

matics and its axiomatization *à la* Bourbaki, writers from the Oulipo group such as Queneau, Roubaud, Perec, and Calvino have all made sufficiently clear the inspiration that they found in these; Primo Levi himself showed how the chemist in him fed the writer (Levi 1990); and the references in Pynchon—beginning with *Gravity's Rainbow*—are not any less evident (cf. Pynchon 1990). It would be presumptuous on my part to move in on the terrain of literary criticism; I will endeavor instead to reverse the current and show all we have to gain by examining the specter of science through the prism of literature. This little reading guide, jottings in a notebook, obviously does not claim to be all-inclusive; it only explores some paths worth following. For a *voyage autour de la science*, then, here are a few companion books I recommend bringing along.

The Mirror

Let's begin by asking literature to introduce science and its practitioners to us. For the ivory tower is short on mirrors, and scientists scarcely know their own image. Luckily there are books where these reflections can be found. And if some scientists think these mirrors reflect a deformed image of themselves, it is perhaps because they simply magnify the reflection, and highlight those features most characteristic of their objects—features that have no reason to be the most flattering.

The increasingly heavy weight exercised upon nineteenth-century culture by science is well-documented, as is the charge that science acted to suffocate sensitivity, to disenchant the world, and to trivialize all moral or aesthetic aspirations. Flaubert, more than anyone else, bears witness to this ascendancy, while at the same time taking a distance from it. Recall some of the entries in the *Dictionnaire des idées reçues*:

Mathematicians: They drain the heart.

Scientists: Science is inborn. Wells of science. To be a scientist, one only needs memory. To fool them.

Science: With respect to religion: "A little bit of science puts it aside, a lot leads back to it."¹

(We'll return further on to the relations between science and religion). We owe to Flaubert one of the best versions of the well-known anecdote of "The Age of the Captain," which plays up the mythical representation—both contemptuous and alarming—that laypersons make of mathematics. Stella Baruk, author of a book about the teaching of mathematics called

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with finesse and humor the brooding of a young physicist who every morning takes the metro from Paris to his laboratory in Orsay, and for whom the imagination shifts from the difficulties posed by his equations, with which he is obsessed, to his neighbor's thighs, with which he is equally obsessed. And Daniele del Giudice, in *Atlas Occidental*, describes with equal success the confrontation in Geneva between an old American writer and a young Italian physicist who works at CERN (Centre Européen de Recherches Nucléaires). This novel offers a compelling description of the colossal equipment used in the domain of particle physics, and the demiurgical dreams of its practitioners.

For all of that, the great men of science do exist. But their biographies too often arise out of hagiography, with the consequence that trees are hiding the forest. To leave the domain of apologetics, one must escape from the overly quaint genre of "the life of scholars" (recall the ironic, charming and tasty pastiche by Gisèle Prassinos with his *Brelin-le-Frou*). Take the case of Oppenheimer (a good example, by the way, of a scientist for whom the overly-fine and overly-critical intelligence kept a great talent from developing into a creative genius; he was missing the necessary grain of folly). After taking over as scientific director of the Manhattan Project (the building of the first nuclear weapons at Los Alamos during the Second World War), Oppenheimer was relieved of his duties after a run-in with the CIA, in which he was brought before the Committee on Un-American Activities during the McCarthy-era hysteria. This ambiguous history, and some of his relations with the CIA which were characterized by a number of compromises, are not well known. (For example, to take over the post at the Manhattan Project, he testified against one of his friends, an American who was sympathetic to the Communists before the war.) This uneasy alliance of a great intelligence and a fragile morality was remarkably described by his victim, Haakon Chevalier, in a novel called *The Man Who Would be God*—a veritable tragedy in which it is the hero's *hubris* that leads to his fall. Rarely has the mixture of arrogant presumption and spineless naiveté typical of some of science's great men been so well described. In this perspective, recall the extraordinary short story by Stig Dagerman, which is both dream-like and ironic, called *Dieu rend visite à Newton*. This story documents a kind of desperate evil perfectly suited to the kind of admiring dislike we cannot help but feel towards Newton.

