The Beginnings of Bacteriology in American Medicine: Works of Frederick Novy 1888-1933

by

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ABSTRACT

Frederick Novy (1864-1957) was a leader among a new breed of full-time bacteriologists at American medical schools in the 1890s. Historians have not provided comprehensive accounts of these early bacteriology researchers. I describe Novy's research and educational activities at the University of Michigan Medical School from 1891-1933, using them as a window to examine the meanings of bacteriology in medicine, medical education and American society.

In his medical school laboratory, Novy focused on designing innovative technology to visualize microbes and their behavior. Novy also used a makeshift bacteriology laboratory to define plague's unusual behavior, although he could not find a biological basis for its aberrancy or convince citizens to adopt anti-plague actions. In addition, Novy developed the first full semester laboratory-based bacteriology course in America in 1889. Novy's activities do not conform to traditional characterizations of early bacteriology in America as a merely practical application of European-derived theories.

What can be learned from Novy's composite activities at a time when laboratory science in medicine was new? His focus was on technical objectivity—devising novel instruments as a means of gaining an accurate understanding of microbes and their behavior. Through his scientific conduct, disinterested motives, and teachings, he embodied a code of ethics—a duty to search for objective truths above other

commitments, whether they be practical application or personal gain. Novy intended to legitimate pure laboratory science, with its disciplined hard work, search for truths, and moral code, by establishing its noble "spirit" as a norm of behavior for all medical students, researchers and practitioners alike.

Novy's colleagues and students viewed his norm of "pure" science as adding legitimacy to a medical profession in need of certainty. Novy's students saw his effort as uplifting the overall quality of medical education. The meanings of Novy's science in American society can be viewed through the novel *Arrowsmith*, a representation of Novy's activities as told by his student, Paul de Kruif. Sinclair Lewis, who collaborated with de Kruif to write *Arrowsmith,* offered laboratory science as having potential to provide a resonant truth and substance to an early 20th century American society portrayed as bereft of meaning.

INTRODUCTION

Histories written about the beginnings of medical bacteriology in America in the late 19th and early 20th century have focused mainly on the activities of bacteriologists working in laboratories located in public health departments.[1] The principal aim of the activities of bacteriology laboratories in these departments was to control disease processes through the application of germ theories of medicine that originated in Europe. These recently created germ theories were centered on the theory that a particular microbe causes a corresponding disease. The role of the public health bacteriology laboratory was to combat disease processes through the use of vaccines, sera, and antitoxins. American bacteriologists working in public health laboratories during this time were primarily interested in how to avoid or destroy germs, not necessarily to understand how they cause disease or how they behave in nature. Consequently, previous histories have depicted American bacteriologists as spectators in an unfolding germ theory drama; the true advancements and discoveries had already taken place in European laboratories. Bacteriology in America during this period has predominantly been portrayed as one of germ theory practice—the application of European-originated germ theory in the domain of American public health.[2]

As early as the 1890s, however, a new trend began to occur in America as bacteriologists began to find posts working full-time in laboratories located at medical schools.[3] At this time, bacteriology was still a new field that was gradually being defined by groups of well-established scientists who worked in laboratories located at medical schools and public health departments.[4] To date, however, historians have not examined what happened in the early bacteriology laboratories located at medical schools, and the subsequent meanings for medicine and bacteriology in America.[5] What did these bacteriologists do in their medical school laboratories? How did their work differ from the work done by American bacteriologists who worked in public health laboratories? Were the premises of their work clearly derived from their European predecessors, or was what they were searching for somehow different? How did these bacteriologists make a scientific life for themselves in medicine? What significance did their scientific work and teaching activities have for medical education and practice and for American society? What type of work did the bacteriologists do outside of their medical school laboratories and how did it differ from their medical school work? How did their activities influence the field of bacteriology in its early stages?

In this dissertation, I will attempt to answer these questions by examining the activities of an American bacteriologist, Frederick George Novy (1864–1957). Novy was a leader among a new breed of full-time, university-based bacteriologists. Novy carried out full-time medical research and taught bacteriology to medical students from 1888 to 1933 in his laboratory at the University of Michigan Medical School. To understand the events in Novy's life as they unfolded, I will use his published and unpublished papers and private correspondences with students, scientists and family located at the Bentley

Historical Library in Ann Arbor, Michigan. My intention is to use Novy's activities and choices as he perceived them as a lens to view laboratory-based scientific medical research and its interaction with medical education, practice, and bacteriology during a transitional moment in American medicine. I will also use letters Novy received from students and colleagues to address how they viewed his medical investigations—as something original, or as derivative of European programs. I will arrange the dissertation both chronologically and thematically. I have not attempted a complete biography, as many of the events of Novy's life have no place in my narrative.

Two overarching themes—the ideal of "pure science" and the aspiration to attain objectivity through technological expertise and instrumental innovation—will appear throughout this dissertation. These themes will emerge in Novy's research investigations, his field work, his teaching activities, and in his vision of scientific medicine. Novy valued above all else the "purity" of medical scientific research without practicality or competing interests entering into his experimental motives. In order to contextualize the high value Novy placed on "pure" science, I will address how 19th century American physicists and chemists had been insisting that medical researchers should perform science for its own sake. In addition, I will examine how Novy's emphasis on instrumental objectivity as a means of demonstrating truths in nature and reaching agreement among scientists had precedence in 19th century American science.

In the early 1880s, American scientists' idea of pure science, as Daniel Kevles has noted, carried the connotation of "high virtue."[6] At that time, physicists such as H.A.Rowland at Johns Hopkins University, and chemists such as Ira Remsen at Johns

Hopkins and Josiah Cooke at Harvard University, had been advocating to establish "pure" science as the norm for science and scientists.[7] Rowland proposed that American scientists ought to be motivated to perform science for the pure love of truth because searching for truth was the highest and most noble order of human pursuit. Rowland and Remsen argued that nature called scientists to study her mysteries, and that scientist's better feelings should urge them in this direction. Scientists, they argued, should be devoted to a work that promised no return except the satisfaction of adding to the sum of human knowledge.

In making a moral plea for "pure" science, scientists like Rowland were reacting against the scientific, technical, and social milieu of the times. They were admonishing a late 19th century American science that they believed had become too focused on practicality and financial gain from inventions.[8] Rowland believed that scientists had been driven for too long by profitable commercial applications that diverted science away from its true mission. Differentiating "pure" science from technological application, he derided those scientists who profited by manufacturing artificial light (e.g., Thomas Edison) and venerated others who explored fundamental properties of natural light. Rowland bound the pure physicist's search for nature's truths to an older American dream of crossing inaccessible terrains in search of a promised land. Just as nature elevated Americans in their westward migration, he argued, it similarly ennobled the scientist.[9] Rowland furthered the parallel between America's westward growth and science by arguing that a few gallant men should give their life for the benefit of science, just as Americans gave their lives for the westward expansion of America.

At stake for scientists like Rowland, Remsen, and Cooke was the role America played in the advancement of science. How, Rowland asked, could America contribute to this advancement if American society valued monetary gain above scientific progress and the most promising scientists therefore lacked motivation to perform pure science? Rowland, Remsen, and Cooke pointed towards Germany as the ideal model for science. Having studied science in Germany during their student years, these American scientists saw first-hand how the German state supported the activity of "pure" science. They valued the orientation of scientists in Germany towards engaging in pure science rather than seeking its practical applications. But after their return to America, they were no longer content to look abroad for their highest inspiration. American scientists, they argued, should follow the German model. They insisted on establishing pure, fundamental science as the standard their own country, fostered through universities, societies, and journals.[10] Rowland in particular believed that American scientists ought to have the feeling that their own country was moving forward—and lead the world in what he termed "the strife for intellectual prizes as we now do in the strife for wealth."[11]

Thus, in the early 1880s, American scientists had already been arguing that the selfless activity of truth seeking should be in itself the highest prize possible. Likewise, American philosophers had also begun to make similar arguments during this time. Charles Peirce, for example, maintained that the man of science should have every idea rationalized, devoting all his energies of his life to the cult of truth, not as he understands it, but as he does not yet understand it.[12] Peirce stated that for the scientist, the quest for new knowledge was power, the summon bonum. Of course, the discoveries of science might ultimately produce practical benefits, philosophers like Peirce acknowledged.

Scientists like Rowland, Remsen and Cooke agreed, but insisted that such benefits should not enter into the motives of scientists as they designed their experiments.

Scientists like Rowland attempted to distance the "pure" scientist from the issue of practicality by differentiating their motives from any possible practical application of their discoveries. Even though their discoveries might someday have practical applications, scientists could remain "pure" because practicality did not enter into their experimental aims or design. Why did physicists like Rowland and chemists like Remsen and Cooke bother to make such a distinction? "Pure" scientists, they believed, were remote from what Rowland described as "crude" or "vulgar" or "disgraceful" matters of commercial practicality.[13] Scientists like Rowland and philosophers like Charles Peirce were arguing for an ascetic form of worldliness, not an economic one. Pure science was held as worthy at a time when the scientist had become a hero in American society, a dedicated sentinel of truth. The man who appreciated science for invention might stand on a lower plane than the discoverer—scientists were prejudiced against the man of patents and practical devices. As John E. Smith argued, to scientists and philosophers, cultivating science to understand nature, not to accumulate wealth, occupied a high seat of honor in late 19th century American culture.[14]

Pure science to these late 19th century American physicists and chemists did more than identifying their work. It established their worth. These scientists operated under a moral imperative—they believed that it was their duty to acquire new knowledge and advance their subject. They also believed it was their obligation to educate student scholars to that which is highest—to demonstrate to his students and the world that there is something high and noble worth living for. The emulation of the German ideal of high science and the passion to establish it as the standard in American science characterized the scientific ethos of elite American universities when Novy entered his undergraduate studies in 1882.

Another major theme that will appear throughout this dissertation is technological and methodological objectivity. As Fernando Vidal and Lorraine Daston maintained, a reliance on technological innovations as a reproducible and objective means of demonstrating truths in nature and of obtaining agreement among scientists had precedence in late 19th century America.[15] Stephen Toulmin argued that during this time, American scientists had hoped that rigorous laboratory techniques and methods would yield universally valid findings and principles that would be more consensual than older experiential methods.[16] Science also offered the promise of a conflict-free society that had progressed from earlier, more uncertain periods to one in which man could gain an understanding of the unpredictable forces of nature.[17] Toulmin maintained that the rational modern scientific mind, committed to rigorous methods and inductions, constituted the mark of cultural sobriety that was a sign of modernity as opposed to prejudice and superstition.[18] In 1885, Josiah Cooke went so far as to say that no educated 19th century man could expect to realize his best possibilities of citizenship without a practical knowledge of the rational methods of experimental science.[19] Thus, Novy began his career during a time when laboratory experimentation was being proposed as a normative ideal by which truths could be demonstrated and objectivity could be attained.

To Novy, the source of knowledge throughout his career would not be the classroom but the laboratory. His emphasis on instrumentation represented an attempt by a medical scientist to get to the things themselves and invite others versed in the methodology of bacteriology to do the same. Novy devised methods and insisted on their reproduction—by himself, his students, and by other investigators in their independent laboratories. By inviting others to demonstrate truths in nature for themselves, Novy was taking out the human element of subjectivity from research. The emphasis he and other scientists placed on machines and instruments represented an attempt to make research objective, free from whatever prejudice the individual self might have. In essence, the machine stood for objectivity. Truth had become a social, collective enterprise, and could be obtained once others had "seen" nature for themselves by using these machines and instruments in their own laboratories. Thus, scientists like Novy assumed that scientific knowledge could be reached once agreement was obtained among peers.

The view of scientific knowledge as a collective affair has been argued by Lorraine Daston and Peter Galison. They argued that objectivity found traction when scientists began to reflect on what they saw as an increasing obstacle to scientific knowledge: themselves.[20] Daston and Galison agree with Thomas Nagel that, the word "objective" implies a neutral omniscience that has always been an unattainable goal.[21] They also agree with Richard Bernstein that conceptions for being an objective scientist can change over time.[22] Objectivity, Daston and Galison argue, can take on different morals, meanings, and practices to fit different expectations for objectivity during a particular era. They related objectivity to what they termed "epistemic values" (e.g., norms that are internalized and enforced by appeal to ethical values in securing knowledge) associated with a specific era. They then proposed that different ideas of what it means to be objective that are either adopted by scientists, or held out expectedly of scientists, changed over time along with these epistemic values.

Daston and Galison trace how different conceptions of objectivity embraced by scientists changed throughout the 19th century. The early 19th century relates to the scientific effort to capture nature "as it was" through idealized artistic representation. Science books of the early 19th century featured elaborately detailed drawings of these phenomena. During the mid-to-late 19th century, however, a different emphasis on objectivity emerged—mechanical objectivity. The view, which emerged in the advent of cameras, was that nature could be differently represented without the taint of human idealism. By mechanical objectivity, Daston and Galison referred to the drive to repress the intervention of the scientist, and to put instead a set of procedures and machines that would represent nature. The key to this "epistemic virtue" is the attempt to take out the human element from the research, to make the research "objective". The machine stood for authenticity. In this move toward objectivity, peer review and scientific scrutiny are tasked with abolishing any traces of subjectivity. Their description of mechanical objectivity in the late 19th century encompasses the period in which Novy was operating.

But mechanically trying to reproduce the world, to show objectivity and scientific self-restraint, according to Daston and Galison, became insufficient as it left out nature's structures. In the late 19th century, structural objectivity, with a focus on technologic innovation that included measurement, logic, replicable, empirical sequences that required observation and detached reasoning of the scientist, came to complement mechanical objectivity. It was an attempt to experience reality first hand with added abstractions: a priori names, formulae, and observational measuring instruments. In effect, the technology and the use of these formulae would enable scientists to express, share and receive facts as perceived without distortion by personal feelings, prejudices, or interpretations. Structural objectivity was not the product of a disciplined individual; scientists could attain objectivity as a result of the sharing of their methods, recordings and their ideas with their colleagues. In the era in which Novy was operating, Daston and Galison offer a social account of the achievement of structural objectivity and the possibility that scientists could reach agreement among themselves about nature's truths.

The desire to attain structural objectivity in bacteriology must be considered in the context of the disputes among scientists about microbes in the late 19th century. As Thomas Worboys has stated, there were many disagreements among late 19th century scientists about what germs were, what they did, and how they came about.[23] Warboys has written about how new methods and techniques allowed agreement to be reached among bacteriologists in several circumstances. For example, Koch's solid agar culture media allowed bacteria to be separated and permitted the concept of specificity to be developed as a shared belief among some bacteriologists. The theme of using instruments to search for truths and to reach agreement will be evident throughout this dissertation, in particular, with regards to Novy's attempt to resolve a dispute about a fundamental bacteriologic theory of heterogenesis, to resolve a controversy about whether plague was present in San Francisco in 1901, and to convince students of bacteriology's relevance during a time when an influential faculty member repudiated the germ theory.

This dissertation will also point circumstances, including Novy's San Francisco field investigation, in which structural objectivity and the emphasis on technology did not result in consensus among scientists. This illustrates Daston and Galison's point that missing from the structuralists' account of their scientific practice was the fact that the scientists' interpretation of the data was not uniform, and could vary according to an individual's training. Scientists use their own schemes of intelligibility to identify structures, and this can vary among scientists according to their training and biases. As Bradford Keeney has pointed out, the ability of scientists to recognize what was in nature depended on their training.[24] Scientists bring ways of understanding and interpreting findings through certain predispositions that relate to their training—they are not a blank slate on which the machines write their impressions. Scientists with different training can each look at a phenomenon and come up with different structural accounts—all objectively. Thus, objectivity is an expression of a particular historical moment, not merely an eternal complementarity between a mind and the knowledge in the world.

During the period in which Novy operated American scientists and philosophers believed that truth was real and that would be determined by experimental means. This conception of truth was put forth by the development of American philosophy of pragmatism in the hands of Charles Peirce and William James in the late 19th century. In 1878, Peirce argued that a community of objective observers could arrive at agreement of what constituted truth only by sharing methods and by experimentally testing ideas for themselves in their own laboratories.[25] William James viewed truth as a process rather than a finished piece of work, and as a communal process, as something that was subject to revision and never established on a secure foundation.[26] As John Dewey pointed out, this truth would undermine traditional conceptions of truth as static and final, perfect and eternal; free from temporal dross.[27] Epistemogically, this represented a new order. Truth was no longer a mirror image of reality that was established on a secure foundation, but a construction through investigation and evaluation in the laboratory, a representation that was subject to revision. This was the evolving view of scientific knowledge in late 19th century America in which Novy entered his career as a medical scientist.

Before introducing Novy, I will describe in greater detail how historians have characterized the early germ period in America through an emphasis on bacteriological work conducted in public health departments. I will set the stage for this discussion by briefly mentioning the story of public health departments in America in the 19th century pre-germ era, as well as the 19th century European germ theory of medicine.

Medical Context: Pre-Germ and Early Germ Period in America: Public Health Departments

Prior to the germ theory, 19th century U.S public health departments focused on rectifying unclean, public, urban environments.[28] The theoretical rationale behind this movement was that pestilence arose from changes in the air due to filthy environments—such as the presence of decomposing animals carcasses, rotting vegetables, or accumulating animal excreta. During this period, public health measures were based on the belief that filthy environments were responsible for contagious diseases. Consequently, interventions to rectify particularly susceptible environments had been the focus of public health campaigns for the restraint of contagion before the germ era.[29] These measures emphasized social reform and a broad array of sanitary efforts—

restraining slaughterhouses, preventing pollution of streams, regulating tenement housing, and improving working environments.[30]

But the public health doctrine identifying absence of filth as a sufficient barrier against contagion was challenged soon after the germ theory was postulated.[31] Historians Barbara Rosenkrantz, John Duffy, and Judith Walzer Leavitt, have identified the 1880s through the early 20th century as a transitional period for public health departments.[32] These authors suggest that in the late 1880s and 1890s the emphasis of public health began to shift away from broad-ranging sanitation programs and was directed instead towards interventions based on pathogen identification and eradication. These interventions were derived from germ theories of medicine that had flourished in Europe in the mid to late 19th century, and were then imported to American public health departments by American-schooled physicians who had furthered their training in Europe. Upon hearing of the new European science of bacteriology, a number of American physicians in the 1880s traveled to Europe to study with Louis Pasteur and Robert Koch. After returning to America, starting in the late 1880s, some physicians began to work in bacteriology laboratories located in the public health institutions that first appeared in U.S. cities. What was happening in Europe that attracted American physicians to travel to Europe in the late 1880s to learn about the germ theories? How did these physicians later apply their knowledge in the United States during outbreaks?

Well before the 19th century, European physicians had speculated that disease could be transmitted from one person to another. As early as the 16th century, for example, the Italian physician Hieronymus Fracastorius conceived of imperceptible living particles that generate and propagate other germs precisely like themselves and are transmitted to other humans as a mechanism for spreading disease.[33] But lacking the technology to empirically test his ideas, Fracastorius would only speculate about germs.[34]

As new optical methods were developed and improved in the 19th century, European scientists began to speculate on the microorganisms they were seeing and the relationship of those microorganisms to disease. Antony van Leeuwenhoek's 17th century single-lens microscope had barely enough power (100X) to visualize the extremely small 0.1 to 0.3 micrometer bacteria, whereas the 19th century double lens compound microscope had sufficient resolving power (400 X) to see but not discriminate among bacteria.[35] Using these new technologies, the German physician Theodor Schwann and the French physicist and engineer Charles Cagniard-Latour postulated in the 1830s that alcoholic fermentation and putrefaction were due to microscopic living beings.[36] Shortly after, the German pathologist Joseph Henle accepted their idea that decompositions of organic materials were due to living agents.[37] Citing their work, Henle extrapolated their theories to human disease, which to him appeared to be a decomposition of body tissues.[38] In 1840, Henle postulated the germ theory of disease—a premise that microbes correspond with specific disease entities.[39]

Henle opined that he did not have the technology at hand to unveil what he referred to as "the secretive lives of invisible organisms."[40] He recognized that the problem of visibility had to be overcome in order for his hypotheses to be empirically tested. He conceded that rigid proof of the nature of contagium through direct observation was not possible, as he asserted "the organisms of the contagium might be too small for our present day optical methods."[41] He called for experimental proof for his hypothesis that a suspected microorganism that had an independent existence could reproduce itself in the sick body, cause disease, and then be eliminated from the body. Henle said, "to prove that the parasites are the causal material, it would be necessary to isolate the animal seeds from the contagious fluid, then observe especially the power of each of these to see if they corresponded. This experiment…cannot be performed."[42] He postulated that a particular organism first must somehow be isolated from the host in order to prove his theory that germs cause disease.

To be empirically tested, Henle knew that his hypothesis—that living organisms were connected with specific disease—had to await further refinements in technology that would permit discriminating, isolating and handling of microscopic organisms. For Henle in the 1840s, the individual characteristics of microbes remained difficult to decipher in spite of the capacity of compound microscopy to sufficiently magnify them.[43] Organisms could not be clarified under the microscope as their borders appeared fuzzy. Technology that allowed bacteria to be seen with greater discrimination and with sharper borders was not available. In addition, stains were not available to contrast bacteria with their background, and different bacteria could not be differentiated according to their morphology. Moreover, the technology Henle desired did not yet exist in 1840—tools that would allow him to separate a suspected microorganism from the disease process and culture it in pure form, rather than a mixture of several colonies.

