 195 –198; quoted in Forman, "Weimar Culture," 13.

[20] See Bourbaki, *Elements of the History of Mathematics.*

Algebra, they thought their large treatise should be introduced by an "abstract packet" summarizing in axiomatic form basic, general notions such as sets, groups, and fields. In July 1935, the group had its first "congress" (as annual summer meetings would later be called) in Auvergne where the penname "N. Bourbaki" was definitely adopted (the first name Nicolas was chosen later).[21]

Looking back to this early period in their later years, some of those belonging to the first group of Bourbakists wished to explain why there was such as need for disseminating mathematical concepts and approaches that seemed rather old viewed from across the Rhine. In their opinion, the reason why axiomatic mathematics, as had been promoted by David Hilbert in Göttingen as early as 1900, had been—until they came about—all but rejected from the French academic scene rested on the fact that a whole generation of mathematicians had been sacrificed in the carnage of World War I. In 1969, Jean Dieudonné thus explained:

> In the great conflict of 1914–1918 the German government and the French government had not understood things in the same manner as far as science was concerned. While the German very seriously put their scientists to work to increase their armies' potential through their discoveries and the amelioration of inventions and processes [that] helped them to fight better, the French, at least at the beginning and for one year or two, had, in a democratic spirit and in a sure patriotic élan that be only be respected, considered that everyone should serve on the front, so much so that the young savants as well as other Frenchmen did their duty on the frontline. The result was a dreadful hecatomb among young French scientists and when one opens the pages of the graduate books of the École normale, one sees enormous whole, enormous voids, large black capital letters meaning that two thirds of a class was cut down by the war. This situation had unfortunate repercussions on French mathematics.[22]

Twenty five years later, Dieudonné's old companion André Weil concurred in those terms:

> Already when I was at the School [=ÉNS], I had been deeply struck by the damage wreaked upon mathematics in France by the 1914–18 war. This war had created a vacuum that my own and subsequent generations were hard pressed to fill. In 1914, the Germans had wisely sought to spare the cream of their young scientific elite and, to a large extent, these people had been sheltered. In France, a misguided notion of equality in the face of sacrifice—no doubt praiseworthy in intent—had led to the opposite policy, whose disastrous consequences can be read, for example, on the monument to the dead of the École normale.[23]

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[21] The Bourbaki literature is growing fast: see Liliane Beaulieu, "A Parisian Café and Ten Proto-Bourbaki Meetings (1934-1935)," *The Mathematical Intelligencer*, 15(1) (1993), 27–35; Beaulieu, "Questions and answers about Bourbaki's early work (1934-1944)," *The Intersection of History and Mathematics*, ed. Sasaki Chikara et al., Basel: Birkhäuser, 241–252; David Aubin, "The Withering Immortality of Nicolas Bourbaki: A Cultural Connector at the Confluence of Mathematics, Structuralism and the Oulipo in France," *Science in Context* 10 (1997), 297–342; and Christian Houzel, "Le rôle de Bourbaki dans les mathématiques du vingtième siècle," *Gazette des Mathématiciens* 100 (2004), 52–63.

[22] Jean Dieudonné, "Regards sur Bourbaki," *Analele universitatii Bucaresti, Matematica-mecanica* 18 (1969), 13-25, on 13-14 ; quoted in Henri Lebesgue, "Lettres d'Henri Lebesgue à Émile Borel," *Cahiers du séminaire d'histoire des mathématiques* 12 (1991), 1-506, on p. 438, n. 976.

[23] André Weil, *The Apprenticeship of a Mathematician*, 1991/2. Compare with what Émile Picard wrote to Henri Villat (28 July 1923): « Il nous faut nous résigner aux temps difficiles où nous vivons, et d'ailleurs, dans l'ordre scientifique, ce ne sont pas les préoccupations financières qui sont les plus graves ; la diminution du nombre des

The Bourbaki thesis can thus be formulated as such: if, compared to the modernity of Göttingen, the postwar French mathematical scene appeared conservative at least up to the mid-1930s, this was due to the fact that young savants had been slaughtered in greater proportion on the Western side of the trenches. Left largely unaddressed in the argument is of course the crucial inference that fewer surviving mathematicians in a generation would necessarily lead to greater attachment to tradition. Before I start examining how well this thesis holds out to the knowledge that is now being constituted about mathematical communities in interwar France, and acknowledging that Bourbaki mathematicians had none of the historical sophistication that is to be found in Forman's work, I believe it is useful to contrast both theses a bit further.

