GERALD L. GEISON

The Private Science of Louis Pasteur

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The Private Science of LOUIS PASTEUR

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Gerald L. Geison

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For Christopher and Andrew

MY FAVORITE SONS

[Pasteur] was the most perfect man who has ever entered the Kingdom of Science.

—STEPHEN PAGET, *Spectator* 1910

. . .

Rarely . . . has history been so falsified—and with so much impudence.

—PHILIPPE DECOURT, "Deuxième lettre à nos amis" 1975

. . .

In France, one can be an anarchist, a communist or a nihilist, but not an anti-Pastorian. A simple question of science has been made into a question of patriotism.

—AUGUSTE LUTAUD, *Pasteur et la rage* 1887

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Preface

FROM THE DAY I began this project, I have been asked why we needed yet another study of Louis Pasteur His career had already been fully described so many times, beginning with the standard two-volume biography by his son-in-law, Rene Vallery-Radot, published in French in 1900 and translated into English a year later

My response was and is fourfold First, Rene Vallery-Radot's standard biography, for all of its detail and other virtues, is hagiographic through and through, and much of the subsequent biographical literature is derivative and similar in tone Second, the last major—in fact still the best—scientific biography of Pasteur, Rene Dubos's *Louis Pasteur Free Lance of Science*, was published almost half a century ago, in 1950 Third, none of the book-length biographies of Pasteur meet current scholarly standards, even Dubos's widely admired book lacks footnotes or other scholarly apparatus, so the sources of his insights are often obscure Fourth, and most important by far, students of the Pastorian saga can now draw on a vast collection of manuscript materials deposited at the Bibliotheque Nationale in Paris This stunning archival collection became generally available to scholars as long ago as the mid-1970s, but surprisingly little use has been made of it thus far Particularly revealing, I think, are the one hundred or so unpublished laboratory notebooks Pasteur left behind, and they serve as crucial sources for the reassessment of his life and career that this book represents

Long ago, I decided not to publish the results of my archival research in isolated bits and pieces Of the chapters that follow, none has appeared in precisely this form Parts of the book, especially Chapter Two, do make liberal use of my essay on Pasteur in the *Dictionary of Scientific Biography*, published in 1974, before I had begun my archival research Chapter Three, on Pasteur's discovery of optical isomers, is a slightly revised version of an article published by James Secord and me in *Isis* in 1988 In fact, that article was based largely on Jim's research on Pasteur's very first (and still unpublished) laboratory notebook, and I am deeply grateful to him for allowing me to repeat so much of that article here Parts of Chapter Five, on the spontaneous generation debate, are adapted from an article that John Farley and I published in 1974 in the *Bulletin of the History of Medicine*, and I am most grateful to John for permission to make use of our collective effort here The other chapters, except for scattered passages, are wholly new, published here for the first time

In the course of producing this book, I have accumulated a heavy burden of debt to a host of people and institutions So long is the list that I have saved it for a separate entry on Acknowledgments at the end of the book By then, I hope my creditors will still be glad to be mentioned there, they are of course absolved of any responsibility for defects in the book There is, however, one debt so large and so overdue that I must acknowledge it here For the plain fact is that this book would never have seen the light of day without the inspiring scholarly example and patient support of my mentor, Larry Holmes

Princeton, New Jersey
August 1994

PART I

Background and Context

ONE

Laboratory Notebooks and the Private Science of Louis Pasteur

IN 1878, WHEN he was fifty-five years old and already a French national hero, Louis Pasteur told his family never to show anyone his private laboratory notebooks [1] For most of a century those instructions were honored Pasteur's notebooks—like the rest of the manuscripts he left behind at his death in 1895—remained in the hands of his immediate family and descendants until 1964 In that year, Pasteur's grandson and last surviving direct male descendant, Dr Pasteur Vallery-Radot, donated the vast majority of the family's collection to the Bibliotheque Nationale in Paris [2] But access to this material was generally restricted until Vallery-Radot's death in 1971, and there was no printed catalog of the collection until 1985 [3]

The Pasteur Collection at the Bibliotheque Nationale is stunning in its size and significance It is a tribute not only to Pasteur's own awesome productivity as scientist and correspondent, but also to the tireless efforts of Pasteur Vallery-Radot, who greatly increased the size of the initial family collection by gathering additional correspondence and manuscripts by and about his grandfather from every conceivable source There are, to be sure, other significant collections of manuscript materials by or relating to Pasteur—at the Academie des sciences and the Archives Nationales in Paris, for example, or at the Wellcome Institute for the History of Medicine in London, and at the National Library of Medicine in Bethesda, Maryland, in the United States But the collection at the Bibliotheque Nationale is the largest and most important by far

As now deposited in the Salle de Manuscrits at the Bibliotheque Nationale, the Papiers Pasteur includes fifteen large bound volumes of correspondence by, to, or about Pasteur Another fifteen volumes contain lecture notes, drafts of published or unpublished manuscripts, speeches, and

related documents Most important, the Papiers Pasteur includes a meticulously preserved collection of more than 140 notebooks in Pasteur's own hand, of which more than one hundred are laboratory notebooks recording his day-to-day scientific activities over the full sweep of his forty years in research Until these manuscripts are deciphered, edited for publication, and subjected to critical scrutiny, our understanding of Pasteur and his work will remain incomplete There is no prospect that this monumental task will be accomplished anytime soon, not even with the stimulus of the centenary of Pasteur's death in 1995 Indeed, the task has not even begun in any systematic way, and a full and proper edition of Pasteur's papers and manuscripts will require a massive investment of time and resources

For the foreseeable future, we shall have to contend with a vast reservoir of unedited and unpublished manuscripts True, Pasteur Vallery-Radot long ago published a small but significant sample of the collection, including notably a four-volume selection of Pasteur's correspondence [4] Some of these letters, when read critically in the light of other sources, already reveal a Pasteur who was more complex and interesting than he has been seen, or indeed wished to be seen Yet even these published letters have been surprisingly under-utilized by students of Pasteur's career They have done little to add nuance or depth to the standard Pastorian legend In the popular imagination, Pasteur remains the great and selfless "benefactor of humanity" who single-handedly slashed through the prejudices of his time to discover a set of scientific principles unmatched in their impact upon the daily lives and well-being of humankind

But as the centenary of Pasteur's death approached, his oft-examined career attracted still greater attention, some of it more critical than the usual celebratory accounts Much of the revaluation now underway has focused on Pasteur the man, whose human foibles and difficult personality have never been entirely absent from the published record but are now gaining wider publicity But Pasteur the scientist is also being subjected to the more systematic critical scrutiny that his importance and influence deserve That is not to suggest that Pasteur's life can be neatly divided into its scientific and nonscientific aspects In some ways, his scientific style seems a virtual extension of his personality, and one theme of this book will be that his scientific beliefs and modus operandi were sometimes profoundly shaped by his personal concerns, including his political, philosophical, and religious instincts

As this book unfolds, it will become clear how much the standard Pastorian legend needs to be qualified, even transformed That point will be made most explicitly in the last chapter, "The Myth of Pasteur," which will also serve as a bibliographical essay of sorts Long before that last chapter, how-

ever, the standard Pastorian saga will begin to unravel For now, I want only to emphasize that the most important revelations in this book are the result of focusing on what I have chosen to call "the private science of Louis Pasteur "

PRIVATE SCIENCE AND LOUIS PASTEUR

The choice of this phrase for the very title of this book deserves a preliminary discussion and justification, if only because some readers may consider it a contradiction in terms If, as many assume, the very definition of science implies a public (usually published) product—if, as Charles Gillispie has written, "science is nothing until reported," or if, in Gerard Piel's words, "without publication, science is dead"[5]—whatever can "private science" mean?