By the late 1870s, the introduction of these technologies and methods brought minute bacterial forms of life into focus for the first time and permitted the experiments to test Henle's germ theory.[44] The Abbe condenser was introduced in the mid-1870s, allowing bacteria to be seen with greater discrimination.[45] Also, aniline dyes first used in the clothing industry allowed different forms of bacteria to be distinguished according to the stain they incorporated, thereby allowing researchers to differentiate among bacteria according to their size, shape, and color.[46] Finally, the development of solidified culture media by Koch in 1876 allowed bacteria to be separated and isolated in pure culture from a specimen taken from humans.[47] Solid media allowed bacteriologists to identify one form of bacteria after a fixed incubation time because it was more reproducible in generating discrete bacterial colonies than liquid media in which several species merged together.[48]

By observing specimens at a fixed time period after growth on solid media, Koch was able to demonstrate that bacteria were the cause of the diseases anthrax in 1876 and erysipelothrix in 1878.[49] For these experiments, Koch used the new microscope apparatus, dyes, and solid media to identify a bacterial strain.[50] By the late 1870s, Koch possessed instruments capable of achieving what Henle in 1840 desired: to visualize organisms. Koch then developed methods to formulate his famous criteria for proof that a bacterium is the cause of a specific disease. Bacteria, he hypothesized, must be isolated in pure culture, then re-injected into healthy animals and induces the same disease as observed in the human. These bacteria must again appear in the artificial disease, and be re-isolated. Koch specified that each step in the sequential process be performed at a specified, fixed time. It was only in this systematic, static way that the bacterial nature of a particular disease process could be proved. In 1884, Koch used these postulates to prove the causal organism of tuberculosis.[51]

The introduction of microscopes, stains, and culture apparatus, which had allowed Koch to make his postulates, also permitted an array of disease producing organisms to be identified by other European investigators in the 1880s and 1890s.[52] The isolation of bacteria that caused gonorhea in 1879, leprosy in 1880, and tuberculosis in 1882 encouraged physicians to embark upon a determined search for the specific microbial causes of other diseases.[53] These microbes included, among others, the bacilli causing Cholera (described by Koch in 1883), Diphtheria (Klebs and Loeffler 1884), and Plague (Yersin 1894).[54] The American neurosurgeon Harvey Cushing called the investigations, in which causal organisms for numerous common infections were isolated, as "new discoveries were being announced like corn popping in a can."[55] Cushing was portraying the excitement of discovery during the decade of the 1880s and 1890s.[56] At this time, scientists first in Europe, then all over the world trained their microscopes on the disease-producing organisms of several human ailments.[57]

By the 1880s, European researchers began to develop methods of applying the germ theory to remedies and diagnostic testing. To actively prevent infection, Pasteur investigated the principle of active immunization—that resistance to pathogens could be produced by the injection of these germs in an attenuated live state.[58] Koch attempted treatment of tuberculosis with active immunization with tuberculin, but this attempt proved unsuccessful.[59] Emil von Behring and Shibasaburo Kitasato, students of Koch in Berlin, showed that they could produce immunity to tetanus in rabbits, which they postulated could be transferred to mice, leading to the idea of passive immunization, meaning the specific serum therapy of diphtheria.[60] This resulted in the dramatic discovery of the diphtheria and tetanus antitoxins—discoveries which made it possible to cure these diseases by injecting the ailing person with an antitoxic serum that could be prepared by earlier immunization of a large animal. Late 19th century bacteriologists viewed this as tangible evidence that rational cures for infectious disease could be based on principles of the germ theory of medicine.[61] The ability of microbes to stimulate antibody production in the blood also had applications in the realm of diagnostic tests for typhoid fever in 1896 and syphilis in 1906.[62]

Thus, the enthusiasm that surrounded the making of previously unseen organisms visible, and devising methods of controlling and identifying them, attracted physicians and aspiring researchers from America to travel abroad in order to learn from the European masters about the new science of bacteriology. These American physicians felt a sense of excitement that surrounded the hurried search for the isolated bacillus of specific diseases in the decade following Koch's discovery of the germ causing tuberculosis, of Pasteur's vaccines, Koch's search for a treatment for tuberculosis, and the 19th century English surgeon Joseph Lister's treatment of infected wounds.[63] They saw bacteriology during this period as a European science filled with discoveries and sensations.

The earliest American bacteriology laboratories in America were established in departments of public health in the late 1880s and were run by European-trained, American-schooled physicians.[64] Many of these physicians brought European training and methods to public health departments in American cities and states, including New York (Hermann Biggs and William Park, 1887), Providence (Charles Chapin 1888), Massachusetts (William Sedgwick 1888) and Michigan (Victor Vaughan and Frederick

Novy 1888).[65] With them, the new European bacteriology was applied to the realm of public health in America to detecting and controlling disease.

The activities of the prominent New York City Health Department laboratory have been well described by historians.[66] The laboratory was furnished with equipment that provided various means of preventing infections, identifying organisms after they had entered the body, and destroying those organisms or nullifying their toxins.[67] In 1894, William Park, who studied bacteriology in Europe, was put in charge of this work as bacteriological diagnostician and inspector of diphtheria.[68] In this laboratory, the discoveries made in Germany were systematically applied to the protection of the community and were able to interrupt the spread of diphtheria. Park produced diphtheria antitoxin, and shortly after 1894, he began work to combat a growing number of killer diseases including tetanus, tuberculosis, scarlet fever and typhoid fever.[69] By the late 1890s, the New York City laboratory began to mass-produce serums and vaccines, allegedly preempting the rise of private industries such as H. K. Mulford Company that eventually would manufacture these products.[70]

Several early and mid-twentieth century physicians who wrote about medical history, such as Stephen Smith, Charles Chapin, Esmond Long, and George Rosen, wrote on the activities of bacteriology laboratories located in public health institutions. These physicians maintained that bacteriological testing permitted public health practices to become more precise and rational than had been possible before. Some attributed this trend to American bacteriologists who trained abroad and then headed the new bacteriology laboratories, allowing them to apply European theories and practices to the setting of American public health.[71] Medical historians writing later in the twentieth century, such as Howard Kramer and John Duffy, echoed these sentiments; or focused almost entirely on the pragmatic activities of the bacteriology laboratories in public health department without specifically addressing whether they were reactive to European theories.[72] Below, I will expand on the arguments made by this group of physicians and historians.

Historians have pointed out that a key activity of a bacteriologic laboratory in the public health setting were to test humans for infection and determine whether prevention or treatment was appropriate. By the late 1890s, the New York City health department laboratory began use of culture tests for diphtheria. By 1913, Bela Schick developed a test to determine the presence of immunity to diphtheria that was used to target preventive measures (e.g.,toxin) for uninfected persons or treatment (e.g., anti-toxin) for infected individuals.[73] Schick's test was a key component of the new public health department strategy, as it allowed workers to target with certainty who should receive a therapeutic or a preventive measure. Commenting on the collective work of bacteriology laboratories in American public health departments, including the Schick test, Stephen Smith, a surgeon and public health officer in New York City Metropolitan Board of Health, noted the "brilliant researches and discoveries abroad were accepted and extended in this country."[74] For Smith, the pragmatic activities of these American bacteriology laboratories were derivative of European germ theories and they provided greater precision to public health strategies.

By the 1890s, microbiology laboratories located in American public health departments provided the scientific means to clean the water supply and purify milk.[75] Coagulants, for example, were added to a mechanical water filtration system to remove bacteria; in addition, chlorine was added to water.[76] By the 1890s, Herman Biggs began to pasteurize milk in order to kill pathogenic bacteria, including bovine tuberculosis.[77] Thus, new developments in bacteriology and chemistry helped the laboratory improve the supervision of municipal milk and water supplies.[78] As improved techniques made possible the routine confirmation of diagnoses of contagious disorders by laboratory methods, health department laboratories expanded rapidly.[79]

By the turn of the 20th century, as the array of diagnostic laboratory tests and therapeutics became more numerous and complex, nearly all public health departments staffed their departments and laboratories with professionals.[80] The head of the department was usually a physician, and the staff included at least one bacteriologist, chemist, sanitary engineer, statistician, and an assortment of inspectors, many of whom had some professional training.[81] As health departments expanded and new professionals were hired, the original sanitary department grew and became divided into branches or bureaus of handling contagious diseases, food inspection, plumbing, and other matters.

As laboratories within public health departments increased in number and quality and expanded in size, many of the former responsibilities of 19th century health boards were shifted to separate municipal departments. Areas of garbage collection, water supply and sewerage, nuisance removal, and occasionally tenements and housing were now handled by separate municipal departments.[82] Bacteriology laboratories shifted the emphasis from man's environment to the control of specific communicable diseases and changed the former activities of the health departments. Consequently, many municipal matters that concerned earlier sanitarians (street cleaning, etc), had gravitated into other hands.

By the early 1900s, Charles Chapin, the superintendent of the Department of Public Health in Rhode Island, had taken note of the new bacteriology laboratories and he began an open assault on the filth theory and his state's undiscriminating cleanups. Chapin argued that bacteriological testing in laboratories eliminated guesswork for public health departments, minimized misuse of biologic products, and resulted in a targeted use of these products in a discriminating fashion.[83] Chapin said that prior to the introduction of bacteriology, public health departments had been "barking up the wrong tree" by removing "everything dirty, everything decaying."[84] Instead of such "indiscriminate attacks on dirt," Chapin argued that health departments should turn their attention to "the mode of transmission of each infection and must discover its most vulnerable point of attack."[85] To Chapin, this meant keeping human feces out of food and drink to fight typhoid fever and cholera, destruction of mosquitoes to combat yellow fever and malaria, vaccination to prevent smallpox, and killing rats to prevent plague.[86] Chapin argued that the advent of vaccines and antitoxins, together with diagnostic testing to guide the persons in whom to use them accurately, provided health workers with a new, targeted method for both preventing and curing contagious disorders. He proposed to use the "new science" of bacteriology to shift the focus of public health away from environmental sanitation and instead prioritize the application of bacteriological methods to public health practice.

Many years after Chapin lived medical historians began to argue that bacteriology allowed for development of public health along more rational lines than had been possible before. George Rosen, a physician and professor of the history of medicine at Yale University Medical School stated in 1958 that as bacteriologists opened a path for the control of infectious diseases on a "more rational, accurate and specific basis."[87] He claimed that the "empirical shotgun methods of an earlier day could now be made more precise and definite."[88] John Duffy, a professor of history at the University of Maryland, also argued in 1992 that the bacteriology laboratory yielded special methods of protection—accurate and precise methods of diagnosing disease, specific immunization against disease and methods of curing disease and saving lives by the use of vaccines, sera and antitoxins.[89] Thus, medical historians maintained that a scientific understanding of the elements involved in the transmission of communicable diseases led health authorities to act with greater discrimination in implementing disease control measures than had been possible previously.[90]

Some medical historians have also argued that bacteriology laboratories added an element of certainty to public health operations that had previously been lacking. Howard Kramer, a mid-20th century medical historian at the University of Iowa, said in 1948 that bacteriology replaced older "fallacious ideas" regarding climate as a predisposing cause of disease, and from then onward, "certainty as to diagnosis, knowledge of the method of disease transmission, and serums and antitoxins became the new tools of public health workers."[91] Kramer noted that by 1900, diphtheria and other diseases were "giving ground as they were faced with man's increasing scientific knowledge."[92] Stephen Smith also felt that bacteriology laboratories made public health departments more credible.[93]

Smith said, “The chief value of bacteriological discoveries has lain in their usefulness to man. In no field have more remarkable advances been achieved than in medicine, both curative and preventive…Knowledge has replaced guess work; experiment has superseded empiricism and superstition.”[94] Kramer and Smith were arguing that the new bacteriological science modernized public health practices by replacing older, less certain, pre-germ ideas.

But some historians contest any implication that bacteriology may have reduced public health departments to scientific considerations alone. Nancy Tomes, for example, argued that social determinants of disease remained important in the germ era.[95] Tomes maintained that it was not until the rise of the new bacteriologically-based “new public health” of the early 20th century that popular education and personal hygiene became imperatives of the movement.[96] Similarly, although Barbara Rosenkrantz acknowledged that the conception of state medicine became increasingly biomedical, as public health officials tried to put their profession on a solid scientific basis, she argued that the public health movement maintained its interest in the broader social and economic determinants of disease.[97] Likewise, Elizabeth Fee asserted that a narrow bacteriology view of public health did not mean there were not competing models for public health research and practice that continued to relate the problems of ill health and disease to the larger social environment.[98] Judith Walzer Leavitt argued that public health policies were not reduced to the point where they relinquished social and cultural considerations.[99] These authors point out that it remains important to relate disease to the larger social environment even in the germ era.

Thomas McKeown argued that improvements in the social environments rather than medical scientific discoveries were the key determinants of declining mortality from infections in 19th century industrialized nations.[100] McKeown emphasized the importance of economic development and accompanying increases in food supplies and per capita income as sources of the historical decline in mortality.[101] On the basis of demographic studies, however, Gretchen Condran argued that economic advance in itself could not have produced the declines in death rates without the efforts of public health officials who carried out specific actions in their communities.[102] Paul Starr agreed that bacteriology had successful applications by providing more focused preventive measures against specific diseases.[103] However, he noted that medical practitioners played an important role in carrying out these measures, which included antiseptic surgery and clinical testing (e.g., performing throat cultures to accompany vaccines).[104] Starr claimed that medical practitioners were anxious about the intrusion of public health in their jurisdiction, and possibly to prevent loss of business, claimed credit for the accomplishments of bacteriologic preventive public health.[105]

Based on the activities of bacteriologists working in public health department laboratories, physicians and historians have characterized the early bacteriology period in America as one of applied rather than original science. Esmond Long, professor of pathology at the University of Pennsylvania, posited that "little original work in the field of bacteriology had been done in this country."[106] Likewise, Duffy said, "Americans contributed little to the development of bacteriology."[107] Rosen stated in the 1890s, "while Americans contributed only in a limited degree to the growth of bacteriological knowledge, they were alert…to its practical implications. Out of this awareness there developed…the diagnostic laboratory for the application of bacteriology."[108] Kramer maintained that Koch believed that Germany contributed most to bacteriological discoveries, but were behind the US in practical application.[109] Kramer, also said that "European germ theories as applied in public health departments in America had awesome possibilities."[110] Rosen stated "American physicians were behind the Europeans in the development of fundamental principles in bacteriologic science, but were fast in the practical application of bacteriological principles."[111] Barnett Cohen, professor of chemistry at Johns Hopkins University, wrote in 1950 that in the late 19th century, "the practical applications of bacteriology carried out in America followed the germ theories of Europe."[112] Paul Starr said, "It has been said that while Europeans made the major theoretical advances in bacteriology, Americans made some of the practical applications."[113]

Clearly, physicians and medical historians have characterized early American bacteriologists working in public health laboratories as having focused their practices on the pragmatic mission of identifying and destroying disease producing germs of humans. But even before these laboratories in America, some writers, physicians and biologists expressed hopes that laboratories would handle contagions. A. B. Palmer, a writer for the *North American Review*, noted in 1882, "modern science has demonstrated that specific diseases are caused by organic living parasites," and he predicted that the "great curative remedies of the future will be antidotes and eliminatives for their destruction or expulsion."[114] In addition, John S. Billings, professor of hygiene at the University of Pennsylvania, writing in the *International Review* in 1882, argued that the practical value of the germ theory to the sanitarian was to base attempts in avoiding, tracking down and destroying germs.[115] Frederick Gorham, professor of biology at Brown University, noted in 1910 that the emphasis of bacteriologists working in public health laboratories is one of “combating disease process”.[116] David Bergey, professor of pathology at the University of Pennsylvania, stated in 1917 that the mission of American bacteriologists is to “develop lab methods to discover and diagnose disease, and the knowledge of the means by which to prevent the spread of diseases.”[117]

One can speculate why physicians and historians have characterized the early bacteriology period in America as one of practical application of existing theories. This narrative has the drama and excitement surrounding the discovery of previously invisible dangerous creatures and the power of vanquishing killer diseases. It was a story told predominantly by early to mid-century physicians who were attracted to medical history topics that were conducive to being told in a linear fashion. In their narrative, new technology enabled previously invisible organisms to be viewed and provided insight into how to counteract the process of how they caused disease. The application of this technology in the bacteriology laboratories located within public health departments resulted in controlling previously lethal diseases. C. E. A. Winslow, chairman of the department of public health at Yale Medical School, captured the compelling drama of their story. In 1950, Winslow said, “This was a thrilling period in the history of our science—the revelation as ‘the science of the infinitely little’—the sudden opening of a whole new world of organic life, fraught with the widest implications for the future welfare of mankind.”[118] Winslow’s comment epitomizes the element of adventure and discovery associated with the conquest of killer diseases that has been so momentous to physicians, medical historians, and the general society.

The epidemiology of diphtheria in America from the late 1890s to the 1940s substantiates Winslow's depiction of a triumphant moment for science in protecting citizens from killer diseases.[119] By the late 1890s, diphtheria could be diagnosed by precise bacteriological methods, the sick person could be treated with diphtheria antitoxin, and well carriers could be detected.[120] Mass immunization—a method developed from knowledge on the use of diphtheria antitoxin—was implemented by public health officials and physicians. By 1940, the disease had been virtually eliminated as a cause of death—declining from 785 cases per 100,000 people in 1894 to 1.1 per 100,000 persons in 1940.[121] Although as McKeown argued, this decline in mortality began before the implementation of active immunization, Rosen argued that the causal role of immunization could not be overlooked.[122] The dramatic story of killer diseases controlled by bacteriology laboratories in public health settings has included the reduction of dysentery and cholera through water purification methods, and a decline in diseases such as tuberculosis by sterilizing milk.[123]

Perhaps this powerful story of control and decline has obscured the original, fundamental, though perhaps less dramatic, investigations that took place in bacteriology laboratories located in universities. These studies may have had been discussed primarily among experts using esoteric language within the field of bacteriology, and their consequences were perhaps not as recognizable to general physicians who wrote about medical history, or later to medical historians. Or perhaps the rewards of their outcomes were not as thrilling as the control of previously lethal killer diseases. Regardless of the reason, systematic accounts of bacteriologists who worked in medical school laboratories during the late 19th and early 20th centuries have been largely left out of historical narratives about early bacteriology in America.

By the 1880s, bacteriological work in America was taking place in laboratories other than those located in public health departments. Most attention has been given to work that involved searching for bacterial organisms that caused agricultural, animal, or human disease.[124] In 1880, for example, Thomas J. Burrill (1839–1916), professor of botany and horticulture at the University of Illinois, had investigated the bacterial cause of pear blight, a disease of plants, in his laboratory.[125] Also, Theobald Smith (1859–1934) and his associate F. L. Kilbourne, of the Bureau of Animal Industry of the U.S. Department of Agriculture in Washington, studied the etiology and transmission of Texas fever.[126] Furthermore, George M. Sternberg, (1838–1915), a U.S. Army Medical Corps officer, was one of the several discoverers of the pneumococcus, a human respiratory pathogen.[127] Thus, the research programs of the American bacteriologists located in these settings can be viewed as extensions from premises and principles originated in Europe.[128] The research conducted was aimed at identifying an expanding array of organisms that cause of a variety of diseases.[129]

The work culminating from bacteriology laboratories that were also beginning to appear in a scant number of medical schools in the 1890s has received only cursory attention from historians. Only passing mention has been given to topics a handful of bacteriologists working in American medical schools had studied. In 1891, William Welch and T. Mitchell Prudden in New York, at the Bellevue Medical College and the College of Physicians and Surgeons respectively, were investigating the gas bacillus,

Bacillus welchii from specimens of blood vessels obtained at human post mortem examinations.[130] Investigative laboratories in bacteriology were also arising under the direction of William Trelease, Edward Birge and Harry Lyman Russell at University of Wisconsin; and Alexander Abbott, Henry Formad, Lawrence Flick, and Joseph McFarland at the University of Pennsylvania; L.H. Pammel at Iowa State College of Agriculture; and Veranus Moore (1859–1931) at Cornell.[131] But historians have not yet explored in depth the type of investigative work conducted in these late 19th century bacteriology laboratories in American medical schools.

Cultural Context.

We have addressed the medical context in which Novy operated and how historians have characterized it. But it is also important to explore the broader cultural context occupied by Novy, his colleagues, students, and other individuals in this late 19th and early 20th century story, in order to place their activities, perceptions and motives into their appropriate historical context. In this section, I will contextualize my narrative by considering some of the broader trends in American culture at this particular historical moment.

Novy's activities and methodologies in public health, and his research investigation and education coincided with dominant beliefs and objectives of the Progressive period in early 20th century American history. In chapter one of my narrative, I will describe the inception of the hygienic laboratory that enlisted the state government to enforce reform through inspection of food and water in the late 19th century. This activity antedated the 20th century progressive movement, but should nonetheless be considered in relation to the beliefs and social ideals of that movement.[132] These beliefs included the expansion of state activities and authority in the realm of public health and a new insistence on expertise, and scientific knowledge in society. Progressive reformers sought to substitute rational and scientific planning and methods for dependence on traditional and ad hoc methods.[133] To replace what they regarded as reliance on chance and local responses, progressive reformers turned to the methods of scientific investigation—data gathering, analysis and prognosis—and to the establishment of permanent agencies. The progressive period also sought to conserve the nation's valuable resources, including human health and wellbeing. The Progressive period was one of optimism—a faith in the reality of progress.[134] Reformers didn't believe that progress was something that might just happen, rather something that was destined to happen through the collective exertions of an entire society.

Throughout the narrative, I will cover Novy's training and growing stature as an expert bacteriologist, medical researcher who carried out original investigations, and medical educator in the eyes of his colleagues and students. These perceptions may be considered in the context of the values that were held in high esteem during the progressive period. The Progressive reformers believed that it was no longer sufficient to put one's faith in common practical knowledge; instead society had to employ highly-trained technical experts. Reformers recognized they were living in a world so complicated that they were indeed needful of these experts.[135] Novy's training as an expert and his focus on the technical aspects of bacteriology were taking place at a time when these qualities were held in high esteem.