Strikingly, as opposed to the Forman thesis, war here is a cause for tightening the clutch of entrenched representations of science, not for shaking old belief systems. As I have shown that it is not war itself but defeat that is actually central in Forman's argument, it would seem to make sense that opposite national experiences regarding the end of the war would lead to opposite reactions in scientific communities. Contrary to Forman's radical claim that social worries can give rise to new scientific principles, the Bourbaki thesis is a rather standard account of social hindrances standing in the way of scientific progress.

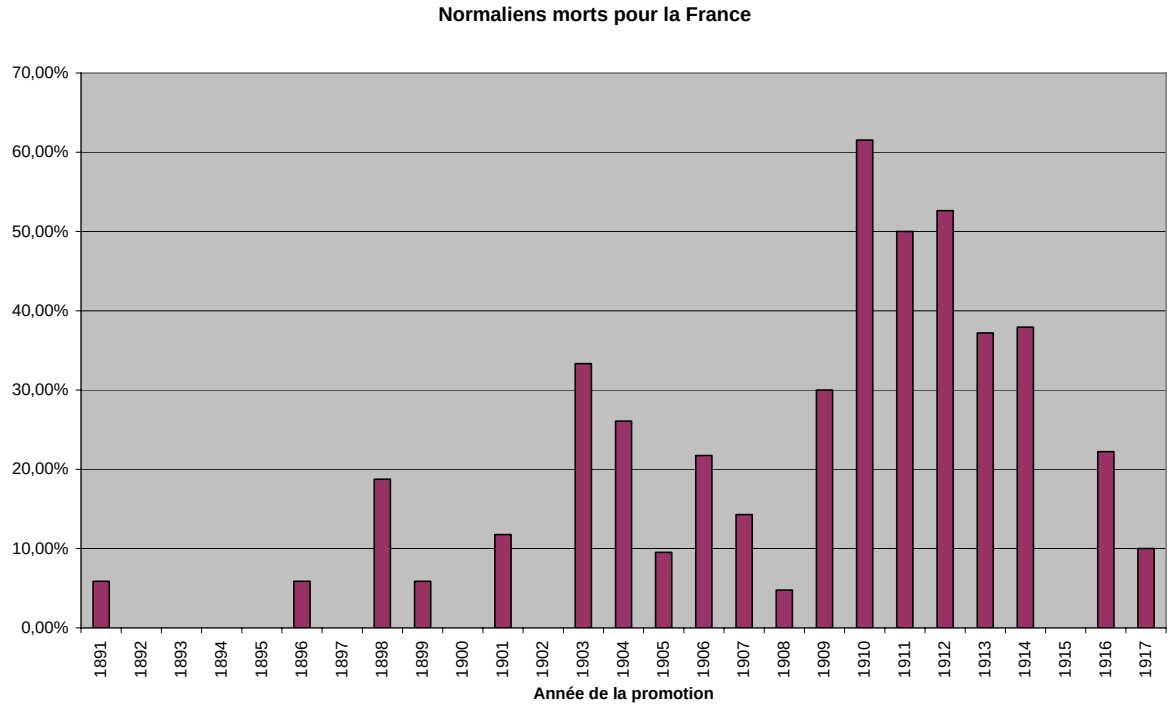
War as such is not bracketed by Bourbakists. Ripple effects are felt more than a decade after the Armistice. There is nothing specific about the argument. Young mathematicians were—just like bakers and bankers—decimated between 1914 and 1918. So, the effect of war on mathematical communities is mostly external to mathematics. No specific war task carried on by them, no social demands for the postwar reconstruction is invoked. War's effect on mathematics is the same it had on every field of human activity. Unlike bakers, however, mathematicians were both harder to train and easier to dispense with. For Bourbaki, war is therefore as tangential to the main argument as it is to Forman's.

Loss Generation and Renewal of the Elite

As Suman Seth has documented in the case of physicists, Dieudonné and Weil's assessment of German science policy during the Great War can easily be contested. But the strong impression that in France a whole generation had been lost to war is undeniable. Borel's wife, the writer Camille Marbo recalled that her husband could not, at the end of the conflict, face the "shadows" haunting the École Normale and resigned his position there. "Back in charge as scientific director, Emile Borel found the school haunted by shadows. Young faces, that would not be seen again, appeared behind every corner."[24] It is worth emphasizing that Borel's own adopted son, his nephew Fernand Lebeau, who had studied physics at the École

travailleurs dans le domaine de la science désintéressée est le point le plus inquiétant. » Archives de l'Académie des Sciences. Fonds Henri Villat. 61 J, file no. 5.

