Managing Uncertainty in the Academy and the Courtroom

Normal Arsenic and Nineteenth-Century Toxicology

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ABSTRACT

This essay explores how the enhanced sensitivity of chemical tests sometimes produced unforeseen and puzzling problems in nineteenth-century toxicology. It focuses on the earliest uses of the Marsh test for arsenic and the controversy surrounding "normal arsenic"—that is, the existence of traces of arsenic in healthy human bodies. The essay follows the circulation of the Marsh test in French toxicology and its appearance in the academy, the laboratory, and the courtroom. The new chemical tests could detect very small quantities of poison, but their high sensitivity also offered new opportunities for imaginative defense attorneys to undermine the credibility of expert witnesses. In this context, toxicologists had to dispel the uncertainty associated with the new method and come up with arguments to refute the many possible criticisms of their findings, among them the appeal to normal arsenic. Meanwhile, new descriptions of animal experiments, autopsies, and cases of poisoning produced a steady flow of empirical data, sometimes supporting but in many cases questioning previous conclusions about the reliability of the chemical tests. This challenging scenario provides many clues about the complex interaction between science and the law in the nineteenth century, particularly how expert authority, credibility, and trustworthiness were constructed, and frequently challenged, in the courtroom.

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97

THE HEROIC HISTORY OF TOXICOLOGY tells how nineteenth-century chemists developed increasingly sensitive, selective, and efficient tests for detecting ever smaller quantities of poisons. Old methods based on occasionally misleading clinical symptoms or subjective ideas about a substance's organoleptic properties were abandoned in favor of the new scientific toxicology based on reliable chemical analysis. The new methods carved out a new role for toxicologists as expert witnesses in the courtroom and made a significant contribution to the control of poisoning in the nineteenth century. The chemical test introduced by James Marsh in 1836 is a milestone in this narrative. Customarily portrayed as an extraordinarily sensitive and highly reliable test, capable of detecting the presence of minute quantities of arsenic (the deadliest and most widely used poison in the nineteenth century), the Marsh test soon became the "chief terror of poisoners," uncovering crimes that previously would have gone undetected and eventually leading to a significant decline in the use of arsenic for murder.[1]

But like many other master narratives of technological progress, the standard picture of the Marsh test's uninterrupted success in the courtroom can be called into question by focusing on issues that are barely mentioned in popular accounts. This essay explores how the enhanced sensitivity of chemical tests sometimes posed unforeseen and disconcerting problems in nineteenth-century toxicology. Granted, the Marsh test was faster and more sensitive than its predecessors, but its use also had an unexpected consequence: it appeared to detect traces of arsenic in healthy human bodies. The discovery of what became known as "normal arsenic" challenged the foundations of nineteenth-century toxicology. Until then, it had been assumed that when a poison was found in the human body, it must have been externally introduced either by accident or by a criminal hand; when toxicologists identified arsenic in a corpse, the finding could be used in court as evidence. But if arsenic turned out to be a natural ingredient of the human body, how could one conclusively ascertain that the arsenic found during an autopsy was the poison used by a murderer and not normal arsenic? In other words, how could one distinguish between normal and criminal arsenic?

Within months of the first public reports of its existence in 1839, normal arsenic caused a furor. A flurry of papers on the topic appeared, presenting a broad range of contrasting views. A fine-grained description of the normal arsenic controversy will highlight the complex interaction between science and the law that emerged during the nineteenth century. New chemical tests could detect very small quantities of poison in the corpses of victims, but their high sensitivity also enabled imaginative defense attorneys to cast doubt on the credibility of experts who provided incriminatory evidence against their clients. Normal arsenic was just one of many arguable sources of impurities that could be used to sow doubt in jurors' minds and cast a positive test as inconclusive. In this context, toxicologists were compelled to present their conclusions in a highly authoritative way, reassuring their audiences of the reliability of the new method and circumventing the many possible sources of criticism. Meanwhile, new descriptions of animal experiments, autopsies, and cases of poisoning produced a continuous flow of new empirical data,

[1] Episodes from the history of toxicology and famous poisoning murders have been described in many popular books. See, e.g., Samuel M. Gerber and Richard Saferstein, eds., *More Chemistry and Crime: From Marsh Arsenic Test to DNA Profile* (New York: American Chemical Society, 1997); John Emsley, *The Elements of Murder: A History of Poison* (Oxford: Oxford Univ. Press, 2005); and the more thoroughgoing work on arsenic poisoning by James C. Whorton, *The Arsenic Century: How Victorian Britain Was Poisoned at Home, Work, and Play* (Oxford: Oxford Univ. Press, 2010), esp. Ch. 4: "The Chief Terror of Poisoners." For a recent overview of the history of forensic medicine see Katherine Watson, *Forensic Medicine in Western Society: A History* (London: Routledge, 2011).

sometimes supporting but in many cases questioning previous conclusions about the purity of reagents or the reliability of chemical tests. All in all, this challenging scenario provides many clues about how expert authority and trustworthiness were constructed and, frequently, challenged in courtrooms.[2]

Unlike most earlier studies, which have focused on nineteenth-century Anglo-American cases, this essay deals with a series of poisoning trials in France between 1838 and 1841, the most famous being the "Lafarge affair." This case is generally mentioned as a landmark in the development of forensic science, thanks to the participation of Mateu Orfila i Rotger (1787–1853), the powerful dean of the Paris Faculty of Medicine and one of the most influential toxicologists in nineteenth-century Europe. Orfila is portrayed in many popular books as the expert who successfully used the Marsh test to detect small quantities of arsenic in Monsieur Lafarge's remains.[2] These heroic narratives not only convey an image of untroubled, inexorable progress but also a plainly diffusionist framework. The Marsh test used very common reagents and simple vessels, but it also required experimental skills that could only be obtained by experts through practical training in the laboratory.[3] This essay will also show that the Marsh test underwent a dramatic transformation in its passage from Britain to France; the test turned out to be a highly *mutable mobile* that could be adapted to many different purposes and circumstances both in the chemistry laboratory and in the courtroom.[4] The same conclusion applies to the normal arsenic controversy, whose changing uses and meanings in scientific academies and courtrooms will be explored in the following pages.[5]

[2] Recent studies on experts, science, and law also provide an excellent framework to deal with the issue. For a general overview see Tal Golan, *Laws of Man and Laws of Nature: A History of Scientific Expert Testimony* (Cambridge, Mass.: Harvard Univ. Press, 2004); and the Focus section on "Science and the Law" edited by D. Graham Burnett, *Isis*, 2007, *98*(3). For more contemporary issues see Sheila Jasanoff, *Science at the Bar: Law, Science, and Technology in America* (Cambridge, Mass.: Harvard Univ. Press, 1995). Most studies of the history of nineteenth-century legal medicine have focused either on toxicology or on forensic psychiatry. Recent studies included Mark Essig, "Science and Sensation: Poison, Murder, and Forensic Medicine in NineteenthCentury America" (Ph.D. diss., Cornell Univ., 2002); Katherine Watson, *Poisoned Lives: English Poisoners and Their Victims* (London: Hambledon, 2004); and Ian Burney, *Poison, Detection, and the Victorian Imagination*

[2] On Orfila see Jose´ R. Bertomeu-Sánchez and Agust´ı Nieto-Galan, eds., *Chemistry, Medicine, and Crime: Mateu Orfila (1787–1853) and His Times* (Sagamore Beach, Mass.: Science History Publications, 2006). On French nineteenth-century legal medicine see Fre´de´ric Chauvaud, *Les experts du crime: La me´decine le´gale en France au XIX sie`cle* (Paris: Aubier, 2000). See also Olivier Leclerc, *Le juge et l'expert: Contribution a` l'e´tude des rapports entre le droit et la science* (Paris: Librairie Ge´nerale de Droit, 2005).

[3] There is a large and well-known body of literature on the circulation of instruments and the replication of experiments. For a very interesting discussion of a contemporary chemical apparatus see Melvyn C. Usselman *et al.*, "Restaging Liebig: A Study in the Replication of Experiments," *Annals of Science*, 2005, *62*:1–55. In spite of the differences in time and contexts, recent historical and sociological analyses of DNA fingerprinting also contain many suggestive ideas for studying the Marsh test, particularly the recent book by Michael Lynch *et al.*, *Truth Machine: The Contentious History of DNA Fingerprinting* (Chicago: Univ. Chicago Press, 2008).

[4] The further discussion is largely based on recent work on the circulation of science, such as James E. Secord, "Knowledge in Transit," *Isis*, 2004, *95*:654–672, and relies on the experience of the group "Science and Technology in the European Periphery." See Kostas Gavroglu *et al*., "Science and Technology in the European Periphery: Some Historiographical Reflections," *History of Science*, 2008, *46*:153–175. Needless to say, the phrase "mutable mobile" refers to Bruno Latour's "immutable mobiles": Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, Mass.: Harvard Univ. Press, 1987).

[5] On scientific controversies see, e.g., Hugo T. Engelhardt and Arthur L. Caplan, eds., *Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology* (Cambridge: Cambridge Univ. Press, 1987); Peter K. Machamer, Marcello Pera, and Aristides Baltas, eds., *Scientific Controversies: Philosophical and Historical Perspectives* (Oxford: Oxford Univ. Press, 2000); and Dominique Raynaud,

(Manchester: Manchester Univ. Press, 2006). On experts and expertise and the "third wave" of science studies see Harry Collins and Robert Evans, *Rethinking Expertise* (Chicago: Univ. Chicago Press, 2007).

Our analysis begins with the introduction of the Marsh test in France in 1838 and continues with the unexpected discovery of normal arsenic and its consequences for toxicological research. The second section studies normal arsenic in its journey from the Parisian laboratories to two famous poisoning trials. The trials compelled Orfila and other toxicologists to adapt the Marsh test in order to deal with the challenging questions concerning possible sources of impurities, including normal arsenic. After an overview of the tensions between judges and expert witnesses in nineteenth-century France, special attention is paid to the way in which Orfila reported his ongoing research, both to his colleagues in the Academy of Medicine and to the judges in the courtrooms. The poisoning trials fueled a huge controversy that soon made its way from southern France to the French Academy of Sciences in Paris. In the following section I summarize the controversy; next I study how normal arsenic was perceived in other European countries during the 1840s. Finally, I move on to the end of the nineteenth century, when the theory of normal arsenic had all but disappeared from the courtroom and toxicological research— but then was brought back to life thanks to the work of Gabriel Bertrand on trace elements.

APPROPRIATING THE MARSH TEST

Arsenic was the most widely employed poison during the first half of the nineteenth century. It was commonly used in everyday life as rat poison as well as in agriculture and other industries. In addition to its wide availability, it was odorless and its mild taste could be masked by the flavor of soups or other foods in which it could easily be mixed. These features made it a cheap and convenient poison. The toxicological study of arsenic involved three types of examination: clinical symptoms, autopsies, and chemical analysis. Unfortunately, the resulting evidence could be dangerously misleading because similar clinical symptoms could be produced by common illnesses and internal anatomical damage varied widely depending on many circumstances that could not be controlled for. Thus, in the first half of the nineteenth century, most toxicologists accepted that chemical analysis—notably, the reduction of the element to its metallic state in a tube—offered the most conclusive proof of arsenic poisoning. The chemical tests were time consuming, however, and most involved the use of hydrogen sulfide and reagents that were neither selective nor sufficiently sensitive, meaning that the results were sometimes inconclusive.

In October 1836 James Marsh (1794–1846) presented his "new method of separating minute quantities of arsenic" to the Royal Society of Arts of London. The method was based on a known property of arsenic: the fact that it combined with hydrogen in the nascent state and yielded arsine. The sample was placed in a flask with arsenic-free zinc and sulfuric acid in order to produce hydrogen. If the sample contained arsenic, arsine was produced and this compound was then decomposed into hydrogen and arsenic, which formed a thin metallic film on the surface of porcelain. The new test was so sensitive that it could detect minute amounts.[7]

Sociologie des controverses scientifiques (Paris: Presses Univ. France, 2003). On controversies in nineteenthcentury Paris see Ann F. La Berge, "Debate as Scientific Practice in Nineteenth-Century Paris: The Controversy over the Microscope," *Perspectives on Science*, 2004, *12*:424–453. On "techno-legal" controversies see Lynch *et al.*, *Truth Machine* (cit. n. 4), esp. Chs. 2 and 7.

[7] James Marsh, "An Account of a Method of Separating Small Quantities of Arsenic from Substances with Which It May Be Mixed," *Edinburgh New Philosophical Journal*, Oct. 1836, *21*:229–236. See Katherine Watson, "Criminal Poisoning in England and the Origins of the Marsh Test for Arsenic," in *Chemistry, Medicine, and*

Crime, ed. Bertomeu-Sánchez and Nieto-Galan (cit. n. 3), pp. 183–207. See also Noel G. Coley, "Alfred Swaine Taylor, MD, FRS (1806–1880): Forensic Toxicologist," *Medical History*, 1991, *35*:409–427, esp. p. 421.