The notion of private science is indeed problematic, and not only in the sense that these commentators probably have in mind Strictly speaking, there may be no such thing as purely private science or knowledge—or even a purely private thought Even the most solitary scientist is heir to a tradition of thought, practices, techniques, training, and social experiences Perhaps this was part of what the Victorian physicist John Tyndall had in mind when he wrote in 1885, in his introduction to the English translation of the first biography of Pasteur, that "[t]he days when angels whispered into the hearkening human ear, secrets which had no root in man's previous knowledge or experience, are gone for ever "[6] Tyndall's immediate purpose was to convey his inductivist skepticism toward the alleged role of "preconceived ideas" in Pasteur's research, but his general point can be extended to the realm of seemingly private thoughts or practices of any sort

For, in fact, there is always a continuum between private thought or practices and public knowledge, whatever the field The thoughts of the individual scientist alone in his or her study or laboratory will perforce be filtered not only through an inherited tradition, but also through the scientist's *anticipations* of audience response to the communication of those ideas The scientist will always be aware that the anticipated audience may be large or small, friendly and receptive, or skeptical or hostile According to the Russian cultural critic Mikhail Bakhtin (1895–1978), thought itself is nothing but "'inner speech,' or social conversations we have learned to perform in our heads " On this view, "when we think, we organize possible 'dialogues' with other people, whose voices and implicit social values live within us "[7] One might even say that something like a "sociology of the mind" is always at work As we shall see in the case of Pasteur, and as the famous example

of Darwin amply reveals, this sociology of the mind can temper, modify, repress, or forever silence a "passing thought "[8]

Similarly, the "private" correspondence of a scientist (or anyone else) is obviously written with at least one recipient in mind In the case of famous correspondents, including the mature Pasteur, some presumably private letters are clearly also being addressed to that larger audience known as "posterity" More generally, as Stephen Jay Gould has suggested, there is little reason to suppose that "private letters somehow reveal the 'real' person underneath his public veneer " This common notion, says Gould, is a "misplaced, romantic Platonism"

> People have no hidden inner essence that is more real than their overt selves If [a scientist] reacted one way to most people in public life, and another to his sister in letters, then the public man is most of the whole We meet a different [scientist] in these letters, not the truer core of an essential personality These letters do not show us the real man They simply remind us once again that people have the damnedest ability to compartmentalize their lives, one can be a fine statesman and a cad at home, a financial genius and an insensitive lout, a lover of dogs and a murderer of people [9]

Gould's point can be extended to private documents of any sort, including even laboratory notebooks They may provide revealing insights into a scientist and his or her work, but they do not offer uniquely privileged access to the "real" story as opposed to the public "myth " In the case at hand, Pasteur's public performances must also be incorporated into our understanding of him and his science, as with any other social actors and their work

"Private science" becomes a still more problematic category when the research involves assistants and collaborators, as it did throughout much of Pasteur's career (and as it does in most modern laboratory research) Even Pasteur, despite his secrecy and "Olympian silence" about the direction of his research, could not always conceal his work or thoughts from his closest collaborators [10] And a few of them did not always and forever honor Pasteur's stricture that the research carried out in his laboratory should remain a totally private affair within the Pastorian circle unless and until he chose to disclose the results himself or specifically authorized others to do so True, Pasteur's collaborators did honor this demand to a degree that may seem astonishing in our less discreet world, and nearly all of them continued to do so even after the master's death But there is evidence to suggest that these severe restrictions on public disclosure did not always sit well with some of Pasteur's assistants and co-workers By 1880, for example, Emile Roux, his major collaborator in research on anthrax, rabies, and other diseases, was warning Pasteur that outsiders had begun to regard his labora-

tory at the Ecole Normale as a "mysterious sanctuary"[11] Eventually, the veil of secrecy was pulled back in part, most notably in the anecdotal reminiscences of Pasteur's own nephew and sometime personal research assistant, Adrien Loir, who did, however, wait half a century to publish his revelations in a widely ignored series of essays that carried the apt title, "In the Shadow of Pasteur"[12]

One could raise still other objections to the whole notion of "private science," but I will proceed as if the term embodies a meaningful distinction Throughout this book, I will use the term "private science" in the informal sense of those scientific activities, techniques, practices, and thoughts that take place more or less "behind the scenes" That definition might be less appropriate in the case of a scientist whose activities and career were less theatrical than Pasteur's, but his carefully orchestrated public performances invite a close examination of the private dress rehearsals Finally, I should stress that my notion of "behind the scenes" is not restricted to activities and thoughts that were literally kept out of public view, but will occasionally be extended to matters that can be found in the published record if one looks hard enough, but have been lost from that collective public memory represented by the standard Pastorian legend

This approach means, among other things, that I will sometimes highlight relatively obscure features of Pasteur's published papers or correspondence, and will pay much closer attention than usual to some of the supporting cast, including a few of the once public but now mostly forgotten critics of the star Nonetheless, the most striking revelations come when one brings to center stage some of the activities and ideas recorded only in Pasteur's unpublished manuscripts This book makes selective use of the full range of the manuscript materials that Pasteur left behind In the most dramatic cases, however—including Pasteur's crowning work on vaccines against anthrax and rabies—the crucial evidence will come from his laboratory notebooks It is therefore worth saying something now about my attitude toward these very special documents

PASTEUR AND HIS LABORATORY NOTEBOOKS

The most private of the manuscript materials Pasteur left behind are the 144 holographic notebooks that his grandson donated to the Bibliotheque Nationale in 1964 Of these 144 notebooks, 42 fall outside the category of laboratory notebooks, consisting instead of collections of newspaper clippings, draft sketches of projected books that never appeared, lecture outlines, and reading and lecture notes The remaining 102 notebooks represent the most precious documents in the Papiers Pasteur They consist of

careful and detailed records of experiments carried out by Pasteur and his collaborators during forty years of active, almost daily research They are the central repository for the private science of Louis Pasteur, the documents he once asked his family to keep forever out of public view During his lifetime, he carefully guarded them from others, including his closest collaborators Even when he left Paris for trips or holidays, Pasteur took the most current of the laboratory notebooks with him His co-workers sometimes experienced inconvenience or worse because of his insistence on total control of the notebooks