[24] Camille Marbo, *A travers deux siècles, souvenirs et rencontres (1883-1967)* (Paris: B. Grasset, 1967). Cf. Charlotte Bigg, "From the Belle-Epoque to the Années Folles: what was the Impact of the WWI on the French physical science?" and Laurent Mazliak, "The Ghosts of the École Normale: Life, Death and Destiny of René Gateaux," talks at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007. « Quand l'École accueillit, au printemps 1919, ceux qui l'avaient quittée en 1914 pour la défense du pays, nul n'y rentra sans un serrement de cœur : elle était trop imprégnée, la vieille maison, du souvenir de ses morts ; nous nous sentions tous en deuil » (p. 129) A. Levassor-Berrus, "Loussert (Maurice-Marie-Joseph), né le 3 mars 1893, mort pour la France, le 25 septembre 1915, devant Saint-Souplet. – Promotion de 1913," Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1920), 129–133.



normale in 1910–13 had been killed in the Marne on 26 September 1915, after which Borel sought active duties and served courageously.[25]

The dreadful numbers are only too well known. In the class that entered the École normale in 1910, to which Lebeau belonged, more than 6 out of 10 science graduates never returned from the war. Fatal casualties in the following two science classes were also above fifty percents (see graph). In speeches made in January 1915, officials noted that out of 195 students enrolled at the École that went to the front, at least 34 were confirmed dead, 15 had disappeared, 21 had been taken prisoners, 64 had been wounded, only 54 or 55 remained unharmed.[26] Altogether a little more than one hundred students or graduates from scientific classes of the École died due to the war.

Numbers are striking but not necessarily eloquent. Since almost all who in France had a professional career in mathematics (or in any other scientific field for that matter) had been though the École normale, it is rather natural to conjecture, as Dieudonné and Weil did, that this dreadful loss may have had important consequences for the field in the following years. But how can one measure it? Who is to say what would the dead have done? How did the surviving members of the cohort respond to this situation? And in particular why would this terrible fact alone have pushed mathematicians away from Hilbertian axiomatic?

Recent work by French historians of mathematics Catherine Goldstein, on the one hand, and Hélène Gispert and Juliette Leloup, on the other, allows us to contest some aspects of the

[25] Henri Lebesgue, "Lettres d'Henri Lebesgue à Émile Borel," *Cahiers du séminaire d'histoire des mathématiques* 12 (1991), 1-506, on p. 438, n. 974; voir R. Deltheil, "F. Lebeau," Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1917), 130–133.
[26] Émile Boutroux, in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1915), 1–4, on 2. Numbers are roughly similar in Ernest Lavisse's speech, 4–6. See also Dominique Pestre, *Physique et physicians en France, 1918-1940* (Paris: éditions des Archives Contemporaines, 1984), Spencer Weart, *Scientists in Power*, etc..

picture of postwar mathematics as it was painted by Bourbaki.[27] Taking the case of number theory, Goldstein shows that there is more continuity in the French preoccupation with the topic than previously thought. Paying attention to the most powerful mathematicians in interwar France (Academicians and professors at the Sorbonne, especially), Gispert and Leloup explain that contrary to the Bourbakists' claims there was considerable renewal in the elite of the period. What is striking however is that most of the people who achieved elite status in that period were born in the decade of the 1870s, that they had received their training before the war, and they had served *as mathematicians* rather than as soldiers during the war.

The only major exception Gispert and Leloup have identified was Gaston Julia (figure). Born in 1893, Julia was fifteen to twenty years younger than any of the "patrons" they discussed. Having just graduated from the École normale in 1914, he was mobilized in a fighting unit, and in 1915 he was severely injured: his nose torn out of his face. During his convalescence, Julia dove in the study of function iteration and achieved his major results for which he was awarded a major prize by the Academy. An influential teacher for future Bourbakists, Julia surely was a constant remainder of the scars war had left on French society.