The test was soon applied in toxicological research in Britain. Alfred Swaine Taylor used it just one year after the publication of Marsh's paper. Elsewhere, Marsh's paper was soon translated into German and was favorably reviewed by the influential chemists Carl Friedrich Mohr and Justus Liebig in the journal *Annalen der Pharmacie und Chemie*. Mohr studied its high sensitivity (whose limits he calculated at 1/500,000 parts), and Liebig affirmed that a sensitivity of this kind was "beyond any imagination." Jacob Berzelius also published a positive review of Marsh's method and suggested some useful improvements. Marsh's paper was translated into French and published with extracts of Mohr's and Liebig's papers in the *Journal de Pharmacie* in November 1837. The Marsh test soon spread in this new setting: a pharmacist from Fontainebleau reported having used it successfully during a poisoning trial as early as May 1838.[6]

These developments suggest that the Marsh test could easily travel via text alone. However, a large amount of tacit knowledge was required to perform it properly, and many local experts who participated in poisoning trials were unable to obtain any trace of arsenic from victims' corpses. Many possible errors might influence the result: the duration of the test, the formation of arsine gas, the size of the flame, the position and distance of the porcelain vessel, and so on—not to mention the different ways of dealing with organic matter (which produced a disturbing foam) and the occasional presence of spots that resembled those caused by arsenic but were in fact caused by antimony or charcoal. If not conducted properly the test might even be dangerous, because failure to control the hydrogen flow could cause fatal detonations. Despite these technical problems, however, many toxicologists soon learned how to perform the Marsh test correctly by studying the written reports published in journals and by repeating the operation over and over again in their laboratories.[7] (See Figure 1.)

Mateu Orfila was one of the first toxicologists to use the Marsh test successfully. He was the most famous toxicologist in France, a popular lecturer and dean of the Paris Faculty of Medicine; his textbooks on legal medicine and toxicology were the authoritative works in the field. Orfila habitually used the laboratory facilities at the Faculty of Medicine to perform animal experiments, notably with dogs; he poisoned them by a variety of means and then analyzed their organs using chemical tests. Orfila adapted the Marsh test to deal with two relevant and interrelated issues: the absorption of poisons and their detection in long-buried corpses. He had been interested in the absorption of poisons since the beginning of his career, and he soon saw that the high sensitivity of the Marsh test for arsenic offered a new way to approach this elusive question. Starting in 1838, he performed numerous experiments with dogs using a modified version of the Marsh test with a bigger flask, new reagents for destroying organic matter, and more detailed instructions as to how

[6] *Annalen der Pharmacie und Chemie*, 1837, *23*:217–227 (the quotation from Liebig is on p. 223); and *Journal de Pharmacie*, 1837, *23*:553–562 (translation of Marsh's paper), 1838, *24*:500–503 (Fontainebleau pharmacist's use of the test). Here and throughout this essay, all translations are mine unless otherwise indicated.

[7] For more details see José Ramón Bertomeu-Sánchez, "Crime, Sensitivity, and Expert Controversies," in *Chemistry, Technology, and Society*, ed. Isabel Malaquias, Ernst Homburg, and Marisa Elvira Callapez (Aveiro: SPQ, 2006), pp. 300–314. There is a large amount of literature on "tacit knowledge" and experimental replication, starting with the famous works of Michael Polanyi. See the recent discussion in Harry Collins, *Tacit and Explicit Knowledge* (Chicago: Univ. Chicago Press, 2010). For a critical review see Katherine Olesko, "Tacit Knowledge and School Formation," *Osiris*, 1993, *8*:16–29. There are also many interesting similarities with the dispersion of theoretical tools such as Feynman diagrams. See David Kaiser, *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics* (Chicago: Univ. Chicago Press, 2005). On the dispersion and malleability of forensic techniques (such as DNA typing) see Lynch *et al.*, *Truth Machine* (cit. n. 4), pp. 83–112.

to distinguish true arsenic spots from those caused by other substances. He also used the clinical data from recent

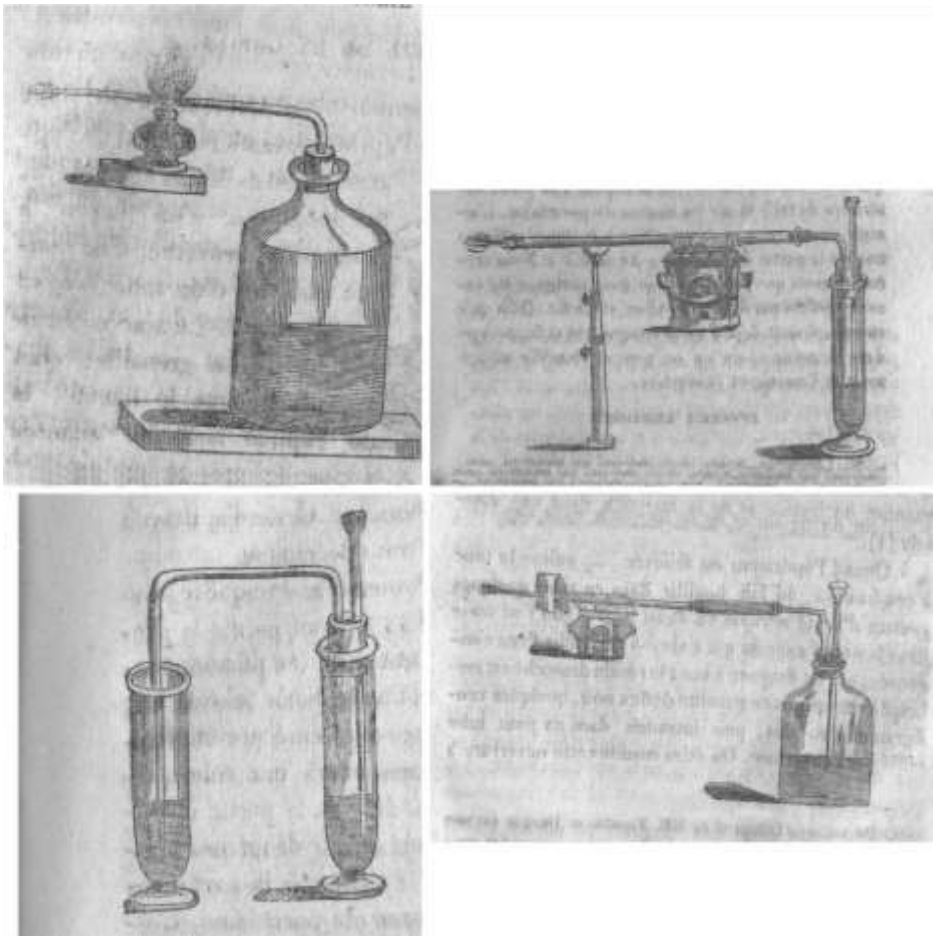

Figure 1. *Apparatus and designs for performing the Marsh test, suggested around 1840 by Orfila (top left), Chevallier (top right), Lassaigne (bottom right), and the Paris Academy of Sciences (bottom left). From A. Chevallier and J. Barse,* Manuel pratique de l'appareil de Marsh ou Guide de l'expert toxicologiste dans la recherche de l'arsenic et de l'antimoine *(Paris: Labe´ , 1843). Courtesy of Instituto de Historia de la Medicina y de la Ciencia "Lo´ pez Pin˜ ero," Valencia.*

poisoning cases, notably two suicides using arsenic. One was the case of Soufflard, a convicted murderer who had committed suicide in March 1839 by ingesting a large amount of arsenic in prison. This was a golden opportunity for Orfila to gather support for his methods in the public arena. Just a few days after the suicide, he performed several tests on Soufflard's blood in the presence of "around 1,200 students" who attended his lectures at the Faculty of Medicine. He obtained a "notable proportion" of absorbed arsenic that could be "seen and touched" by the audience. During the following week, Orfila delivered a talk

at the Paris Academy of Medicine in which he described his experiences and discussed the problem of absorption, showing Soufflard's stomach to his colleagues.[8]

As his British colleague Robert Christison later noted, the study of the absorption of arsenic was "pregnant alike with interesting physiological deductions and valuable medico-legal applications." Indeed, there were many valuable applications for legal medicine. Absorption took place only in living bodies, so its effects made it possible to distinguish between poisons introduced before and after the victim's death—a detail of particular relevance during a poisoning trial.[9] Moreover, if the process of absorption was identified, toxicologists could look for arsenic not only in vomit and in the gastrointestinal tract but also in other organs and fluids such as the liver, spleen, kidneys, muscles, blood, and urine. The new method could be applied to long-buried bodies, in which the stomach or vomit were not available—a forensic problem that Orfila had recently analyzed with Octave Lesueur (his brother-in-law) in their book on "legal exhumations." Orfila enthusiastically described the consequences of his research at the beginning of 1839. The Marsh test seemed to herald a new era in which all poisoning crimes would be successfully solved by forensic experts: "From now on, crime will be successfully hunted down to its last refuge because, without doubt, several poisons acting by absorption will be detected in different tissues of animal economy. This great problem of legal medicine will soon be solved by new research in that direction, founded on the work I have just read. Probably you already foresee that it will shed light on certain points of physiology and therapeutics."[10]

Orfila's enthusiasm was shared by many toxicologists and judges, who placed high hopes in the Marsh test, as it seemed likely to deter would-be murderers from using arsenic forever. A new range of problems appeared when the test was adapted to the study of absorbed arsenic, however. To begin with, a new culture of purity was required owing to the test's high sensitivity and the minute range of absorbed poison to be detected, so great care was needed in the handling of samples, reagents, and vessels in order to avoid contamination. The inventor of the test, James Marsh, had already highlighted the question of purity, but it was particularly crucial when looking for absorbed arsenic. Larger quantities of samples were necessary to detect minute quantities of arsenic, and so many more reagents and bigger flasks were used. The purity of the reagents (zinc, sulfuric or nitric acid, and so forth) and the possible presence of arsenic in the copper vessels used to boil corpses took on great importance in Orfila's method. Furthermore, the high sensitivity and the small quantities of absorbed poison meant that the greatest care was needed during the extraction and transport of suspect substances. Of course, the widespread use of arsenic increased the likelihood that the presence of small quantities of the substance in a body might not necessarily indicate deliberate poisoning; for instance, the cadaver might have been transported or kept on wood painted with green arsenic coloring or buried in a graveyard with arsenical soil. Jules Barse, who started his career as an expert at the end of the 1830s, remembered those days as a mixture of hope and confusion: "the facts multiplied infinitely . . . arsenic was found everywhere. Soon it was found that this new method, this radiant light, merely revealed a situation of total chaos." In the 1840s, many forensic

[8] Mateu Orfila, "De l'empoisonnement par l'acide arse´nieux," *Bulletin de l'Acade´mie Royale de Me´decine*, 1839, *3*:676–683; and *L'Expe´rience*, 28 Mar. 1839, *91*:208.

[9] Robert Christison, *A Treatise on Poisons*, 4th ed. (Edinburgh: Black, 1845), p. 289; and Mateu Orfila, *Traite´ des poisons*, 2nd ed. (Paris: Crochard, 1818), Vol. 1, pp. 15–22 (on the details of absorption).

[10] Mateu Orfila and Octave Lesueur, *Traite´ des exhumations juridiques* (Paris: Be´chet, 1831); and Orfila, "Me´moire sur l'empoisonnement par l'acide arse´nieux," *Bull. Acad. Roy. Me´d.*, 1839, *3*:426–464, on p. 464. See also Archives of the Acade´mie de Me´decine de Paris, *Proce`s-verbaux—Se´ances ge´ne´rales* (session of 29 Jan. 1839).

physicians like Barse called for new methods for handling and transporting samples. In fact, the high sensitivity of the Marsh test introduced many potential "organizational contingencies" that could produce misleading results at any point along the "chain of custody" between the crime scene and the court.[11] Recognition of these almost unlimited sources of impurity was capitalized on by defense attorneys keen to challenge the conclusions of high-sensitivity tests (including Orfila's modified version of the Marsh test) able to detect very small quantities of poison.[12]

AN INCOVENIENT DISCOVERY BEHIND THE SCENES

The most puzzling source of impurity was found inside the human body itself just a few months after the introduction of the Marsh test in France and was subsequently named "normal arsenic." The discovery was announced by Jean-Pierre Couerbe (1805–1867), a physician who is likely to have attended Orfila's lectures in Paris and who had been trained in practical chemistry at the laboratory of the pharmacist Pierre-Joseph Pelletier. Couerbe was not a famous researcher, and even though he claimed to have lectured on legal medicine and toxicology, his earlier work was focused on physiology and chemical analysis of the human body; it was probably this interest that led him to explore the issue of normal arsenic. He had published several papers on new alkaloids, an important study on the chemistry and physiology of the human brain, and several minor works on mineral chemistry and chemical analysis, including some suggested improvements of Liebig's *Kaliapparat* for organic analysis. During the spring of 1838, Couerbe informed Orfila that he had found arsenic when analyzing putrefied corpses exhumed from graveyards. Neither Couerbe nor Orfila could conclusively identify the source of the arsenic, so they decided to work together using the Marsh test on corpses at the laboratory of the Paris Faculty of Medicine. With the help of Orfila's assistant Lesueur they found evidence of the presence of arsenic in the bones.[13]

The discovery of normal arsenic was not as surprising as it might appear. Other "normal poisons" were being discovered around that time, and toxicologists such as Alphonse Devergie and Orfila had suggested a variety of strategies for addressing the medico-legal consequences of these discoveries. In October 1838 Orfila was involved in a case in which the key issue was the normal presence of lead and copper in the human body. In two papers presented at the Academy of Sciences, he discussed whether it was possible to distinguish normal quantities of these metals from those caused by poisoning. He also announced his intention to extend his research to other poisons, such as mercury and arsenic.[14] On 30 October 1838 Orfila presented a paper on lead poisoning dealing with similar questions, and at this session he submitted a sealed note introducing the topic of normal arsenic.