In late November 1886, for example, while Pasteur was resting at a villa on the Italian Riviera for the sake of his fading health, his collaborators in Paris were suddenly faced with a legal problem connected with the death of a boy who had undergone the Pastorian rabies treatment (a story to which we shall return in Chapter Nine) As we know from his retrospective personal testimony, Pasteur's nephew-assistant Adrien Loir had to be dispatched quickly to Italy in order to retrieve important details about the boy's treatment—information that was recorded only in a laboratory notebook the master had taken with him to the Italian villa [13] Earlier, in July 1883, when Emile Roux wanted to gather together some of the results of his important work on rabies for his doctoral thesis, he had to seek Pasteur's permission to use information recorded in the laboratory notebooks To ensure the master's assent, Roux promised to expose only those results already made known in a general way in Pasteur's published papers, submitted a draft version to the master for his corrections and revisions, and "inscribed your [i e , Pasteur's] name on the first page of this exposition of studies that belong to you "[14]

In 1896, a year after Pasteur's death, Roux gave a revealing, if surprisingly restrained, account of the master's proprietary attitude toward his laboratory notebooks Roux's account also deserves attention because it reveals the extent to which the work in Pasteur's laboratory had become a collaborative affair by the time Roux participated in it

> In order to be nearer the work, master and disciples lived in l'Ecole Normale Pasteur was always the first to arrive, every morning, at 8 o'clock, I heard his hasty step over the loose pavement in front of the room which I occupied at the extremity of the laboratory As soon as he had entered, a bit of paper and pencil in his hand, he went to the thermostat to take note of the state of the [microbial] cultures and descended to the basement to see the experimental animals Then we made autopsies, cultures and the microscopic examinations Then Pasteur wrote out what had just been observed He left to no one the care of keeping the experimental records, he set down most of the data which we gave him in all its details How many pages he has thus covered, with

his little irregular, close-pressed handwriting, with drawings on the margin and references, all mixed up, difficult to read for those not accustomed to it, but kept nevertheless with extreme care! Nothing was set down which had not been established, once things were written, they became for Pasteur incontestable verities When in our discussions, this argument resounded, "It is in the record book,' none of us dared to reply The notes being taken, we agreed upon the experiments to be made, Pasteur stood at his desk ready to write what should be decided upon

Then we spent the afternoon in making the experiments agreed upon Pasteur returned toward five o'clock He informed himself immediately of all that had been done and took notes, his notebook in hand, he went to verify the tickets fastened on the cages, then he told us of the interesting communications heard at the [Academie des sciences earlier in the afternoon] and talked of the experiments in progress [15]

As Roux reports, Pasteur did indeed keep a detailed and meticulous record of the experiments carried out in his laboratory I have never counted the pages that Pasteur filled with experimental data in his sometimes crabbed and microscopic hand, but they probably exceed ten thousand As some of the illustrations in this book suggest, the task of deciphering and interpreting Pasteur's entries is often daunting Like most laboratory notebooks, Pasteur's usually consist of bare records of experiments, with only occasional hints as to their aim or theoretical significance The meaning of such documents cannot begin to be grasped without an intimate familiarity with the scientist's published work Beyond that, their would-be interpreter should ideally possess a combination of skills akin to those of the paleographer, cryptographer, and mind-reader It is a species of detective work in which tantalizing clues too often lead to dead ends

But the effort is exhilarating as well as exhausting Words cannot fully convey the sense of excitement that comes from turning the pages of any one of Pasteur's laboratory notebooks It is as if one were looking over his shoulder as he designed and carried out experiments ranging from the trivial to the profound The laboratory notebooks form a virtually unbroken chain of documents that record Pasteur's day-to-day dialogue with a sometimes recalcitrant nature They are, I think, the most revealing of all the manuscript materials he left behind Perhaps that is to be expected, since Pasteur did after all spend most of his waking hours at work in the laboratory

To produce a detailed account of all of Pasteur's one hundred laboratory notebooks, several decades of work will surely be required I have therefore focused attention instead on a few episodes in Pasteur's career where there are distinct—and sometimes astonishing—discrepancies between the

results reported in his published papers and those recorded in his private manuscripts This approach is open to several objections It is one thing to be selective in order to reduce the task to manageable limits But why choose such special and possibly misleading criteria? If most of Pasteur's published accounts are consonant with his laboratory records, why focus on the exceptions? Can such an approach give us a balanced assessment of Pasteur's usual scientific practice? Will not the full range of his achievement be lost through such an episodic treatment of his career? And is this not an especially suspect approach at a time when so much public attention is being drawn to a few spectacular examples of real or alleged fraud in science?[16] Is even Pasteur to be swept up in the current fashion for muckraking exposes of science and its legendary heroes?

Only as this book unfolds can the reader begin to judge whether or how far these objections have been met But it may be useful to address them in a preliminary way even now In doing so, I will be able to clarify my aims and to insist on some of the virtues of my approach Let me emphasize at once that I have no intention of denying Pasteur's greatness as a scientist To be sure, my definition or conception of a "great scientist" may differ somewhat from the conventional For me, there is no reason to suppose that a great scientist must also display personal humility, selfless behavior, ethical superiority, or political and religious neutrality The historical record often enough reveals the opposite For me, past scientists are not great insofar as they were the "first" to advance concepts that look "right" in the light of current knowledge, nor insofar as they adhered to the precepts of an allegedly clear-cut Scientific Method that their lessers and rivals presumably violated For me, rather, past scientists are great insofar as they persuaded their peers to adopt their ideas and techniques and insofar as those ideas and techniques were fertile in the investigation and resolution of important research problems Pasteur was no exemplar of modesty, selflessness, ethically superior conduct, or political and religious neutrality Nor was he always "first," "right," or a rigorous practitioner of the Scientific Method as usually conceived But he was a remarkably effective and persuasive advocate for his views, and his concepts and techniques were immensely fertile in the pursuit of a wide range of important scientific and technical problems By these criteria, he deserves his reputation as one of the greatest scientists who ever lived

But let me turn, at greater length, to the more specific objection that it is misleading and unfair to adopt an episodic approach that emphasizes the "exceptional" discrepancies between Pasteur's published writings and his "private science " To begin with, the episodes on which I focus are far from trivial each concerns a major phase or turning point in Pasteur's research

Nor are they concentrated in any narrow field or period of his career. They span his active career and concern fields as varied as crystallography, molecular asymmetry, fermentation, spontaneous generation, vaccination and immunization, and veterinary and human medicine. The three episodes examined most closely here through the use of Pasteur's laboratory notebooks concern his first great discovery (of optical isomers in the tartrates), his most famous public experiment (the anthrax vaccination experiment at Pouilly-le-Fort), and his most famous achievement of all (the application of a rabies vaccine to human subjects). With the admittedly significant exception of his investigation of the silkworm diseases, the only major topics of Pasteur's research that receive no focused attention here are his conceptually undistinguished studies on the manufacture and preservation of vinegar, wine, and beer.

Nor is it likely that the discrepancies on which I focus are really exceptional. My sample is far from complete. Many additional examples will surely emerge as the entire corpus of Pasteur's notebooks is subjected to systematic analysis. On the other hand, it is crucial to emphasize that the discrepancies between Pasteur's public and private science do fall into two very different categories of very different significance.