Mathematical War Cultures

In view of recent historiography, the Bourbaki thesis therefore seems right on the whole in its identification of war as an important factor in the shaping of the French interwar mathematical scene, but unconvincing in explaining *how* the war could play such a role. To me, the questions that this raises are whether there were specific aspects of the war culture which may in the postwar have impregnated mathematical practice, as well as the common representations of the field? And if so, how can one recover these aspects despite widespread tendencies, then and now, to bracket the war?

To approach such questions, Catherine Goldstein has recently drawn attention to questions of scale.[28] On the international and national scale, we know that the war had crucial consequences for the organization of science. At the level of disciplines, as the Forman thesis demonstrated, effects are notoriously harder to discern. But at individual levels, war often was a scarring experience. To disentangle various scales, one may draw on recent work by cultural

[27] Hélène Gispert and Juliette Leloup, "Des patrons des mathématiques en France dans l'entre-deux-guerres," sumitted to *Revue d'histoire des sciences*, juin 2006; Catherine Goldstein, "Number Theory Wars," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

[28] Catherine Goldstein, "Number Theory Wars," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

historians of the Great War. After all, one wonders why scientists and mathematicians should necessarily react to war in ways utterly different from those of their contemporaries, and the more so, if their experiences were not obviously distinct. In their book *14-18: Understanding the War*, Audoin-Rouzeau and Becker wished to "recover" deep cultural meanings of the war, that is, they wished to devise tools enabling us to understand aspects of the war that now seem wholly incomprehensible.[29]

Audouin-Rouzeau and Becker's book structures the understanding of the war around three main themes: violence and the "brutalization" of societies on a large scale; the perception of the war as "crusade" subsuming all other peripheral concerns and geared towards high moral goals; and the politics of mourning that underlies the return to peace in the postwar years.[30] In my view, a historical analysis of mathematical war cultures would comprise a study of the images of mathematics in times of war and of the representations of mathematicians' roles in society while paying careful attention to actual mathematical practices deployed and developed for war purposes. And I feel that these can be only be undertaken by paying close attention at the level of individual experience.

During World War I, French mathematicians were split in three overlapping groups, or better had three types of non-exclusive trajectories. First there were those who served in the army, either in fighting posts or in the supply corps. Then, there were those, usually older, not drafted and who embraced organisational roles: as leaders of the scientific war effort or as "intellectual crusaders."[31] Finally, a number of them were able to apply their mathematical skills directly to solve problems that seemed—directly or not—relevant to the waging of war.[32] I obviously do not have the space here to give detail accounts of any of these groups' activities. But I think I hope to be able to give some ideas of the way in which paying proper

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[29] For a useful long-term survey of WWI historiography, see Antoine Prost and Jay Winter *The Great War in History*, 2004. For an interesting and, at times, enlightening critique of the approach discussed here, see however Nicolas Offenstadt, Philippe Olivera, Emmanuelle Picard and Frédéric Rousseau, "A propos d'une notion récente : la 'culture de guerre'," in *Guerres, paix et sociétés, 1911-1946*, ed. F. Rousseau (Neuilly:Atlande, 2004), 667–74.

[30] In France cultural histories of the Great War have directly informed new approaches to the history of medicine, in particular by Sophie Delaporte. It has also inspired the work of Anne Rasmussen and Christophe Prochasson, *Au Nom de la Patrie. Les Intellectuels et la Première Guerre Mondiale (1910-1919)* (Paris: La Découverte, 1996). In *Le Sabre et l'épouvette*, considering scientists as intellectuals, Rasmussen understands the reaction of scientists to the declaration of war in the context of crisis and renewal which seemed to have been characteristic of the prewar period. She focuses on the various forms of scientific mobilization and introduced a lucid chronology (spontaneous mobilization 1914-1915, demobilization, and organized remobilization esp. in 1917-1918). To illustrate the brutalization of the language in mathematics, one may recall Camille Jordan's eulogy where Robert d'Adhémar writes: "Là où il a été, la tranchée est nettoyée." See Robert d'Adéhmar, "Camille Jordan, de l'Académie des sciences (5 janvier 1838 – 21 janvier 1922)," *Revue générales des sciences pures et appliquées* 33 (1922), 65-66, on 66. Note that Jordan lost three sons and one grandson during WWI, all killed in action Charles capitaine d'artillerie coloniale (1914), Pierre capitaine d'infanterie (1914), Louis (1915) and his grandson Camille mortally wounded at Verdun in February 1916.