Throughout the narrative, I will also explore the spirit and ideals of scientific medicine that Novy both professed and represented to his students and colleagues—ideals of discipline, hard work and the search for solid truths in nature. I will consider this ideal of scientific medicine in the context of the anxieties of the historic moment. Late 19th century Victorian America was a changing and uncertain world in which traditional ideas and values were under threat.[136] Religion, for example, was being challenged by Darwinian theories of evolution.[137] Furthermore, traditional hierarchies that placed the male gender on top were being disputed, and men began to fear the implications of a positive evaluation of women's independence.[138] In addition, traditional modes of human relationships that developed in small, isolated communities were being disrupted by social patterns of urbanization, immigration, and interconnectedness due newly constructed means of travel.[139] Industrial technology seemed to be propelling America from a rural society marked by tradition and community into a baffling mixture of urban cultures. By the 1880s, American society had become increasingly complex. Small towns, where interpersonal relations had been predictable, gave way to cities where people were increasingly subject to conditions and networks of authority beyond their control and beyond their comprehension.[140] The decade of the 1880s began with a severe and prolonged depression that returned in the early 1890s when labor disputes entered into the vocabulary of Americans rich and poor.[141] Labor issues, the protests of women against their inferior status, the nature of the developing monopoly system, and the decline of the family farm seemed to threaten traditional ways of American life.[142]

The consequences of these shifting social, economic, and cultural arrangements were frightening to Americans in the late 19th century.[143] In this uncertain world in which social and economic change rapidly transformed traditions, Americans in the 1880s and 1890s retreated to hard work and the search for solid truths.[144] Some Americans hoped that scientific interrogation would counter the uncertainties of the 1890s and bring forth strong conceptions of truth.[145] The emulation of the ideals of scientists who used rigorous inductive methods to arrive at solid truths by many citizens in this narrative follows this larger trend in American culture.

A belief in truth and progress is a consistent theme in the voices in many characters of this narrative. This belief must be considered in the context of late Victorian optimism. Beliefs that laboratory work would lead towards the advancement of society through the application of rigorous scientific methods drew on strains of late Victorian optimism.[146] This narrative signifies the power of science to apprehend nature. But it also indicates the power of science to manipulate and control nature. America at this time was becoming an imperialistic world power during the Spanish American War and a nation whose politicians were proclaiming was entering its peak of influence and importance.[147] The advancement of science and the assimilation of science in medicine in America was occurring at a time when America was advancing militarily and industrially. With the assimilation of science, medicine as a profession was becoming more potent and powerful during a time when America as a nation was becoming more powerful. The narrative takes place in the late 19th and early 20th century when the beneficence of science was held as an ideal by many sectors of society, including educators, physicians, students, and popular authors like Sinclair Lewis, and at a time when science was powerful but not yet vexed.[148]

Thesis

In the following chapters, I will examine the research program carried out by Frederick Novy in his bacteriology laboratory at the University of Michigan medical school, his field work in San Francisco, and his educational activities. I will then explore the meaning of all of his activities—research and education combined—for the professions of medicine and bacteriology. I will use the novel *Arrowsmith* as a vehicle to explore the meanings of Novy's activities for these professions as well as for early 20th century American society. The popular, accessible novel, *Arrowsmith*, was the result of a 1925 collaboration between the author Sinclair Lewis and one of Novy's students, Paul de Kruif. In his fiction writing, Lewis patterned Max Gottlieb, a fictional professor of bacteriology who epitomized the ideal of science in medicine, after de Kruif's depiction of Novy. At various points throughout the text, I note the many similarities between the activities, ideas, and personal characteristics of Novy and Lewis' depiction of Gottlieb. I will also incorporate into the text themes of Novy's scientific attitudes, research conduct and educational objectives that de Kruif captured from his first-hand experience with Novy and brought forth to the novel. Below, I offer a brief synopsis of the plot of *Arrowsmith*, and then briefly describe each chapter in this dissertation.

Arrowsmith focuses on the sentimental education and moral growth of Martin Arrowsmith from youth to adulthood. Martin is a medical student at the University of Winnemac, a Midwestern American University at the turn of the 20th century. He is disillusioned with medical teaching which he felt was passed on from one generation to another without being subject to rigorous scrutiny. Martin is conflicted throughout the novel as he highly regards the healing aspects of medicine, as symbolized by Dr. Silva, but is most strongly attracted to ideal of medical research, as symbolized by Max Gottlieb. Following graduation, Martin takes on various jobs—country doctor, public health physician, pathologist working in a clinic, but in each circumstance his surroundings alienate him. With the help of Gottlieb, the beacon toward which Martin's wandering spirit increasingly veers throughout the novel, Martin is hired by the prestigious McGurk Research Institute in New York. Martin achieves newfound scientific celebrity after testing his discovery, a bacteriophage against the plague bacillus, with therapeutic success but without scientific rigor while losing his first wife to the plague. He abandons his prestigious position and his new wealthy wife to retreat to the woods and work in a homemade laboratory in pursuit of scientific truth. At the end, Martin, having been educated painfully in the ways of the world, achieves a life that is in accordance with his true self.

Chapter one of this dissertation serves as a background for Novy's subsequent research investigations and medical educational activities that I address in later chapters. In chapter one, I will describe the rise of the Michigan hygienic bacteriology laboratory and how Victor Vaughan, professor of physiological chemistry at the University of Michigan, and Novy set an agenda for original research investigation in the context of public health duties. I will then outline Novy's early life, education, and aspirations to become a full-time medical researcher. I will address his atypical career path for a medical researcher at the time—Novy became a chemist before he became a physician. The content of his advanced chemistry courses along with its emphasis on experimental and instrumental design would later become evident in his methodology and choice of topics when he became an independent researcher in bacteriology.

In chapter two, I will pursue what Novy actually did in his medical school laboratory. Novy gravitated towards the instrumental side of microbiology—not only in microscopy and culturing methods, but the melding of the principles and methods of chemistry with microbiology—to understand basic biology of microbes and their behavior. His training in chemistry became evident in his orientation towards technological innovation as well as the topics he investigated—bacterial metabolism and microbic respiration. I show how he devised new instruments and methods that allowed him to "visualize" organisms at the cellular level and bacterial products on the molecular level. In addition, his innovative use of dynamic observations allowed him to explore a new dimension of microbiology in order to understand the changing appearances of microbes over time and the behavior of these individual forms. I argue that in devising the novel laboratory-based methods, Novy did not restrict his laboratory-based inquiry to controlling disease in humans and some of his experiments bore no relation to his European predecessors. During his lifetime, Novy's colleagues and students considered him to be a pure scientist who carried out fundamental research.

In chapter three, I will look into Novy's activities outside of his medical school laboratory. In 1901, he and a team of commissioners traveled to San Francisco's Chinatown in order to work from the site of an outbreak of illness. The commissioners worked on-site in San Francisco for two months, hoping to resolve a question regarding whether plague was present as the population was not exhibiting classic signs. Novy seized an opportunity in research investigation by gaining access to specimens taken from environmental settings which would not necessarily have been available to him at a medical school to show the evolution of a disease in its environmental setting. By demonstrating how the plague bacillus could occur in people who did not have classic signs and could also occur in a non-epidemic form, Novy use his bacteriology laboratory in an attempt to redefine a disease in a medical and public health context. Novy concluded that plague could exist beyond the clinical scenario that had traditionally been thought to define plague. But Novy was at an impasse because he could not scientifically explain why plague in San Francisco was behaving in an unusual pattern. Furthermore, his bacteriogically-based conclusion did not convince physicians and citizens of San Francisco who defined plague by its social disruption, historical decimation of populations, and terror. The city did not implement aggressive anti-plague measures based on his findings, but did so when it fit their overall needs. For the remainder of his long career, Novy remained in his medical school laboratory and did not become involved in other field investigations.

In chapter four, I will address how Novy used his research activities in Michigan as a basis for medical education activities. In 1889, Novy developed the first intensive, full semester lecture-laboratory course in bacteriology taught in America. It was his intention to make the medical education more scientific by taking this key step in expanding the basic science curriculum. I will ask what Novy was trying to accomplish with his course, and argue that it was his intention to instruct not only the discipline of bacteriology in a hands-on fashion, but also to instill what he termed the "spirit of scientific research" in all first year-students. For Novy, the spirit was a broad term that included cognitive skills, a moral imperative that valued searching for occult truths in nature above all competing motives and a commitment to discipline, hard work, independence, and the obligation to actively explore new knowledge in the laboratory. I will argue that Novy was using science to build the character of all students, not only to sharpen the minds of the few who were destined for a research career. Novy never explicitly defined how an understanding of a basic understanding of microbial behavior was directly relevant to the practice of medicine. Nevertheless, in insisting that his scientific bacteriology course, and a group of other laboratory-based courses, were essential for all medical students, Novy allowed medical education to become more democratic than in Germany, where bacteriology was taught only to those destined to become researchers.

In chapter five, I will use letters that some students voluntarily wrote to Novy to explore their impressions of Novy's educational intentions and activities. These letters do not represent the voices of all students who took Novy's class, but they do show how the students who wrote to him embraced the broad meanings of the spirit of science that Novy both professed and symbolized to them. By instilling a unifying spirit that stressed a search for an underlying truth above all competing motives and hard work, Novy was able to create a culture of science among a cadre of students who were destined to enter practice and research alike. By making scientific medicine relevant for all students and creating a group of adherents, Novy was able to create something novel: an enduring discipline and department of bacteriology in a medical school setting. Students who wrote to him had faith that a technocratic expert like Novy, using precise tools and methods, could create a more reliable, more truthful profession than the older, ad hoc experiential methods of an earlier era. *Arrowsmith* fictionalized the transformative potential of laboratory science in providing verifiable truths to a medical culture that Lewis portrayed as lacking certainty and credibility. In addition, broader themes of progressivism in early 20th century America were reflected in students' belief that the techniques and methods of science were tools, which if used by a qualified expert, could yield truths that existed in nature and provide innumerable practical benefits to mankind.

In chapter six, I will investigate how Novy's original, fundamental research activities helped to contribute to the construction of bacteriology as an evolving medical discipline in America. Bacteriology was a new field in the 1890s, and Novy and a cadre of other scientists rallied around the theme of basic research as a way to unify a field that they believed was becoming fragmented by its large variety of practical applications, and as a way of distinguishing their jurisdiction from other fields, including pathology. But I will argue that Novy and his colleagues argued that the relationship between bacteriology and pathology was fluid. When seeking funding for his laboratory, Novy preserved linkages between bacteriology and pathology by making arguments for state-support of bacteriology activities that led to interventions to prevent human disease. But when making arguments that defined bacteriology as a specialized field, such as to support the creation of an independent department within his institution, Novy accentuated the ruptures between bacteriology and pathology on the basis that bacteriology was not limited to the domain of human disease.

In chapter seven, I will show how Novy succeeded in his aspirations to become a full-time researcher who contributed to the sum of knowledge but did not have to practice medicine. He was atypical in that he succeeded, as most American physicians who aspired to become full-time researchers during this period took care of patients also. I will show how Novy made active choices to remain in one academic setting for his entire career. In the process of making these choices, he revealed how he revealed the facets of his research operation that he valued most highly—among others, the independence to choose research topics without constraints of practicality. By showing that it was possible to make a career in medicine, outside of simply caring for patients, Novy became a leading figure in establishing experimental investigations in the laboratory as a foundation for a medical career in America.

In this thesis, my goal is to portray Novy's story in accord with his own aspirations—an account of how an aspiring medical researcher established a scientific career in medicine, what he did in the laboratory, and what meanings this had for American medicine and for bacteriology. I wish to explore how a transitional figure like Novy approached the theme of research investigation and medical education. To consider problems as Novy saw them privately in his personal writings provides an access that is one layer closer to the actual perceptions of a scientist than the manuscripts and texts published in the medical literature would have allowed in isolation. Moreover, the use of private sources shows the process of concepts evolving not just the finished products of published work. In this thesis, I use an account of a physician who preferred hypotheses on microbiology and its implications to health, rather than reliance on traditional clinical practice as a vehicle to view the beginnings of bacteriology and biomedicine in America.

Novy’s story is in many ways one of success in that his efforts helped to make American medicine scientific, as it remains today. In this thesis, I intend to study and explain Novy’s views of science, without necessarily sharing them or judging them. Novy was a champion of the merits of laboratory science and succeeded in his goal to firmly establish science in medical education and practice. Thus, any impression in this dissertation of preference for making medicine scientific may be due to the methodology of tracing Novy’s career. Any connotation that science has represented an advance over previous practices may be due to the use of Sinclair Lewis’ idealized portrayal of science in his novel *Arrowsmith*. I do not intend to depict Novy as a heroic figure of medicine or to argue that his work represented a triumph over traditional medical ideas and practices. Nor do I wish to portray Novy’s advocacy of laboratory science as having a dehumanizing influence that was at the root of perceived failings of modern medicine. I do not intend to blame Novy for the perceived failings of a modern medicine he never envisioned or reward him for its subsequent successes. Rather, I will try to credit him for his own vision of medical research and the ideals of the brand of scientific medicine that he espoused.

CHAPTER 1

Origins of Bacteriology at Michigan and Frederick Novy

Introduction: In this chapter, I trace the origin of the Hygienic Laboratory of the University of Michigan. To provide a background of the laboratory and its original mission, I will first explore the roots of both the Michigan Public Health Department and the University of Michigan Medical School. These two institutions became connected through the vision of Victor Vaughan, the laboratory's founder. By the 1880s, Vaughan became convinced for a need for a state laboratory to perform bacteriological analysis of water, milk, and other substances in order to provide surveillance and for preventive measures as well.

While acknowledging the practical mission of the hygienic laboratory, Vaughan's major interest was to carry out fundamental, independent research. Vaughan sought and successfully obtained funding from the state legislature to build and equip the laboratory for these purposes. Shortly after establishing the laboratory, Vaughan and Frederick Novy, who was hired as an assistant in the laboratory by Vaughan, decided to travel to study bacteriology with Koch at the Hygienic Institute of Berlin and Louis Pasteur in Paris. Why did they travel to Europe in pursuit of an idea they already held? They recognized the need to learn bacteriology in the two laboratories of the world where advanced training in the new science was offered by "master" scientists. But they also went to preserve the purity of their science—to learn exacting experimental techniques in well-equipped laboratories from scientists who valued the independence of scientists tochoose their own research topics, design their own experiments, and work out their own solutions.

Vaughan and Novy returned to America along with many aspiring American doctors who studied in Europe in the 1880s. Ken Ludmerer, Thomas Bonner, and William Rothstein have maintained that when these physicians returned to America, the majority learned that American medical schools had little interest in full-time faculty appointments in bacteriology. Consequently, most American physicians returning from European study resorted to practicing medicine in order to make a living. But Novy was unusual in that he became a full-time faculty member who was able to obtain funding from the state to support his laboratory and his fundamental research intentions. He began his career by seeking to create a niche as a fundamental researcher while holding a position with practical duties that involved public health service and instruction of medical students. Novy believed his fundamental research intentions would complement and not contradict the practical responsibilities that were expected of him.

In order to provide a foundation for Novy's career aspirations after he graduated from medical school, I will explore his early background and his training in chemistry in college and graduate school. I will also describe his German training, and the elements of this experience that made an impression on him—the disciplined, hard work and the autonomy of the investigator—that he tried to replicate after he returned to America.

The Michigan Department of Health

From its creation in 1873, the Michigan board of health set a progressive goal to acquire vital statistics of diseases that threatened the public wellbeing and to provide rational, systematic means for their prevention.[1] The founder of the Michigan board, Dr. Henry Baker, had become convinced of the need for a state board of health. At this time, the state health agency was gaining public support because of the frequency with which illuminating oil, used in homes and the workplace, was exploding and resulting in fires, property damage, injuries and deaths. This was compounded by a scare about the use of arsenic in wallpaper.[2] Baker had been involved in army hygiene and sanitation during the Civil War and subsequently served on the Michigan State Board of Agriculture.[3] After reading the first report of the Massachusetts Board of Health, Baker persuaded the Michigan State Medical Society to promote a similar agency for Michigan. His medical partner, Dr. Ira Bartholomew, was president of the state medical society and was elected to the state legislature.[4] With Bartholomew advocating in the legislature, the Michigan State Board was established in 1873.[5]

The first members appointed to the Michigan board, four physicians and two ministers, set out a comprehensive program. Baker, who was chosen secretary, was a strong advocate of vital statistics. Due to Baker's influence, the Michigan board sought to compile statistics on sicknesses among people, including diarrheal illnesses, and circumstances, conditions, and habits that influenced the health of the people, such as hazardous illuminating oil and the hygiene of school buildings.[6] The board also had an educational mission in teaching citizens about how to avoid potentially harmful environmental exposures, such as poisonous wallpaper. The board conducted sanitary investigations and drafted regulations in regard to water supply, disposal of excreta, and the heating and ventilation of any public institution or building.[7] Thus, the professional members of the original board set a progressive agenda from the start.

In the 1870s, the Michigan board began outreach activities in towns throughout the state. The board worked with the legislature to enact a law in 1877 that required each township to appoint a health officer to report on health and sanitary conditions.[8]The law created a need for qualified health officers and led the board to begin conducting sanitary science examinations in 1878 in order to certify the officers. Candidates were subjected to testing in biology, diseases, physical science, sanitary engineering and sanitary inspection. Thus, the first Michigan Health Department sought to recruit professionals on its staff as well as its board.

The Michigan board during the 1870s conducted a range of ambitious projects.[9] The board performed investigations on adulterations of foods such as maple syrup, published pamphlets and yearly reports of its activities, and instituted an effective health education campaign.[10] As the state law requiring all Michigan communities to establish health boards gradually took effect held two sanitary conventions early in 1880. They were designed to inform and encourage local health officials and to educate the public. As of 1882, the Michigan board had sixteen standing committees dealing with a wide range of health and sanitation topics, including an analysis of various foods, such as milk, ice cream, and maple syrup. Samples were collected throughout the state and sent to a central physiological chemistry laboratory at the University of Michigan. A report on adulterations of food was made by a professor of physiological chemistry, Albert Prescott.[11] During that year, a newly appointed member of the Board of Health, Victor

Vaughan, professor of hygiene and public health at the University of Michigan, lectured the public on how to eat a nutritious diet.[12]

Who was Victor Vaughan? Vaughan (1851-1929) was born at Mount Airy, Missouri. He graduated from Mt. Pleasant College in Fayette, Missouri in 1872. He entered the University of Michigan in 1874 to study chemistry. He received a doctorate in chemistry in 1876 and a medical degree in 1878. For twenty years following his graduation in medicine, Vaughan was engaged in active medical practice.[13] But his interests centered on laboratory work, particularly the relationship between chemistry and hygienic science. Through his association with the Michigan Department of Health, he was to investigate poisonings from cheese and other milk products and he furthered his interest in toxicology and epidemiology. He began his work when bacteriology was in its infancy, and he soon became interested in investigating whether the poisonous products were in some way the result of bacterial action. This interest led to his establishing the hygienic laboratory and a life-long research collaboration with his favorite student and laboratory assistant, Frederick Novy. His role in establishing the laboratory and in setting the research agenda for the laboratory will be explored in further detail below. In recognition of his scholarly contributions on preventive medicine, epidemiology, and food poisonings, Vaughan first became an Assistant Professor of Chemistry in 1880 at the University of Michigan, and then professor of hygiene and physiological chemistry in 1887. In 1891, he was made Dean of the Medical school, a position he held until his retirement in 1921.[14]

In the mid-1880s, the statistical surveillances of the Department of Public Health led Vaughan to consider that poisonous outbreaks were potentially caused by infectious diseases. In 1883, an outbreak of cheese poisoning affected hundreds of persons in widely scattered parts of Michigan, and it was followed by an epidemic of poisoning from ice cream.[15] In 1884, Vaughan traveled to various townships to inspect local markets then returned to his laboratory to analyze food samples that had been purchased in grocery stores.[16] Vaughan found evidence of fishmongers hiding signs of decomposition by removal of fish's eyes and coloring the gills with blood.[17] He also went to a cheese factory in southeastern Michigan, Lenawee County, that had been identified as one of the sources of poisonous cheese. Vaughan speculated that the tainted cheese was due to the products of bacterial contamination.[18] Vaughan, however, admittedly did not have a bacteriology laboratory to test his hypothesis.

The Hygienic Laboratory at the University of Michigan

The speculation of infectious outbreaks prompted Vaughan to call for a hygienic laboratory that could perform bacteriological testing of suspected specimens.[19] Vaughan, who headed a special committee of the Michigan board members, conferred with the regents of University of Michigan about establishing a state hygienic laboratory at the university.[20] To the regents, Vaughan argued that the location of the laboratory within the university would be mutually beneficial: the presence of the laboratory would strengthen the science department at the university by providing specimens for analysis, and the hygienic laboratory would be enriched by existing science in departments at the university.[21] Vaughan argued, "This laboratory should naturally belong to the University and have all the advantages of the association with the other departments...In union there is strength, and in the association of these departments there will be felt an influence in the direction of scientific thought and investigation which will redound to the interest of the University and the state at large."[22]

To the regents, Vaughan also maintained the university had traditionally focused on purely scholarly subjects such as the literature and language of ancient Greece, but it ought to pay more attention to pragmatic issues such as the health of its own citizens. He said to the regents, "Would it not be well to give a little attention to the prevention of disease? Shall it leave from its curriculum altogether the study of the prevention of diseases which afflict human life? Are the lives of citizens of so little value?"[23] In his justification of a university location for the hygienic laboratory, Vaughan made an argument that the university's academic mission contains a fundamental duty to public service. A university-based hygienic laboratory would drive the school in a more practical direction.