LABORATORY NOTEBOOKS, SCIENTIFIC FRAUD, AND THE RHETORICAL CONSTRUCTION OF SCIENTIFIC KNOWLEDGE

Most of the discrepancies between Pasteur's public and private science are of a sort that will come as no great surprise to working scientists, or to anyone who has been attentive to recent historical scholarship on laboratory notebooks. To these audiences, it will be obvious that such discrepancies are part and parcel of the process by which "raw data" are transformed into published "results." In the interests of brevity, clarity, logical coherence, and rhetorical power, the published record always projects a more or less distorted image of what the scientist "really" did.

For some reason, laboratory notebooks were long overlooked by historians of science, but their virtues as a strategic site of inquiry have become evident in recent years. The recognition of their special value owes much to the pioneering work of M. D. Grmek and F. L. Holmes, both of whom used the laboratory notebooks of Pasteur's friend and contemporary, the great French physiologist Claude Bernard (1813–1878), to produce two brilliant and complementary books published twenty years ago. Grmek's book of 1973 focused on Bernard's work on poisons (notably curare and carbon

monoxide), while Holmes's book of 1974 gave an exhaustive account of Bernard's early research in digestive physiology[17] In the wake of these pathbreaking works, other valuable analyses of laboratory notebooks have already appeared—two striking examples being David Gooding's work on the notebooks of Michael Faraday (1791–1867) and Gerald Holton's investigation of the laboratory notes of the American Nobel laureate in physics, Robert Millikan (1868–1953) [18] But it is Holmes who has become the leading advocate and practitioner of the study of laboratory notebooks In the years since his book on Bernard, Holmes has produced comparably detailed and insightful analyses of the laboratory notebooks of the great eighteenth-century French chemist Antoine Lavoisier (1746–1794) and Nobel laureate biochemist Hans Krebs (1900–1981) of "Krebs Cycle" fame [19] We can surely expect other significant studies of this sort as historians uncover more examples of scientists who have earned our gratitude by preserving these traces of their daily work in the very special literary genre known as the laboratory notebook

Much remains to be done in this line of research But in every case thus far in which records of "private science" have been closely investigated, one can detect discrepancies of one sort or another between these records and published accounts Even the best scientists routinely dismiss uncongenial data as aberrations, arising from "bad runs," and therefore omit or "suppress" them from the published record Equivocal experiments are sometimes transformed into decisive results The order in which experiments were performed is sometimes reversed And the actual nature or direction of research is otherwise simplified, telescoped, and generally "tidied up " There is rarely anything sinister about such practices, rarely any intention to deceive, and their existence has long been recognized As long ago as the seventeenth century, Francis Bacon noted that "never any knowledge was delivered in the same order it was invented," while Leibniz expressed his wish that "authors would give us the history of their discoveries and the steps by which they have arrived at them "[20] From time to time ever since, scientists and others, including the influential American sociologist of science Robert K Merton, have drawn renewed attention to this "failure of the public record to record the actual course of scientific inquiry"[21]

More recently, analysts of the scientific enterprise have moved from expressions of regret about the discrepancies between private and public science to a recognition of their rhetorical import in the construction of scientific knowledge through the literary genre of the scientific paper In the case of Millikan, for example, Holton shows us a country bumpkin from rural Illinois who was initially so naive about the genre that he included *all* of his experimental data about the quantity of charge on the electron, supporting

his view of its unitary charge by publicly assigning more or fewer "stars" to what he considered good or bad runs Millikan was quickly enlightened by his experience and the advice of others, never again did he resort to public displays of his less persuasive data And Holton insists that Millikan's later published papers can actually be seen as "better" (i e , more persuasive) science than that represented in his first paper, with its needlessly candid full disclosures [22]

More recently still, Holmes has extended his approach beyond the analysis of laboratory notebooks to ask broader questions about the history of the practice of laboratory record keeping and its relation to the published record of science In the case of Lavoisier, Holmes has shown the extent to which a scientist's ideas can be altered in the very process of "writing up" the results from laboratory notebooks for publication, and in the case of Krebs he has had the rare opportunity of comparing his historical reconstructions of events from laboratory notebooks with Krebs's own recollections of his investigative trail In neither of these cases, nor in the case of Bernard, does Holmes suggest that his historical actors engaged in deliberately deceptive practices Instead, he maintains that Lavoisier, Bernard, and Krebs simply and wisely adopted the standard practices and rhetorical strategies that always intervene between private laboratory records and their effective and persuasive presentation in the public domain [23]

Against this background, it should be clear that Pasteur was not committing "scientific fraud" whenever his laboratory notebooks reveal a course of research different from that recorded in his published works Long before his day, and perhaps especially in France, the institutionalization of the scientific paper—its progressive codification into a formulaic literary genre—had reached a point that discouraged instructive disclosures of the sort Bacon and Leibniz once thought might emerge from a closer fit between private research and its public presentation [24] On Holmes's account, the institutionalized scientific paper did not (and does not) deliberately "suppress" uncongenial private data, but rather seeks to provide an efficient and authoritative public presentation of the most pertinent results to an expert audience with little need of elaborate additional detail [25] By Pasteur's day, a pattern of formulaic discrepancies between public and private science was already long-standing and widespread, if not overtly sanctioned

But the existence of this practice does not make such discrepancies insignificant or uninteresting, in Pasteur's case or any other Precisely because they were and are so common, these formulaic discrepancies deserve much closer attention To ignore or trivialize them is to miss the force of Peter Medawar's now-hackneyed warning that "scientific 'papers' [do] not merely conceal but actively misrepresent the reasoning that goes into the work they

describe "[26] As Medawar suggests, to rely solely on the published record is to distort our understanding and appreciation of science as it actually gets done The effect is impoverishing in several respects By making the results of scientific inquiry look more decisive and straightforward than they really are, the published record tends to conceal the pliability of nature It eviscerates science of its most creative features by conveying the impression that imagination, passion, and artistry have no place in scientific research It makes it seem as if scientific achievement and innovation result not from the impassioned activity of committed hands and minds, but rather from passive acquiescence in the sterile precepts of the so-called Scientific Method More specifically, as Medawar emphasizes, the published record tacitly endorses a naive and long-outmoded "inductivist" or "empiricist" philosophy of science, according to which scientific truth emerges from the innocent and unprejudiced observation of raw facts The superficially objective and dispassionate image of science thus conveyed is bought at the price of much of its zest and human appeal The construction of scientific knowledge is a much more interesting process than its published record suggests

There are, of course, those who insist that "genuine" scientific knowledge is independent of the process by which any particular scientist arrives at his or her conclusions In very different ways, philosophers and sociologists of science tend to be suspicious of historical studies of individual "scientific creativity" For philosophers in the tradition of Karl Popper, such studies seem to be pursuing a will-o'-the-wisp, an elusive "psychology of discovery," at the expense of a clear-cut "logic of justification " For them, the object of study is the published text, and the "scientificity" of a given text is to be assessed in terms of logical and methodological criteria that transcend particular individuals, particular social groups, or any contingent historical circumstances

For sociologists of knowledge, by contrast, studies of individual scientific activity run the risk of ignoring the extent to which scientific knowledge is a community affair—the outcome of a complex process of social negotiation On this view, scientific knowledge is constructed within a culturally limited space For some, the boundaries of that space are set by the broadly cultural "interests" of participants More recently, attention seems to have shifted to more sharply localized, "internal" material and technical constraints—a trend that may invite the risk (or opportunity) of a return to positivist or inductivist epistemologies

Often lost from sight in such theoretical discussions is the real individual scientist who tries to navigate a safe passage between the constraints of empirical evidence on the one hand and personal or social interests on the

other. To chart such individual passages is certainly to leave aside some important general issues about the nature and construction of scientific knowledge. Yet there remains a place for studies of individual scientists and their creative activity. To proceed as if scientific knowledge were somehow achieved all apart from the activity of individual scientists is itself a distortion of reality. For the historian, one way to reduce such distortions is to explore the process of scientific research as recorded day to day in surviving laboratory notebooks.