[31] Others like Élie Cartan preferred to take care the hospital set up in the building of the École normale.

[32] During World War I, it was not always immediately obvious what mathematicians's contribution to the war might be. As late as 1917, some American mathematicians seemed not to know how they should be put to work: "Thus far, I have failed to find any place in which mathematical work is of use in connection with the war." Oswald Veblen to George David Birkhoff (19 May 1917). Even after he was commissioned a captain in the Ordnance Officers Reserve Corps, Veblen wrote: "Recently I received a letter from O. W. Richardson in reply to an inquiry as to what there was to do for mathematicians in war. He says there is practically nothing that requires real mathematics. From other sources I know of an important application of the problem of Apollonius (circle tangent to 3 given circle) but the real scientific interest in this is physical. I am not expecting to find any considerable math[ematica]l interest in my new department." Veblen to Birkhoff (10 September 1917) HUG 4213.2, box 7.

attention to mathematical war cultures leads to crucial insights about postwar representations and practices of mathematics.

Necrologies of *Normalien* mathematicians are a good place to start to unveil the utter violence that was experienced by this generation. On August 26, 1914, a young mathematics professor from Lille University, Jean Clairin was killed in battle: "his forehead, his noble forehead, broken by a bullet."[33] Three days later, Jean Merlin went missing. Born in the same year as Clairin (1876), he was working at the Lyons Observatory at the end of July 1914, but was by inclination a mathematician. His thesis on group theory and his work on number theory and on relativity theory had been positively received.

> On August 29, [1914,] several men of his regiment saw him fall at the Anozel Pass, his jaw and shoulders hit by shrapnel. Our troops were then retiring; Germans were occupying Saint-Dié. One had to leave him there. He was found dead, on September 6, with a man of his regiment, on the edge of a forest, in a place called Fonchraupt, near Saint-Dié, a few kilometres away from Anozel. What befell to our friend during those eight days? It makes the heart bleed to think of it.[34]

Gaston Julia himself wrote an obituary for his "prodigiously loving friend," Paul Lambert.[35] This is a touching document in which Julia vividly recalls his love of life and his intellectual capabilities. With Borel's nephew, Lebeau, and other now deceased classmates, Julia wrote, they formed a joyous band, cycling around Paris, reciting poetry, and working on mathematics. About his friend's broken future, Julia wrote:

> It would be adventurous to make prognosis, and I cannot here put side by side my friend and such an authentic and indisputable glory as Galois, but I cannot refrain from saying that I often thought of this immortal genius by living close to Lambert: the had many resemblances in their tastes, they were both very precocious, they both died very young and tragically.[36]

As the mathematician Jacques Hadamard would say: "For a certain number of years, there has been in France a remarkable school of young mathematicians, thanks to which our country fear, on that ground, no comparison."[37] Who indeed is to say what fallen mathematicians might have been able to accomplish later? The question might not seem so relevant to the historian, but it was to contemporaries.

There were thousands of such stories repeated in all sorts of places. What seems most striking to me, however, is the complete lack of suggestion, even after war had for a long time been

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[33] Ollivier, "Clairin (Jean), né à Nîmes e 13 novembre 1876, tué à l'ennemi à Thun-l'Évêque (Nord) le 26 août 1914. – Promotion de 1896," Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1917), 83–85.
[34] Jacques Chevalier, "Merlin (Jean), né à Rennes le 9 mai 1876, tombé au champ d'honneur le 29 août 1914 au col d'Anozel. – Promotion de 1898," in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1915), 53–56. Cf. also Prix Becquerel, *CRAS* 161 (1915), 890.
[35] Gaston Julian (sic), "Lambert (Paul-Jean-Étienne), né à Annecy le 27 février 1894, tué à l'ennemi près de Fontenoy (Aisne) le 15 mars 1915. – Promotion de 1911," in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1919), 109-113.
[36] Julia, "Lambert," 110.
[37] Jacques Hadamard, "Lery (Georges), né à Limours le 28 avril 1880, tué à l'ennemi le 10 septembre 1914. Promotion de 1899," in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1916), 112–116, on 115.