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[11] Jules Barse, *Manuel de la cour d'assises* (Paris: Labe´, 1845), p. 151. See also Lynch *et al.*, *Truth Machine* (cit. n. 4), p. 66; see pp. 113–141, 228–254, for a discussion of "technical, legal and administrative fixes" in the resolution of controversies. For a contemporary discussion about necessary changes in "administrative fixes" see Barse, "Consultation me´dico-le´gale sur les rapports judiciaires de MM. Darles et Pipe, d'Yssengaux, et de MM. Orfila, Chevallier et Ollivier (d'Angers)," *Annales d'Hygie`ne Publique et de Me´decine Le´gale*, 1842, *28*:148–168, esp. pp. 152–155; and Barse, *Manuel de la cour d'assises*.

[12] See Bertomeu-Sánchez and Nieto-Galan, eds., *Chemistry, Medicine, and Crime* (cit. n. 3), particularly the papers by Ian Burney, Anne Crowther, Katherine Watson, and Jose´ Ramo´n Bertomeu.

[13] Jean-Pierre Couerbe, "Lettre a` M. le Re´dacteur de la Re´vue Scientifique," *Gazette des Ho^pitaux*, 1840, *13*(122):485; and Couerbe, "Re´ponse aux observations de M. Orfila au sujet de la lettre que j'ai adresse´e a` l'Acade´mie des Sciences," *ibid.*, 1840, *13*(27):106–107.

[14] Mateu Orfila, "Affaire d'empoisonnement porte´e devant la Cour d'Assises de la Co^te-d'Or," *Bull. Acad. Roy. Me´d.*, 1838, *3*:93–112. See also Orfila, "Empoisonnement par les sels de plomb," *ibid.*, pp. 161–177.

Sealed letters were a common way of reporting ongoing research at the Paris Academy of Medicine, and they were sometimes used to claim priority in scientific discovery. This suggests that Orfila regarded normal arsenic as a very important discovery for which he was concerned to claim credit, even if he was far from grasping all its implications at that time. The note, which was filed away until Orfila requested that it be opened several months later, stated that Couerbe had informed him that some analyses seemed to suggest that a "certain quantity" of arsenic was "developed" during the putrefaction of human corpses. Orfila announced that he was working with Couerbe on the large number of questions this discovery had raised: "How does arsenic appear during putrefaction? Could animal matters take it from soil? Does it come from arsenates, which often accompany phosphates and may be reduced by organic matter? Might it be the result of a transformation? These are the questions to address."[15]

This list of questions shows the degree of uncertainty that surrounded the research on normal arsenic from the very beginning. The phenomenon of normal arsenic emerged at a time—the late 1830s—when new tests of chemical sensitivity were beginning to make their mark. Like Rene´ Blondlot's famous N-rays, this story also involved an overeager assistant (in this case Couerbe) who was intent on stressing the importance of his role and many puzzling problems concerning the replication of the relevant experiment. However, normal arsenic can hardly be regarded as an example of "pathological" or "junk" science. And as it was a discovery that challenged his new toxicological methods, it is difficult to imagine that Orfila would have selected biased data or converted random noise into an apparently meaningful pattern in order to draw attention to normal arsenic.[16]

In fact, Orfila could hardly make the new research public unless he found a way to mitigate the potentially disastrous consequences of this discovery. From the beginning, he urged Couerbe to proceed cautiously because the new data might "strike terror in society." When talking about the discovery some years later, he noted that "normal arsenic was a perturbing element," a "terrible blow" (*un coup funeste*) for legal medicine, because— with that discovery—when arsenic was found in a corpse during a poisoning trial attorneys and judges could always ask whether it was "part of normal arsenic or (whether) it was caused by poisoning." In another publication he offered more details about the reasons for keeping the discovery of normal arsenic secret:

> At that time I was working on the absorption of arsenic. . . . It became essential to develop my research a little further in order to know whether there is an arsenic compound in the body of animals and human corpses, correctly assuming that, later, when physicians were asked to decide whether the arsenic obtained from blood and different organs comes from poisoning, it would always be objected that *perhaps the metal . . . might be a natural part of our tissues*.[17]

[15] The note was read at the Academy of Medicine session of 2 Apr. 1839 and printed in *Bull. Acad. Roy. Me´d.*, 1839, *3*:683. On the practice of using sealed letters to report ongoing research and establish priority claims see George Weisz, *The Medical Mandarins: The French Academy of Medicine in the Nineteenth and Early Twentieth Centuries* (Oxford: Oxford Univ. Press, 1995); and Maurice Crosland, *Science under Control: The French Academy of Sciences, 1795–1914* (Cambridge: Cambridge Univ. Press, 1992).

[16] See Irving Langmuir, "Pathological Science," *Physics Today*, 1989, *42*(10):36–48; this paper was presented in a colloquium in 1953. See also P. W. Huber, *Galileo's Revenge: Junk Science in the Courtroom* (New York: Basic, 1991), esp. p. 28. For a very different approach to the N-rays episode see Malcolm Ashmore, "The Theatre of the Blind," *Social Studies of Science*, 1993, *21*:67–106.

[17] *Gaz. Ho´pitaux*, 1839, *12*(149):593 ("strike terror in society"); Mateu Orfila, "Empoisonnement par l'arsenic: Observations sur le dernier me´moire de M. A. Devergie," *Ann. Hyg. Publique Me´d. Le´gale*, 1840, *24*:298–313, on pp. 312–313; and Orfila, "De l'arsenic naturellement contenu dans le corps de l'homme," *Bull. Acad. Roy. Me´d.*, 1839, *4*:178–203, on p. 179 (emphasis in the original).

On 15 January 1839 Orfila submitted another sealed letter to the Academy of Medicine in which he suggested a way of dealing with the problem: normal arsenic was apparently not dissolved in boiling water, and it seemed to be concentrated in the bones. Thus, boiling the corpse and examining only the internal organs like the liver seemed to be a way of circumventing the problem.[18] At the end of that month, Orfila gave the enthusiastic lecture mentioned in the preceding section on his new methods for detecting absorbed arsenic in which he predicted that "crime will be successfully hunted down to its last refuge." He did not deal explicitly with the problem of normal arsenic, although he reported some relevant animal experiments. After demonstrating the presence of absorbed arsenic in poisoned dogs, Orfila proved by several negative tests with nonpoisoned animals that, if arsenic "naturally exists in dogs, it cannot be detected when treating the corpses of these animals by means of the reagents and methods I have employed." Similar comparative tests were carried out in several corpses, showing that arsenic was never found in nonpoisoned bodies when Orfila's methods were carefully followed. In other words, Orfila believed that he had found an effective way to distinguish between normal and absorbed arsenic, even if he was not yet ready to publicize his research on normal arsenic in full. The tension of the moment can be felt in one of the final statements, in which Orfila cautiously remarked:

> The strength of my conclusion would not be undermined even if it were subsequently demonstrated that an arsenic compound naturally existed in some parts of the human body. My experiments have proved that this compound is insoluble in boiling water, so, in order to dissolve and detect any arsenic that had been absorbed, it is enough to treat the corpse in boiling water; the arsenic compound, assuming for a moment that it exists, would not be dissolved by this liquid.[19]

In this paragraph, Orfila uses the hypothesis of normal arsenic to support the validity of his method, claiming that he had considered even the most unlikely situations. But we know that Orfila and Couerbe had been obtaining arsenic from nonpoisoned corpses for many months, so he could hardly have regarded the existence of the normal arsenic as just a faint possibility. This episode tells us a great deal about Orfila's communicative strategies when dealing with sensitive matters and uncertainties in forensic research: he was anticipating possible criticisms before unveiling all the details of his research on normal arsenic, which, as he was well aware, could be used against the claims he made for his high-sensitivity methods.

Orfila's research on normal arsenic was finally disclosed at the session of the Paris Academy of Sciences of 2 April 1839, at which the two sealed notes were opened and read. For the first time, Orfila offered a long report on his recent research on the absorption of arsenic, in which he explicitly dealt with the issue of normal arsenic. He claimed that his research with Couerbe had shown the existence of a "small proportion" of an arsenical compound in the human body. But he added that "society should not be alarmed by this discovery, because it is easy to know whether or not the arsenic extracted from corpses comes from poisoning." Orfila suggested that investigators avoid the parts of the body (particularly the bones) in which normal arsenic was found and proposed the examination of internal organs, such as the liver, in which his reagents had not identified any normal

[18] This note, too, was read at the Academy of Medicine session of 2 Apr. 1839 and printed in *Bull. Acad. Roy. Me´d.*, 1839, *3*:683–684.

[19] Orfila, "Me´moire sur l'empoisonnement par l'acide arse´nieux" (cit. n. 12), pp. 435, 436–439, 439–442; and Report of Session of the Academy of Medicine, *Archives Ge´ne´rales de Me´decine*, 1839, *4*:373–375, on p. 375.

arsenic. He also drew attention to the differences in the solubility of normal and absorbed arsenic. He acknowledged that many issues remained unclear and that further research was needed, but, feeling more confident about his own methods, he announced the results of an experiment that would frequently be used by defense attorneys to discredit his methods in the years to come: his finding of arsenic in an ordinary soup made of beef and vegetables. And he concluded that "if further experiments confirm these results, it will be proved that the everyday beef soup contains an arsenic compound, which is provided by the bones and perhaps by the muscles, dissolved in the water thanks to the lactic acid of the meat and the acids contained in the vegetables." The discovery caused a great sensation and was soon widely reported in journals both in France and abroad.[20]

A new challenge now arose from a different quarter. Orfila's assistant, Couerbe, felt that he had not received due recognition for his work, even though Orfila had mentioned his collaboration, and a priority dispute over the discovery of normal arsenic blew up at the end of 1839, just after one of the famous trials to be discussed in the next section. The dispute began with a note sent by Couerbe to the Academy of Sciences and published in the *Gazette des Ho ̂pitaux*. Orfila responded to the note in *Esculape* (a journal that supported his views in the subsequent quarrel). The controversy was fueled by Couerbe's replies, which were backed by Franc ̧ois-Vincent Raspail (1794–1878), the famous Republican activist who challenged Orfila's toxicological methods in many poisoning trials. The dispute was even reported in foreign journals, reflecting the interest that normal arsenic aroused among toxicologists throughout Europe.[21]

IN THE COURTROOM

Orfila attributed the priority controversy to his participation as an expert witness in several poisoning trials. He acknowledged that Couerbe had been the first to point out that arsenic could be found in the human body but noted that he had been the one who was compelled to deal with the "medico-legal" consequences of the discovery:

> Leaving aside the chemical part of the work, which Couerbe and I had decided to study together, I have dealt alone with the medico-legal question whose answer was essential for enlightening the juries in a serious affair which was recently judged at the Cour d'Assises de la Co ̂te d'Or. I could not have appeared in that court if I had been unable to prove that the internal organs of Nicolas Mercier had presented arsenic to the Parisian experts only because he had been poisoned by an arsenical preparation.

Orfila was referring to one of the first major trials in which he applied his new method, the Mercier affair in Dijon. Thanks to changes in the French legal system during the early nineteenth century, he had become one of the most famous and authoritative expert witnesses in French courtrooms. The new "Code d'Instruction Criminelle" (1808) established (in articles 43 and 44) that the examining magistrate (*juge d'instruction*) had to

[20] Archives of the Acade ́mie de Me ́decine de Paris, *Proce `s-verbaux—Se ́ances ge ́ne ́rales* (session of 2 Apr. 1839); and Mateu Orfila, "De l'empoisonnement par l'acide arse ́nieux," *Bull. Acad. Roy. Me ́d.*, 1839, *3*:676–683, on p. 682 (beef soup). For a report from a foreign journal see, e.g., *Repertorium fu ̈r die Pharmacie*, 1839, *17*:123–126.