That is not to say—to repeat a point already made—that these private documents somehow permit direct access to the "real" work of the scientist. Even laboratory notebooks are incomplete *traces* of activity, much of which remains tacit, none of which can be observed directly, and all of which must be deduced from recorded inscriptions that are often difficult to decipher and interpret. Sociologists and anthropologists of knowledge have the advantage of being able to interview and observe participants *in the very process* of doing science, and some important results have already emerged from recent research along these lines. Responding—sometimes explicitly—to Medawar's challenge to subject science to "an ethological enquiry," to study what scientists actually *do* by "listening at the keyhole," some sociologists and anthropologists of science, notably Harry Collins and Bruno Latour, have uncovered important elements of what is variously called the "private," "personal," "tacit," or "craft" knowledge that is fundamental to the actual practice of science but finds few echoes in the published literature—or, for that matter, in unpublished laboratory notebooks. These sociologists or anthropologists can watch the scientist go about his or her "craftsman's work" and thus observe the nonverbal activity that accompanies and gives rise to verbal and other symbolic accounts. In short, they can go much further toward recovering the actual *activity* of science before it becomes encoded in fading and incomplete verbal or graphic "inscriptions," including laboratory notebooks.[27]

But if historians lack these advantages, they can be relatively sure that the episodes they choose to study are already known to be of special interest. Anthropologists of science may hang around a laboratory for a year or more and witness no obvious peaks of productivity. Historians, by contrast, can be selective in their choice of notebooks, which nonetheless bring them closer in time and place to the creative work of scientists than do any published results. At a minimum, laboratory notebooks give the historian another set of "texts" to read, and the work of Grmek, Holmes, Holton, and others has already provided ample evidence that a comparison of these "private" texts with the published literature can yield important insights of general significance.

In the spectacular case of Pasteur, we are fortunate to have a complete set of his unpublished laboratory notebooks—those one-hundred-odd tidy and meticulously preserved records of his day-to-day research By exploring his laboratory notebooks in the full context of his life, work, and social setting, we can gain unusual insight into the construction of scientific knowledge at the concrete level of an extraordinarily creative individual scientist

This book can only begin the task, and for the most part these more general concerns will only emerge implicitly Yet it should gradually become clear that some of Pasteur's most important work often failed to conform to ordinary notions of proper Scientific Method In particular, it will become clear that Pasteur sometimes clung tenaciously to "preconceived ideas" even in the face of powerful evidence against them And it should also eventually become clear just how far the direction of his research and his published accounts of it were shaped by personal ambition and political and religious concerns We will become aware of his ingenious capacity for producing empirical evidence in support of positions he held a priori In other words, one aim of this book is to show the extent to which nature can be rendered pliable in the hands of a scientist of Pasteur's skill, artistry, and ingenuity But it will also suggest that not even Pasteur's prodigious talent always sufficed to twist the lion's tail in the direction he sought Nature is open to a rich diversity of interpretations, but it will not yield to all

PASTEUR AND THE ETHICS OF BIOMEDICAL RESEARCH

These themes and issues continue to appear in the second part of the book, which concerns episodes in Pasteur's veterinary and biomedical research But now an additional focus begins to take center stage, and it relates directly to the second and very different category of discrepancies between Pasteur's public and private science Here we deal not with mere acquiescence in the formulaic genre of scientific papers and the associated "inductivist" image of science, but with discrepancies between Pasteur's public and private science in cases where the word "deception" no longer seems so inappropriate, and even "fraud" does not seem entirely out of line in the case of one or two major episodes These are serious allegations, and they will be treated with the care they deserve

Only a very few episodes are in question here, and two of them are so close in time and so similar in nature that it is better to conflate them into one Moreover, as we shall see, this "double episode" is relatively easy to explain and excuse, since it concerns "therapeutic experiments" on seemingly doomed victims of rabies and is at worst an example of deception by

omission Instead of informing the public and the scientific community of the dramatic results of these two human trials, Pasteur chose to remain completely silent

The other episodes concern the two most celebrated achievements in Pasteur's career his bold public demonstration of a vaccine against anthrax in sheep at Pouilly-le-Fort in 1881, and the first known application of his rabies vaccine to a human subject, young Joseph Meister, in July 1885 In the first case, as we shall see, Pasteur deliberately deceived the public and the scientific community about the nature of the vaccine used in the experiments at Pouilly-le-Fort In the second case, the nature of Pasteur's deception is less clear-cut, but here too we will find some striking discrepancies between the public and private versions of the famous story of Joseph Meister

Let it be clear at the outset that I am less concerned to *expose* Pasteur's public deceptions than to *explain* them True, the ascription of motives to historical actors is a notoriously risky business, and this is very definitely the case here In every case, it is possible to offer exculpatory explanations for Pasteur's behavior—though credulity is sometimes strained, especially in the case of the sheep-vaccination experiments at Pouilly-le-Fort and certain aspects of his work on rabies But the effort to analyze Pasteur's ethically dubious deceptions is justified by the importance of the larger questions these few episodes raise In what circumstances, and under what pressures, is a scientist of Pasteur's stature tempted to deceive? To what extent is such conduct explicable in terms of personal circumstances or character, and to what extent in terms of a competitive ethos or other more general cultural forces? Are the presumed norms of scientific conduct always reconcilable? Do scientific advance and the public welfare sometimes require scientists to tell "white lies"? How can the public or even other scientists be expected to appreciate the intuitive basis for actions that cannot be fully justified in strictly "scientific" terms? Is there a difference between "scientific ethics" and "medical ethics"? Especially in the face of dread disease and terrified people, how much prior evidence from animal experiments is required before preventive measures are applied to human cases? At least implicitly, Pasteur's deceptions raise these and other equally important questions about the ethics of research in general and of biomedical research in particular

But in the midst of these absorbing and more or less timeless issues, it should not be forgotten that our subject is a particular individual in a specific historical context We must not wrench Pasteur from his historical circumstances for the sake of facile insights into our current concerns There are profound differences between the intellectual, social, and ethical

climate of his day and our own His ethical conduct, like his scientific achievements and practices, should and will be assessed by applying criteria and standards that were recognized by his contemporaries and, indeed, by Pasteur himself

WHAT DO WE DO WHEN PRIVATE SCIENCE BECOMES PUBLIC KNOWLEDGE?