Vaughan's argument in 1887 that both universities and government science agencies and were duty bound to public service was not totally new. At the federal level, the Library of Congress was created in 1800 and was expanded in the 1880s to provide scholars and scientific investigators access to primary sources.[24] The federal government also funded the Geological Survey in 1879 to map the territories of the US, study the mineral resource deposits of the public domain, and advance scientific understanding of the natural environment.[25] In addition, the Morrill Acts of 1862 and 1890 granted federally controlled land to states to endow land grant colleges whose mission was to teach practical agriculture, science and engineering, as opposed to the traditional liberal arts curriculum.[26] Through the extension programs of these colleges, citizens and farmers were taught to use resources more efficiently and effectively. Furthermore, the call of duty of public service for a university was later emphasized during the progressive era in 1904, when the University of Wisconsin president, Charles Van Hise, maintained that research conducted at the university should be applied to solve practical problems—improving health, quality of the environment, and agriculture for all citizens of the state.[27]

Vaughan's arguments about the mutually beneficial relationship of the hygienic laboratory and the university can be considered in the context of President James Angell's educational reforms at Michigan. In arguing that the hygienic laboratory would make the university more useful in promoting the welfare of the people and that training in sanitary science was as worthy as training in any other science or in art or literature, Vaughan was advocating change. At Michigan, Angell was a main instigator of change towards a modern university.[28] President from 1871 until 1909, Angell involved himself in the development of the university's activities and pressed for the growth of practical subjects, particularly the natural sciences. He felt these subjects, unlike the focus on the antiquities, were of use to mankind and were worthy of advanced instruction at the graduate level.[29] Angell expanded the topics of courses offered to undergraduates, including modern languages, science, engineering, and laboratory-based courses.[30] He also promoted independent study and original research in laboratories, the introduction and expansion of the elective system, and the creation of voluntary chapel services, which had previously been required.[31] Angell insisted that the University promote education and research in all areas of learning, new and old.[32] He also sought to invigorate the University's professional schools—medical and law--which he felt should be integrated with the spirit of university life.[33] At Michigan, Vaughan himself exemplified this trend, as in 1884 he offered a practical course called "Sanitary Science," dealing with the analysis of water, foods, and drugs, in the chemistry department on campus.[34] To encourage further integration of the university's medical school with the sciences on campus, Angell routinely attended the biweekly faculty meetings held by the medical school.[35]

The rise of modern universities in America in the 1880s encompassed the time when Angell and Vaughan advocated for educational reform and a closer relationship between the professional schools and the basic science departments at Michigan. Angell reasoned that a closer relationship would enhance the quality of the science at the medical school, as well as provide opportunity for practical applications of the basic sciences. This stance was also being advocated in the 1880s by Presidents Charles Eliot at Harvard, then later in the 1890s by Daniel Gilman at Johns Hopkins and Andrew White at Cornell.[36] Thus, Angell's idea of educational reform, with the new sciences being offered in addition to older courses, was consistent with the vision of a modern university promoted by other American college presidents during this time.[37] Vaughan himself acknowledged that universities older than Michigan, including Oxford and Harvard, had begun to construct new departments and courses to "meet the wants of the time."[38]

Vaughan's argument to locate the laboratory within the university resonated with the regents, who were eager to strengthen the sciences through linkages of the university with the state. After gaining the approval of the regents, Vaughan requested funding from the state legislature to organize and equip a suitable hygienic laboratory which he argued was "absolutely essential to the best interests of the people of this state for their preservation and well-being."[39] To the legislature, Vaughan argued that it is the duty and responsibility of the state to provide support to protect its citizens from disease, as had been done in other countries. He said, "Nearly every civilized country is now manifesting great interest in the protection of the health and the prolongation of the lives of its citizens. Germany has established a number of hygienic institutes in connection with its universities. The municipal laboratory in Paris is maintained by the city, and…from this knowledge the wisest enactments against food adulterations have been made and are enforced."[40] Vaughan was reminding the legislature that precedent had been set in other countries regarding the duty of the state to fund well-equipped hygienic laboratories, and he argued that America should follow their lead.

Vaughan's arguments proved successful. In a joint petition with a group of regents of the University, the Michigan State Legislature granted $35,000 to the University to build and equip a laboratory for hygiene in the building that housed the Michigan physics department, beginning June 24, 1887 and ready to be occupied by autumn, 1888.[41] It was constructed according to Vaughan's wishes: a building of 80 by 60 feet, two stories high with furnishings, apparatus, and reagents.[42] Thus, the location of the medical school in proximity to a university provided a new home for the hygienic laboratory and, according to Vaughan, made higher standards for public health feasible. Vaughan's assistant in the laboratory, his industrious student, Frederick Novy, was thrilled with the laboratory facility funded by the sated, saying, "Success eventually crowned the efforts of the board and a generous appropriation by the legislature…"[43] Furthermore, because the building cost $28,000 to construct, Novy and Vaughan had a portion of the $35,000 state grant left over to pay for additional equipment and reagents on an ongoing basis.[44] Novy credited the state legislature for supporting a "well-constructed and well-equipped laboratory that [would be] suitable for [his]…purposes"[45]

Although the hygienic laboratory did not officially open until 1888, as early as October 1887 Vaughan laid out his goals and his agenda for the laboratory.[46] Vaughan and Novy would begin to perform bacterial analyses of specimens from ill patients (e.g., sputum and other substances) and also analyses of milk, water, meats and other substances to search for pathogenic bacteria.[47] Vaughan prioritized his goals and identified original research in bacteriology and biology as the primary duty of the facility and staff.[48] Thus, Vaughan's goals of the hygienic laboratory were aligned with Angell's overall vision of the modern university. Vaughan said, "Research work constitutes the real raison d'etre of a laboratory."[49]

Vaughan's insistence on original research and instruction also must be understood within the context of the overarching effort to make medicine more scientific at the University of Michigan Medical School. Opened in 1850, the medical school differed from proprietary schools in having its building on the campus of a university and by employing professors who were paid salaries. Many proprietary medical schools located outside of academia had two three-month semesters and teachers were paid with fees received through their private practices. At Michigan, the original two-year curriculum, composed of two four-month semesters, was principally composed of didactic lectures.

With the 1881 hiring of Henry Sewell, research had begun in one laboratory-based scientific discipline, physiology.[50] Sewell extended the physiology lectures from 30 to 80 lectures and from one to two terms in order to illustrate his lectures to medical students, although the course did not have a laboratory component. To accommodate the extended time in physiology, as well as the extended number of courses Vaughan offered in sanitary science, in 1884 the total course of study was extended from two to three years.[51]

By the late 1880s, Vaughan increasingly stressed the model of the investigator-educator. He expected Novy to serve not only as an assistant researcher in the hygienic laboratory, but also to teach a course in bacteriology. When Vaughan became the dean of the medical school in 1891, he became intent on reshaping the entire medical school into a center of advanced teaching and research. In accomplishing this, Vaughan sought to foster a culture of "scientific medicine" by assembling a cadre of "expert" faculty in an array of fields that included physiology (Henry Sewell and Warren Lombard), pharmacology (John Jacob Abel and Arthur Cushney), anatomy (Franklin Mall), internal medicine (George Dock), pathology (Aldred Warthin) and, in 1891, physiological chemistry and hygiene (Frederick Novy).[52]

Who was Novy**?**

Frederick Novy had been Vaughan's most promising medical student when Vaughan appointed him assistant director of the hygienic laboratory in 1888.[53] Novy studied chemistry as an undergraduate at the University of Michigan. Upon graduation in 1886, he went on to receive a doctorate in physiological chemistry in 1890 before receiving a medical degree from Michigan in 1891. As a medical student at Michigan, Novy traveled to Europe to learn bacteriology. Upon return to America, he sought to perform scientific medical investigation on a full-time basis. Novy successfully made a career for himself as a laboratory-based medical researcher. Well before the end of his career in 1935, he had received worldwide recognition among scientists and clinicians for his influential research on microbes and their behavior. Below, I will use Novy's private notes to begin a chronological exploration of his youth, education, and early career. While an exploration of what he wrote in his private letters to family and colleagues, diaries, and classroom notes does not provide a complete account of what he really thought, the private notes do provide some insight into his motives and impressions of his early life.

Novy was born in Chicago on December 9, 1864, the same year in which his parents, emigrated from Bohemia, in what is now the Czech Republic, seeking greater security than seemed possible amongst the political turmoil in their homeland.[54] In the 1860s, Bohemia was ruled by the Austrian Empire, as the Czech nationalists who called for autonomy for Bohemia from Austria had been defeated during the Revolution of 1848. Following their defeat, many Czech nationalists were constitutional monarchs and remained loyal to the central Hapsburg Emperor. But by 1861, an opposing political faction, consisting of the Bohemian aristocracy who favored the renewal of the old Bohemian Crown, emerged. By 1864, tensions were mounting between the Austrian Empire and the Kingdom of Prussia over the unification of the German states that anteceded the 1866 Austro-Prussian War fought in Bohemia. It is possible that Novy's father, who was as a sergeant in the Austrian army, spoke Czech, and had been a master tailor in Bohemia, was in favor of 1848 nationalism and labor movements.[55] From his father, Novy felt that he received a sense of discipline and a drive for precise accomplishment.[56] In Chicago, Novy lived in a multi-family dwelling, and both of his parents worked jobs in order to make a living, his mother as a milliner. Both parents were pious, worshipping Catholics.

Well before high school, young Fred became a dedicated student.[57] At home, he often went from the dinner table directly to his study.[58] By high school, his major interest was in history and in chemistry.[59] Novy particularly enjoyed classical Greek and Roman history and archeology.[60] During his senior high school year in Chicago, Novy's interest ranged from ancient Egyptian, to Greek, ancient Roman and medieval history.[61] Although Novy's primary academic focus would soon veer towards science, this early interest in history would carry over into his professional life as he later emphasized history in his scientific articles and lectures.[62]

By his junior year of high school, Novy's interest in science veered towards chemistry and involved laboratory experimentation and research investigation.[63] He was influenced by a chemistry teacher, Marc Delafontaine, who performed original investigations in chemistry.[64] Novy became intrigued by Delafontaine's experiments and his claim that he had discovered several elements.[65] Under Delafontaine's guidance, Novy soon began to perform experiments of his own in chemistry in a laboratory that Novy constructed beneath the back wooden stairs of his multiple family dwelling. On one occasion, Novy noted he had succeeded in making an unstable gas—phosgene gas, which exploded and blew up part of the stairs and nearly set fire to his family's house. He was allowed to continue his home experiments, but thereafter, his father relegated Novy's experiments to a backyard woodshed.[66]

Delafontaine became increasingly impressed with Novy's efforts at experimentation and invited Novy to his home, where Delafontaine showed him his laboratory and instruments, including his microscope and spectroscopes. Influenced by this visit, Novy resolved to earn enough money to buy a microscope of his own. In September 1880, Novy was hired for a job in the stacks of the Chicago Public Library. For the next two years, he worked evenings and Saturdays in the library.[67] With part of his earnings, he purchased a microscope.[68]

Novy was intrigued by the opportunities of his local, natural environment and began to seek ways to use his instrument to unveil microscopic inhabitants in nature. Novy began to search ponds and fields for life invisible to the naked eye.[69] In the late 19th century, this sort of behavior—searching the natural environment for specimens to observe microscopic organisms with microscopes—was practiced by other amateur scientists.[70] Novy collected specimens from ponds and swamp lands on the outskirts of Chicago, particularly Lincoln Park and Chicago's south side, to empirically test for various forms of microscopic life, including algae.[71] Novy purchased his microscope from a microscopist who then invited Novy to attend a meeting of the Chicago Microscopical Club.[72] A dozen amateur microscopists, with their microscopes and specimens, attended.[73] At the meeting, Novy and other microscopists presented specimens they had collected around the Chicago surroundings.[74]

One of the specimens Novy collected was in a form of *Volvox*, a free-swimming freshwater single-celled alga found in ponds, ditches, and shallow puddles. He had read that *Volvox* was an exclusively European organism. But with the help of the amateur microscopists, Novy found that this alga, propelled by whip-like structures called flagella that allowed it to dart under his view, could also be found in America. After finding *Volvox*, he wrote that he looked up in the literature what he had observed in nature, to see if what he was observing had been described before.[75] It was in one of the books on free living protozoa that Novy first read and took notes on trypanosomes—another unicellular, motile, flagella-propelled organism that would later figure prominently in his work as a medical investigator.

Delafontaine wanted to assist Novy in his explorations and he viewed Albert B. Prescott, professor of physiological chemistry at the University of Michigan, as an authority in chemistry. Like Vaughan, Prescott taught both at the medical school and in the chemistry department of the university. In 1881, Novy wrote to Prescott asking for a list of the chemistry books used in the courses he taught at Michigan. He received a handwritten list of all books used, covering all of the courses in chemistry. With the assistance of the buyer for the library who ordered the books at a discount, Novy purchased a set of three volumes: *A Treatise on Chemistry*, by Roscoe and Schorlemmer, an *Encyclopedia of Chemistry*, and a large *Micrographic Dictionary*, by Griffith and Henfrey. Novy began to acquire a library about the principles and methods of chemistry.[76]

As an amateur scientist, Novy had become drawn towards the methods of chemistry and of testing hypotheses in the laboratory. Having decided to follow his chief interest and become a chemist, at age seventeen, Novy chose to enter the University of Michigan—a decision perhaps influenced by Delafontaine's recommendation of Prescott as a reputable organic chemist. Novy's parents, however, were not affluent. Furthermore, his father was not fond of Novy's desire to become a chemist, as the career choices available to those majoring in chemistry at this time remained uncertain. Nevertheless, Novy remained steadfast, and told his parents that he would enter and pay for college on his own if they could not help him.[77] His exceedingly understanding and receptive parents met this wish by themselves moving to Ann Arbor and starting life again in that city. There the young Novy, who had no siblings, could pursue his college course while living at home—a house that remained Novy's primary residence until his death in 1957.[78]

Novy entered Michigan in 1882 at a time when, under Angell's presidency, the school was becoming modern. Novy was exposed to modern and practical subjects, including the natural sciences and modern languages, as well as elective courses that included independent study and research in chemistry.[79] As a freshman undergraduate, Novy took advantage of the growing variety of subjects that were available, including the study of French and German.[80] He also studied logic and rhetoric. Although intellectually stimulated by the subject of logic; he became skeptical of this discipline's ability to arrive at truths. Logic alone, he wrote in an essay in 1883, was a "useful discipline" in that it helped to "generate coherent hypotheses," but it did lack an avenue available to "empirically test the validity" of these hypotheses.[81] He enjoyed a course in geology, particularly the opportunity to "grind and mount fossils", but again wrote in his notebooks that this science was mainly "observational of natural phenomena" and lacked "opportunities to test hypotheses experimentally."[82]

By the conclusion of his freshman year, Novy's studies in other subjects reinforced his preexisting inclination towards the pursuit of chemistry. In a lecture-laboratory course in physiological chemistry course he took with Prescott in 1883, Novy wrote that "actual laboratory work" provided him with an opportunity not only to "test hypotheses" by "support(ing) it by demonstrable facts."[83] He noted that by learning precise chemical methods through laboratory exercises of known experiments, he could "acquire carefulness in design [and] manipulation of instruments and the confidence in the methods" which it is necessary to have before "entering upon independent research in this science."[84] His comments suggest that he was drawn towards chemistry not only because it provided him an opportunity to empirically test hypotheses through the use of specialized methodology in the laboratory, but also to develop proficiency in the construction and workings of complex instruments he would need for independent investigation.

By the end of Novy's sophomore year, he gravitated towards taking electives in chemistry. In the new advanced elective courses, students were asked to carry out exercises of known chemical equations, but also given the opportunity to devise equipment and design their own experiments independently to test hypotheses. In regard to an independent course taught by John Langley in 1885, Novy wrote that such training will "impart the power to create questions and the ability to develop methods and instruments necessary to carry on independent investigations."[85] Novy's laboratory notebook for a course he took with Langley demonstrates how he designed and constructed chemical apparatus to detect gasses emitted as a result of the interactions of chemical compounds he used in his equations.[86] [Figure 1.1] In addition, he helped design a machine for gas analysis that he found in one of the chemical labs. Langley, told Novy to work on its design, and to analyze the gases in the Bunsen flame. Novy designed, with Langley's guidance, a method for drawing off the gases at various levels.[87]

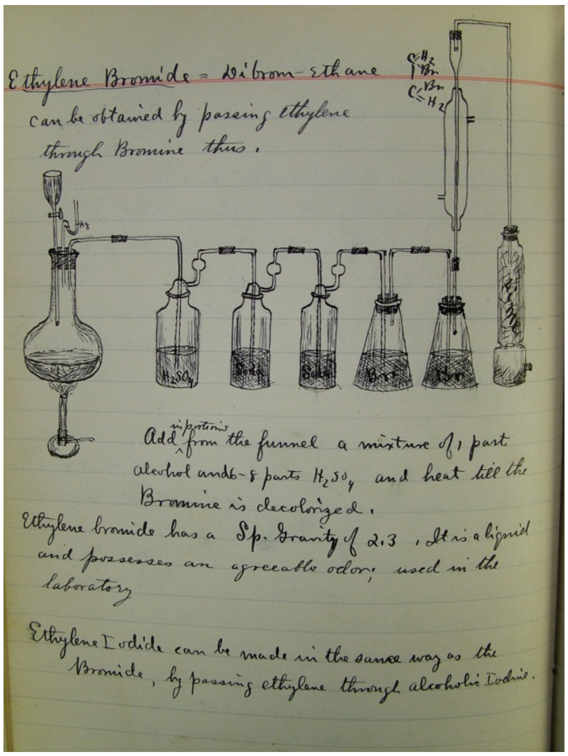


Figure 1.1. Notebook from Novy's college independent study course in 1885. In this experiment, students were asked to design experimental equipment to detect the product of a chemical reaction between two compounds. Novy designed this experiment to determine whether a gas was emitted from a chemical reaction between two compounds—ethylene and bromide. Novy designed this elaborate system to determine whether the gas ethane was produced as a result of a chemical reaction between ethylene, which was heated to the left of the picture, and bromide, which is contained in the sequential bottles moving to the right of the picture. Novy was attracted to these independent study courses in chemistry because he relished the

process of designing complex apparatus that enabled him to carry out his experiments and test the hypothesis at hand. (Courtesy of Bentley Library)

Novy's increasing proficiency in devising innovative techniques to solve chemical problems and his ability to perform independent investigation became evident to his professors. In a letter of recommendation for Novy, Prescott stated, "I regard Mr.F.G.Novy as a student of unusual ability and a young man who gives excellent promise of success both as a teacher and as a worker in science. He is a man of sterling qualities."[88] Novy's abilities led his teachers to rely on him to assist with their instruction. For example, in the fall of his senior year, Novy was asked to teach one of the chemistry classes when the instructor had to leave because of illness. In the spring of his senior year William Campbell, Novy's professor of physical chemistry, wrote that Novy conducted the class for five weeks when Campbell was ill and unable to attend class.[89]

In 1883, a course in physiological chemistry taught by Prescott exposed Novy to issues of public health.[90] Prescott figured prominently in Angell's educational reform, as he had been applying physiological chemistry investigations to the realm of public health. He performed investigations relating to chemical analyses of adulterated foods, which were sent to his laboratory by the State Department of Health. Prescott lectured about the unscrupulous practice of food adulteration and its vitiating influence on the public, including the mixture of paraffin and sugar that was deceitfully sold as honey, or colored beef tallow sold as butter.[91] He also lectured on adulterated butter and testing sugar sold as pure cane, and found that it contained corn starch—added to give it bulk.[92] He said, "the dangers of adulteration are underrated when it is supposed that falsified food can be tolerated without depraving the public purpose and impairing the sacred safeguards of human life."[93] Prescott was clearly equating commercial fraud with health risks, as he did not specify what the specific health dangers of ingesting beef tallow, excess amounts of corn starch, or paraffin were. Thus, his view of adulteration was a moral one rather than a strictly medical one. Nonetheless, Prescott's views of protecting the public from injury through the application of science in the realm of public health was a subject that Novy would return to in his later professional years.

In 1886, Novy was one of three undergraduate students who received a degree in a program of expanded sciences that was newly created at Michigan—the Bachelor of Science degree.[94] The educational reforms of the 1880s provided Novy the opportunity to take advanced courses and independent study with professors like Prescott, who also taught at the medical school. By the time of his graduation, Novy had been increasingly drawn toward independent study courses where he could devise new apparatus to empirically test hypotheses in a laboratory setting, as opposed to the speculations that he felt characterized subjects like logic.[95]

After graduation in 1886, Novy returned to Chicago where he sought a position as a high school chemistry teacher or as a chemist. His reference letters from college professors endorsed him for either position.[96] Novy, however, decided against teaching chemistry in high school, perhaps because he felt there was not ample opportunity to carry out research in such a position.[97] He began to look for a job as an analytical chemist. In Chicago, he found three men doing such work, and all three depended upon work other than chemistry for their livelihood. Novy inquired about jobs at several places, including the stock yards of Armour Packing Company. According to Novy's recollection years later, he told P. D. Armour, the president of the company, that he was a chemist and explained the nature of his work and the potential importance of analyzing the waste products of the packing industry. Armour said he would hire him only on the condition that Novy would guarantee that the equivalent of his salary would be returned to the company in earnings accruing directly from his work. Looking back on this episode after his retirement, Novy considered Armour's response a turning point in his career. He felt that to industrialists like Armour had not adequately valued chemists.[98]

While seeking work in Chicago, Prescott invited Novy to return to Ann Arbor in 1886 as an assistant in organic chemistry at a salary of two hundred dollars per year. Novy accepted Prescott's offer. During the next year, Novy taught classes in organic chemistry and toxicology at the University of Michigan and studied toward a Master of Science degree, a newly offered course of graduate study ushered in along with Angell's reforms. Upon graduation, Novy presented a thesis on "Cocaine and its derivatives," in which he described the chemical structural formulas of several alkaloid derivatives of cocaine that he had made.[99] Novy was one of two students at Michigan to receive a Master of Science degree in June 1887.[100]

While a student in graduate school, Novy taught physiological chemistry along with Vaughan, who persuaded him to take a position in the university as instructor of physiological chemistry. In the fall of 1887 Novy again took up teaching duties at Michigan, and began working towards a doctor of science (Sc.D) degree in physiological chemistry, which he received in 1890. In 1888, while still enrolled as a doctoral student, he also opted to enter medical school without specific knowledge of whether the type of experimental research he had come to know in chemistry might be feasible in the medical profession. In all of Novy's notes, he never explicitly stated why he wanted to enter medical school. One can speculate that his interest in the medical field was sparked by his two professors of physiological chemistry who also taught at the medical school, Prescott and Vaughan.