The Beaker

Still, we must understand what science is. In this interrogation on the nature, the value, and the status of scientific activity, which is the everyday activity of epistemology, we should not neglect the extraordinary contribution of literary texts. This essence of science that we seek to isolate is sometimes rendered in literature by a more subtle distillation of elements than what is accomplished by the heavy analyses of the philosophy of science. In short, fractional distillation is more efficient than mechanical sorting.

Our era has witnessed the forging, beyond scientific rationalism, of a finer, more relative and more contextual conception of scientific knowledge. From Duhem to Feyerabend and Foucault, through Popper and Lakatos (and even Bachelard, though it is necessary to demonstrate this against accepted wisdom), we see a progressive blurring of the lines of scientific criteria and the norms of rationality. It is not surprising to find in literature dazzling intuitions and striking utterances from this movement.

To begin, a constitutive example. Nineteenth-century culture was polarized between the scientific upsurge (positivist, modernist, naturalist) and resistances to it (romantic, symbolist). Few were able to avoid this struggle. But there was one major exception: Victor Hugo, a man who amazingly rode both currents simultaneously. This is illustrated by the magnificent text *L'Art et la science*, initially the third chapter of *William Shakespeare*, which Hugo wrote as a preface to François-Victor's (his son's) translations of Shakespeare. We find therein a comparison between art and science that is not explosively original; Hugo affirms in this text the absolute character of art and the relative character of science, and suggests that art does not understand the idea of progress whereas science is characterized by that very notion. But the force of Hugo's writing elevates these ideas from the realm of the banal; and for our purposes, Hugo provides a concept of scientific progress that is well ahead of the positivism of his time. This progress, for Hugo, is neither linear nor quantitative nor cumulative. He writes:

La science est autre.

Le relatif, qui la gouverne, s'y imprime; et cette série d'empreintes du relatif, de plus en plus ressemblantes au réel, constitue la certitude mobile de l'homme.

En science, des choses ont été chefs-d'oeuvre et ne le sont plus. La machine de Marly a été chef-d'oeuvre.

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containing an array of specialized optical equipment—lenses, mirrors, and so forth. And here is how the protagonist arrives at understanding the goal of their predecessor, the constructor of the castle:

... la lumière était pour lui un symbole d'évidence, de vérité, sans doute se passionnait-il pour ses jeux à la surface des bassins du parc, dans le feuillage des arbres, sur le brillant des armures, il considérait les reflets, s'attachait aux ombres, s'ingéniait à retrouver leurs sources, à force d'observations patientes, à prévoir leur emplacement, leur éclat, à prédire leur densité. Ainsi en arrivera-t-il sans doute, peu à peu, à s'interroger sur l'infailibilité présumée de la nature. Elle était trop à son aise dans son élément, ses manifestations y étaient trop diffuses, trop complexes pour qu'il osât attaquer chez elle; il se retira alors dans sa tour ("Natura rerum magis se prodit per vexationes artis quam in libertate propria" cite-t-il), afin de la mieux cerner dans l'espace d'un laboratoire. (Bramly, 1979, p. 146)

It is a matter of trapping the light when its guard is down. For there are no laws without exceptions! And light, similar to the citizen, would not always obey the law. So the heroes of the book reconstruct the "light trap" and then lie in wait:

"La lumière se comporte avec une telle assurance. Pareille à ces géants immémoriaux qui se croyaient invincibles, elle s'avance à visage découvert. Elle est en fait l'esclave de ses habitudes." Alors il table sur l'effet de surprise, sur une possible distraction. "Exploisons sa suffisance, dit-il; nous avons créé ce piège, l'avons créé de toutes pièces, l'avons pourvu de ramifications infinies et changeantes: les imprévisibles circuits où nous la forçons, la prendrons bien un jour au dépourvu—il suffit d'une faute!—ils la décontenanceront, elle trébuchera, une étourderie, nous lui ferons perdre pied une fois au moins. Commençons par endormir sa méfiance; contentons-nous, pour le moment de problèmes aisés, d'amicales promenades, elle faillira, m'assure-t-il, vous verrez, lorsque se mettront réellement en branle les impénétrables rouages de notre machine, lorsque nous l'entraînerons dans nos dédales les plus secrets". (Bramly, 1979, p. 153)