At this point, it will prove useful to circle back to the beginning of this chapter and to disclose the context in which Pasteur instructed his family to keep his laboratory notebooks forever out of the public eye Pasteur did not fear the exposure of some deep and dark secret recorded only in his notebooks Instead, his directive was a plausible response to a specific wrenching experience he had just gone through

In February 1878, Pasteur mourned the death of his friend and compatriot, the great experimental physiologist Claude Bernard About six months later, one of Bernard's disciples instigated the publication of some fragmentary laboratory notes he had left behind The contents of Bernard's hitherto private notes surprised Pasteur and their publication placed him in an awkward position In essence, these private notes disputed Pasteur's "germ theory" of fermentation While alive, Bernard had never challenged that theory in public nor even in conversation with Pasteur Pasteur felt obliged to respond to these now public manuscript notes, lest his deeply held theory of fermentation be undermined by appeal to the authority of the revered Bernard If he felt uncomfortable about attacking the private work of his late friend and frequent public supporter, who could no longer disavow or defend the experiments in question, Pasteur did nonetheless publish a full-length critique of Bernard's manuscript notes By carefully repeating Bernard's experiments and comparing them with his own, Pasteur went a long way toward establishing his claim that Bernard's results were mistaken, dubious, or misinterpreted Both in tone and substance, the critique was devastating [28]

Pasteur's conduct in this affair was by no means universally approved Half a century later, Paul de Kruif, whose best-selling book *The Microbe Hunters* did so much to popularize Pasteur's work in the United States, fulminated against Pasteur's behavior in this case For de Kruif, Pasteur's conduct when faced with the publication of Bernard's private notes served as the most striking example of his inability to accept criticism of any sort Worse yet, it displayed Pasteur's willingness to stomp on the grave of

a revered and recently deceased colleague solely for the sake of his own reputation.[29]

Pasteur was himself concerned that this tirade against Bernard would be unpopular among important segments of the French scientific community and larger public. To justify his assault against the work of one of France's scientific heroes, Pasteur adopted a two-pronged strategy. On the one hand, he impugned the motives of the man who had arranged for the publication of Bernard's private notes, the distinguished French chemist Marcellin Berthelot (1827–1907), a long-standing advocate of a modified "chemical" theory of fermentation as opposed to Pasteur's strictly "biological" theory. Pasteur accused Berthelot of misusing and debasing Bernard's reputation by publishing these crude preliminary experiments. If his critique tarnished Bernard's memory, Pasteur insisted, then Berthelot must accept much of the responsibility. For it was he who had tried to bolster his own misguided and doomed campaign against the germ theory of fermentation by bringing unauthorized public attention to bear on Bernard's private and preliminary experiments on fermentation.[30]

But Pasteur also justified his critique on methodological grounds. For him, Bernard's manuscript notes represented an instructive example of the danger of "systems" and "preconceived ideas." Bernard himself had done much to expose this danger in his famous *Introduction to the Study of Experimental Medicine* (1865), a masterful discussion of Scientific Method by one of its leading practitioners. Yet somehow, Pasteur insisted, Bernard had forgotten his own wise precepts in these private notes on fermentation. Bernard had been led astray, Pasteur continued, by his a priori conviction of a fundamental opposition between organic syntheses and organic decompositions. He supposed that organic syntheses were peculiarly vital phenomena, while organic decompositions—including fermentation, combustion, and putrefaction—were physicochemical rather than vital processes. For Bernard, in effect, organic syntheses were associated with life, while fermentation and other organic decompositions were associated with death. Because Pasteur's theory linked fermentation with life, Bernard privately rejected it and undertook experiments in hopes of refuting it. In Pasteur's eyes, Bernard was secretly opposed to the biological or germ theory of fermentation because it clashed with his general conception of organic processes—with his "system" of "preconceived ideas" about such phenomena.[31]

It is less important here to assess the validity of Pasteur's charges against Berthelot and Bernard than to recall that they arose in response to the posthumous and unauthorized publication of Bernard's laboratory notes. For it was also in response to this event that Pasteur instructed his family to

protect the privacy of his own notebooks [32] He clearly feared that the publication of some of his laboratory notes might do similar damage to his reputation At that point, he was presumably concerned only about his reputation for experimental probity and methodological propriety, for none of the ethically dubious episodes discussed in this book had yet occurred

Pasteur criticized Bernard's posthumously published notes in large part to defend his own theory of fermentation But he also seized the opportunity to draw methodological lessons from Bernard's once-private laboratory notes In doing so, Pasteur supplied an inadvertent precedent and justification for exposing his own manuscripts to critical scrutiny And the results, as we shall see, bear no resemblance to the lesson that Pasteur professed to find in Bernard's manuscript notes

In presenting Bernard's private experiments as an example of the "tyranny of preconceived ideas," Pasteur wrote as if he were surprised to discover that a scientist of Bernard's stature and methodological self-consciousness could sometimes stray from the path of objectivity He expressed dismay that even Bernard could sometimes be seduced by that "greatest derangement of the mind believing things because one wants to believe them "[33] In the context of this polemic, Pasteur presented himself as a practitioner of the "inductive scientific method, working outside of theories "[34] Yet elsewhere he spoke of the fertility of his own "preconceived ideas,"[35] and he sometimes seemed to advocate something like the hypothetico-deductive method now favored by many philosophers of science

In truth, Pasteur did not think very deeply about questions of Scientific Method, and he presented conflicting accounts of his own methodology depending on the audience and purpose at hand To understand and appreciate Pasteur's scientific modus operandi, it is essential to examine what he actually did in his laboratory rather than to read his scattered and inconsistent remarks about Scientific Method The crucial source for penetrating the ways in which Pasteur produced scientific knowledge is the extensive set of laboratory notebooks he left behind Unlike Bernard's notebooks, moreover, Pasteur's manuscripts also bring us face-to-face with important questions about the ethics of biomedical research To that extent, we may hope to learn even more from them

Given Pasteur's concern about exposing his laboratory notebooks to public scrutiny, it may seem surprising that they survived him at all, let alone that he should have preserved them so meticulously Perhaps his concern passed with time, but there is no reason to suppose that he would have welcomed the prospect of a future inquiry of the sort embodied in this book or other recent scholarship It may be doubted, in short, that Pasteur saved his laboratory notebooks with future historians in mind True, he did pro-

fess great interest in the history of science, even suggesting that it should be taught as part of the regular science curriculum at the Ecole Normale Superieure [36] He often sprinkled his memoirs and lectures with historical allusions and wrote a substantial historical article on the life and work of Lavoisier [37] As a working scientist, however, Pasteur valued the history of science only insofar as he thought it could advance the cause of science and scientists He held a heroic conception of the history of science according to which great men bring us ever closer to absolute truths about nature And when he proposed that the history of science be incorporated into the science curriculum at the Ecole Normale, he did so in the belief that it might inspire students to respect and honor their elders and forebears by revealing how difficult it was to produce original scientific work [38]