Novy entered medical school at a time when the course of study was three years. In 1888, Michigan's program, like most medical school programs, consisted of one course of lectures, taken twice, that covered a period of six months.[101] Subjects that Novy took during his first two years included descriptive anatomy, comparative embryology (a course that presented an evolutionary view of human development), histology and microscopy, physiology, sanitary science, and materia medica and therapeutics.[102] Subjects in his second year included pathological anatomy, physiology, general pathology, practice of medicine, medical jurisprudence, systematic surgery, obstetrics, and diseases of women and children. The majority of these courses were taught in classroom halls by didactic lecture, with the exception of anatomy, in which students dissected cadavers in a dissection room, and the occasional demonstration, such as in surgery and physiology.[103] Subjects in his third year were taught in clinic settings. These included clinical medicine, clinical surgery, clinical gynecology and diseases of children, and diseases of the skin, ophthalmology and otology, eye and ear clinic.

Novy felt that the medical school curriculum did not provide a chance for students to critically evaluate the information they received in lecture halls. He noted that the professor in his 1889 course “Practice of Medicine,” Henry Lyster, focused on fixed descriptions of disease. Novy said that Lyster “describes and categorizes diseases, but does not…encourage students to make inquiries [about them]. There are no laboratory exercises…to teach students how to investigate the causes [of disease]...”[104] To Novy, Lyster stressed that medicine was a defined body of knowledge and that a student’s task was to master that knowledge rather than being challenged to enlarge it. Novy viewed the state of medical knowledge as provisional noting for most diseases a “need to expand our knowledge about causality, prevention, and treatment.”[105] He felt medical courses should allow increased “opportunity for students to question and eventually design experiments” to empirically test received wisdom.[106] For Novy, the didacticism of his lecture courses belied the tentativeness of medical knowledge.

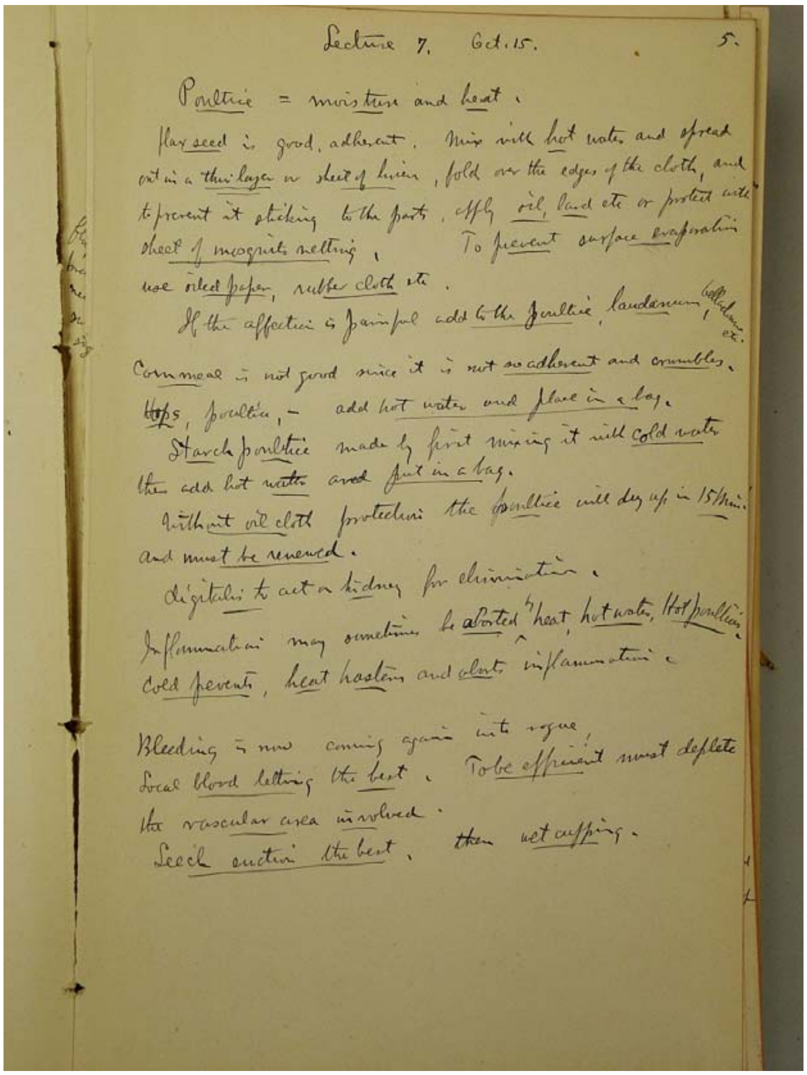
Novy’s medical student notes also explore the consequences of lacking understanding of causality and therapies for diseases like diphtheria. In his notes on a 1888 lecture by Lyster on this disease, Novy recorded detailed clinical features of the disease, and then wrote:

> The prognosis is guarded. Because bacteria cause the disease and abound in the membrane and its exudates, the poisonous material produced locally enters the blood and when absorbed causes symptoms. There is no antidote certain to neutralize the poison and arrest the disease. Efforts to destroy the germs in the throat include gargles of potassium permanganate…or flowers of sulfur blown into the throat through a quill. A spray of carbolic acid with limewater might loosen the membrane which may then be expelled. Gentle bloodletting, clysters

> and cupping are attempted... The exudates in the larynx and trachea suffocate the child and mechanical attempts to remove the membrane are unsuccessful. The disease exhausts all remedies. In [many] cases death follows. As the nature of this disease is better understood, more effectual antidotes may be discovered.[107]

Novy's classroom notes do not allow one to distinguish his voice from Lyster's. Nonetheless, his notes focus on the limitations of medical knowledge and the unavailability of effective therapy to reverse the disease's course. They convey the helplessness physicians felt when caring for a child dying with diphtheria, despite available therapies. They also show an orientation towards understanding the mechanisms that underlay disease and to assess the efficacy of therapies.

Diseases for which the medical profession had no effective therapy highlighted for Novy and Lyster the need for new knowledge in medicine. But how could one arrive at such knowledge? In medicine, he felt that "blind faith should be put to the test"—that there should be skepticism of received knowledge.[108] He also felt there was a need to supplement lectures with laboratory courses to foster critical thought and actively test hypotheses empirically.[109] Novy commented on the lack of opportunity for students to "investigate the underlying cause of diseases in the laboratory".[110] Furthermore, Novy was doubtful as to whether some of the treatments proposed by his professors were necessary or useful at all. [Figure 1.2] As he wrote in his medical school notebook in his second year course, "Materia Medica and Therapeutics," regarding his professor Walter Christopher who recommended the use of clysters (enemas with a syringe) for general fevers, diphtheria, scarlet fever, mumps, and malaria: "Would identical therapy be effective for different diseases that likely have distinct causes? Would there be improvement in symptoms of some conditions without any therapy at all?[111] Novy questioned whether some therapies medical students were taught to dispense were really necessary at all and how one could judge the efficacy of those therapies.



Lecture 7. Oct. 15. 5.

Poultice = moisture and heat.
Flax seed is good, adherent. Mix with hot water and spread
out in a thin layer on sheet of linen, fold over the edges of the cloth, and
to prevent it sticking to the parts, apply oil, lard etc or protect with
sheet of mosquito netting. To prevent surface evaporation
use oiled paper, rubber cloth etc.
If the affection is painful add to the poultice, laudanum, belladonna etc.
Cornmeal is not good since it is not so adherent and crumbles.
Hops, poultice, – add hot water and place in a bag.
Starch poultice made by first mixing it with cold water
then add hot water and put in a bag.
Without oil cloth protection the poultice will dry up in 15 min.
and must be renewed.
Digitalis to act on kidney for elimination.
Inflammation may sometimes be aborted by heat, hot water, Hot poultice.
Cold prevents, heat hastens and aborts inflammation.

Bleeding is now coming again into vogue,
Local blood letting the best. To be efficient must deplete
the vascular area involved.
Leech suction the best, then wet cupping.

Figure 1.2. Notes Novy took as a medical student during his "Materia Medica and Therapeutics" lecture course, October 15, 1889. In this lecture on treatment of inflammation, his professor Walter Christopher wrote on the various options physicians had to treat inflammation, ranging from poultice, bloodletting, cupping, and leeches. Novy's lecture notes show that Christopher felt that the application of leeches were the most effective treatment, whereas others, such as bleeding, came in

and out of popularity. In the absence of a scientific system to test the effectiveness of various therapies, as he had been familiar with in his college chemistry classes, Novy wondered how physicians determined which agents among the therapeutic alternatives would be the most effective. (Courtesy of Bentley Library)

Novy believed that there was a need for new knowledge in medicine and he knew that new medical knowledge would not come from an uncritical, passive reception of didactic lectures given by his professors in lecture halls. Novy's objection to learning by "blind faith" is a theme that would persist throughout his entire career; it was one he would pass on to his students, including de Kruif. Not surprisingly, it is also a central theme in *Arrowsmith*. In Lewis's novel, the medical student Martin Arrowsmith's challenge of his teacher's lectures mirrors Novy's. Like Novy, Martin challenged the idea of his materia medica professor, Lloyd Davidson that students should accept what was being taught without critically questioning its validity. Lewis wrote,

> Davidson taught students that most important of all things: the proper drugs to give a patient particularly when you cannot discover what the matter with him is. His class listened with zeal…But Martin was rebellious. He inquired, 'How do they know ichthyol is good for erysipelas?'...Davidson replied, 'How do they know? Why, my critical young friend, because thousands of physicians have used it for years and found their patients getting better, and that's how they know'. Martin answered, But honest doctor, wouldn't the patients maybe have gotten better anyway?...Have they ever experimented on a whole slew of patients together with controls?"…Davidson replied, "My statements may be accepted…because they are conclusions of wise men

> through many ages. You will accept and you will study and you will memorize because I tell you to.[112]

The need to have faith in doubt as a route to true knowledge rather than "blind" faith in the teaching of one's professor is a critical theme in Novy's scientific method and notion of "spirit of science" that he developed as a professor (see chapter 3). Like Novy, Martin believed that truth could not be apprehended by passive learning of a didactic lecture, it required active participation in a laboratory setting.

Novy believed that medicine was in need of a "scientific" methodology that could "verify its claims of establishing a diagnosis and determine the efficacy of recommended therapies."[113] But how could medicine be made scientific in the manner that Novy wished? He had been familiar with laboratory-based scientific methodologies as an undergraduate student in chemistry. In medical school, he became interested in Henry Sewell's course in physiology, particularly in the illustrations of his lectures with demonstrations of circulation.[114] To combine his own inclination for laboratory science towards medicine, Novy looked towards Europe.

Gradually Novy became even more attracted to a new European science he felt had potential relevance in medicine—bacteriology. Through his association with Vaughan, both in graduate school and in medical school, Novy had heard about this new laboratory based science that had potential applications in medicine. He grew convinced that bacteriology was a unique sphere where the scientific methodology he learned in chemistry could be applied in a laboratory setting to medicine.[115] Together with Vaughan, he became interested in how to apply bacteriology in Novy's capacity as assistant in the hygienic laboratory at Michigan. He felt that the self-acquired skill in microscopic zoology he developed in high school could be combined with his knowledge of physiological chemistry and put to use in this new science.[116]

One of Novy's early responsibilities in the hygienic laboratory was to analyze the chemical and bacterial contents of potentially tainted water.[117] But Novy acknowledged there were no bacteriologists at the university with whom he could study.[118] To learn about bacteriology, Novy resorted to using his knowledge of German to read one of the very few handbooks which had so far been written, *Die Methoden der Bakterien-Forschung*, by Ferdinand Hueppe in Germany in 1887.[119] But Novy recognized there was a lack of proper bacteriological equipment and resources at Michigan, and he realized that he did not have the necessary training in bacteriologic techniques to carry out his responsibilities. In 1887, Novy stated there was a "need for a fully equipped bacteriology laboratory at the University" and that "it was evident that first-hand knowledge of bacteriological technique could only be obtained by going abroad for a course of instruction in the 'new science.'"[120] When he learned that Hueppe was to give a bacteriology course in Wiesbaden, Novy asked Vaughan if he could travel to Germany to take Hueppe's course. Vaughan suggested that they both go.[121] Vaughan also recommended that they train first in the laboratories of Koch in Berlin and Pasteur in Paris. Novy was among several others in his generation who opted to cross the Atlantic to meet the European investigators in their labs. As he wrote in the diary that he wished to learn Koch and Pasteur's exacting techniques of the new science so that he could make his own lasting contributions to the field.[122]

In the summer of 1888, Vaughan traveled with Novy to the Institute of Pasteur in Paris, then Berlin, where they heard lectures by Koch and took a laboratory course in bacteriology taught by Koch's assistant, Karl Fraenkel.[123] While abroad, Novy wrote in his diary that he hoped to return to America to "make use of the bacteriologic methods and skills [he had] acquired in Berlin…as a foundation for [his] career in medical research and education."[124] Shortly after his return to the U. S., Novy wrote an account of the daily routine in Fraenkel's student laboratory, and its exacting methods and intensive instruction.[125] Novy marveled at the spacious and well-equipped German laboratories and the dedicated time German researchers had to carry out their work. Novy wrote that it was essential to recreate these conditions in America in order for the rigorous scientific techniques that characterized German bacteriological research to flourish domestically.[126] Novy wrote that he would use the "unsurpassed, spacious and properly-equipped facilities" he saw at the Berlin Institute as a model for the Hygienic Laboratory in Michigan.[127]

In addition to the diary he kept while studying in Berlin, Novy wrote about his impressions of his German experience elsewhere. In an article he wrote in 1888, he identified the components of his experience at the Hygienic Laboratory that influenced him.[128] He wrote how he admired the rigorous experimental methodology practiced by his esteemed masters, Robert Koch and Karl Fraenkel. He also delighted in the disciplined habits that his expert teachers cultivated in and expected of their students. He idealized the enthusiasm Fraenkel exhibited for his research, and treasured the freedom and encouragement Fraenkel gave to his pupils to choose their projects and then work out their solutions. He also admired how Fraenkel's personal instruction aided students through his criticism of their work on an individual basis. In the article, Novy acknowledged that he would use these elements of the Berlin Hygienic Laboratory—the rigorous experimental methodology and the autonomy the professors gave their students to work out problems in particular—as a model for the research and educational components of the newly formed Michigan Hygienic Laboratory.

In a letter written to Fraenkel in 1890, Novy reiterated that his experience in the Hygienic Institute at Berlin provided foundation of his now burgeoning laboratory at Michigan.[129] Novy openly admitted to Fraenkel that he owed much to the example of his German experience. Novy admired the German assumption that teaching at the university level had to be based on original research, and that serious research only existed in the disciplines of fundamental laboratory science. Novy reiterated that the facility at the Institute was "unsurpassed", and it was the only one of its kind where such rigorous instruction was imparted. To Fraenkel, Novy lamented that too few institutions had introduced similar courses in their curricula. Novy acknowledged that he was initiating a course in Michigan that was patterned after Koch and Fraenkel's in Berlin. At Michigan, students would be taught the methods of bacteriology and research in a laboratory setting, and given the autonomy to work out problems on their own.

There is no further direct records about what Novy learned from his experience in Germany other than what he recorded in his Berlin diary in 1888, the article he published later that year, and his letter to Fraenkel. However, one can gain additional insight into how Novy's German experience may have influenced him by examining what has been written about the experience of other American students who studied in Germany during that historic period. Thomas Bonner, Joseph Ben-David, William Rothstein, and Charles McClelland, for example, have each addressed the ways in which the German experience influenced American students. Bonner maintained that American students admired the strengths of the German system—the uniformly high standards, the excitement of doing original work, the freedom enjoyed by the scientist, the unity of research and teaching, the advanced degree of specialization, and the superbly equipped laboratories that were led by men on the frontiers of medical research.[130] Bonner maintained that students were stirred by the scientific ideology they experienced in Germany that swept away all doubts they may have had about the value of laboratory-based science in medicine.[131] Joseph Ben-David and William Rothstein have addressed how the many Americans learned from the creative investigations of eminent German scientists who were based in urban institutes and who were unconnected with German universities.[132] Charles McClelland claimed that students were inspired by the charismatic activities of the university professors and caught onto the German ideal that research was a sacred calling and that serious research was carried out only in the basic sciences.[133]

According to Rothstein and Ben-David, however fired these ambitions of returning students to remake the American medical education system may have been, when these physicians returned to America, most discovered that most American medical schools had little interest in full-time faculty appointments in their disciplines. Rothstein and Ben-David claimed that American medical schools continued to regard basic sciences as of secondary importance. Consequently, as noted by Kenneth Ludmerer, most American physicians who studied in Germany resorted to practicing medicine in order to make a living as they were unable to unable to obtain full time positions at schools and make medical science their life.[134]

But historians have addressed what a few famous American physicians learned when they went abroad to study in Germany in the 1880s and tried to recast their German experience in their American institutions. The few, elite physicians who were then able to establish full-time positions at American medical schools owed much to their German experience. Donald Fleming has written on how William Welch, Professor of Pathology at Johns Hopkins Hospital, learned from the creative investigations of the German masters at the Hygienic Institute, then attempted to transplant his German experience to his pathology laboratory at Johns Hopkins University.[135] Thomas Bonner wrote how Henry Sewell, Professor of Physiology at the University of Michigan, after returning from Germany, acknowledged that he tried to recreate "the sanctuary of science" he had only previously experienced in Germany.[136] Similarly, Franklin Mall, Professor of Anatomy at Johns Hopkins University, sought to recreate the environment of fostering critical thinking and allow students to maintain freedom to select independent projects of their own.[137]

When Novy returned to Europe for further study in 1890, he was entering his last year of medical school and was newly married to Grace Garwood. Novy wrote to Grace that he wanted to find a position after graduation that would allow him to "devote (his) time exclusively to scientific investigation and education."[138] Novy's letters depict his views of opportunities that were available in America upon his return from Europe, views that are, to use the words of Charles Rosenberg, "constrained by particular configurations of perceived reality."[139] Novy's notes to Grace never mention private practice, and there is no indication that he ever considered practicing medicine.[140] Novy's letters reveal that he actively avoided working in public health departments. From 1894 to 1896, he was a member of the Michigan Board of Health. But Novy's notes show that he decided against continued work in state health departments on the grounds that they would entail "duties and responsibilities" that would encumber his "focus on laboratory research endeavors".[141] Novy's decision to avoid public health activities because they would derail him from his laboratory research focus in a theme that is evident in *Arrowsmith*. In that novel, the protagonist Martin explains that his dislike of public health activities is, in part, due to the "mundane activities took him away from his real love of the laboratory."[142]

Novy's special training allowed him to secure a full time position, which enabled him to pursue his research and teaching interests. His initial academic appointment as instructor of hygiene at the University of Michigan Medical School in 1888 was followed after graduation in 1891 with the title of junior professor of hygiene and physiological chemistry.[143] This type of position—university based and funded without clinical practice duties, had recently been established in American medical schools in the late 1880s following the introduction of physiology into the medical curriculum.[144] By the early 1890s, this type of position was beginning to expand beyond physiology to include other disciplines, but very few slots were available in just a handful of medical schools.[145] Given the limited number of full-time research positions available, most Americans who went to Europe to study bacteriology in the 1880s returned to America to practice medicine or work in laboratories in public health departments.[146] But Novy remained convinced that a university setting in America would provide him with the tools he would need to succeed in his scientific research—adequate laboratory space, appropriate equipment and designated time to perform his work.[147] These elements would be absent in private practice, he noted, because the ad hoc patronage arrangements required to "establish a practice would be too time consuming to permit laboratory research."[148]

Novy's ability to obtain a full-time position in research without a clinical practice was atypical for the time, as many physicians who were aspiring medical researchers, including Vaughan, worked in a private practice in order to make a living.[149] Novy's true love was the laboratory, and his decision not to avoid activities that would divert his effort away from the laboratory, including public health responsibilities or practice, is echoed in *Arrowsmith*. In *Arrowsmith*, Lewis writes, "Gottlieb was…never interested in practicing medicine. His youthful researches in the physics of sound convinced him of the need of the quantitative method in the medical sciences. Then Koch's discoveries drew him into biology."[150] Novy himself acknowledged that a university position would be less lucrative than private practice, a concern that was not trivial for him at a time by 1894 when two of his five children had already been born.[151] In that year, Novy's yearly salary was $2,000 at a time when a successful private practitioner who courted paying patients could earn as much as $20,000 per year.[152]

<u>Public Health Service and Research: working in the Michigan Hygienic Laboratory</u>

Some of Vaughan and Novy's initial activity was to use chemical analysis to uncover what they described as fraudulent practices of adulterating milk and other substances.[153]They found that dairy operators skimmed cream from milk and added an adulterant to restore bulk. Dairy operators also added sodium bicarbonate to neutralize lactic acid as fast as it is formed.[154] By chemically analyzing milk sold in Michigan, Novy knew that enterprising but unscrupulous dairymen were able to turn swill milk—a thin bluish liquid nearly devoid of fat taken from cows who were fed a residue of alcohol—into a rich creamy mixture by adding generous quantities of magnesia, chalk, and plaster of paris. Novy tested samples of milk and reported that samples purporting to contain nutritious milk had in fact been adulterated by water, chalk, sugar, and other substances.[155]Tainted milk, as exposed by Novy and Vaughan, became such a public issue in Michigan that state laws were passed in the 1891 to regulate the quality of milk and the prohibition of any form of adulteration of milk.[156] Novy also detected cases of adulterations of ice cream.[157] Later, Novy's investigations revealed another type of fraud through the promotion of a so-called, local anesthetic, stenocarpine.[158] Novy argued that the substance had no such activity, and having thus been exposed, the mixture was withdrawn from the market.[159]

The duties of Vaughan and Novy in the hygienic laboratory in the late 1880s offer an opportunity to view how the medical and public health profession responded to problems of capitalism and entrepreneurialism before the progressive era. In late 19th century America, some unscrupulous capitalists, operating in an unregulated market in the recently industrialized post-Civil War nation, were producing unsafe products. The exposure of fraud by the hygienic laboratory underscores the prominent role played by rising middle class professionals who directed the hygienic laboratory. Novy wrote, "the examination of milk purports to contain all the nutrients of milk, but it is scarcely necessary to say that such a claim is entirely preposterous and shows at once upon its face its fraudulent nature and harm to the public."[160] Like Prescott, Novy when referring to "public harm" was using the term broadly, and he fused economic fraud with health risks as the true health risks of ingesting these products had not yet been studied at the time. Furthermore, Novy and Vaughan's arguments conflated nutritional, intoxicant, and bacterial health harms. Nonetheless, Novy went on to argue that due to the duplicitous claims of manufactures, it was the duty of the state to regulate unsafe products of capitalist manufactures. Thus, by working with Vaughan to utilize public health regulation to minimize adulteration of milk and other products, Novy and Vaughan worked to make reforms to protect consumers from unsafe practices and to undermine the wealthy capitalist hegemony during the late 19th century.