over, that talents were wasted by sending students and young scientists to the front. Rare was the necrologist that even so much as implied that fallen soldiers might have served their country better by working as scientists. This reminds us that we should be cautious about assumptions we may have about the proper role of scientists during the Great War. People have often implicitly or explicitly assumed that scientists might have been more useful to the war effort by working in labs, computing bureaus or factories. From the point of view of contemporaries, this assumption was probably false. On 26 September 1914, Sergeant Pierre Abeille who had the possibility to serve in the rear explained why he sought fighting duty as such: "However useful, my place was not in an office." According to the sous-préfet Abeille who would be killed less than two months later, the intellect was most useful as a model for less educated men.[38]

Widely shared at the time, the notion that the proper place of the intellectual or (of the scientist) was on the front has often been solely interpreted as a symptom for the irrational patriotic exaltation that overtook all belligerent countries. But some new research concerning the American Civil War has recently shown that regiments led by the Bostonian university-trained elite statistically were more efficient in battle and suffered fewer casualties than others. Reading novels and witness accounts, such as those of Maurice Genevoix (who was a Normalien) for example [*Ceux de 14*], reinforced my impression that because of the quality of leadership they demonstrated on the front, many intellectuals and scientists might indeed have served their countries best by risking death and sometimes by being killed.[39]

In the case of fallen *Normaliens*, destined to be the intellectual elite of the nation, sorrows are often full of regret for the irreparable loss suffered by the country. Like Julia, most writers refuse to blow up eventual prospects. But all feel that their contribution to the "*grand travail* [that] is awaiting us the day after victory" would be missing. Each dead seems to strengthen a resolve this confers new duties to the survivors. The director of the École normale, Ernest Lavisse, wrote: the idea that our children died in vain would be "unbearable." [40] The recent graduate Julia added about Lambert: "He is among the dead who are to the living a reason to live in order to substitute them in the task that was taken from their hands."[41]

Following the death of his comrade, Julia felt a duty to fulfil a mission, in the strictest sense of the term. He was sent into an unknown world, that of postwar France, to realize the hopes

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[38] *La Dernière Lettre écrite par des soldats français tombés au champ d'honneur 1914 – 1918*, choisies par des pères qui pleurent un enfant mort pour la France et par d'anciens combattants réunis sous la présidence de M. le maréchal Foch (Paris: Union des Pères et Mères dont les fils sont morts pour la Patrie ; Ligue des Chefs de Section et des Soldats combattants ; E. Flammarion, 1922), 13. Abeille died on November 12, 1914 in Vingré (Aisne).

[39] See James M. McPherson, "Brahmins at War," *New York Review of Books*, vol. 52, no. 15 (October 6, 2005), 34-35. Author of *For Cause and Camarades : Why Men Fought in the Civil War* (Oxford : Oxford Univ. Press, 1997), McPherson writes, in this paper concerned with the mobilization of the Bostonian elite in the American Civil War, that he might have underestimated the importance of leadership in the constitution of efficient combat units.

[40] Both quotes above from Ernest Lavisse, in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1915), 4–6, on 5–6. Cf. also Jacques Hadamard, "Lery (Georges), né à Limours le 28 avril 1880, tué à l'ennemi le 10 septembre 1914. Promotion de 1899," in Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1916), 112–116: "S'il est vrai que, pleurant nos morts de cette guerre, nous ne devons pas oublier la grandeur de la cause qu'ils ont servie, s'il faut nous rappeler que, dans l'espace de quelques mois ou de quelques jours, ils auront vécu, en effort et en action, l'équivalent de longues existences, combien cette pensée nous est doublement nécessaire lorsqu'il s'agit d'êtres de cette valeur, dont nous savions si bien à l'avance tout ce que l'humanité et le pays pouvaient attendre !" (p. 116).

[41] Julia, "Lambert," 113.

of the dead. During the war, Frenchmen had the feeling of partaking in something that was greater than them.[42] Many sought to perpetuate this feeling, working for the university (Albert Châtelet's case studied by Goldstein), for science popularization (Perrin's case studied by Charlotte Bigg), etc.

Similarly, during the war, Academicians felt as if they were called to serve on the intellectual battlefront. There is now considerable historical material documenting ideologies promoted by elite scientists during the war. Forman himself has written an important paper on it.[43] Extreme pronouncements by Pierre Duhem, Émile Durkheim, or Émile Picard, just to cite three of the most influential scientists of the time, about the deviant nature of German science have been discussed many times. The subsequent ostracism that struck German and Austrian scientists has also been well documented. I will therefore not come back too much on these here.