If Pasteur believed that a future study of his own laboratory notebooks or other manuscripts might contribute toward these or other worthy goals, he did not say so The pains he took to preserve his notebooks can almost surely be traced instead to two very different considerations (1) he repeatedly returned to his records of old experiments to inspire or test new ideas, and in that sense his laboratory notebooks were of direct and continuing utility to him, and (2) like a pack rat, he saved absolutely *everything* anyway, as many an archivist would attest after trying to make sense of the mounds of isolated and sometimes trivial slips of paper he left behind

We are, in any case, fortunate that Pasteur left us these detailed records of his ongoing research Indeed, one's sense of gratitude is so great that one might feel almost churlish about using them in any way that their author did not intend or foresee But Pasteur's notebooks are now public property, available to anyone who gains access to the manuscript room of the Bibliotheque Nationale in Paris In an important sense, it is no longer possible to invade Pasteur's privacy, for his "private science" has now become part of the public domain We are thus, in some ways, placed in a situation like the one facing Pasteur upon the publication of Bernard's laboratory notes on fermentation And it is precisely for that reason that we can insist that the standard Pastorian legend requires revision and even transformation As the contents of these once private documents find their way into public view, a fuller, deeper, and quite different version of the Pasteur story will perforce emerge There is, in effect, a new "history of Pasteur" to be written

TWO

Pasteur in Brief

PASTEUR sprang from humble roots. For centuries his ancestors lived and worked as agricultural laborers, tenant farmers, and then modest tradesmen in the Franche-Comté, on the eastern border of France. The shift from agriculture to trade came five generations before Louis was born. For two generations, in the early eighteenth century, the Pasteurs were millers in service to the Count of Udressier. Pasteur's three immediate male ancestors, including his father, were small-scale tanners. His father, Jean-Joseph Pasteur (1791–1865), was drafted into the French army at the age of twenty. Assigned to the celebrated Third Regiment of Napoleon's army, he served with distinction in the Peninsular War. By 1814, when he was discharged, he had attained the rank of sergeant major and had been awarded the cross of the Legion of Honor. Jean-Joseph Pasteur often looked back proudly to his brief military service, and he instilled in his only son a yearning for those glorious days when Napoleon and France seemed on top of the world.[1]

Upon his return to civilian life, Jean-Joseph settled into his work as a tanner, initially at Besançon, where his father had plied the same trade. In 1816, he married Jeanne Etiennette Roqui, daughter of a gardener from an old proletarian family of the Franche-Comté. They moved to Dole, where the first four of their five children were born. Louis, their third child, was born two days after Christmas in 1822. He was preceded by a son who died in infancy and a daughter born in 1818. Two more daughters came later. Pasteur thus grew up as the only brother of three sisters. The family moved twice before Louis was five, first to Marnoz, the native village of the Roqui family, and then in 1827 to the neighboring town of Arbois, on the Cuisance River, where a tannery had become available for lease. As at his birthplace in Dole, the tannery was also home, the family being lodged above the half-dozen tanning tubs that provided its modest income. It was Arbois, a picturesque town of eight thousand inhabitants in the foothills of the Jura mountains, that Pasteur came to think of as home and to which he later returned for extended summer vacations and at moments of family tragedy.[2]

As one might expect in a family whose men had long worked as modest tradesmen, Louis absorbed at the hearth the traditional values of the petit bourgeoisie—familial loyalty, moral earnestness, respect for hard work, and concern for financial security. His father, who had received little formal education, had no greater ambition for his son than that he should become a teacher in a local lycée, an elite upper-level secondary school. This modest aspiration seems entirely in keeping with Louis's early performance at school. Until quite near the end of his secondary schooling, he was considered just a cut above the average student. Only his genuine, if immature, artistic talent seemed to promise anything at all exceptional. Several of Pasteur's early portraits of family, friends, and teachers have been preserved. Two sensitive character sketches of his parents, done when he was a teenager, reveal a talent quite beyond the ordinary. His powerful visual imagination and aesthetic sense come through in some of his later scientific work, especially that in crystallography.

ACADEMIC CAREER

If Pasteur ever seriously considered a career as an artist, he was dissuaded by his pragmatic father and by his mentors at the Collège d'Arbois, who gradually came to appreciate his scholastic talents. During the academic year 1837–1838, when he was fifteen, Louis swept the school prizes. He was now encouraged to prepare for the Ecole Normale Supérieure in Paris, the institution of choice for those seeking a career in French secondary and higher education. With admission to the Ecole Normale as the eventual goal, it was arranged that he enter a preparatory boarding school in Paris. Within a month, however, Louis returned to Arbois, overwhelmed by homesickness. His superb performance again that year at the Collège d'Arbois kept alive his ambition to enter the Ecole Normale.

To secure his baccalaureate in letters, the standard entrée to professional careers in France, Pasteur had to pursue his studies beyond the offerings of the Collège d'Arbois, which lacked the requisite class in philosophy. He therefore matriculated at the Collège Royale de Besançon, forty kilometers from Arbois, where he was awarded the degree in August 1840, three months shy of his eighteenth birthday. He received a mark of "good" in all subjects except elementary science, in which he was considered "very good." Now determined to seek entrance to the science section of the Ecole Normale, Louis stayed at the collège in Besançon to prepare for a second baccalaureate degree, this one in science. His family's financial burdens were eased by his appointment there as "preparation master" or tutor, which paid room and board as well as a small annual salary. After two years

of study in the class of special mathematics, Pasteur received his baccalaureate in science in August 1842, though in physics he was considered merely "passable" and in chemistry "mediocre " Two weeks later he was declared admissible to the Ecole Normale, but he was dissatisfied with his rank of fifteenth among twenty-two candidates and declined admission for the time being

In September 1842, having also considered a career as an engineer, Pasteur took, but failed, the entrance examination of the famous Ecole Polytechnique in Paris [3] He then decided to spend another year preparing for the Ecole Normale To do so, he returned to Paris and a boarding school run by one M Barbet, himself a Franc-Comtois This time, unlike four years before, he overcame his homesickness and stayed at the school, whose students attended the classes of the Lycee Saint-Louis, one of the leading preparatory schools for the Ecole Normale By now Pasteur's discipline and diligence were beginning to be matched by his achievements At the end of his first year in Paris, he took first prize in physics at the Lycee Saint-Louis and was admitted fourth on the list of candidates to the science section of the Ecole Normale, which he entered at the start of the next academic year

For the next five years, from his twenty-first through his twenty-sixth year, Pasteur studied and worked at the Ecole Normale To qualify for a position in secondary education, he competed in the two national certifying examinations, the *license* and the *agregation* He placed seventh in the *license* competition of 1845 and third in the physical sciences in the *agrégation* of 1846 In October 1846 he was appointed *preparateur* in chemistry at the Ecole Normale, a position that allowed him to continue working toward his doctorate In August 1847 Pasteur became *docteur-es-sciences* on the basis of theses in both physics and chemistry While awaiting appointment elsewhere, he continued to serve as *preparateur* in chemistry at the Ecole Normale and quickly began to win a reputation in scientific circles for his work on the relation between chemical composition, crystalline structure, and optical activity in organic compounds