[21] *Comptes Rendus Hebdomadaires des Se ́ances de l'Acade ́mie des Sciences*, 1839, *9*:809, 826; and *L'Esculape*, 22 Dec. 1839, *1*(29):166. On priority controversies see Jose ́ R. Bertomeu-Sánchez, "Animal Experiments, Vital Forces and Courtrooms: Mateu Orfila, François Magendie and the Study of Poisons in Nineteenth-Century France." *Ann. Sci.*, 2012, *69*:1–29.

be assisted by one or two physicians when a violent death was suspected.[22] Under oath, the experts produced a written report answering the questions of the magistrate concerning the circumstances and nature of the crime. According to another famous expert, Alphonse Devergie, who participated in many trials and published an authoritative textbook on legal chemistry, the report was expected to include a preliminary section with a "presentation of the facts" (*l'exposition des faits*)—that is, a detailed description of all the relevant data (clinical symptoms, postmortem observations, chemical tests, and so forth), including inconclusive experiments or negative results. At the end of the report, Devergie asserted, the final conclusions had to be based on the whole set of "medical facts." The forensic physician had to organize the information, grouping similar data, assessing the value of all the evidence, and noting any inconclusive results. Recognizing the problems pertaining to causation, Devergie mentioned two different tendencies among French legal physicians: those who regarded the conclusions as merely "the rigorous consequence of every fact" and those who thought that they were the "expression of the moral conviction" of the physician. Devergie held to the latter view, applying the following interpretation of the role of experts in courts:

> Physicians are asked by law to interpret facts which the law cannot know. She [the law] puts the physician in her role and place regarding these facts; she qualifies him as an expert, that is, she recognizes his competence to judge. She does not ask him to account for the reasons of the judgment he makes; she accepts it, she acknowledges it because she is unable to invalidate it. Thus, the law addresses herself to the moral conviction of the physician.[23]

By referring to the experts' "moral conviction," Devergie was comparing their role to the roles assigned to judges and jurors and addressing one of the most puzzling and lasting problems of the French legal system: the tensions between the role of experts as mere providers of factual data (that is, as the assistants of the magistrates) and their judgments and interpretations of the data, which overlapped with the function carried out by judges and jurors. Referring to the wide-ranging role of experts in the courtrooms, some late nineteenth-century legal commentators said that they almost became "temporary magistrates".[24]

The final conclusions were frequently questioned by other experts, and disagreements often arose. Judges could ask a team of two or three experts to prepare a report; the experts might disagree, about minor issues or substantial ones, or sometimes owing to their different perceptions as to what constituted an adequate causal explanation. In such cases, the judge might request new reports from a new group of experts and might accept the

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[22] *L'Esculape*, 22 Dec. 1839, *1*(29):166. The *juge d'instruction* is the person who conducts the criminal investigation. On the differences between the French system and the British and American adversarial systems see Leclerc, *Le juge et l'expert* (cit. n. 3), pp. 361–398.

[23] Alphonse Devergie, *Traite´ the´orique et pratique de me´decine le´gale* (Paris: Baillie`re, 1836), Vol. 1, pp. 15–16, 17. For more information about expert reports and the French legal system see Fre´de´ric Chauvaud and Laurence Dumoulin, *Experts et expertise judiciaire: France, XIXe et XXe sie`cles* (Rennes: Presses Univ. Rennes, 2003), pp. 192–198.

[24] The overlapping roles of judges and experts created tensions in the nineteenth-century French courts. See Chauvaud, *Les experts du crime* (cit. n. 3); and Leclerc, *Le juge et l'expert* (cit. n. 3). The expression "*une magistratude momentane´e*" was used by Andre´ Lefe`vre, *L'expertise devant les juridictions civiles* (Caen: Lanier, 1913), p. 48; it is quoted by Chauvaud and Dumoulin, *Experts et expertise judiciaire*, p. 243. See also Magali Bloch, "Justice et science au 19e sie`cle ou la difficile re´pression du crime d'empoisonnement," *Recherches Contemporaines*, 1997, *4*:101–123, esp. pp. 119–123. The issue was particularly important in forensic psychiatry. See Laurence Guignard, *Juger la folie: La folie criminelle devant les Assises au XIXe sie`cle* (Paris: Presses Univ. France, 2010).

involvement of experts proposed by the defense or the prosecution—as happened in the trials discussed in the following pages. The four expert reports prepared for the Lafarge trial represented an exceptional situation, but a request for an additional report was by no means rare, particularly in cases in which medical and scientific data played a major role as incriminatory evidence or when chemical tests were performed by inexperienced physicians and the results were inconclusive.[25]

Facing the reluctance of jurors to submit guilty verdicts involving the death penalty, judges were keen to obtain conclusive expert reports that left no uncertainty or doubt. As a result, they urged the experts to confine their advice to the realm of definite facts. This "legal construction of facts" was sometimes a source of tensions between experts and judges.[26] "Give conclusions!" demanded a judge at Riom of the experts during a famous poisoning case in 1843. "Toxicology cannot admit a doubt of this kind," he continued. "Poisoning either occurred or did not occur." In his reply Orfila reminded the public that the complexity of toxicological work did not always allow for such definite conclusions and that sometimes experts could do no more than assert that poisoning was "probable, very probable or extremely probable." Devergie reported that he had been told by many judges that experts had often "thrown them into almost complete uncertainty" because they "were unable to understand the reasons for the experts' hesitations."[27]

The tensions between the tentative character of experts' conclusions and the judges' insistence on cast-iron facts underpinned the adoption of the new chemical tests in French toxicology. At first sight, tests based on the reduction of arsenic (like the Marsh test) seemed to limit the interpretative role of experts: metallic arsenic could now be dramatically presented in court as the *corpus delicti*.[28] However, the previous section has shown that the high sensitivity of the Marsh test introduced new problems: misleading arseniclike substances and minute impurities in vessels and reagents (which the new tests detected) could produce false-positive results. Normal arsenic allowed for further interpretative flexibility because it could be claimed that the detected arsenic was just a standard ingredient of the human body. In the hands of creative experts and astute lawyers, it was an excellent device for questioning the factuality of the results yielded by the Marsh test, reducing that test's dramatic power to display the criminal weapon in the rather theatrical atmosphere of nineteenth-century courtrooms.

[25] See Guignard, *Juger la folie*, p. 244, which mentions a trial in which ten different experts participated; see also Ch. 9, esp. pp. 233, 241–242. Regarding disagreements as to adequate causal explanation see Gary Edmond and David Mercer, "Rebels without a Cause? Judges, Medical and Scientific Evidence, and the Uses of Causation," in *Causation in Law and Medicine*, ed. Ian Freckelton and Danuta Mendelson (Aldershot: Ashgate, 2002), pp. 83–121.

[26] See Leclerc, *Le juge et l'expert* (cit. n. 3), pp. 91–124, for a discussion of the legal construction of factuality in the French system. On the problem of "sanction nullification" and jury mitigation of punishment in nineteenth-century France see James M. Donovan, *Juries and the Transformation of Criminal Justice in France in the Nineteenth and Twentieth Centuries* (Chapel Hill: Univ. North Carolina Press, 2010), pp. 5–6, 37–48.

[27] Mateu Orfila, "Quelques re´flexions critiques sur les moyens de conclure en me´decine le´gale, et sur la pre´tendue localisation des poisons," *Ann. Hyg. Publique Me´d. Le´gale*, 1844, *31*:430–443, on p. 435; and Devergie, *Traite´ the´orique et pratique de me´decine le´gale* (cit. n. 25), Vol. 1, p. 18. Similar views were expressed by other experts. See Chauvaud and Dumoulin, *Experts et expertise judiciaire* (cit. n. 25), p. 209.

[28] On this issue see Burney, *Poison, Detection, and the Victorian Imagination* (cit. n. 2), pp. 78–115. The conclusions are also in tune with recent studies on popularization of science that show the active role of lay audiences. For a recent review see Jonathan Topham, "Rethinking the History of Science Popularization/Popular Science," in *Popularizing Science and Technology in the European Periphery, 1800–2000*, ed. Faidra Papanelopoulou, Agust´ın Nieto-Galan, and Enrique Perdiguero (London: Ashgate, 2009), pp. 1–21; and the Focus section on "Historicizing 'Popular Science,'" *Isis*, 2009, *100*(2).

FAMOUS TRIALS

These technical, scientific, and legal developments were accompanied by a dramatic increase in arsenic poisoning cases at the end of the 1830s. Moreover, the two most famous trials in which Orfila participated (the Mercier and Lafarge affairs) shared some features that made them particularly well suited to his new methods: inconclusive data from clinical symptoms and autopsies, long-buried corpses, no remains of suspicious liquids or stomach contents (which meant, as Orfila had claimed during his lectures at the Paris Academy of Medicine, that only absorbed poison could be investigated), several expert reports, and, last but not least, the failure of local experts to detect arsenic by means of old chemical methods or, sometimes, a rather careless application of the Marsh test. The trials took place at the time when Orfila was researching normal arsenic, between 1839 and 1840, and were surrounded by controversy fueled by the participation of Franc¸oisVincent Raspail and by the extensive coverage in newspapers, particularly during the Lafarge affair.

Nicolas Mercier died in December 1838 after some painful vomiting episodes. The examining magistrate requested an autopsy, which was performed by a group of local doctors. They found evidence of poisoning perpetrated by means of a "corrosive and irritating substance." Another group of experts, comprising a physician, an engineer, and a pharmacist, performed several chemical tests (including the Marsh test) on the substances found in Mercier's stomach and intestines, but they could not obtain any trace of arsenic. In view of these inconclusive results, in March 1839 the investigating magistrate asked Orfila and other Parisian toxicologists to express their views on the case. They answered that even if the clinical symptoms and the autopsy might suggest arsenic poisoning, "in the absence of proof . . . by extracting the poison by means of chemical analysis, the symptoms and alterations of organs were insufficient to decide whether this man died as result of poisoning." They went on: "We . . . wish the *juge d'instruction* to note that one of us, M. Orfila, has recently found new ways of detecting the existence of absorbed arsenic, passed into the blood and organs apart from those into which it was introduced. Today, it would be still possible to search for this metal in the remains of Nicolas Mercier's body."[29]

Needless to say, Orfila was referring to his new method for detecting absorbed arsenic.[30]In April 1839, half of Mercier's liver (one of the organs in which arsenic was believed to be absorbed) was boiled in water so as to avoid possible contamination by normal arsenic—which, Orfila believed, was insoluble in water and located predominantly in bone. The solution was then completely evaporated and the remaining solid deposit was treated with nitric acid and introduced into a modified Marsh apparatus, in which several arsenic-like black spots were produced. Similar positive results were obtained from other parts of Mercier's body. Adding these data to the reports of clinical symptoms and the autopsy, Orfila, Ollivier d'Angers, and Lesueur boldly claimed in June 1839 that "we have no hesitation in concluding that the death of Nicolas Mercier has to be attributed to an arsenical preparation." However, the other Parisian toxicologist, Alphonse Devergie, added a personal remark to the report, suggesting that, even if there were "great presumptions" of

[29] The report by the local doctors and other documents from the trial were reprinted in Francesco Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic et documents me´dico-le´gaux sur cet empoisonnement; par . . . suivis de la de´position de M. Raspail devant la cour d'assises de Dijon* (Paris: Gardembas, 1840), pp. 7–8 ("corrosive and irritating substance"), 16–17 (no trace of arsenic). The affair is described in the *Gazette des Tribunaux*, 2 and 3 Dec. 1839. For the concerns about "the absence of proof" and the suggestion that Orfila's new method might be used see *Me´moires de l'Acade´mie Royale de Me´decine*, 1841, 9:1–57, on pp. 7–8; the concluding quotation can also be found in Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic*, p. 20.