To ensure pure drinking water that was free of pathogenic microbes, the laboratory conducted bacteriological testing of samples of drinking water sent to them from regions throughout the state.[161] In their laboratory, Vaughan and Novy combined chemical and bacteriological analysis to evaluate the samples for purity and to check for pathogens.[162] Testing the water with this degree of scrutiny revealed a high prevalence of impure drinking water.[163] After having operated for 10 years, Vaughan noted that in 85 of the 400 samples submitted to the laboratory, the germ of typhoid fever had been found in the water supply.[164] These analyses led to a variety of public health measures to attempt sterilization of the supply of drinking water, including the installation of resins and filters in the water supply. Vaughan said of his work detecting typhoid fever in the drinking water, "If this work will cause people to give more attention to the purity of their drinking water, many lives will be saved. Figures can be greatly reduced if people will cease polluting the soil about their homes with slops, garbage, cesspools and privy vaults, and will see to it that their drinking water is pure beyond question."[165] By 1887 Vaughan had begun to spotlight laboratory activities that actually could prevent disease.

Novy noted that the comprehensive aspect of the Michigan laboratory in combining chemical analysis with bacteriological analysis was unique for its time. He argued that it was only through such scrutiny that the drinking water supply had been properly tested for pathogenic bacteria and the public was protected against harm. Novy referred to the hygienic laboratory as "the pioneer of its kind in this country" because its ability to detect unsafe water through comprehensive analyses.[166] Novy recognized that other states have "followed in the footsteps of Michigan" but none, he claimed, have laid a "broader and more thorough foundation for work in hygiene."[167] Novy argued that hygienic laboratories that did not have bacteriological capabilities were unable to adequately perform investigations of epidemic diseases.[168] Per Novy's view, the Michigan lab was unique because it had two-fold ability: in chemistry to test for the adulteration of milk, and in bacteriology to determine whether milk was contaminated with microorganisms.[169] Novy, in fact, attributed his ability to find poison-producing bacilli in milk, ice cream and in cheese to the comprehensive capabilities of his laboratory.[170]

Vaughan reported to the secretary of the department of health that Novy had begun to do "original" work in the context of providing public health service by 1891. According to Vaughan, Novy discovered two poisons in cultures of the bacillus of Hog cholera, and attempted to obtain immunity in rats against the active germs of the disease—all in the line of carrying out his public health duties.[171] In addition, in their investigations of sampling water for surveillance purposes from a town in Michigan's Upper Peninsula, Iron Mountain, Novy began to perform experiments on the metabolism of the typhoid bacillus they had isolated. Novy used what he termed the "syrupy sediment" of water from Iron Mountain that was not evident in control water from Ann Arbor, and then cultured pure colonies of typhoid bacteria. Novy postulated that the syrupy sediment represented the products of metabolism, or ptomaines, of bacteria, and induced vomiting in cats when he injected the cell free sediment into the structure below their skin, the subcutaneous tissue.[172]

Vaughan's multifaceted vision had thus begun to materialize. From the outset in 1887, Vaughan envisioned that the hygienic laboratory would consist of a dual purpose: to provide practical service in the realm of public health and also to perform original investigation into the cause of disease.[173] After the laboratory had been in operation for 10 years, Vaughan assessed the performance of the laboratory according to the goals.[174] In 1897, Vaughan stated that results of "original investigation"—including the isolation of new bacterial poisons found in drinking water, and others in the stool of children with summer diarrhea, and others from poisonous cheese—had been published in nearly 50 articles.[175] In his ten-year assessment, Vaughan said, "Scientific facts bearing upon the causation and prevention of disease are to be discovered and verified, not merely accepted at second hand. For this reason investigations have been pursued along many different lines."[176] Thus, Vaughan emphasized the importance of the laboratory itself in original research, and also noted the key role that education would likely play.

Novy, like Vaughan, argued for a broad scope of the hygienic lab and stressed the potential for performing original research.[177] Novy said, "The first step in the establishment of the lab was taken at a meeting of the state board in October 1886, when a resolution was passed that the regents be requested to consider the advisability of establishing a lab in which basic and original investigations—chemical, microscopical and biological can be carried on."[178] Novy felt that the location of the state bacteriology lab within a medical school provided the potential for performing original research.[179]

Novy distinguished between what he termed research of an "original" or "fundamental" nature and "practical" investigations.[180] He was not opposed to his experimental findings eventually having a practical application. Indeed, when that was the case, he highlighted those circumstances. He simply felt that the "purest" science in bacteriology was motivated by a desire to understand the basic behavior of microbes, and he did not wish to restrict his future investigations solely to pathogenic organisms and how to prevent, attenuate, or kill them. In Novy's words in 1900, the laboratory was "called into existence by the fundamental desire or demand for knowledge of the hidden facts which bore upon microbes as well as for the causation of disease. The first object therefore of such an institute is to carry on original investigations whereby the bounds of knowledge will be materially widened."[181] Novy insisted that the motives for original research be to search for occult truths rather than be guided by practical relevance.

Novy emphasized original medical investigation while simultaneously acknowledging his public health responsibilities. He stated, "the practical application of known facts in elucidating health problems and in preventing disease constitutes another aim of the lab. The sanitary analysis of water, milk, butter and foods in general; the identification of disease producing organisms in suspected: tuberculosis, diphtheria, typhoid fever and in other affections render such a laboratory directly useful to the community."[182] Novy's research aim was compatible with his public health goal. In late 19th century, as Terrie Romano has pointed out, scientific medicine was seen as an array of medical activities based in the physical and chemical sciences, and in medical practices rooted in these sciences.[183] At the time, chemical analysis of food and water and sanitary measures based on such testing were considered scientific. Thus, the various duties that Novy performed in the public health laboratory, including what he himself termed public health service as well as original investigation, were connected to a common theme in the 19th century—by standards of the day, Novy operated scientifically in all of these arenas.

Novy, along with Vaughan, stressed the vital importance of an adequate laboratory facility, one that was properly equipped with sufficient space to satisfy his multiple obligations. He considered Koch's laboratory as the standard for a properly equipped laboratory in an adequate space. While in Berlin in 1888, Vaughan and Novy purchased the necessary equipment for his new laboratory in Ann Arbor so that it could become a suitable research space.[184] He then advocated for more space and equipment when the demand for processing specimens exceeded the capacity of the laboratory to perform these duties.[185] In the ensuing years, Novy would argue for supplemental space on an ongoing basis as the activities of the laboratory expanded.[186] Novy would take advantage of enthusiasm surrounding bacteriological discoveries of the late 19th century, including his own, to push for improved facilities in which to extend their searches for the causative factors of diseases, for improved means of preventing and controlling disease and to perform fundamental work about the behavior of organisms.

During the 1880s, the well-equipped Michigan hygienic laboratory occupied an anomalous position in the America.[187] Noting the scarcity of well-equipped research laboratories located in university settings in America, Novy said, “There are not many universities here where laboratories well equipped for research work are maintained.”[188] The inclusion of a research component as a major aim of the hygienic laboratory underscores the pivotal role of both the state and of the growing modern university in enabling medical research in 19th century America. With the support of the Michigan legislature for the hygienic laboratory, Novy had an adequate facility in which to carry out the fundamental investigations that he was trained to perform. Combined with the income he received from the medical school, Novy was able to devote his entire efforts to medical research in a properly equipped laboratory. These two items—full salary support from the medical school and a state supported laboratory—furnished Novy with the ingredients he needed to establish his institutional base and to pursue full-time medical research. Novy’s success in establishing himself must take into account the medical school dean who shared in his desire to develop medical laboratory science and President Angell who broadly encouraged the growth of medical science within the scope of the university.

While Novy recognized the importance of having a laboratory in a university setting for purposes of research, he also felt this setting provided a springboard for instruction of medical students. Medical education was a priority from the inception of the laboratory, and he felt that educational opportunities were inexorably linked to research. Novy said, “The third and by no means the least important object of a hygienic lab is that of instruction. That department is really useful which combines teaching with original research and in a university it is difficult to conceive how one can be fostered without the other.”[189] Novy felt that the need for research and education justified the location of the hygienic laboratory within a university setting.

Public health laboratories at American Institutions

In the late 19th century, Novy had not been the only American to come back from Europe filled with ideas for establishing his own new bacteriological laboratory and research institution in America. The outpouring of the new European bacteriological knowledge created unprecedented optimism, excitement, and hope among other American physicians who returned to their country after training in Europe. Scientists and health officials, believing that the wave of discovery could be only the beginning, took advantage of the enthusiasm surrounding the discovery of bacteria to push for improved means of preventing or controlling diseases.[190] In several large cities, groups drew up plans for institutes that were to be devoted to producing anti-rabies serum, selling the serum, and administering it to patients. Pharmaceutical firms also began expanding their laboratory facilities in order to take advantage of the large new market for sera and vaccines.[191] These developments set up a potential conflict between private and public labs as sources of biologic products. Thus, conflict became evident in 1925 when the University of Wisconsin decided to capture the commercial benefits of its faculty’s research.[192] The University of Wisconsin required all faculty to assign the rights to patents arising from their work to the Wisconsin Alumni Research Foundation (WARF), which then attempted to license the technology and share proceeds with the inventing faculty member. Notwithstanding these potential conflicts, in the late 19th century, research and public bacteriological health laboratories were established in private American institutions other than Michigan.

Similarly, scientists and health officials began to advocate for the construction of a number of health related hygienic laboratories to be located at universities. The result was the founding of public health hygienic laboratories located at three privately-funded universities: New York University (1886), University of Pennsylvania (1889) and Johns Hopkins (1893).[193] While historians have acknowledged that these university-related laboratories began to appear in the 1880s and 1890s in America, no study has systematically examined what individual researchers did in such laboratories. Were they exclusively investigating practical issues that had applications in the realm of public health only? Were they doing something other than extending the searches for the causative factors of disease or searching for improved means of preventing or controlling disease? If so, what were these research agendas and what types of hypotheses were bacteriologists trying to test?

Conclusion

In this chapter, I have emphasized Novy's desire to accomplish original, fundamental research in his hygienic laboratory. I have shown how Novy and Vaughan opted to learn bacteriological methods and research techniques in Germany, and import them with the idea of then making their own original investigations. Novy was stirred by the strengths of the German system—the high standards he learned from studying closely with exacting, master scientists, the excitement of carrying out original, fundamental work, the autonomy enjoyed by the scientist, and the superbly-equipped laboratories. The German ideal of medical science melded seamlessly with the inclination towards independent research Novy had previously shown while studying chemistry. With Vaughan, Novy tried to recast the unity of research and teaching he witnessed first-hand in Germany at the Hygienic Laboratory of the University of Michigan Medical School.

Novy in one sense had an ideal set up to launch his independent laboratory research and education program at Michigan. He possessed the ability, and exhibited since childhood the zeal and dedication required for scientific experimentation. His studies in medical school and abroad reinforced his belief in scientific experimentation as a reliable means to apprehend new knowledge. He was committed to the belief that students should not passively accept information received in lecture halls as knowledge. Rather, they should have the opportunity to demonstrate truths for themselves in the setting of a lecture-laboratory course. Having amassed the highest credentials of the day in chemistry and in bacteriology, he had positioned himself to succeed in his goals to teach a lecture-laboratory course in a medical school setting and to carry out fundamental medical research on a full-time basis.

Notwithstanding his qualifications as an expert, establishing himself as a full-time researcher and educator was not a straightforward task. For example, how would he justify his career goal to perform basic biologic research in microbiology when his duty as a state employee was to provide practical service? Furthermore, how would he legitimate his basic research interests in a medical profession whose mission to heal was inherently a practical one. In chapters five and six, I will explore the arguments Novy made in order to justify these basic research activities. In this chapter, I have maintained that Novy forthrightly argued to the state legislature who funded his hygienic laboratory that his primary interest was fundamental, pure research. Furthermore, I have shown how he made this argument at a moment he and Vaughan were assembling the environment he would need to succeed: a fully equipped laboratory and a full-time faculty position.

In creating this environment, Novy had the help and encouragement of Vaughan, his enabling, like-minded mentor who ensured that Novy had no competing clinical responsibilities to carry out his research work. It was from this specially crafted elite position that the fledgling Novy embarked on his independent research program. With Vaughan's backing, Novy situated his professional obligations in such a fashion that they provided minimal diversions from the activity from which he derived the greatest satisfaction—laboratory research. [Figure 1.3]

Figure 1.3. Novy posed portrait, circa 1892. At this moment, Novy was a junior professor of physiological chemistry. He was the assistant to Vaughan in the Hygienic laboratory at the University of Michigan. He had earned his doctorate degree in physiological chemistry, his medical degree, and obtained special training in bacteriology in the laboratories of Koch and Pasteur. He was poised to embark on his own independent research career.

Historians such as Edward Rothstein and Ken Ludmerer have maintained that the vast majority of American students who had returned from studying in Europe in the 1880s resorted to practicing medicine in America. They have pointed out that full-time research positions did not exist in the majority of medical schools at the time. There are, nevertheless, examples of a few famous researchers returning from Europe, such as William Welch and Franklin Mall who were hired by Johns Hopkins University to recreate their European ideals and fulfill the vision of the university's wealthy benefactor to create a modern research university in America.[194]

The present study adds to the existing literature by showing how one aspiring medical researcher in the 1880s who set medical science, not medical practice, as his goal in life accomplished his aspirations. Unlike Welch or Mall, who were employees of a university comfortably endowed by a wealthy philanthropist to promote independent research, Novy was an employee of a state university that had inherently practical duties. As I will argue in the following chapters, it was within the context of the institutions' practical mission that Novy was able to accomplish his goal of carrying out fundamental, basic microbiologic research. In the forthcoming chapters, I will address the specific research agenda and educational activities carried out by this employee of a state university, stirred by his scientific training in chemistry and the scientific ideology he witnessed first-hand in Europe.

In the next chapter, I will address the research Novy actually did in his university-located hygienic laboratory. How did his early orientation towards instrumental design and methodology in chemistry manifest itself throughout his work? How did the emphasis on creativity and independence he learned in Germany show itself in his projects? How did he use his public health duties in the hygienic laboratory as a springboard for independent research investigation? To answer these questions, I will examine the work that Novy carried out, what type of questions was he interested in exploring, and how did he go about trying to answer them.

CHAPTER 2

What Novy Did in his Medical School Laboratory

Introduction: This chapter explores the research Novy actually conducted in his laboratory. I will ask what his motives, goals and aims were in the laboratory. From what premises did his research start? How did his first training as a chemist influence his research orientation and how did a chemical viewpoint appear throughout his microbiological investigations? How was his work related to his European experience? What did he accomplish in the laboratory? How did his peers view his work?

Historians have not examined the work late 19th and early 20th century bacteriologists have carried out in their medical school laboratories. Historians have viewed this time as a period of germ hunters working from European-derived premises and extending a list of discoveries of new disease-producing germs or by applying principles that originated in Europe to public health strategies in America.[1] One aim of this chapter is to determine whether that characterization also applies to the work done by a bacteriologist who performed medical investigation in a medical school setting.

Novy's scientific peers and students did not view his work as practical or derivative of European theories. Rather, they viewed his research as original and pure. In this chapter, I will explore why they may have considered Novy a "pure" researcher. I will examine Novy's work at Michigan by referencing his published manuscripts as well as the unpublished laboratory notebooks he used to write his hypotheses, record his primary data, and write his preliminary conclusions. Using these sources, I will show how his research program was not limited to attenuating or killing disease-producing organisms. Rather, he was interested in learning about the basic biological aspects of microbes. By looking at the research program carried out by an American bacteriologist in his laboratory from the late 1880s to the 1920s, I conclude that American bacteriology was not strictly a period of applied theories, but was also one in which original investigation was performed.

In this chapter, I will argue that Novy's work focused on technological innovations to visualize microbes and their biological and chemical behavior in nature. He devised new equipment that enabled other researchers and students to visualize microbes on the cellular level, and to apprehend their basic biologic behavior, as determined by their metabolism and gas exchange, on the cellular level. Novy was interested in learning how microbes survive in nature and in determining how some organisms cause disease in animals. To determine the behavior of protozoa in nature, Novy devised a novel, dynamic culture system. This system enabled him to reproduce the particular morphological forms of parasites as they evolved over time and to determine the distinct behavior of individual morphological forms. Prior to this time, bacteriology had involved static observations at specified time points.

In his studies, Novy focused on developing new instruments as an objective means to yield new knowledge. Novy insisted on repeating his experiments to ensure the results were reproducible before he published them. He then meticulously documented his techniques and methodology in his published papers, in part, so students and other colleagues could replicate his methods and verify his findings. New knowledge to Novy involved a consensus among scientists using similar instruments in independent laboratories, not simply the proclamation of an individual scientist in an isolated laboratory. New knowledge for Novy was a communal process, reached by agreement among investigators. Novy's orientation towards instrumental design and innovation to objectively visualize truths in nature and resolve disputes in medical science was not new in late 19th century America, and were also emphasized by scientists in other fields.

Before exploring Novy's actual experiments and their meaning, I will first describe Novy's personal laboratory space and the equipment housed in the laboratory. Historians who have written on medical researchers and laboratory workers have not provided methodical descriptions of the space in which they worked and the instruments they used. But given Novy's orientation towards instruments, and the fact that the laboratory was the location where Novy spent the majority of his time on a day-to-day basis, it is essential to describe his laboratory and his equipment.

Novy's Laboratory Space

It is important to describe Novy's laboratory space, the instruments that occupied it, and how he used them because Novy worked in the space—day and night as we shall see, for over forth years. In order to understand what Novy did, it is first necessary to describe where he did it. What did his laboratory look like? What type of equipment did he use to carry out his experiments, and how did he use those tools? Accounts of bacteriologists who have worked in microbiology laboratories have not given a systematic account of the laboratory space or how the designated equipment was put to use. Some accounts have given passing mention of laboratories during this period as housing a microscope, slides, staining agents, and culture plates. But Novy's laboratory and the equipment it contained were much more complex than the image conveyed by other historical accounts. Previous descriptions of laboratories underestimate the degree of specialization that Novy's laboratory space and equipment provided him in the late 19th century to perform his experiments. Novy's laboratory was a fluid space, as he was constantly devising new or revising existing apparatus during his career. Taking this into account, I will first describe the core apparatus that he used in his laboratory in the 1890s.

Novy's initial laboratory space was approximately 500 square feet and it had three rows of benches. He had a much smaller personal office with a desk that was connected to the laboratory itself. The laboratory contained a variety of specialized apparatus that was distributed atop these benches.[2] The equipment filled up the available bench space with little room to spare. Figure 2.1A shows Novy as a 28 year old man performing an experiment in 1891 in a laboratory containing a variety of equipment. The picture seems at odds with how one may imagine a bacteriology laboratory from this period to appear. The equipment in Novy's laboratory is more complex than a simplified image of a laboratory containing a microscope, an incubator, culture media, and slides. What was the equipment that sat atop Novy's benches, and how did he use that equipment? Below, I will examine articles and texts that Novy wrote to describe the specialized and complex instruments that occupied his laboratory, and the methods, and procedures Novy utilized and innovated. [Figure 2.1 B, C].

Figure 2.1 A.

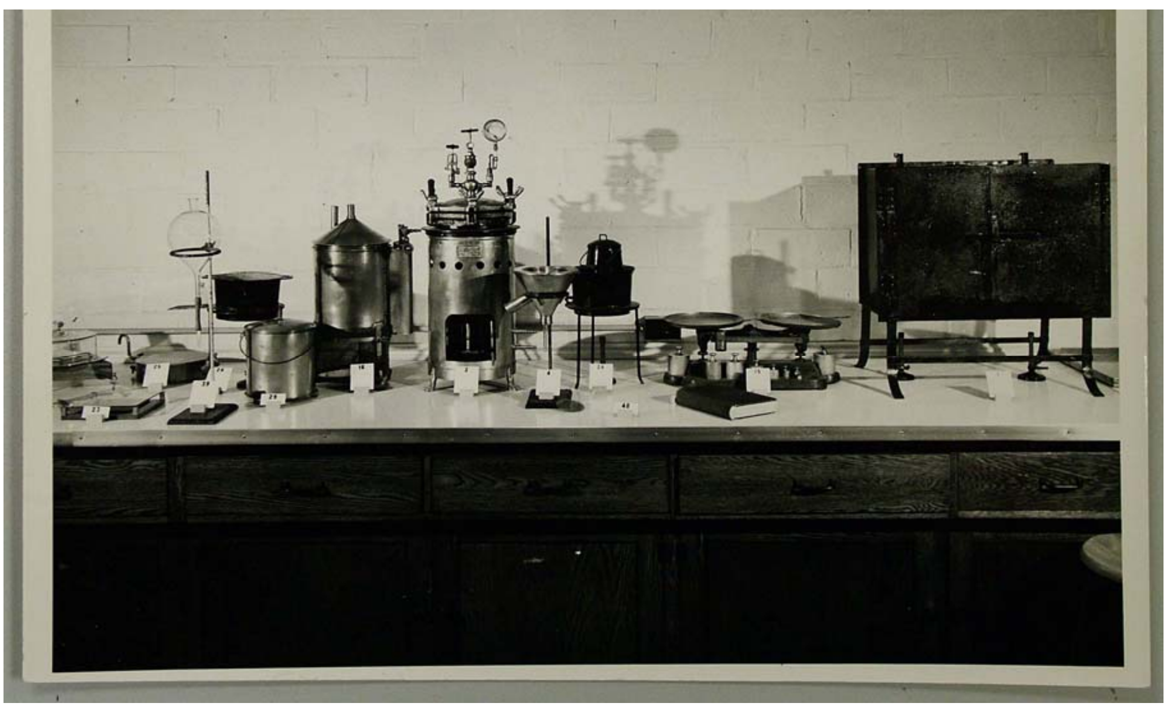


Figure 2.1 B.