Certainly by this point, if not long before, Pasteur had far outgrown his father's early aspirations for him The prospect of a teaching career in a provincial lycee no longer satisfied him Like other candidates for positions in the state educational system, Louis did still expect to begin his career in the French provinces But he now hoped to be spared the heavy lycee teaching load and to be appointed instead to a university-level faculty of science, where he might be able to continue his research And he already had his sights firmly fixed on an eventual career among the scientific elite in Paris [4]

When revolution rocked Paris in February 1848, young Louis at first took no part But in April, after the Second Republic had been declared, he briefly

joined the National Guard, a municipal militia charged with the maintenance of civil order, and contributed his savings of 150 francs to the republican cause [5] At the end of May 1848, when his immediate future was yet to be settled, his mother suddenly fell sick and died, apparently the victim of a cerebral hemorrhage Pasteur blamed her death partly on her anxiety about his living in strife-torn Paris His father, who shared this concern, now also had sole responsibility for Louis's three sisters, all of whom were still at home in Arbois and one of whom had been severely retarded since being struck by a cerebral fever at the age of three Louis knew that some of his father's anxieties would be reduced if he left Paris He therefore asked the Ministry of Public Instruction to release him from his position at the Ecole Normale and to appoint him instead to some provincial post, even if that meant that he would be forced to go to a lycee

On 16 September 1848, Pasteur was named professor of physics at the lycee in Dijon, though he was allowed to remain in Paris through the first days of November in order to complete some exciting new research on optical activity and crystalline asymmetry in tartaric and racemic acid When his duties at the lycee could no longer be postponed, he took consolation in the relative proximity of Dijon to his father and sisters and in his expectation that he would not be there for long [6] Pasteur's prediction was confirmed even sooner than he expected By late December 1848, just a few weeks after he started teaching at Dijon, he had applied for and won appointment as *professeur suppleant* (acting professor) of chemistry at the Faculty of Sciences in Strasbourg After a fleeting concern about the possible effects of this distant move on his family, he eagerly looked forward to his transfer of duties, finally arriving in Strasbourg toward the end of January 1849 [7]

A whirlwind courtship must have begun right away, for in less than a month he proposed marriage to Marie Laurent, daughter of the rector of the Strasbourg Academy In a formal letter of proposal to her father, dated 10 February 1849, Pasteur spoke of his family's solvent but modest financial circumstances, putting the value of its total assets at no more than 50,000 francs, which he had already decided should go to his sisters All that he had to offer, he wrote, was "good health, a good nature, and my position in the University"[8] At the age of twenty-six, he married Marie Laurent on 29 May 1849

At Strasbourg, where he spent nearly six years, Pasteur continued and greatly extended his work on optical activity and crystalline asymmetry in spite of expanding teaching duties From 1850 on, his letters reveal an increasing impatience with his position as acting professor While pressing his claims upon his friends and the Ministry of Public Instruction, he followed closely the rumors and intrigues of French academic life in hopes of

securing a more satisfactory position. In November 1852, immediately after a well-publicized voyage to Germany and Austria in search of racemic acid, Pasteur was promoted to titular professor of chemistry at Strasbourg. In 1853, for his work on racemic acid and crystallography, he received a prize of 1,500 francs from the Société de Pharmacie and membership in the Legion of Honor. His reputation was already such as to bring his name into consideration for membership in the Académie des sciences in Paris, though in fact nearly a decade was to pass before that long-standing ambition was finally realized.

By September 1854, it was clear that Pasteur was going to be named professor of chemistry and dean of the newly established Faculty of Sciences at Lille, though the appointment did not become official until 2 December 1854. Located at the center of the most flourishing industrial region in France, the Faculty at Lille was designed in part to bring science to the service of local industry. In his inaugural address at Lille, Pasteur strongly supported this goal as well as two innovations brought to the French faculties of science by imperial decree of 22 August 1854: the opportunity for students to do their own laboratory work; and the creation of a new diploma, the "certificate of capacity in the applied sciences," designed for students who wished to become factory managers and to be awarded at the end of two years of theoretical and practical studies at the faculties of science.[9]

In his three years as dean of the Faculty of Sciences at Lille, Pasteur displayed considerable administrative and organizational talent. Under his leadership, laboratory teaching was soon established in all scientific subjects there. With regard to the teaching of "applied" subjects, however, Pasteur moved more cautiously, emphasizing that "theory is the mother of practice" and that without theory, "practice is mere routine born of habit."[10] Despite some pressure from the Ministry of Public Instruction, he resisted any emphasis on applied subjects at the expense of basic science and opposed suggestions that the Lille Faculty should train secondary teachers. He also consistently emphasized that professors at the Faculty owed allegiance to scientific research as well as to teaching, and complained that too many of the auditors were idle amateurs who sought mere entertainment or immediately "useful" information. Equally frustrating to Pasteur was the conservatism of Lille industrialists, their lack of attention to basic science, and their aversion to scientifically trained employees.[11]

For his part, Pasteur believed he was fulfilling his duty to forge bonds between industry and the Faculty at Lille. Among other things, he led his students on excursions to metallurgical factories in Belgium and undertook

to test manures for the department of the Nord. In his own courses, he taught the principles and techniques of bleaching, of sugar making and refining, and especially of fermentation and the manufacture of beetroot alcohol, an important local industry. During part of 1856, by which time his research interests had turned to fermentation, Pasteur went regularly to the beetroot alcohol factory of M. Bigo, where he sought to discover the cause of and remedies for recent disappointments in the quality of that product. Such efforts had just begun to yield results when, in September 1857, the directorship of scientific studies at the Ecole Normale fell vacant. Pasteur immediately announced his intention of seeking the position at his alma mater, insisting that the Ecole Normale had become "but a shadow of its former self," beset with apathy and in need of vigorous new leadership.[12]

On 22 October 1857, at the age of thirty-four, Pasteur was named director of scientific studies at the Ecole Normale as well as administrator, which made him responsible for "the surveillance of the economic and hygienic management, the care of general discipline, intercourse with the families of the pupils and the literary or scientific establishments frequented by them."[13] These positions carried with them neither laboratory nor allowance for research expenses, and in order to continue his scientific work, Pasteur was obliged to evade bureaucratic regulations and to rely on his own ingenuity. He managed at once to secure the use of two tiny unoccupied rooms in an attic of the Ecole Normale, where he pursued his research on fermentation despite being unable to stand at full height. With the tacit collusion of colleagues in the bureaucracy, he covered the small costs of essential equipment and supplies by diverting funds from the household budget of the Ecole Normale.[14]

In December 1859 Pasteur gained possession of a small pavilion at the Ecole Normale, which was considerably expanded in 1862. For this expansion, he clearly depended on the support of Emperor Louis Napoleon, whom he had approached by way of the imperial aide-de-camp and to whom he revealed his intention of working on the diseases of wine and infectious diseases in general. Within a few years, through constant appeals to governmental officials, Pasteur had also secured the services of a series of research assistants, funds to cover the expenses of field trips in connection with his studies of fermentation, and an annual laboratory allowance of 2,000 francs.

In his new laboratory at the Ecole Normale, Pasteur continually expanded his research interests and achievements. His well-publicized efforts on behalf of the germ theory of fermentation and against the doctrine of spontaneous generation brought him new honors and recognition. On