[30] Orfila, "Me´moire sur l'empoisonnement par l'acide arse´nieux" (cit. n. 12), p. 461.

arsenic poisoning, it still remained to be proved that Mercier had not used any arsenical preparation (like Fowler's famous solution) for medicinal purposes and that the soil in which his corpse was buried did not contain any arsenical compound. These two questions were frequently raised in poisoning trials in the following years, and indeed the fact that arsenic was sometimes found in graveyard soils turned out to be one of the most lasting criticisms leveled against the high-sensitivity tests.[31]

In addition to their written reports for the examining magistrate, experts could also be asked to go to court to discuss their results. Here they often faced what they sometimes regarded as naive and inopportune questions. They also expressed concerns about the potential damage that such oral hearings could inflict on their authority and credibility.[32]Thanks to his earlier experiences as an expert witness, Orfila was acquainted with the deconstructive features of courtrooms, so before discussing his report on the Mercier case at the Dijon court he performed new animal experiments and chemical analyses in order to ward off possible criticisms of his high-sensitivity method. At the end of the summer of 1839 he delivered a series of lectures at the Academy of Medicine reviewing the main problems: the possible arsenical impurities in reagents and vessels, the extraction of absorbed arsenic, the presence of arsenic in graveyard soils, and, of course, normal arsenic. In this last paper, Orfila showed the existence of arsenic in human bones by means of several analyses, and he still claimed that "when performing medico-legal research into arsenic poisoning, it was always possible to ascertain" whether the arsenic identified by the Marsh test was normal or absorbed, provided that his instructions regarding reagents and chemical manipulations were strictly followed. The conclusions seemed to be so soundly based on experimental data that Orfila even sent copies of his papers to the defense attorney in the Mercier case.[33]

Although he was careful to sound authoritative in public, Orfila's private research on normal arsenic continued to produce unexpected results and to add to the uncertainty surrounding his method. On 25 November 1839 he submitted a new sealed note to the Academy of Medicine of Paris in which he affirmed that arsenic could be obtained from the internal organs of nonpoisoned bodies by means of a new method. He still claimed, however, that it was possible to distinguish between normal and absorbed arsenic by using certain reagents. In any case, the tone of the sealed letter clearly shows that, in spite of his public claims, Orfila's research on normal arsenic was very much work in progress. The contrast between public rhetoric and private research became more marked when Orfila was asked to discuss his results in court during the Mercier affair, just a few days after he had submitted the note to the academy. The judge asked him about the arsenic found in soups, and Orfila's decisive answer contrasted notably with the tentative tone of the sealed note:

Judge: Have you not written that arsenic could be found even in soup?

[31] Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic* (cit. n. 31), p. 21. Regarding arsenic in graveyard soils see J. H. Wagner, "Die Verwendung von Arsen zum Giftmord unter besonderer Beru¨cksichtigung des Problems der arsenikhaltigen Friedhofserde," *Pro Medico*, 1952, *21*:161–164.

[32] See Chauvaud, *Les experts du crime* (cit. n. 3), p. 54; and Chauvaud and Dumoulin, *Experts et expertise judiciaire* (cit. n. 25), pp. 53–54.

[33] Mateu Orfila, " Me´moire sur les moyens de s'assurer que l'arsenic, obtenu des organes ou` il a e´te´ porte´ par absorption, ne provient pas des re´actifs, ni des vases employe´s a` la recherche me´dico-le´gale de ce poison," *Bull. Acad. Roy. Me´d.*, 1839, *3*:1049–1073; Orfila, "Me´moire sur les terrains des cimetie`res," *ibid.*, 1839, *4*:40–56; and Orfila, "De l'arsenic naturellement contenu dans le corps de l'homme," *ibid.*, pp. 178–203, on p. 181. That Orfila sent copies of his papers to the defense attorney is reported in Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic* (cit. n. 31), p. 4.

> Orfila: Yes, it comes from the normal arsenic contained in the bones, but, remarkably, it is never found in the liver; and we found it [arsenic] in Mercier's liver.[34]

The episode not only reveals interesting differences between Orfila's discourses in the academy and in the courtroom but also shows how expert authority could be challenged when technical, rather esoteric information (animal experiments with normal arsenic) was translated into data that were meaningful ("arsenic-in-the-soup") for lay audiences such as judges, lawyers, and jurors. As noted above, the new Marsh test seemed to circumvent many of these problems by producing arsenic in its metallic form as the actual criminal tool used by the poisoner, a material proof that could be seen and touched by jurors. But the test's high sensitivity and the discovery of normal arsenic made it even harder for toxicologists to present convincing proofs in the courtroom.[35]

In spite of these difficulties, Orfila's communicative strategies and scientific authority were enough to garner support for his new methods, which soon gained acceptance along with the idea of normal arsenic. The methods were used by many local experts and were commonly mentioned by judges and lawyers in 1839 and 1840. In June 1840, in the course of another case, Orfila defended the main conclusions of his expert report against both Raspail's skeptical arguments and the objections made by lawyers and jurors, who were acquainted with the recent developments concerning normal arsenic. One of the jurors remarked that the test had been performed on the whole corpse of the victim, including her bones, so he asked Orfila whether "it could be possible to affirm that the arsenic yielded by means of the Marsh apparatus was in fact the normal arsenic of bones." Orfila answered this serious objection by pointing to the alleged differences in the solubility of normal and absorbed arsenic: "the [normal] arsenic cannot be extracted from bones by means of boiling water . . . , strong acids are needed; so, even if the analyzed liquids were obtained by boiling the victim's bones, the liquid could never contain an atom of the normal arsenic found in bones."[36]

Just over a month later, in August 1840, Orfila enthusiastically reviewed a list of five poisoning trials in which he or other experts had successfully employed his new method for detecting absorbed poison. At the end of the paper, Orfila summarized the main arguments that defense attorneys used to undermine his conclusions, from general considerations such as the novelty of the method and the fact that it had not been sufficiently tested to particular issues related to the small quantities of arsenic involved and the broad spectrum of sources of impurities: vessels, reagents, arsenical graveyards, and, of course, normal arsenic: "Normal arsenic, as predicted, played a principal role here: how can you persuade juries that the minute quantity of arsenic which has been obtained [by means of the Marsh test] was not furnished by the arsenical preparation which is naturally contained by the human body?"[37]

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[34] Archives of the Acade´mie de Me´decine de Paris, Plis cachete´s, no. 52, 25 Nov. 1839; and *Gaz. Tribunaux*, 2 and 3 Dec. 1839, *15*(4441):106 (exchange with judge). Louis Mercier (the father of Nicolas Mercier) was sentenced to life imprisonment.

[35] On this issue see Burney, *Poison, Detection, and the Victorian Imagination* (cit. n. 2), pp. 97–101.

[36] *Le Droit*, 10 June 1840, *5*(138):561. See also *Gaz. Tribunaux*, 6 June 1840, *15*(4600):761–762. This exchange occurred at the trial of Antoine Rigal, who was accused of poisoning his wife, at the Albi court. A similar discussion took place during the trial of Victorine Cumon in Perigueux. See *Gaz. Tribunaux*, 9 and 10 July 1840.

[37] Mateu Orfila, "Me´moire sur plusieurs affaires d'empoisonnement par l'arsenic, re´cemment juge´es par les cours d'assisses du royaume," *Bull. Acad. Roy. Me´d.*, 1840, *5*:465–475, on p. 474. See also J. B. Caventou and C. P. Ollivier d'Angers, "Observation d'empoisonnement par l'acide arse´nieux," *ibid.*, 1839, *4*:275–282. [40] See note 31, above.

Some months later, when Orfila's paper was reprinted in the *Me´moires de l'Acade´mie Royale de Me´decine*, he added a new poisoning trial to the list, perhaps the most famous of those in which he would participate: the Lafarge affair.[40] The affair started at the beginning of 1840, when Charles Lafarge died after a short illness and his wife was accused of poisoning him with arsenic. The local experts performed several chemical analyses with reagents on the liquids found in Lafarge's digestive tract, but their results were inconclusive owing to a common accident: a tube had suddenly broken when they were performing the reduction of metallic arsenic. Madame Lafarge's defense lawyer contacted Orfila, who in turn answered that, without a finding of metallic arsenic, the results of the local experts' tests were inconclusive. During the oral hearings, the experts claimed that they had found evidence of arsenic poisoning, even though they had not obtained the telltale metallic ring that indicated the presence of arsenic. The judge asked them whether they were acquainted with recent developments in toxicology, particularly with the issue of normal arsenic:

> Judge: But were you acquainted with the progress of science? Has it not been acknowledged for some time that the human body in its normal state contains some arsenic?
> Expert (M. Massenat): It has been recognized that the bones of adult humans contain some arsenic but, in order to obtain it, the bones have to be calcinated and treated with sulfuric acid and the Marsh apparatus. It is a new discovery arising from the works of 1840, but it by no means proves that we acted incorrectly with the substances which were brought to us, and above all we did nothing that might have produced normal arsenic.[38]

Another letter from Orfila, again criticizing the conclusions of the local experts, prompted a new analysis. Experts from Limoges analyzed Lafarge's remains in September 1840 using the Marsh test, but, unlike the first experts, they could not obtain any trace of arsenic from the remains of the victim's stomach and digestive liquids. (See Figure 2.) In view of these contradictory results, the judge ordered the first and second groups of experts to work together on new chemical analyses. The new tests faced additional problems because the two previous examinations had used up most of the remaining parts of the victim's digestive tract. Thus, Lafarge's cadaver was exhumed and some samples were taken and analyzed in an improvised laboratory set up near the courtroom. During the session of 9 September 1840, the experts stated that they had been unable to find any trace of arsenic in M. Lafarge's exhumed organs. Madame Lafarge's lawyer called for his client's release. However, the judge requested a fourth, definitive test from a group of three experts from Paris, one of whom was Orfila. This was another opportunity to demonstrate the power of the new high-sensitivity methods for detecting absorbed arsenic in a long-buried corpse. After performing new tests, and amid great excitement, Orfila read the final report, in which he affirmed that he had indeed found arsenic in Lafarge's body. He provided a likely explanation of the differences between his results and those of

[38] See the main documents of the trial in *Proce`s de Mme Lafarge* (Paris: Pagnerre, 1840); the quotation is from p. 114. More details can be found in Bertomeu-Sánchez and Nieto-Galan, eds., *Chemistry, Medicine, and Crime* (cit. n. 3), pp. 207–243.

Figure 2. *Daguerreotype representing a group of experts performing a Marsh test (right). According to J. Plantadis (*Bulletin de la Socie´ te´ d'Histoire de la Pharmacie, *1921), the pharmacist Le´ onard Borie, one of the experts who participated in the Lafarge affair, was the author of this daguerreotype. Courtesy of Archives De´ partementales de la Corre` ze (22 Fi 366).*

the three earlier chemical tests and remarked that the arsenic detected came neither from the reagents nor from the earth in which the body was buried; nor did it belong to the "arsenic portion that naturally exists in the human body." In his report, Orfila again stressed the idea that normal arsenic was located only in the bones; therefore, any arsenic he discovered in his analysis of the internal organs would necessarily have been absorbed:

> Thanks to my experiments, which I started 18 months ago, today it is acknowledged that there naturally exists in the bones of humans and many other animals a finely small quantity of arsenic; but it is also acknowledged that, following the current method, not even the smallest trace of arsenic is ever obtained from the human stomach, liver, spleen, kidneys, heart or lungs. We operated not on the bones but on the internal organs. Therefore, what we removed is not normal arsenic.[39]

EXPERT CONTROVERSIES

The most challenging criticism of Orfila's new methods came from Franc¸ois-Vincent Raspail and Francesco Rognetta, who helped the defense as expert witnesses during the Mercier and Lafarge trials. Both Raspail and Rognetta had already been involved in controversies with Orfila; they were well-known Republicans, while Orfila was clearly committed to the royalist Orleanist regime and was ready to employ his academic and political influence against his enemies. Raspail often complained of the unfairness of

[39] *Proce`s de Mme Lafarge*, pp. 352–353, 356. Like Louis Mercier, Marie Lafarge was sentenced to life imprisonment.

pitting "an all-powerful expert in the administration" against "simple provincial pharmacists, with no other power than their own good reputation, and with no other authority than their knowledge and probity." Orfila was one of those who decided "university appointments and dismissals in Paris," and Raspail pointed out the likelihood that at some point the local experts might be "involved in the harassments of some institution, or be led to apply for a position." Certainly, there is evidence that Orfila exploited his academic and political power when he deemed it necessary. During his dispute with Rognetta on arsenic treatments, which reached its climax during the summer of 1839, the Italian physician was put under arrest and questioned by the prefect of police. At the police station he met Orfila, who asked him to write a letter admitting that some of his earlier assertions were wrong. Rognetta refused, and, if we are to believe his account of this strange encounter, Orfila threatened to prevent him from lecturing at the Paris Faculty of Medicine and from practicing medicine—and even to have him expelled from France.[40]

Rognetta's and Raspail's criticisms focused on the dramatic differences between the test results of the local and the Parisian experts. How was it possible that local experts did not find any trace of arsenic in the gastrointestinal tract, as would be expected in a case of arsenic poisoning? In view of this negative result, they noted the risks of relying on a new method that identified only very small quantities of arsenic. This "homeopathic legal chemistry," as it was termed by Raspail, would be hard put to avoid all the possible sources of minute impurities in reagents and vessels, graveyard soils, and normal arsenic. Ignoring Occam's razor, Rognetta and Raspail employed their creative imaginations to suggest as many sources of arsenic contamination as possible. For example, they argued that arsenic might be passed to the buried corpses by natural forces that chemical experiments at the laboratory were unable to detect. In addition, unknown phenomena taking place during the process of putrefaction might spread the normal arsenic from the bones to other parts of the corpse.[41]

Apart from highlighting particular areas of uncertainty, Raspail and Rognetta also discussed more general epistemological questions concerning the differences in legal and scientific evidence and the tensions between the open-ended character of scientific research and the necessity of closure in courts of law and the irreparable consequences of legal decisions, particularly in cases in which the life of the defendant was at stake.[42]Nineteenth-century forensic medicine was largely a science made for courts. In the case of normal arsenic, Orfila's research developed in parallel with the legal proceedings in which he participated as an expert witness, so he is sure to have felt the tension between the law's need for reliable knowledge and the uncertain ability of science to provide it. Moreover, the Marsh test raised questions that were at the cutting edge of toxicological knowledge at the time. In Sheila Jasanoff's terms, Orfila's claims were "uncertain" and "fluid," rather than supported by "a backdrop" of largely settled "mainstream knowledge."