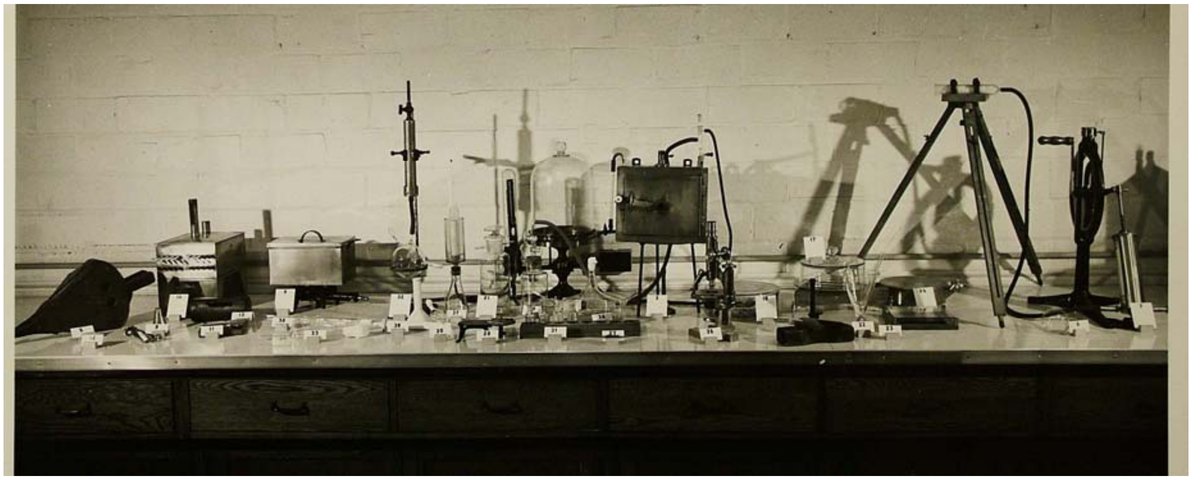


Figure 2.1 C.

Figure 2.1.A-C. Novy working in his medical school laboratory bench and the instruments he used. (Courtesy of Bentley Library)

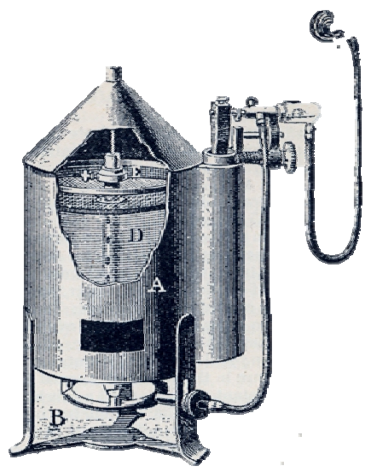
2.1 A. Novy as a young scientist at work recording data from an experiment he is conducting at his lab bench at the start of his career in 1892. His elaborate, specialized instruments and reagents filled the tops of the research benches in his laboratory. Glassware was stored in cabinets underneath the benchtop. He is performing experiments to trap the gas produced by anaerobic bacteria then chemically analyze them. The large diagonal arm device is Hesse's gas producer used to obtain the gas products from bacteria themselves. The domed shaped glass devices on the bench are devices used to culture anaerobic bacteria.

2.1 B,C. Novy's bacteriology instruments displayed on top of a laboratory bench. The diverse and specialized instruments in the picture are elaborated below. Some of the individual equipment in picture 2.1 B includes: a steam sterilizer, an autoclave, a funnel with a sidearm, a glass globe, Petri dishes, a stand, and a scale. Some of the instruments in picture 2.1 C include an incubator, an anaerobic jar, a tripod for air analysis (Hesse apparatus for gas analysis), an instrument sterilizer, a microscope, and anaerobic culture apparatus.

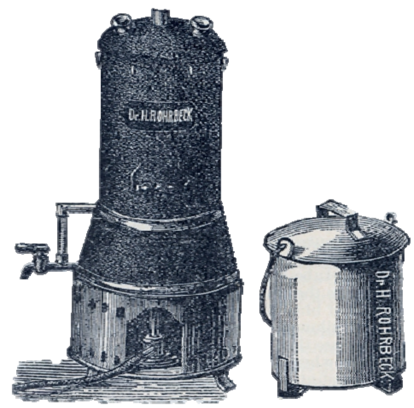
A variety of equipment was used to devise culture material, as Novy was constantly creating variations in culture media in his attempts to identify organisms in clinical situations where others had been unable to do so. Novy prepared the culture media in his laboratory. This laborious procedure required glass flasks of several varieties, funnels, suction pumps, metal stands, metal cages, steam sterilizers, and an autoclave.[3] To make liquid bouillon media, he purchased beef, placed it in a flask with water, and then boiled the water in a glass container called a water bath. In order to filter out impurities, he passed the fluid through a funnel with cotton in the angle of the funnel. [Figure 2.2 A] A suction pump below the angle then pumped the liquid media through a sidearm of the flask to a larger glass container, which was then placed in a steam sterilizer.[4] [Figure 2.2 B] To fill media into individual test tubes that were ultimately used to culture microbes, a globe with media was placed in a metal platform with tubes with stopcocks carrying media into the various test tubes.[5] [Figure 2.2 C] The tubes were placed in a specialized wire basket, which was then enclosed in an autoclave for final sterilization. [Figure 2.2 D] For solid media, gelatin was added to the bouillon broth, and instead of test tubes, the globe with gelatin media was carried to individual petri dishes, and a glass pipette was used to transfer media from one to another dish. [Figure 2.2 E]

Figure 2.2A. Laboratory Apparatus to filter liquid media from impurities and to measure media into tubes. The boiled bullion liquid was poured in a funnel and filtered with

cotton. The liquid passed through a glass rod that passes through the center. The funnel was inserted into a strong vacuum flask with a sidearm, which was connected to an air pump. The media was then suctioned through the air pump into a container.

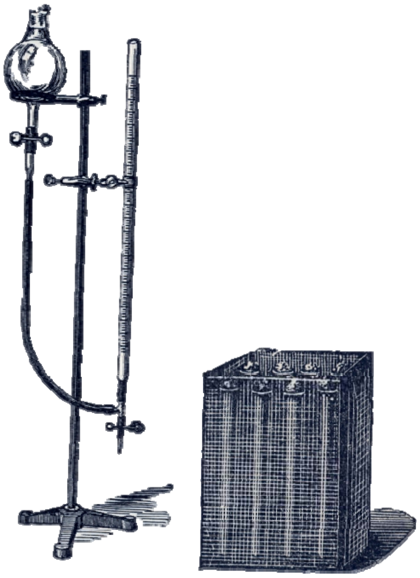


Koch Sterilizer



Novy Sterilizer

Figure 2.2B. Steam sterilizers were used to ensure that the liquid media was free of bacteria. Different varieties of steam sterilizers were produced, including the Koch, Roux and Novy sterilizers. All operated on the same principle, but were made of different materials and were of different dimensions. The instrument on the Left is a Roux water bath for sterilizing liquids. The instrument on the right is the Novy Steam Sterilizer. Steam sterilization was used for the sterilization of liquid serum, milk, and other fluids such as culture media. The temperatures reached by steam sterilization, 58 degrees Celsius, was high enough to destroy vegetating forms of bacteria when used for one hour, but not the spores. The steam sterilizers were large (about 30 cm in diameter), heavy (made of cast iron), and heated with a burner placed in a door in the bottom cylinder of the sterilizer.



Chapter 2.2 C. Globe receiver for filling media into tubes, with burette attachment, and wire basked for sterilizing tubes. Steam-sterilized media was poured into a globe. The globe was placed in a metal platform with tubes with stopcocks carrying media into the various test tubes. The tubes were then placed in a wire basket.

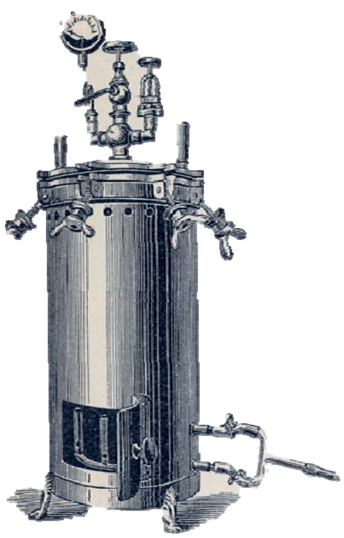


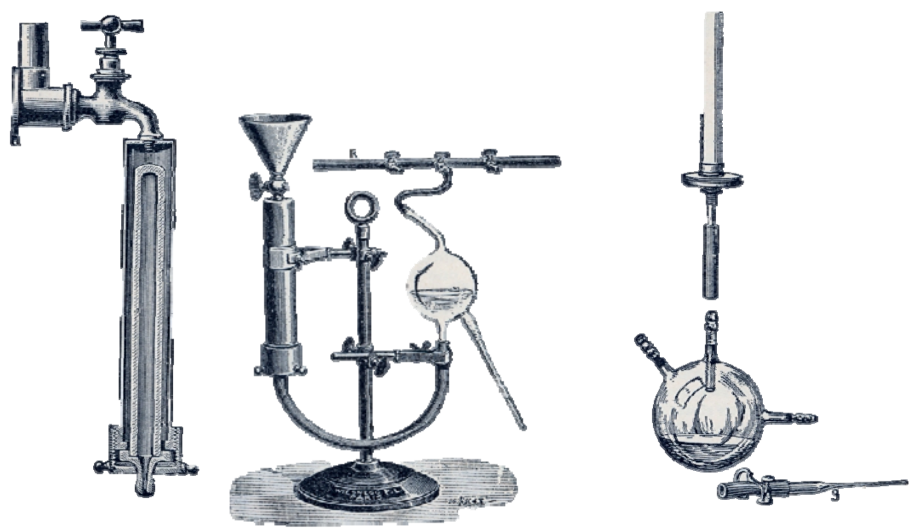
Figure 2.2D. A Chamberland Autoclave for sterilizing by steam under pressure. An autoclave for final sterilization of liquid media. The autoclave is an instrument that provides sterilization by steam under pressure. As a result, the temperature reached by autoclaving is higher than that by regular steam sterilization—up to 120 degrees Celsius. A temperature this high can eliminate spores as well as the bacteria

themselves. It was used as a final sterilization for liquid or solid agar, as well as for glassware--tubes, flasks, and glass tubing.

Figure 2.2 E. Petri Dish and Glass pipettes of Pasteur. Glass pipettes used to transfer media from a test tube to another container, the Petri dish. The latter was used for solid media—gelatin containing bullion that solidified when cooled.

Throughout the years, Novy experimented with augmenting standard media by adding a variety of nutrients, changing incubation times and temperatures, and reducing the oxygen content of the atmosphere. He fashioned these variations in attempts to cultivate microbes in situations where others could not—particularly anaerobic bacteria, spirochetes, trypanosomes, and leishmania. Originally he used potatoes for media, devising specialized test tubes for them; but he later abandoned this technology in favor of adding gelatin to bouillon in order to create solid media.

A different technique—sterilization by filtration—was carried out in the laboratory with the use of a variety of filtration equipment. This technique served to further sterilize liquid media that may have been exposed to the air or contaminated by bacteria. One technique consisted of a filter made of unglazed porcelain (Pasteur-Chamberland Filter) in which the liquid was passed through and bacteria were absorbed in the porcelain. Another was the Berkefeld filter and Martin's filter, each of which contained a filter paper. [Figure 2.2 F] Both filters were put into use in the laboratory for another purpose—to separate the soluble products of bacteria from solid cells. Toxins of pathogenic bacteria as well as ptomaines of metabolism that Novy studied were prepared this way. Additionally, Novy used the filtration process to demonstrate the existence of the so-called, ultra-microscopic organisms—those that could not grow on any culture media, regardless of the type and number of nutrients that was included the culture media. Novy recognized that common bacteria did not pass through the filter, but that some diseases contained a cause so minute that it passed through both the Berkefeld and the Pasteur Chamberland filters. Novy was not the first to use these filters.



Pasteur-Chamberlain Martin Berkefeld

Figure 2.2 F Filtration devices used to filter out bacteria from media. The porcelain of the Pasteur-Chamberland filter (lefthand) absorbed bacteria, and the filter paper of Martin (Middle)or Berkefeld (Right) removed bacteria according to size. Both filters were used for other purposes: to separate products of bacteria (e.g., ptomaines, toxins) from the bacterial cells themselves, or to search for “ultramicroscopic” forms of infection.

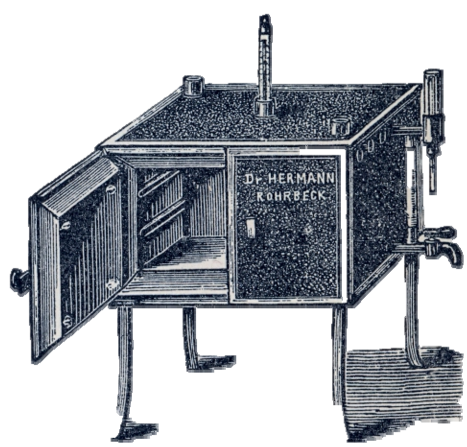
In the laboratory at that time, all flasks, test tubes, syringes, and pipettes were made from glass and therefore were reused—but first needed to be sterilized after use.[6]

Equipment was washed then placed in an autoclave in order to sterilize the tube by killing any bacteria that had adhered to the equipment. Given the high volume of experimentation in his laboratory, the autoclave was in constant use in Novy's laboratory. [Figure 2.2D]

A diverse array of instruments was needed to actually inoculate bacteria and other microbes onto culture media, then isolate bacteria from this media. Medical students were expected to acquire these techniques at the end of their one semester laboratory course (see chapter 4). Novy note that danger to workers in the laboratory, stemming from accidental contact and subsequent infection with pathogenic microbes, is avoidable and rare if proper techniques are followed.[7] The following steps were usually undertaken to complete this process: a flame-sterilized straight spatula or wire loop made of platinum was used to transfer bacteria from a clinical specimen into culture media. Glass pipettes were also used to transfer liquid from specimens to culture media. The wire loop was used to streak a specimen onto solid, gelatin agar in a Petri dish. The straight spatula was used to perform a stab inoculation into solid media in a test tube. [Figure 2.2G] Following inoculation with clinical specimens, test tubes were placed in a metal basket, and Petri dishes were placed in a metal container. The tubes and dishes were then placed in an incubator to heat at a steady temperature of 34 to 37 degrees centigrade for 48 hours depending on the organism. Pathogenic bacteria grew best at body temperatures, and the colonies of plates were observed and tested at a predetermined time for identification of the organism. In the late 1890s, a Novy or Koch incubator was used for this purpose; it was a large piece of equipment that by the early 1900s included a thermoregulator to keep the temperature constant and cell growth more constant. [Figure 2.2 H]


Spatula and Spear Wire Loop Technique

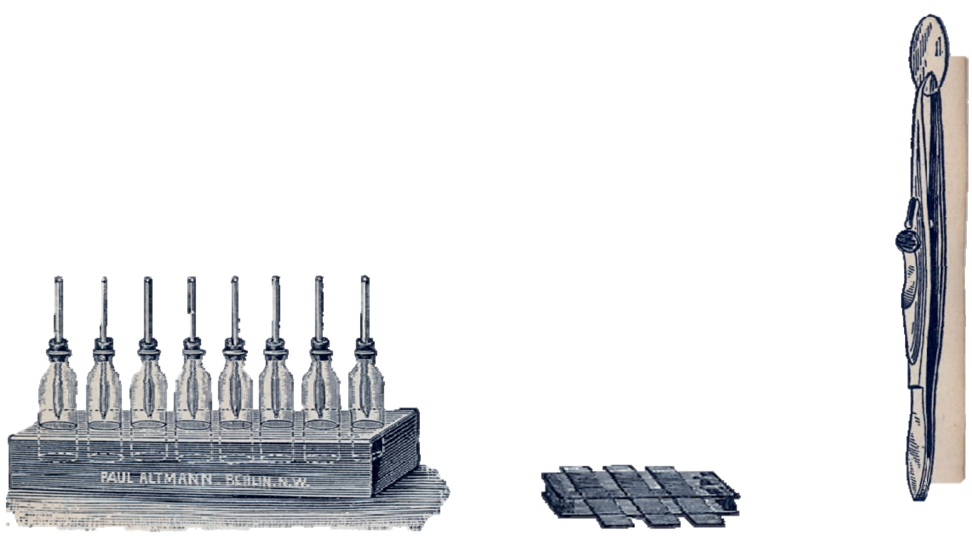
Figure 2.2G. A Roux spatula and Nuttal platinum spear. A wire loop was used to streak bacteria onto solid agar in a Petri dish or in a test tube.



Koch Incubator Novy Thermoregulator

Figure 2.2H. Koch's incubator with a Novy thermoregulator was used to keep the temperature at a constant 38 degrees Celsius in order to optimize bacterial growth.

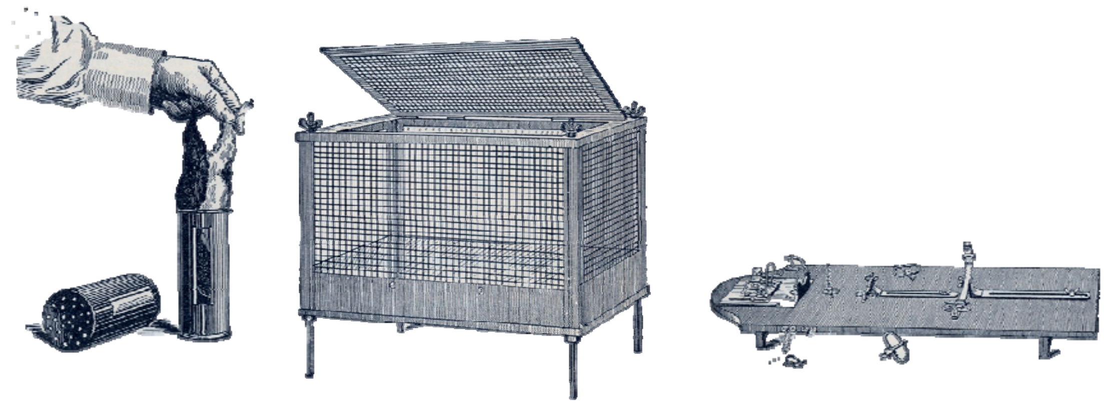
To identify the bacteria that grew in pure culture on a plate, Novy used morphological criteria. He described the gross features of the colony as it appeared on agar plates—shape and size of the colony and whether the bacteria produced pigments. He then used a variety of instruments to characterize the bacteria themselves. For this, he needed again a wire loop to pick off a bacterial colony, and he put it onto a glass slide held with forceps that contained sterile water. After letting the solution air dry, he heated the desiccated residue gently with a flame, and then used Gram’s method to stain the bacteria—first using gentian violet, then decolorizing with alcohol, and finally counterstaining with the aniline dye safranin. Each solution was kept in containers adjacent to a water faucet so that slides could be washed between each staining step. [Figure 2.2 I]



Staining Solutions Glass Slides Forcepts

Figure 2.2 I. (Left) Stand for multiple dye solutions required for staining bacteria and mycobacteria from specimens that were smeared onto slides. For bacterial dyes, the various solutions included crystal violet, Gram's iodine, alcohol, safranin, fuscin, and methylene blue. For staining mycobacteria, the various dye solutions included carbolfuchsin, acid alcohol and methylene blue. (Middle) slides where clinical specimens were smeared. (Left) Forceps for holding specimen-containing slides while applying various dye solutions for staining.

To determine whether bacteria that grew on a plate were pathogenic, Novy injected a pure colony of bacteria into test animals: guinea pigs, mice, or rats. To do this, he again used a wire loop to isolate a colony, a syringe and needle, an animal facility, and an animal holder. He placed the bacterial colony into aqueous solution, then injected or “transferred” the solution into the guinea pig either intraperitoneally, subcutaneously, intra-tracheally, or intra-ocularly, depending on hypotheses about the route of natural transmission.[8] The idea was to see if Koch’s postulates would be satisfied. Novy had an area in his laboratory to observe guinea pigs that had been inoculated, and also a facility to perform an autopsy when they died. From the diseased tissue of the guinea pig, he was to retrieve the same bacteria that he had injected into them, thereby establishing causality. To carry out the animal experiments, he had special instruments, including animal cages to house the animals prior to inoculation, an animal holder to keep the animal still during moments of animal transfer, and containers to house the animals in his laboratory after they had been inoculated and prior to sacrificing the animals. [Figure 2.2 J]



Latapie’s Animal Holder Vaughan Cage Voges’ Holder for Small Animals

Figure 2.2 J. Various apparatus for small animals including rabbits, guinea pigs, rats, mice, and birds during experiments. (Left) An animal holder used to secure and stabilize animals during a bacterial transfer. (Middle) Cage for animals stored in laboratory, including guinea-pigs and rabbits. The cage occupied a significant amount of laboratory space, as the dimensions were 30 cm height, 38 cm deep, and 54 cm wide. (Right) The Voges holder was use for taking temperatures and for injecting small animals (note window on side of holder).