There is in this novelistic web a remarkable intuition concerning the homology between scientific research and police investigations. The researcher, like the detective, is more interested in infractions than in respect for the law! The routine, for the policemen as for the scientist, is that of verification: papers in order, formulas obeyed. But the game is that of the chase beyond the margins of law. In contrast to the cold image projected by science to laypersons, there is no greater excitement for the researcher than to discover an exception to the accepted laws, a limit to the validity of accepted theories. The day that Einstein's theory of relativity shows a fault will not be a day of mourning but of glory for the scientist who has managed to close the light trap upon a delinquent photon. Bramly's fiction

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admirably illuminates the tracking down of illegality that underlies scientific research. By stressing the contingency of laws of nature, fiction helps us to understand the violence they inflict (to the mind, at least), as do the laws of society. The rebellion inspired by the constraints of natural laws deserves to be taken into account by the producers and the mediators of science in their relations with laypersons, and should force them to ask themselves about the underlying significance of the judicial, normative and legitimizing forms that scientific knowledge assumes.

We shall conclude this brief introduction to the epistemological usage of literature by an incursion into the work of Brecht. If there is one writer in our century who sustained a protracted and intense relation with the realm of science, employing it both as an integral part of his work and as a means of illuminating the inherent contradictions of science (which, as a good dialectician, he assumed beforehand), it was indeed Brecht. Numerous references to the method, the spirit or the practice of science permeate his texts (for example, *Le Petit Organon* or *L'Achat du Cuivre*), his poems, his *Journal*, his stories (*Histoires d'almanach*, *Dialogues d'exilés*) and his theater (*Turandot*, *Homme pour Homme*, etc.), in the end providing the essential material for his last major work, *La Vie de Galilée*—to which we will return further on. We will satisfy ourselves for the moment with some aphorisms from *Me-Ti ou Le Livre des Retournements*, wherein Brecht shows himself to be a precursor of the salubrious anarchist epistemology, or even better: dadaist, after Feyerabend (*Contre la méthode*), with perhaps an extra degree of liberty in the dialectical irony:

It would be both easy and beneficial if science were to be considered as a means for discovering the unscientific character of scientific affirmations and methods. (Brecht, 1968, p. 79, *my translation from the French*)

One will recall without surprise that Feyerabend had in fact been involved in theater in his younger days and worked with Brecht. Here is at least one example where the influence of literature upon epistemology is direct and proved. . . .

The Touchstone

Finally, it is necessary to inquire into our own conceptions of science, particularly because it is playing an increasingly important role in society. Shouldn't we therefore allocate more of our attention to those texts in which novelists or dramatists have highlighted these debates and conflicts?

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To do so provides us with a site for our fieldwork, a proving ground for our arguments, a touchstone with which to test the strength and the relevance of our ideas.

And so to the recurring debate on the relations between science and religion, and to its modern avatars. The accepted wisdom already ironized by Flaubert ("a little bit of science puts it aside, a lot leads back to it") never ceases to return to fashion—a successful book written in 1991 by a Catholic academic and two catholic journalists is ample proof of this. It is obviously more intelligent for spiritualist movements, rather than opposing science and denigrating it, to try to co-opt it. The inevitable epistemological confusion that surrounds the emergence of new scientific concepts provides a cultural broth that is nourishing enough to sustain diverse visions of the world. Thus, in the first decades of this century, we tried to base a notion of human free will on the supposed indeterminacy of the quantum theory—and some went to the very heart of the electron to find it. Today, it is cosmology and the ambiguous "anthropic principle" (according to which the Universe, the structure of its laws, and the value of its fundamental constants are adjusted with great precision to allow for the emergence of a human intelligence capable of understanding it) that are solicited by religious apologists. Or sometimes, the most brutal formulations of a biological evolutionism are invoked, in which teleology and theology meet (following the lead of Teilhard de Chardin). In the face of this assiduous exploitation, the necessary return to methodological prudence and the affirmation of the indispensable separation between science and religion and the secularism of research, seem to have little impact. The rationalist critique, driven back by definition to a defensive stance, has all of the qualities of Sisyphus's task. Another strategy is nonetheless possible in this debate of ideas: rather than affronting directly the heavy alliance (which is not new) between spiritualism and scientism, it may be useful to attack from behind. This road is opened up to us with virtuosity and intelligence in a novel by John Updike called *Roger's Version*. The narrator is a professor of theology at an American university in New England. Fifty years old, he has left the clergy to teach and do research (on Christian heresies of the first centuries). He is confronted by a young computer scientist, Dale Kohler, who is trying to convince the Department of Theology to take an interest in contemporary science, and hopes to take on the following subject for his thesis:

To demonstrate from existing physical and biological data, through the use of models and manipulations on the electronic digital computer, the existence of God, i.e., of a purposive and determining intelligence behind all phenomena. (76)

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John Updike's interest in science is far from contingent, since he has written some remarkable poems in the Lucretian spirit, on physical themes, which reflect a perfect scientific accuracy (*Seven Odes to Natural Phenomena*, 1988b).

If the relations between science and religion pose problems, what can we say about the relations between science and politics, which are today crucial for the evolution of our societies—except that it is urgent to put our conceptions to the test. It is Brecht who here offers an effective touchstone, with *The Life of Galileo*. This work occupies a major place in his *oeuvre*. It went through at least three versions, the first in the 1930s, when the theoretician of "theatre of the scientific era" clearly used reference to science as the basis of his methodology. Science offered him a model of the conjunction between rationality and efficacy; the scientist appeared to him as the ideal figure of the intellectual—producing a true discourse and acting justly. Regardless of his theory of distanciation, in this first version Brecht made Galileo an essentially positive hero, fighting for the freedom of knowledge and the liberation of men. During the Second World War, Brecht profoundly modified the play, initially under the influence of a much more skeptical vision of the hero proposed by Charles Laughton, who resumed the role, and then under the impact of the atomic bomb dropped on Hiroshima on August 5, 1945, which brought Brecht to dialecticize his conceptions with respect to the relations between science and society, or rather, with respect to the social role of the scientist. The final version is of an impressive complexity, while remaining faithful—and this is Brecht's genius—to the historical facts surrounding Galileo's life and work.⁴ I can but refer you here to a more detailed analysis (Lévy-Leblond 1979)—and content myself with citing the final great self-criticism by Galileo—which certainly does not claim to be historically true, but is a call to the twentieth-century researcher:

The battle to measure the sky was won by doubt; but credulity still prevents the Roman housewife from winning her battle for milk. Science... is involved in both battles. If mankind goes on stumbling in a pearly haze of superstition and outworn words and remains too ignorant to make full use of its own strength, it will never be able to use the forces of nature which science has discovered. What end are you scientists working for? To my mind, the only purpose of science is to lighten the toil of human existence. If scientists, browbeaten by selfish rulers, confine themselves to the accumulation of knowledge for the sake of knowledge, science will be crippled and your new machines will only mean new hardships. Given time, you may well discover everything there is to discover, but your progress will be progression away from humanity. The gulf between you and

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humanity may one day be so wide that the response to your exultation about some new achievement will be a universal outcry of horror. (94)

How could we possibly not take seriously today this plea by Galileo? At the time of his death in 1956, Brecht was still working on this theme, envisioning a play about a contemporary physicist, drawing on the lives of both Einstein and Oppenheimer, in which he would recover and renew the Promethean myth. In a characteristically Brechtian reversal, Prometheus here would have been chained by men for having delivered to the gods, to those in power, the secret of fire—a superb metaphor for the discovery of nuclear energy! Over and above its explicit content, the work of Brecht, in its very dynamic, constitutes a powerful touchstone to test our conceptions about the social role and the political responsibility of researchers, and it acts as a witness to the evolution of these conceptions at the end of the century. This is demonstrated by the concomitant evolution of criticism and commentaries on Brecht's work (Lévy-Leblond 1979).