Like many other nineteenth-century toxicologists, Orfila was trapped between using older but widely tested methods and introducing brand new ones that were sensitive but also

[40] Franc¸ois-Vincent Raspail, *Accusation d'empoisonnement par l'arsenic* (Paris: Gazette des Hoˆpitaux, 1840), p. 24; and *Gaz. Hoˆpitaux*, 1839, *12*(103):409 (Orfila's threats against Rognetta).

[41] Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic* (cit. n. 31), pp. 26, 68–70 (Raspail's expert report on the Mercier affair).

[42] On this issue see Michelle Taruffo, "Conocimiento cient´ıfico y esta´ndares de prueba," *Bolet´ın Mexicano de Derecho Comparado*, 2005, *38*(114):1285–1312; and Taruffo, *La prueba de los hechos* (Madrid: Trotta, 2002). See also Jasanoff, *Science at the Bar* (cit. n. 2), esp. pp. 42–68.

more vulnerable to unknown sources of error.[43] In court, expert witnesses and defense attorneys took every opportunity to stress the risk of error, arguing that this new method for searching for absorbed arsenic had been presented in public only a few months before the Mercier trial and could not have been thoroughly tested by the academic community.

The mutating nature of the Marsh test was another source of doubt and criticism. The *Toxicological Catechism* written in 1841 by a local apothecary involved in one of the famous poisoning trials affirmed that "there is no week in which the Marsh apparatus is not modified, which obviously proves that it always presents serious inconveniences." During the discussion with Orfila in the course of the Mercier trial, Raspail affirmed: "Gentlemen, you must doubt the omnipotence of legal chemistry because it refutes itself every six months"; that is, toxicological tests were soon outdated and surpassed by new ones. Thus, even granting that all known sources of error had been considered, who could positively affirm that subsequent studies would not discover further unknown substances capable of producing the same misleading results? And, after a guilty verdict and a death sentence, who could restore the guillotined head of the defendant when the chemical error was finally acknowledged? As he stressed these points, Raspail's skepticism regarding the scientific evidence was in tune with the growing concern about judicial errors in the French legal system during the nineteenth century.[44]

Surprisingly, in the midst of such a great controversy, the very existence of normal arsenic was never questioned either by Orfila or by his fierce critics, Raspail and Rognetta. In fact, the controversy served to spread the new research on normal arsenic, which had now met with wide acceptance—and not only in France. A brief summary was published in the *Lancet* just a few weeks after the verdict of the Mercier trial, stating that "the experiments performed by MM. Orfila, Devergie, etc. demonstrated that Mercier's body contained arsenic in addition to that which is naturally found in the human body." The paper also described the method used by Orfila to reach this conclusion: "in the normal state, when the liver is treated with nitric acid, it never furnishes arsenic, but the liver of Mercier did." Similar papers were published in many other European and American journals in the following years.[45]

Neither did Raspail question the existence of normal arsenic in the long, critical review of Orfila's methods that he published after the Lafarge trial and that was answered by Orfila and other experts. Again, Raspail presented compelling arguments combining a generally skeptical tone with some specific empirical data, sometimes even drawing on Orfila's own experiments in order to strengthen his case. For instance, he offered a highly embellished version of the 1839 experiments showing the presence of arsenic in beef soup—even affirming that it had been found by Orfila in "various Parisian restaurants," when in fact the soup in question had been prepared by Orfila as part of a controlled experiment—and asked rhetorically who could possibly trust an expert who found arsenic almost

[43] This issue was already raised by the famous nineteenth-century German analytical chemist Carl Fresenius. See William A. Campbell, "Some Landmarks in the History of Arsenic Testing," *Chemistry in Britain*, 1965, *1*:198–202. See also Jasanoff, *Science at the Bar*, pp. 50–52, 209–210, on p. 210.

[44] Le´onard Borie, *Cate´chisme toxicologique ou essai sur l'empoisonnement, a` l'usage des cours d'assises et des tribunaux* (Tulle: Drappeau Fre`res, 1841), p. 71; and *Gaz. Ho˜pitaux*, 31 Dec. 1839, p. 609 (quoting Raspail). See also Rognetta, *Nouvelle me´thode de traitement de l'empoisonnement par l'arsenic* (cit. n. 31), pp. 40–41; and *Gaz. Ho˜pitaux*, 11 June 1840, p. 69. On the growing concern about judicial mistakes see Chauvaud, *Les experts du crime* (cit. n. 3), pp. 62–70; and Chauvaud and Dumoulin, *Experts et expertise judiciaire* (cit. n. 25), pp. 230–240.

[45] *Lancet*, 14 Dec. 1839, *1*:451–453, on p. 452. See also *Chemist*, 1840, *1*:25; *Boston Medical and Surgical Journal*, 1840, *22*:117–119; and *New York Journal of Medicine and Surgery*, 1840, *3–4*:228–231.

everywhere. (See Figure 3 and Frontispiece.)[46] During the following months, Raspail published similar criticisms in the journal *La Gazette des Ho˚pitaux*, using any newly available data to attack the reliability of Orfila's conclusions. For instance, he reported the recent experiments on normal arsenic carried out by a Belgian professor of chemistry, Victor van den Broeck, who, at a recent session of the Belgian Academy of Science, had claimed to have found arsenic in normal human blood; this, according to Raspail, represented a further rebuttal of Orfila's methods.[47]

The controversy between Orfila and Raspail sparked an intense debate inside the Paris medical community that spread to other academic and social contexts during the following months. The controversy reached its peak in 1841, when special sessions were held at the Academy of Sciences and the Academy of Medicine. The debate was not confined to the scientific and medical community: audiences comprising people from many walks of life attended lectures on toxicology at the Paris Faculty of Medicine and crowded courtrooms in which accused poisoners were on trial. Medical, scientific, and popular journals dealt at length with the Lafarge drama, not only in France but elsewhere in Europe.[48]

AN UNEXPECTED TWIST

In the midst of the controversy prompted by the Lafarge affair, the story of normal arsenic took a new turn. At the end of 1840 a pharmacist, Charles Flandin (1803–1891), and a glassblower, Ferdinand Philippe Danger (b. 1802), read a paper on "medico-legal researches on arsenic" at the Academy of Sciences. They reported several experiments using the Marsh test and concluded that "there was no normal arsenic." Special committees were created at both the Academy of Sciences and the Academy of Medicine in order to reassess the Marsh test and to monitor the ensuing debate. The committee of the Academy of Sciences asked Orfila to repeat his experiments in their presence; to his surprise, he was unable to obtain any trace of normal arsenic.[49] It seems that Orfila had studied the problem during the fall of 1840, when he submitted a new sealed note to the Academy of Medicine, although it was not opened until July 1841. In the note, Orfila affirmed that he had been unable to obtain any trace of normal arsenic since September 1840—that is, during the Lafarge affair, in which he had claimed that it was easy to distinguish between normal and absorbed arsenic. Moreover, the sealed note suggested possible sources of impurities (reagents, ingested drugs) that he had never admitted in the courtroom:

> Does arsenic really exist in the bones? I have been searching for it in vain for one month by using the same methods which have detected it until now. Perhaps the bones I analyzed and employed for my first report belonged to persons who had been administered arsenic as a drug?

[46] Raspail, *Accusation d'empoisonnement par l'arsenic* (cit. n. 43), p. 125. Raspail claimed that Orfila had performed "two hundred experiments" in order to prove that "the soup of various Parisian restaurants was arsenical," and he affirmed that the final source of arsenic was the reagents employed by Orfila. For the response to Raspail's review see Antoine Bussy, Charles P. Ollivier, and Mateu Orfila, *Re´ponse aux e´crits de M. Raspail sur l'affaire de Tulle* (Paris: Be´chet, 1840).

[47] *Gaz. Ho˚pitaux*, 1840, *13*:541.

[48] See Bertomeu-Sánchez and Nieto-Galan, eds., *Chemistry, Medicine, and Crime* (cit. n. 3), pp. 207–243.

[49] Regarding Flandin and Danger's findings see *Gaz. Ho˚pitaux*, 1840, *13*:607; and *Compt. Rend. Acad. Sci.*, 1840, *40*:1038–1040, 1841, *41*:118–119, 333–336. See also *Bull. Acad. Roy. Me´d.*, 1841, *6*:558–560, 565–566. The report of the Academy of Sciences was published by Henri-Victor Regnault, "Rapport sur plusieurs memoires concernant l'emploi du proce´de´ de Marsh, dans les recherches de me´decine le´gale," *Compt. Rend. Acad. Sci.*, 1841, *12*:1076–1109; for the new experiments by Orfila see p. 1096.

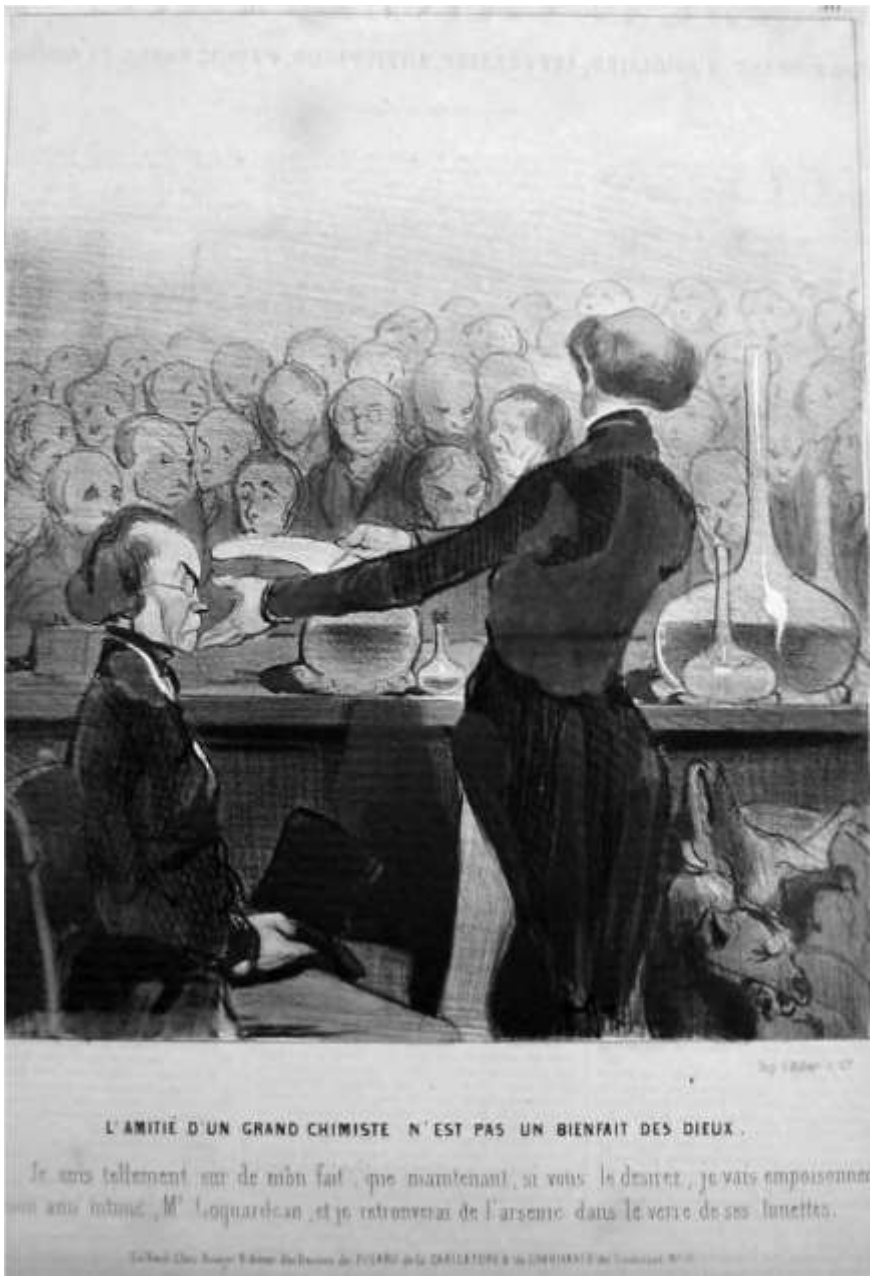

Figure 3. *"L'amitie´ d'un grand chimiste n'est pas un bienfait des dieux." Hand-colored lithograph caricature by Honore´ Daumier. The character representing Orfila (on the right) affirms, "I am so sure of my facts that now I am going to poison my intimate friend . . . and I will retrieve arsenic in his spectacle lenses." Courtesy of Chemical Heritage Foundation, Philadelphia, Fine Art Collection (FA 2000.001.142).*