Let me just underscore that placing those reactions in the framework of war cultures, relocating them in individual trajectories has helped to understand them better. Take the case of Picard, for example. As early as November 1914, he writes to his ex-student Henri Villat: "I have two sons and two sons-in-law on the front; the latter two are at present wounded. These are times of anguish." Three of Picard's sons would die during the war. As one might expect, this was hard on him. On October 1916, he wrote:

> My health has not been brilliant for the last few months, my nervous system was unable to find its balance back. […] No matter how distant the end of the war may now appear, it will nonetheless happen one day, and the fight will then erupt again under a new form against a perfidious enemy who, however depressed he may be, will try to rise again from his defeat. Men of my age will never know quiet days again.[44]

Picard's leading role in staunchly resisting the inclusion of German scientists in the new international institutions set up after the war is well known and has been harshly criticized ever since. The narrow-mindedness of such statements has often been discussed, but their intellectual importance has scarcely been carefully examined.

In August 1915, the geologist Edmond Perrier presented his book *France et Allemagne* to the Academy, in which he explained that there was "a parallel between the high aspirations of French Science and the often too practical side of German science." The genius of the Germans, he claimed, is to have known how to apply French disinterested science. In October of the same year, Picard presented his pamphlet titled "The History of Science and the Pretension of German Science" where he said: "I insist on the so often formal character of German scientific writing."[45] He went on:

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[42] Travelling through France in 1917, the American envoy Joseph Butler wrote: "In France the individual has disappeared; he has been swallowed by the State; the nation in its dire necessity, obeying the law of self-preservation has practically obliterated the individuals as such. He has become simply a small part in a great whole, a whole so inconceivably more important that any of its parts that all of them are completely subordinated." Joseph G. Butler, Jr., *A Journey through France in War Time* (Cleveland: The Penton Press, 1917), 273.

[43] Forman, "Scientific Internationalism and the Weimar Physicists."

[44] Picard to Villat (5 October 1916). Villat Papers, archives de l'Académie des sciences.

[45] All quotes from this paragraph and the next are taken from *CRAS* 161 (1915), 96 and 410. See also Emile Picard, "L'histoire des sciences et les prétensions de la science allemande," *Revue des deux mondes* 28 (1915), 55–79 and Pierre Duhem, "Quelques réflexions sur la science allemande," *Revue des deux mondes* 25 (1915), 657–686.

> German science has the tendency to posit *a priori* notions and concepts and to follow indefinitely the consequences, without worrying about their agreement with reality, and even while taking pleasure from distancing itself from common sense.

As it was defined during that year, "German science" was simultaneously too abstract and too applied. In contrast, "French science" was both commonsensical and disinterested. A consensus therefore slowly emerged As the physicist Arsène d'Arsonval expressed it in December 1917: "Our culture is not a 'soulless' culture; it does not aim at immediate utilitarianism (perhaps not enough), but it respects, develops individuality, the original and inventive faculties of the intelligences. These qualities have, industrially, saved France." A year later, the former prime minister and mathematician Paul Painlevé similarly extolled the disinterested nature of French science. Perhaps was it too theoretical, but it was this spirit that both preserved the morality of Science and tightened the links between science and industry. "These are great lessons that should not be wasted, great results that must outlive the time of battles."

More importantly perhaps, those lessons were not just those learned from wartime ideologues but also from those who had taken part in the scientific mobilization.[46] At Gâvre, on the Atlantic Coast, a dozen mathematicians participated to the revision of computing methods for ranging tables, especially in view of developing anti-aircraft canons.[47] In Paris, Sorbonne professors organized teams composed of hundreds of mathematics high school teachers for the same purpose. In designing instruments and methods to locate enemy artillery pieces by the sounds they emitted, mathematicians, physicists, and astronomers intensely collaborated with military engineers and geodesists.[48] The development of the theory of flight similarly hinged interdisciplinary cooperation. The way this experience was reintegrated in the civilian life of mathematician has just barely started to be examined by historians.