Brecht's vision in his *Life of Galileo* nevertheless is limited in its conception—tragic yet optimistic—of a scientist who *could have*, had he so desired, escaped from the powers that be, in order to put science in the service of the oppressed:

As a scientist, I had a unique opportunity. In my time astronomy reached the market place. Under these very special circumstances, one man's steadfastness might have had tremendous repercussions. If I had held out, scientists might have developed something like the physicians' Hippocratic Oath, the vow to use their knowledge only for the good of mankind. As things stand now, the best we can hope for is a generation of inventive dwarfs who can be hired for any purpose. Furthermore, I have come to the conclusion, Sarti, that I was never in any real danger. For a few years I was as strong as the authorities. And yet I handed the powerful my knowledge to use, or not to use, or to misuse as served their purposes. I have betrayed my calling. A man who does what I have done, cannot be tolerated in the ranks of science. (94)

This over-evaluation of the individual role of the researcher and of his autonomy might perhaps have been put into question in Brecht's unfinished works. But there is a sequel, and a reply, to *The Life of Galileo*. It is a tragi-comedy, *The Physicists*, by Friedrich Dürrenmatt—who overtly made claim to an affiliation between his work and that of Brecht. The play is contemporary, set on the shores of Lake Léman, in a delux psychiatric clinic directed by Doctor Mathilde von Zahn, a reputed disciple of Jung. In the clinic, three of the patients imagine themselves as being physicists: one thinks he is Einstein, the second Newton and the third Möbius, supposedly the most famous contemporary physicist who in fact strangely disappeared

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'Daumal, Pierre Boule, François Weyergans and many others). But I don't have a calling for writing an anthology—and to each his own reading.⁶

Some Lessons

In speaking of the assistance literature can give science, it is not by chance that I use as headings three instruments—the mirror, the beaker, the touchstone—which belong more to the alchemist's laboratory than to that of the modern researcher. For behind the transmutation of matter—inert or living—which the nuclear physicist or genetic biologist achieves with such ease today, there was the transformation of the spirit and human conscience aimed at by the predecessors of modern sciences, and one would not venture to suggest that the inheritors of the tradition have come a long way. This is why we, as scientists, should think beyond literature's works and what they can say about science, to an *essential* practice of literature—criticism. If it goes without saying that there exists in literature, as in painting or music, an explicit activity of *critique*, specific and recognized as such, this is far from being the case for science. Scientists' pretension to be themselves, alone, the masters of evaluating and orientating scientific research is no more acceptable before the law than would be an alignment between judge and interested party in whatever other domain. In addition, the process of internal arbitration in the scientific community is in obvious crisis today. Therefore, what we need is a veritable *critique* of science, just as there exists a *critique* of literature or painting—but I will not develop this theme further here (see Goldsmith 1986, 1990; Lévy-Leblond, 1989a).

Thus what literature could offer to science are lessons in etiquette, in morality and in preservation. And a few lessons in imagination. Rare and unpredictable as they may be, occasions do exist where a certain literary work could at a given point suggest the solution to a scientific problem. We can at least in retrospect detect certain helpful premonitions, such as the poetic solution to a major cosmological enigma, the "paradox of night's darkness": if the universe is infinite and homogenous, then in no matter what direction we look our gaze should run into a star (just as someone walking in the forest and looking around runs into a tree)—thus the sky should appear to us as uniformly bright as the sun. Cosmology only recently discovered the solution to this paradox, a century after Edgar Allen Poe had an intuition of it, as seen in *Eureka* (for the history and solution of the enigma, see Harrison, 1990). Without absurdly seeking

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answers to all of science's problems in the pages of novels, we are not prevented from thinking that a greater familiarity with literary fiction can only limber up and develop the scientific imagination.