> Could it be that the sulfuric acid used in the operation contained by chance some traces of arsenic or arsenious acid? Whatever the answer, the issue deserves to be studied again and I am working on it.[50]

Thanks to this note, Orfila could claim priority in the discovery of the "nonexistence" of normal arsenic, in much the same way as he had defended its existence in his priority dispute with Couerbe some months before. He claimed that the issue was well known in his laboratory and that he had informed other physicians and chemists. But in front of his colleagues at the Paris Academy of Medicine he recognized that it was "something inexplicable, most probably a mistake that I am not yet able to understand."[51] In another publication he affirmed: "In 1840, we obtained from bones truly arsenical stains with all the *physical and chemical characteristics*. These results were constant and today, following exactly the same practices and using the same pure reagents as before, we have not obtained them. There is something obscure which has to be clarified."[52]

Orfila was never able to determine what had been wrong with his experiments. The final reports of the commissions of the Academy of Sciences and the Academy of Medicine concluded that there was no evidence of the existence of normal arsenic. Orfila argued that it was just a minor error in a complex issue and, making a virtue of necessity, he claimed that the disappearance of normal arsenic would be a boost to his toxicological methods, because defense attorneys could never again employ this issue in order to undermine his conclusions:

> Be this as it may, it is a comforting truth that the absence of arsenic in the human body in the normal state will draw the most solid support for my medico-legal system. You know how defense attorneys have employed the existence of normal arsenic for their own advantage. It was made to travel from the bones to the internal organs; this precious last resort will no longer be available to them, and it suffices to detect the presence of arsenic in some of our viscera in order to be sure that this arsenic has been ingested.[53]

STILL ALIVE AND MOVING AWAY

Orfila was again overoptimistic in his conclusions. The concept of normal arsenic would survive for many years in courtrooms and academies before it finally faded away. In

[50] Archives of the Acade´mie de Me´decine de Paris, *Proce`s-verbaux—Se´ances ge´ne´rales* (session of 13 July 1841). The note is signed "Paris, 3 Nov. 1840." Later on, Flandin would affirm that the sealed note was just another trick employed by Orfila to claim priority in the discovery of the "nonexistence" of normal arsenic. See Charles Flandin, *Traite´ des poisons* (Paris: Bachelier, 1846–1853), Vol. 1, pp. 734–735. Further details are provided in an anonymous (but well-informed) paper: "Examen historique et critique de la question arsenicale," *Revue Scientifique*, 1841, *7*:261–289. Orfila offered his own version of the matter in the last edition of his textbook on toxicology: Mateu Orfila, *Traite´ de toxicologie*, 5th ed. (Paris: Labe´, 1852), Vol. 1, pp. 544–546. He also claimed priority for the discovery of the nonexistence of normal arsenic in his autobiography written during the late 1840s. See Jose´ R. Bertomeu and Josep M. Vidal, *Mateu Orfila: Autobiografia i corresponde`ncia* (Mao´: IME, 2011), pp. 192–193.

[51] *Bull. Acad. Roy. Me´d.*, 1841, *6*:864–865 (session of 13 July 1841). During the previous months, Orfila was asked by the Academy of Medicine to express his views concerning normal arsenic, but he refused to open the sealed note until July 1841, when the reports of the Academy of Medicine and the Academy of Sciences were published. See *ibid.*, p. 471, reporting the session of 16 Feb. 1841.

[52] Mateu Orfila, *Rapport sur les moyens de constater la pre´sence de l'arsenic dans d'empoissonnement par ce toxique* (Paris: Baillie`re, 1841), pp. 42–43 (emphasis in the original). See also Orfila, "Lettre . . . sur le meilleur moyen a` employer pour la recherche de l'arsenic, dans les cas d'empoisonnement," *Ann. Hyg. Publique Me´d. Le´gale*, 1842, *27*:447–453. Many other toxicologists had accepted the idea of normal arsenic during the previous years. See Alphonse Devergie, "Me´moire sur l'empoisonnement par l'arsenic," *ibid.*, 1840, *24*:136–180.

[53] *Bull. Acad. Roy. Me´d.*, 1841, *6*:865 (session of 13 July 1841).

France, in spite of the authoritative report from the Academy of Sciences, the idea was used in court during the 1840s. In 1844, during a poisoning trial in which Flandin and Danger participated as toxicologists, the judge asked Flandin whether the "small quantity of arsenic" that had been found in the victims' corpses "could be normal arsenic." Flandin responded that, after the report of the Academy of Sciences, no chemist still believed in the existence of normal arsenic.[54] Scientific debate on the very existence of other "normal" poisons endured for many years. Relying on the experiments with normal arsenic, toxicologists such as Flandin and Danger argued that poisonous substances could not exist in the healthy human body. Others, such as Orfila and Jules Barse, supported the opposite view and affirmed that several normal poisons (such as copper and lead) had already been found. The debate came to a head during the Pouchon affair (1842), in which a large amount of lead was found in the victim's corpse and the experts discussed whether lead might be a normal constituent of the human body.[55]

In other countries, Orfila's experiments met with skepticism and in some cases were reviewed in full and criticized by toxicologists. In Britain, George Owen Rees (1813–1889), head of the chemical laboratory at Guy's Hospital in London, repeated the analysis of large quantities of human bones and did not obtain any traces of arsenic. Well aware of the importance of the issue for legal medicine, he looked for some explanation of Orfila's results, suggesting possible misleading chemical reactions or contamination in reagents and vessels. "Notwithstanding my high estimation and respect" for Orfila, affirmed Rees, "I could not resist the conclusion that his great fame as a philosopher had betrayed him into something like boldness on the one hand, and carelessness on the other." In spite of this early criticism and the circulation of the report of the Academy of Sciences, the concept of normal arsenic survived for a long time in British courtrooms. Speaking in 1848, the famous British toxicologist Alfred Swaine Taylor affirmed: "It is singular how long an error in Medical Jurisprudence, when once diffused, will continue to find circulation . . . although the experiments upon which it was based may have been long since refuted." "No case of poisoning by arsenic now comes to trial," he continued, "in which the most ingenious objections founded upon [Orfila's] first and incorrect experiments are not urged to the chemical evidence of the presence of the poison." As Ian Burney remarks, the controversies surrounding normal arsenic exerted their greatest influence in Britain; they were used as a warning against importing foreign enthusiasms into native medico-legal practice and in support of local British practices against those of the Continent. Taylor also used normal arsenic for rhetorical ends during the famous William Palmer affair. In other cases, commentators pointed to the mistakes surrounding normal arsenic in order to stress the contingency of chemical knowledge and its possible unreliability when used in trials.[56]

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[54] *Journal de Me´decine, de Chirurgie et de Pharmacie*, 1845, *3*:195. See also Flandin, *Traite´ des poisons* (cit. n. 53), Vol. 1, pp. 665–684.

[55] Mateu Orfila, "Affaire d'empoisonnement par un compose´ de plomb," *Ann. Hyg. Publique Me´d. Le´gale*, 1844, *31*:131–294. See also Jules Barse, "De l'existence du plomb et du cuivre contenus dans l'e´conomie de l'homme," *Journal de Chimie Me´dicale*, 1843, *9*:571–581; Alphonse Devergie, "Note adresse´e a` l'Acade´mie des Sciences sur le cuivre et le plomb naturellement contenus dans les organes de l'homme," *Ann. Hyg. Publique Me´d. Le´gale*, 1845, *33*:142–150; and F. P. Danger and C. Flandin, "De l'empoisonnement par le cuivre," *Compt. Rend. Acad. Sci.*, 1843, *17*:153–157.

[56] See George Owen Rees, "On the Existence of Arsenic as a Natural Constituent of Human Bones," *Guy's Hospital Reports*, 1841, *6*:163–171, quoted in N. G. Coley, "George Owen Rees, MD, FRS (1813–89): Pioneer of Medical Chemistry," *Med. Hist.*, 1986, *30*:173–190, on p. 181; Alfred S. Taylor, *On Poisons in Relation to Medical Jurisprudence* (London: J. Churchill, 1848), p. 350, quoted in Ian Burney, "Bones of Contention: Mateu

The discovery of normal arsenic had been reported very early in German journals, but influential authors such as Johann Andreas Buchner (1783–1852) cast doubts on Orfila's conclusions, pointing out possible sources of impurities and misleading results. Additional doubts were raised some months later by a professor at the University of Kiel, Christian Heinrich Pfaff (1773–1852). Pfaff, who had already published some papers on the Marsh test, performed several analyses on human bones and could not obtain any trace of normal arsenic; he suggested that Orfila's results were produced by the reduction of tin oxide found in the porcelain vessels, which could yield misleading arsenic-like black stains in the Marsh apparatus. In early 1842 the pharmacists A. G. Hirsch and Adolf Duflos published a long book with a full review of the toxicology of arsenic; they discussed their own experiments that failed to find normal arsenic, which led them to the categorical conclusion that "bones do not contain any normal arsenic." The report of the Paris Academy of Sciences, summarized at the end of this book, just confirmed the skepticism of German toxicologists regarding normal arsenic. The episode was employed by Hugo Reinsch (1809–1884) to underline the dangers of the Marsh test and to support his own method for arsenic research, which became one of the most important nineteenth-century toxicological tests.[60]

In other countries, the concept of normal arsenic survived for many years in toxicological textbooks. The most famous nineteenth-century toxicologist in Spain, Pere Mata i Fontanet (1811–1877), who studied with Orfila in Paris, included the discovery of normal arsenic in several of the textbooks that he published during the late 1840s. In 1844 he affirmed that "arsenic exists in the human body in normal conditions," as "Cuerbe [*sic*] and Orfila have proved." He never changed his mind and continued to defend the existence of normal arsenic in other successful textbooks published during the 1860s and 1870s.[61]

This discussion shows that the controversy traveled all over Europe and involved a large and heterogeneous group of active participants, not only experts from different backgrounds (physicians, pharmacists, chemists, and so forth) but also judges, lawyers, journalists, and the general public who crowded the courtrooms during famous poisoning trials. This hybrid and extended scenario explains why the controversy did not reach a decisive resolution, even after the authoritative report of the Paris Academy of Sciences. However, in spite of exceptional cases such as Pere Mata's textbooks, by the end of the 1870s normal arsenic had almost completely disappeared from the scientific and legal arena. In 1884, a popular textbook written by the surgeon and barrister Alexander Wynter Blyth (1844–1921) included a single line on normal arsenic in a long chapter on arsenic poisoning. Blyth merely affirmed that "Conie`rbe [*sic*] and Orfila have both asserted that arsenic is a normal constituent of the bone—a statement which has been repeatedly

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Orfila, Normal Arsenic, and British Toxicology," in *Chemistry, Medicine, and Crime*, ed. Bertomeu-Sánchez and Nieto-Galan (cit. n. 3), pp. 243–261, on p. 255; and Burney, *Poison, Detection, and the Victorian Imagination* (cit. n. 2), pp. 100–104.

[60] A translation of Orfila's paper on normal arsenic was published in *Zeitschrift fu¨r die Staatsarzneikunde*, 1840, *20*(3):180–209. For the German reactions to reports on normal arsenic see Johannes A. Buchner, "Orfilas Entdeckung des arseniksauren Kalkes in menschlichen Knochen," *Rep. Pharmacie*, 1839, *17*:123–126; Christian H. Pfaff, "Briefliche Mittheilungen [u¨ber] Orfilas vermeintliche Entdeckung des Arseniks in Knochen," *ibid.*, 1841, *24*:106–108; Adolf G. Hirsch and Adolf Duflos, *Das Arsenik* (Breslau: Hirt, 1842), pp. 43–48; and Hugo Reinsch, *Das Arsenik* (Nuremberg: Schrag, 1843), pp. 43–44.

[61] Pedro Mata, *Vademecum de medicina y cirug´ıa legal* (Madrid: Manini, 1844), p. 636; and Mata, *Tratado de medicina y cirug´ıa legal* (Madrid: Bailly-Ballie`re, 1874–1875), pp. 1065–1066. At the beginning of the twentieth century the information on normal arsenic was revised in the posthumous edition of the *Tratado* (Madrid, 1903–1904), Vol. 4, pp. 301–311.

disproved."[57] It seemed, by the end of the 1870s, that the slow dispersion of technical and administrative "fixes," starting with the report of the Paris Academy of Sciences in 1841, had brought the long debate on normal arsenic to an end. But, as in other techno-legal controversies, the closure was not permanent: at the end of the nineteenth century, the new findings of Armand Gautier and Gabriel Bertrand changed the scenario yet again, moving the story of normal arsenic to a new disciplinary field.