Conclusion

Reflecting on the good that came out of his role in setting up a team to work on anti-aircraft defense in WWI commented: "Kaiser William and I, jointly, did a good service to science in diverting both [Ralph H.] Fowler and E. A[rthur] Milne for pure mathematics to other fields."[49] In France, the inflection mathematicians gave to their work towards more applied

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[46] About his friend, Albert Châtelet wrote : « son esprit était surtout attiré par la recherche de la simplicité, de la concision et de l'élégance. Ce sont des qualités bien françaises et l'on conçoit que Marty ne pouvait guère aimer les démonstrations longues et pénibles de M. Hilbert, ni la prolixité et le lourd fatras d'éruditions des élèves allemands de Goettingue » (p. 58). See his "Marty (Joseph), né le 12 février 1885 à Rodez, tué sur le champ de bataille à Séraucourt (Meuse) le 10 septembre 1914. – Promotion de 1905," Association amicale de secours des anciens élèves de l'Ecole normale supérieure (Paris), *Réunion générale annuelle* (1915), 56–59.

[47] I have given an account of ballistic work in "The War of Guns and Mathematics: French Mathematicians, Ballisticians and Artillerymen in WWI," talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

[48] On this topic, the work of Martina Schiavon is enlightening. Cf. *Le Sabre et l'éprouvette* and her talk at the meeting on "Mathematics and Mathematicians through World War I" held at the Centre international de rencontres mathématiques (CIRM) in Luminy, Marseilles, January 21-26, 2007.

[49] A.V. Hill, "Memories and Reflections," 3 vols. Churchill College Archives, Cambridge, 920 HIL. Elsewhere he ironically commented: "They prostituted their brains so effectively that, starting from being pure mathematicians they became respectively, Fowler one of the most eminent applied mathematician , and Milne an equally eminent astronomer" (p. 124). The work of British mathematicians in war service has been studied in detailed by June Barrow-Green whom I want to thank for guiding me through Hill's papers.

domains (such as probability theory) is also striking.[50] But more generally, we could say that postwar French mathematics was characterized by at least three major traits. First, there is a widespread sense in the community that, as surviving intellectuals after a bloody war, mathematicians have national and moral duties to fulfil. Second, the relevance of academic mathematics to military concerns appears clearly after experiences of active collaboration between professional military men and drafted mathematicians. Finally, a consensus seemed to emerge that postwar mathematics would have to find a middle ground between the pure and the applied. The improbable rise of Henri Villat (a specialist in fluid mechanics whose theories were both incredibly abstruse and empirically wrong) nicely underlines the direction taken by French mathematics at the time.[51] The goal of mathematics was to derive universally applicable theorems (especially in the area of analysis which remained a « French » specialty, while staying pertinent to military and civil engineers. Obviously, the mathematician was not to provide solutions to concrete problems. But in postwar France one of his moral and national duties was to safeguard the right *esprit* in which problems were to be tackled.

To me, one of the reasons why the Bourbaki thesis cannot be fully satisfying to the historian of science is precisely because it avoids directly dealing with World War I, and therefore cannot paint a textured portrait of the war cultures that were so important for the postwar period. Whether this conclusion can be extended to the Forman thesis, I cannot say with full confidence. But I find that some work about the way in which German physicists participated in the war—Suman Seth's in particular—to be at least highly suggestive that it may be.

Since the 1970s, when Paul Forman wrote his fascinating paper, the history of science has been swept not so much by the linguistic, but by what I would want to call the "practical" turn. Understood as practice, which can be recovered in particular through a close look at material cultures, science acquired a new character. When the "practical turn" is taken, the war is not seen as a parenthesis, nor so much as solely a basis for future development, but rather as a crucial step in two longer processes. The first is the deepening of the impact of technoscience on Western society, industry and war, and the massive investment consented by the State. The second large-scale process could be called, for lack of a better term, the "modernization" of science: the deep transformations associated with quantum mechanics and relativity theory, as well as the rise of the axiomatic, structuralist conception of mathematics.[52] To me, the Forman thesis suggests is that both processes are not unrelated with one another and that recovering the scientist's experience during the First World War should help us understanding why this was so.

[50] One may cite in this respect: Jules Haag, Maurice Fréchet, Paul Lévy, Émile Borel,…

[51] See my "Audacity or Precision: The Paradoxes of Henri Villat's Fluid Mechanics in Interwar France," talk at "International Conference on the History of Fluid Mechanics," Rauischholzshausen, October 2006.

[52] I have tried to follow this approach in my study of George David Birkhoff's *Dynamical Systems*, in *Landmark Writings in Western Mathematics, 1640-1940*, ed. Ivor Grattan-Guinness, Amsterdam: Elsevier, 2005, 871–881.