Finally, and more seriously, literature can quite simply offer science lessons in writing. If scientists must, as I believe, read the books that speak to us about science (and with more pertinence and vigor than most theoretical essays), then they must also read, read all books, and, for a start, with the purpose of learning how to write! It would be a study worth undertaking to investigate the poverty, the schematic nature and the mediocrity of scientific writing. The rigid formal codification which is the rule today in professional research publications is accompanied by a loss in thinking and in communication. This banalization of writing has serious consequences for communication between scientists and laypersons. We should hail as a positive step toward renewing and enriching mediations between the scientific milieu and the public the emergence of a concern for writing and written form, in the books which we, in France, prefer to call "de culture scientifique" rather than "de vulgarisation scientifique." To take but a few recent examples which I have good reason to know: Stella Baruk shows the power of language in the practice and teaching of mathematics, and puts it into play in her books, including the *Dictionnaire de mathématiques élémentaires*, which is above all a dictionary of language. The botanist Francis Hallé, writing on the Tropics, fills his book with literary citations from Conrad to Duras, and wished to borrow his title from Serge Gainsbourg: *Sous le soleil, exactement...* The mathematician Ivar Ekeland roots his book *Au Hasard* in the text and spirit of the Scandinavian sagas. The biologist Jacques Ninio, in *La Biologie buissonnière*, alternates recent developments in science with more personal contributions, in the form of short stories. There is even a recent series aimed at the widest possible audience, of veritable novels on contemporary research, written by writers in collaboration with scientists, complete with illustrations (Pelot, Coppens et Liberatore, 1990). Fiction is not just turning to the history of sciences: in *Night Thoughts of a Classical Physicist*, historian Russell McCormmach uses the novelistic form to synthesize his academic research and retrace the upheavals of science at the beginning of the century. This return to literature can also be seen in the movement to renovate the great French institutions of scientific and technical cultural. One after the other the Musée d'Histoire Naturelle and the Musée National des Techniques have felt the need to solidly root their image and to replenish their spirit through small literary anthologies, collections of visions and emotions that they were able to inspire (Taquet, 1991; Mercier, 1992)

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We scientists are too isolated. We are invited once in a while to leave our laboratories and to present our findings to the world. But we are so badly brought-up, so awkward, that often our clumsiness bores and our brutality exasperates society. We also need someone to take care of us and of our science, someone to reach out to us, help us, police us. Dürrenmatt understood; *Albert Einstein*, his ironic and salutary meditation on Einstein and Spinoza, given as an invited talk to students and researchers given at the Zurich Ecole polytechnique, begins as follows:

If I accepted the invitation of the Federal Polytechnical School to give a talk on Einstein, it is for the following reason: at present, mathematics, physical and natural sciences and philosophy are so interdependent that the layperson must also attempt to cut through this Gordian Knot. For to leave physicists, mathematicians and philosophers to themselves is to irrevocably return them to the ghetto of their specialization where, forgotten and disconcerted, they are at the mercy of the technocrats and the ideologues, as they have always been and as they will forever be. (Dürrenmatt, 1982, p. 9, my translation)

Thanks to the novelists, the playwrights, the poets, for not abandoning us to ourselves.

Université de Nice
translated by Robert F. Barsky

NOTES

1. *Translator's note:* In translating this article, I have tried to preserve the lively and engaging style of the original. In so doing, I have sometimes resorted to interpreting metaphors or images into English by using non-literal translations that are nonetheless faithful to the meaning of the original text. When English translations for texts cited were unavailable, I either translated them myself (indicated by *my translation*) or simply transcribed the original French.

2. Queneau has pointed out that the quintessential example of arduous mathematic labor, the elaboration of the table of logarithms used by lycées for decades, was authored by . . . M.M. Bouvard and Ratinet.

3. The margins of science, where so many quixotic cranks are roaming, still await the studies they merit, and which might shed a crude light on "normal" science (Lévy-Leblond 1980b). In the meantime, it is still to a novel by Queneau, *Les Enfants du limon*, that we owe the most serious recognition of these margins.

4. Only Antoine Vitez, in what was his last production, was able to fully render the richness and power of this play by Brecht at the *Comédie Française*. Happily it was captured on film by Hugo Santiago.

5. For a general study of the relations between science and theater, see the works of Daniel Raichvarg (Raichvarg, 1992a).

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