EPILOGUE: REDISCOVERING NORMAL ARSENIC, 1876–1905

The history of normal arsenic took a new turn during the last third of the nineteenth century. In a paper published in 1876, Armand Emile Justin Gautier (1837–1920), who became professor of chemistry at the Paris Faculty of Medicine in 1884, suggested new methods for the destruction of organic substances by using nitric acid, addressing a very old problem posed by the use of the Marsh test. His research on arsenic arose owing to his interest in the pharmacology of arsenical compounds, particularly cacodylic acid. He introduced a quantitative approach to identify the organs in which arsenic was fixed, and he noted the presence of high quantities of arsenic in the thyroid gland even in persons who had not been poisoned. His quantitative approach allowed him to establish a difference between normal and criminal arsenic: he determined that normal arsenic was found only in very small quantities and in particular parts of the body. The new findings were regarded not so much as a challenge to toxicologists but, rather, as an important contribution to pharmacology and nutrition science. In the paper he read at the Academy of Sciences, Gautier urged his colleagues to study the physiological role of substances such as arsenic, which were components of the human body but present only in very small quantities. And he claimed that this research heralded "a completely new biological chemistry" that was "full of promise for the future."[58]

The rediscovery of normal arsenic was received with skepticism. In the following years, several authors attempted to replicate Gautier's experiments, but not all of them obtained normal arsenic. Some argued that the source of normal arsenic was contamination by industry, soils, and so on—in other words, that arsenic was not a normal ingredient of the human body.[59] The issue was analyzed in depth at the beginning of the twentieth century by Gabriel Bertrand (1867–1962), who had recently been appointed head of the Department of Biological Chemistry at the Pasteur Institute in Paris. He concluded that the differences in the results were due not to industrial contamination but to the sensitivity of the Marsh test and to the varying purity of the reagents used. In order to gather evidence for his views, he planned a field research project with the support of Prince Albert I of Monaco, who participated in many oceanographic studies. Prince Albert invited Bertrand on board his yacht the *Princesse Alice*, and together they collected many marine specimens far away from industrial centers, even venturing into the Atlantic. Bertrand also analyzed birds and even a sheep they found in the Azores. He designed a special apparatus for performing his analyses at sea and repeated the trials on his return to Paris. The results confirmed that

[57] Alexander Wynter Blyth, *Poisons: Their Effects and Detection* (London: Charles Griffin, 1884), p. 531.

[58] Armand Gautier, "Sur la recherche et le dosage de l'arsenic dans les matie`res animales," *Annales de Chimie et de Physique*, 1876, *7*:384–410; and Gautier, "Sur l'existence normale de l'arsenic chez les animaux, et sa localisation dans certains organes," *Compt. Rend. Acad. Sci.*, 1899, *129*:929–936, on p. 935. See also Gautier, "Origines alimentaires de l'arsenic normal," *ibid.*, 1904, *139*:101–108.

[59] Armand Gautier, "L'arsenic existe normalement chez les animaux et se localise surtout dans leurs organes ectodermiques," *Compt. Rend. Acad. Sci.*, 1902, *134*:1394–1399. For a review of the debate see Adolf Schmidtmann, *Handbuch der gerichtlichen Medizin* (Berlin: Hirschwald, 1905–1907), pp. 913–917.

normal arsenic was present even in animals that had never been exposed to any imaginable source of contamination. Bertrand published the results in a series of studies supported by the Monaco government; he continued to work on the topic in the following years and discovered other "trace elements," which he called "oligoelements." Thanks to Bertrand, normal arsenic moved from toxicology to the quieter waters of nutrition science, but a great deal of uncertainty continued to surround its physiological role, the sources of safe dietary intake, and the levels at which it became toxic.[60]

CONCLUSIONS

Normal arsenic was rediscovered in a new disciplinary context. The main interests of Gautier and Bertrand were pharmacology and nutrition science rather than toxicology. Moreover, the nature of the debate had changed substantially from the 1840s to the 1900s. Not only had a new quantitative approach been introduced by Gautier, but the risks and goals of his work were also different. In the early days, Orfila's initial research was motivated by his participation as a medical expert in poisoning trials at the end of the 1830s. The skeptical atmosphere of the law court was a breeding ground for controversies: priority disputes, heated academic debates, and disagreements between experts in the courtroom. The controversy took on a life of its own and was exploited for a broad range of purposes both before and after the issue of normal arsenic had been settled by an authoritative report of the Paris Academy of Sciences.

This discussion highlights the complex process of the dispersion of forensic techniques such as the Marsh test and also their malleable design. It questions the diffusionist image of the "same" techniques moving from an idealized basic research laboratory to the sites of forensic application.[61] The Marsh test was substantially transformed when it moved from Britain to France and was adapted by Orfila to meet his own research interests in the absorption of poisons, work with promising theoretical and practical consequences for physiology and toxicology. This study also challenges the heroic narratives of the history of toxicology, which see the development of the discipline as a steady progression toward increasingly sensitive, selective, and rapid methods. The Marsh test provided a very fast, highly sensitive method for detecting minute quantities of arsenic. However, as we have seen, its high sensitivity gave rise to a wide range of deconstructing arguments developed by the creative minds of authors such as Rognetta and Raspail, who were able to play an adversarial role vis-a`-vis other expert witnesses such as Orfila in the inquisitorial legal system of nineteenth-century France. Defense attorneys took every available chance to obtain expert advice for their clients by means of letters, public assessments, or visits to specialists.

In this skeptical atmosphere, Orfila's prudence in communicating the uncertainties surrounding his new method and the alarming issue of normal arsenic is easy to understand. The information provided by Couerbe was secretly preserved in several sealed notes that were not opened until Orfila had found a way to distinguish between normal and absorbed arsenic (it soon turned out to be a fallacious solution, but it worked for several years). It

[60] Gabriel Bertrand, *Recherches sur l'existence normale de l'arsenic dans l'organisme* (Monaco: Imprimerie de Monaco, 1903). See also World Health Organisation, *Trace Elements in Human Nutrition and Health* (Geneva: WHO, 1996), pp. 217–218. For a popular account dealing with the "sociochemistry" of arsenic see William R. Cullen, *Is Arsenic an Aphrodisiac? The Sociochemistry of an Element* (Cambridge: Royal Society of Chemistry, 2008).

[61] On this point see Lynch *et al.*, *Truth Machine* (cit. n. 4), pp. 83–112; see esp. pp. 86–98 on the dispersion of the "same" forensic techniques.

would be misleading, however, to qualify the situation as an example of "junk" or "pathological" science. On the contrary, the exceptional story of normal arsenic uncovers many common features of the everyday activity of nineteenth-century toxicologists.

Toxicologists were involved in complex communicative activities addressed not only to their colleagues but also to lay audiences such as judges, attorneys, and juries. Their results had to be expressed in a way that was both comprehensible to nonscientific minds and authoritative enough to meet the high standards of proof expected in criminal trials. At first sight, the Marsh test seemed to be better suited to this purpose than the preexisting chemical tests. By reducing arsenic to its metallic state, toxicologists like Orfila could claim to present the real *corpus delicti* in its material form: the arsenical black spots yielded by the Marsh test in porcelain vessels or glass tubes seemed to be irrefutable evidence, unlike the data produced by reagent tests, clinical symptoms, or autopsies, which were beyond the understanding of laypeople. In other words, the Marsh test provided compelling evidence that seemed to reduce the interpretative role of experts and enhanced the factual nature of expert reports, in tune with the expectations of judges and examining magistrates keen to "reduce the role of the expert to the domain of facts."[67]

However, this analysis has shown a more complex scenario, which offered many opportunities to deconstruct the toxicologists' claims about the purely empirical character of the black spots obtained by means of the Marsh test. These critical issues included the large number of possible sources of contamination in vessels, reagents, or even graveyards and the discovery of many substances that could produce misleading, arsenic-like black spots in the Marsh apparatus. But, as Orfila recognized, normal arsenic was perhaps the strongest challenge to the reliability of the Marsh test, and it was widely used by the defense in courts, even many years after it had been dismissed by the scientific community. So it is easy to understand why Orfila offered such tiny snippets of information about normal arsenic during the first years of his investigations.

After his initial enthusiasm for the Marsh test, Orfila very soon acknowledged that its enhanced sensitivity made mandatory a new culture of purity that was very difficult to transport from his laboratory to autopsy halls and courtrooms. This was a problem more related to the nature of toxicological work than to some unforeseen pitfall of the test itself. Gabriel Bertrand's wonderful voyage in search of remote and uncontaminated specimens offers a good example of how the issue could be successfully tackled in other disciplinary arenas. Yet no *Princesse Alice* was waiting for nineteenth-century toxicologists, who never had full control over their working spaces, specimens, or research agendas. Nineteenth-century toxicology took place in a complex context that included laboratories, academies, courtrooms, and, sometimes, political offices. The questions raised in the courts by lawyers and judges encouraged toxicologists like Orfila to perform new animal experiments in order to refine their methods and gain credibility and authority. The poisoning trials were also a source of relevant information for toxicologists, who gathered large amounts of unique clinical and chemical data when preparing their expert reports. Access to these data was crucial for Orfila in the midst of the controversies concerning normal arsenic and other sources of impurities.

Nineteenth-century courtrooms were not only skeptical spaces in which scientific claims might be deconstructed (for instance, claims about the reliability and sensitivity of

[67] On the "cantonnement de l'expert dans le domaine du fait" see Leclerc, *Le juge et l'expert* (cit. n. 3).

the Marsh test), but also centers for the production of new empirical data through their prompting of clinical studies, autopsies, chemical analysis, and research on problems such as those related to contaminated reagents, arsenical soils, and normal arsenic. Some of these problems were never thoroughly resolved during the trials but sparked expert controversies that were settled, over time, in academic institutions. In contrast to other cases, the episode analyzed here reveals the limitations of the deconstructive power of the law when dealing with cutting-edge science: the highly controversial poisoning trials *could not* "render transparent domains of contingency"—in our case, the uncertainties caused by normal arsenic—which were eventually brought to light by "science's culturally bounded querying procedures"—that is, those of the Paris Academy of Sciences.[62]

So the story of normal arsenic is a good example of the wide but complex circulation of knowledge, objects, and practices (but also uncertainties and controversies) between the courtrooms and academies that characterized nineteenth-century toxicology. Normal arsenic was accepted as a matter of fact by the experts, who contradicted each other on many other issues during the Mercier and Lafarge trials. Skeptical experts such as Raspail and Rognetta highlighted many possible problems with the Marsh test, but they never questioned the existence of normal arsenic—which, as Orfila remarked, offered many opportunities for undermining the incriminatory value of chemical tests. The only issue discussed during the poisoning trials was the possibility of making a real distinction between normal and absorbed arsenic. The very existence of normal arsenic was questioned, however, by chemists (some of whom lived in other countries) who did not participate as expert witnesses in these trials. Finally, many months later, the issue was fully reviewed by a special commission of the most powerful French scientific institution, the Paris Academy of Sciences. The report included mostly technical (but also administrative) "fixes" in order to bring the controversy surrounding the Marsh test to a close. However, the final conclusion—namely, that normal arsenic was an experimental error—confirmed that earlier concerns about the possible failures of the Marsh test were far from simple products of skepticism and antagonism, thus highlighting the risk of judicial mistakes when experts played the role of judges in criminal trials. In this way, normal arsenic also contributed to the long-lasting controversy over the boundaries between the roles of experts and judges in the French legal system.

Moving from the general discussion about science and the law to the more mundane details of this story, one cannot help but note some obscure points about normal arsenic that Orfila never fully clarified. The full review of the academy's commission and Orfila's subsequent experiments did not provide any satisfactory explanations for the experimental errors that led many toxicologists—not only Orfila—to accept normal arsenic for a number of years. Perhaps the real sources of normal arsenic were not the bones but some unnoticed impurities in the reagents used by Orfila? Or maybe, as other toxicologists argued, Orfila never obtained real arsenic from human bones, but only some misleading arsenic-like black spots? And perhaps we should see normal arsenic not as a mistake, but as a pioneering discovery of a trace element *avant la lettre*? Underlining the tensions between science and the law, the history of normal arsenic will probably remain "one of the most impenetrable mysteries" of nineteenth-century toxicology.[63]

[62] The quotations draw on Jasanoff, *Science at the Bar* (cit. n. 2), p. 214. See also Lynch *et al.*, *Truth Machine* (cit. n. 4), pp. 18–20, on the practical and circumscribed character of "courtroom deconstruction."

[63] "Avouons qu'il y a dans ce qui concerne l'histoire de l'arsenic dit *normal* un myste`re des plus impe´ne´trables": Orfila, *Traite´ de toxicologie* (1852) (cit. n. 53), pp. 547–548.