Thus, Novy worked in a specialized, personalized space. It was well stocked with sophisticated instruments. In the sections below, I will describe what experiments Novy performed using this space. As his experimental program matured over the years, he devised a series of innovative technology that allowed him to isolate and view the dynamic behavior of various microbes over time. These newly-developed tools bore his name—equipment to exclude oxygen to culture anaerobic bacteria (the Novy jar), specialized forceps to grab onto slides (Novy forceps), and culture media for parasites (Novy media). [Figure 2.2K] He also used a device called a collodium sac to culture the spirochetal cause of relapsing fever. And of course, he devised specialized chemistry equipment that allowed him view the behavior of microbes from a chemical viewpoint.

[Figure 2.2L] Below, I will describe some of the specialized equipment he used in the context of the experiments he was carrying out.

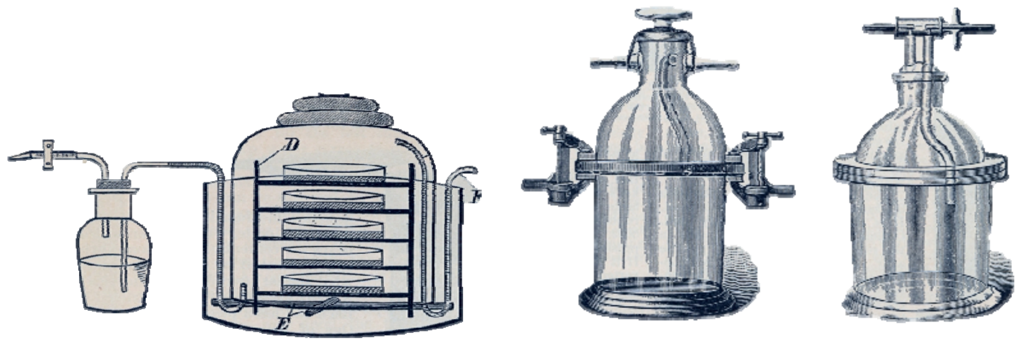
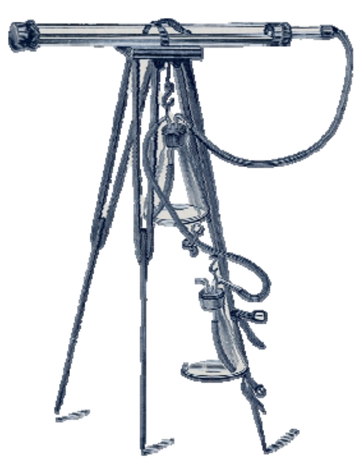


Figure 2.2 K.Three variations of Novy's jar for culturing anaerobes. In each instrument, oxygen was pumped out of the atmosphere in the jar. In the schematic drawing on the left, Petri dishes with solid agar containing streaked bacteria were vertically stacked in an atmosphere where oxygen was displaced by a vacuum pump. A modification in the middle shows an improved seal obtained by the use of vices surrounding a side lip. The glass jar on the right contained a special stopcock for vacuum culture. This was a more recent modification made to improve upon the amount of oxygen displaced from the inner jar environment.



Hesse's Apparatus for gas analysis

Figure 2.2 L. Hesse's apparatus designed to obtain gas produced by bacteria. The gas can then be subjected to chemical analysis. Gas produced by bacteria can be retrieved in a roll tube which could then be dislodged and studies.

Using Innovative Techniques to make visible microbes and their behavior

In 1893, Novy used his hygienic work as a foundation to carry out his original investigation in developing methods to culture anaerobic organisms in 1893.[9] In one series of experiments, while testing the chemical components of milk for purity, Novy was interested in isolating nucleins from milk samples he received. In the 1890s, researchers such as Novy studied nucleins, the phosphate-rich acidic chemicals found in the nucleus of cells, which are often located in circulating white blood cells, but also contained in milk.[10] Novy's initial hypothesis was that nucleins may elicit an antibody response when injected into rabbits, and that he could then have a model whereby he could study immunity in rabbits to see if they were protective against future challenge with bacteria.[11] Novy first sought to digest the nucleins from milk. He added casein, a phosphoprotein that accounted for nearly 20 percent of the milk he studied. Subsequently, he purified the nuclein, and injected the purified residue into rabbits. Unexpectedly, the injected rabbits died. Novy postulated a bacterium caused the death of the rabbits. To test his hypothesis, he decided to first start with conventional bacteriological techniques. Using standard bacteriological testing of tissues of the deceased rabbits, he observed a bacillus by Gram's stain taken from blood specimens of deceased rabbits. But he was unable to culture an organism from this specimen using conventional broth and agar aerobic culture techniques.

Novy did not abandon his theory of a bacterial cause for the rabbit's death. He postulated that stained but not cultivable organism was an "obligate" anaerobe—ones that required complete exclusion of oxygen to be cultivated—a condition that could not be achieved because existing anaerobic culture techniques did not completely deplete the environment of oxygen.[12] Existing anaerobic instruments permitted "facultative" anaerobes—those that prefer a reduced oxygen concentration to grow but do not require an absolute oxygen free environment. When Novy was a student he had been called upon to design complex apparatus to solve problems in chemistry; he now resorted to technological innovation to approach the problem of how to isolate obligate anaerobic organisms.

In the early 1890s, Novy began to devise various instruments to completely exclude oxygen from anaerobic culture environment. He devised a bottle with a special stopcock for the entrance and exit of gas out of the environment of the culture medium, thereby completely depriving bacteria of oxygen so they could grow on solid gelatin culture plates.[13] The apparatus, which became known as the Novy anaerobic jar, permitted obligate anaerobic bacteria to be cultivated. Novy used the jar to isolate an organism he called *Bacillus novy* in culture from rabbit specimens that died after being injected with nuclein.[14] Novy concluded that previous apparatus did not completely exclude oxygen from the media and could not identify the obligate anaerobes that caused fatal septicemia in animals with "malignant edema".[15]

Novy devised innovative techniques to visualize anaerobes as the cause of disease.[16] Novy's innovative technology, the "Novy jar" would eventually become standard equipment in his own laboratory and in the laboratories of others.[17] Novy and others, for example, used his apparatus for culturing other anaerobic bacteria that caused human disease, including the botulism bacillus that was to be responsible for an outbreak of commercial botulism in the early 20^{th} century. [Figure 2.3]

Figure 2.3. Novy used his anaerobic equipment to isolate anaerobic bacteria from respiratory specimens from humans with botulism or from environmental sources (soil). This is a Gram's stain of a colony from an anaerobic culture. It is a slide Novy used in his bacteriology course; the subject was anaerobic bacteria. (Courtesy of Bentley Library)

Novy soon turned his attention to devising innovative techniques to isolate in pure culture protozoa.[18] At this time, nothing was known about how to cultivate protozoa in artificial media and it had not been attempted.[19] In the late 1890s and early 1900s, Novy first tried to use cell-free gelatin media to cultivate malaria and coccidia, an obligate intracellular protozoa of rabbits. Despite multiple repetitive attempts using a variety of nutrients and chemical supplements to his media, he was unable to do so.[20] He eventually reasoned that his incapability was due to the fact that protozoa he was attempting to cultivate were confined to cells, an environment he was unable to reproduce in the cell-free culture media he was using.[21] Novy reasoned that free swimming protozoa could avoid this limitation and may be more amenable to culture on the cell-free, agar media he had available.

To circumvent the problem of his inability to create a cell-containing culture media, Novy turned his attention towards targeting extracellular, motile protozoa for culturing.[22] Novy had previously been interested in cell-free, unicellular organisms when he was studying the *Volvox* algae swimming freely in the ponds of Chicago. He remembered reading about the trypanosome, and he reasoned that this parasitic organism might suit his purpose for culturing as it had a cell free stage in the blood of humans.[23] Novy acknowledged that David Bruce had already recognized the etiologic role of trypanosomes in causing human disease in 1894, when he began to investigate sleeping sickness or nagana in Zululand and found the disease was due to the presence of *Trypanosoma brucei*, in human blood.[24] Bruce had shown the presence of trypanosomes by making a blood smear using the acidic dye eosin--he did not attempt to culture the organism on artificial media. Nevertheless, Bruce and Koch were able to show that the trypanosome was transmitted from infected animals to healthy animals or to man by the bite of the tsetse fly, *Glossina morsitans*. During his travels in East Africa in 1898, Koch had encountered a similar disease Bruce had earlier recognized, and Koch considered this to be identical with surra, or sleeping sickness caused by trypanosomes in humans in India.[25]

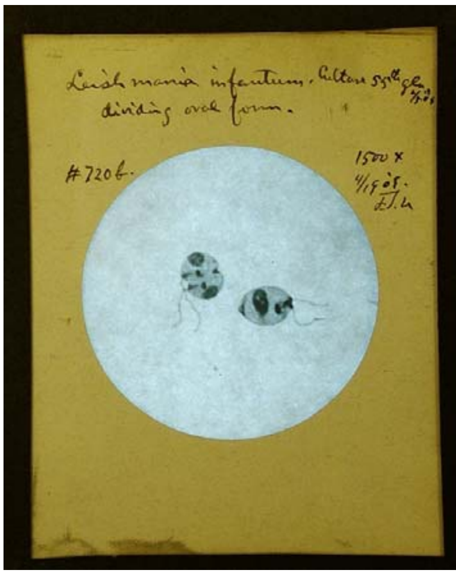
As trypanosomes were found, by routine staining techniques, to be present in the blood of rats in London and India without having caused specific disease, Novy postulated that trypanosomes would also be found in the blood of rats in the United

States.[26] He summoned some of his students to catch wild grey rats, and he indeed found trypanosomes in the blood of these rats using a stain of hematoxylin and eosin dye.[27]In an attempt to create a laboratory animal model, Novy then sought to keep the organisms alive by means of transferring the bloody material from the wild gray rat to the white rat that he used in the laboratory.[28] By creating such an animal model, he was therefore able to maintain a supply of material to use for experimentation in the laboratory.

Novy and his students then sought to culture the trypanosomes from the white rats by inoculating them on blood agar supplemented by various nutrients. He had innumerable failed attempts to grow the organism on solid agar.[29] But to his surprise, he found that forms of the organisms grew not in the blood, but in the "water of condensation" from agar composed of blood. He also found that in the water of condensation, the organism assumed a new shape and configuration that he termed a "rosette form," and that hundreds of these would be grouped together as small, motile cells.[30] Neither Bruce nor Koch had seen these forms in their stains of blood taken from patients with nagana. Novy believed that the freely moving rosette was a form of *Trypanosoma lewisii*, the common rat trypanosome, as it matured over time. He reasoned that the trypanosomes in their various forms might prefer the liquid in which to swim and mature over time. Solid media had become standard media in bacteriology, as it allowed more precise identification of bacterial colonies after a fixed period of incubation than liquid media. But Novy reasoned that solid media may have restrained protozal growth into mature forms.[31]

Novy compelled one of his students, Ward MacNeal, to work with him to devise a reliable procedure for growing pure cultures of trypanosomes. Instead of solid media, they would attempt to use the condensation water of slanted tubes of blood agar. They varied the experimental environment by adding additional bullion nutrients, adding alkali to the media, reducing the oxygen content by culturing in Novy tubes, and lowering the temperature of incubation to 30 degrees centigrade. After many months of laborious testing, in 1903 they identified an environment in which the trypanosomes flourished—temperature of 35 degrees centigrade, media supplemented with additional bullion, adding alkali to the media, and an incubation period of three days.[32] Using sequential, frequent observations, Novy identified the multiple forms he had successfully cultivated from rats as *Trypanosoma lewisii* as they evolved over time. He deemed that none of the forms he had identified in media, which he termed "Novy-MacNeal," were pathogenic to rats or to humans.[33] His results, after publication in 1903, attracted worldwide scientific attention because he had produced the first media in which protozoa could be grown artificially in a laboratory and in which the changing forms could be made visible to researchers through his dynamic culture system.[34]

In his publications on Trypanosomes, Novy methodically detailed the rigorous methods he used to culture the parasite and observe its morphologic changes over time, with the intent that other investigators could use his methods for their own experiments.[35] [Figure 2.4 A-G] He devoted considerable attention in all of his papers to his methods, describing his techniques in a level of detail that journal editors considered extensive for its time.[36] Novy described the special conditions that are required to create a culture medium that will isolate the organism—a blood agar consisting of equal parts of defibrinated rabbit's blood and nutrient-enriched agar with alkali.[37] He melted the blood agar and then cooled it to 50 degrees Centigrade, after which the rabbit blood was added and mixed. The tubes were then inoculated and kept so that water of condensation accumulated at the bottom and incubated aerobically for three to five days. They were closed with rubber caps and then set aside at room temperature for one week. No colonies developed in the condensed water, but a loopful of opaque fluid from the surface yielded trypanosomes in purity, when placed on a slide and examined microscopically.[38]



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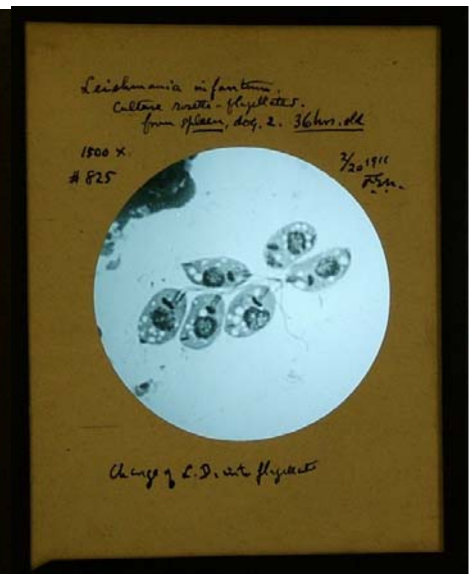

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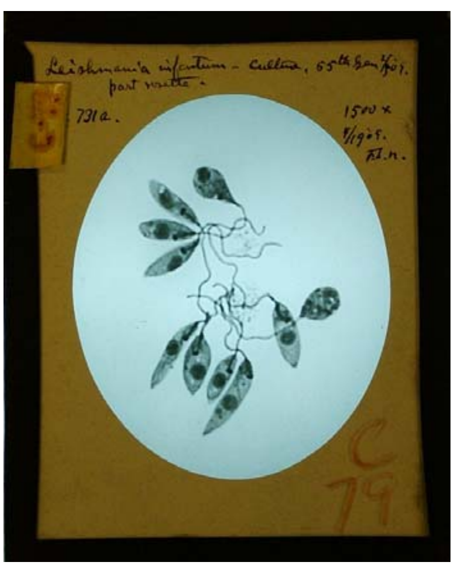

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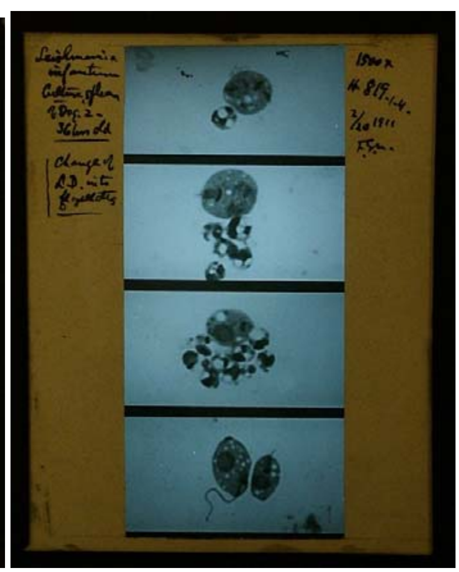

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Figure 2.4. Morphological changes of leishmania as the organism evolves in Novy's culture system over time. Novy then correlated the changes in morphology in the culture system with the changes in morphology in nature as the organism matures in its vector, the sandfly, and its host, the human or the dog. The pictures are taken through Novy's microscope and made into lantern slides that he used for his microbiology course at the medical school. Novy jotted information in his own hand in the margins of the slide.

2.4 A.Oval form. The small oval forms are the earliest forms in culture system. They have a longitudinal kinetoplast and divide longitudinally. Novy refers to them as Leishman-Donovan body, or LD forms.

2.4 B. The oval forms maturing into flagellated, promastigote forms, with a cluster of forms that have a 'rosette appearance'. The flagellated forms, or promastigote forms, are similar to crithidia of trypanosomes in that they have an anterior basal granule (a kinetoplast). But unlike trypanosomes, they do not have an undulating membrane.

2.4 C. Mature elongated promastigote forms.

2.4.D. Dynamics of the small, oval LD forms maturing into flagellated promastigote forms.

2.4 E. Novy was the first to show that the promastigote was the infective form, as he introduced promastigotes into dogs. Inside specialized tissue white cells in the spleen, or splenic macrophages, promastigotes multiply into small, oval LD forms. This picture shows the splenic aspirate from an infected dog, showing the small, oval LD forms inside splenic macrophages. By showing the LD forms in intracellular splenic macrophages, Novy was able to correlate the dynamic changes of the organism in his culture system with the organism's host and its environment. Novy postulated that the sandfly ingested LD bodies, and in the gut of the sandfly, mature into promastigotes.

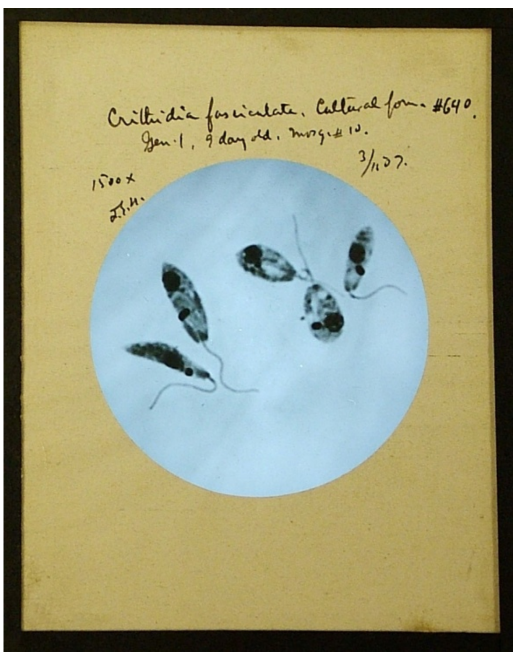
Other investigators, including Charles Nicolle, director of the Pasteur Institute of Tunis, followed Novy's methodology and were able to reproduce his results by culturing trypanosomes.[39] Novy received recognition worldwide for devising methods of culturing trypanosomes and for showing other researchers how to do so. David Bruce credited Novy with "throwing light on the trypanosome."[40] William Councilman, head of the Department of Pathology at Harvard Medical School, wrote to Novy, "I have been reading your paper with the greatest of interest, and heartily hope that you will be able to throw some more light on the dark ways of the Trypanosome."[41] William Welch commented on the significance of Novy's work, stating, "For the first time it has been possible to obtain strictly pure cultures of an animal protozoa."[42] Winslow claimed that cultivating trypanosomes was Novy's most ingenious contribution to microbiology.[43]

Novy's growing reputation for his ability to culture organisms in situations where others were could not attract the attention of investigators throughout the world. They sent Novy specimens by mail, retrieved from humans or animals in diverse environmental settings, hoping that Novy would be able to devise a system to culture an organism from the specimens.[44] Consequently, Novy's laboratory at Michigan, which was equipped with specialized instruments to isolate parasites, was not required to travel to endemic locations in which these diseases were occurring. In the years to come, Novy would receive an increasing diversity of specimens from field workers throughout the world taken from patients with relapsing fever from New York (1903), specimens from the Philippines taken from patients with surra (1909) and specimens from Montana of patients with tick born infections.[45] Carlos Gorgas sent specimens taken from workers in the fields of Panama during the construction of the canal in 1907, who had developed relapsing fever.[46]

In 1904, Novy tried to culture the virulent etiologic agent of nagana, *Trypanosome brucei*, from a human specimen that Bruce himself had sent to Novy's laboratory.[47] The conditions that Novy had used to culture *T lewisii* did not succeed in isolating trypanosomes from the specimen, but Novy kept trying to alter the media, and vary the temperature, acidity, and oxygen content of the experimental environment in an attempt to isolate *T brucei* from the specimens.[48] Novy was eventually successful in arriving at experimental conditions that permitted the isolation of *T brucei* from the specimen—a higher temperature (37 degrees centigrade), lower acidity (no addition of alkali) and shorter incubation period (two days) than *T lewisii*.[49] Novy also grew *T evansi*, obtaining the material from a case of surra from the Philippines.[50]

Novy sought to expand on the innovative techniques he had used to visualize trypanosomes to cultivate other protozoa. Charles Nicolle from the Pasteur Institute sent Novy a specimen from a human from Tunis with leishmaniasis.[51] Novy attempted to use the MacNeal Novy media to culture the organism, but was unable to do so.[52] After further modifications by Charles Nicolle, Novy was able to isolate the protozoa leishmania by further manipulations of the MacNeal Novy media with the addition of yeast extract and beef extract, which he now called Novy, MacNeal and Nicolle (N:N:N) media.[53] As

Novy had done with trypanosomes, he then observed his cultures every fifteen minutes and described the morphologic changes of the actively moving leishmania organisms as they matured over time. The organism began as an oval form with a large nucleus and accessory nucleus, and sequentially matured over a 48 hour period to a promastigote form, meaning the accessory nucleus was at the anterior portion of the organism where the whip-like flagella arose.[Figure 2.5 A-G] He then correlated the development of these forms in laboratory culture system with their appearance as the “parasite” adapted to its various hosts and vectors in nature.[54] Novy referred to nonpathogenic protozoa, such as *T evansi*, as protozoa, but he referred to protozoa that caused disease in humans or other animals, such as *L donovani*, “parasites”.[55]



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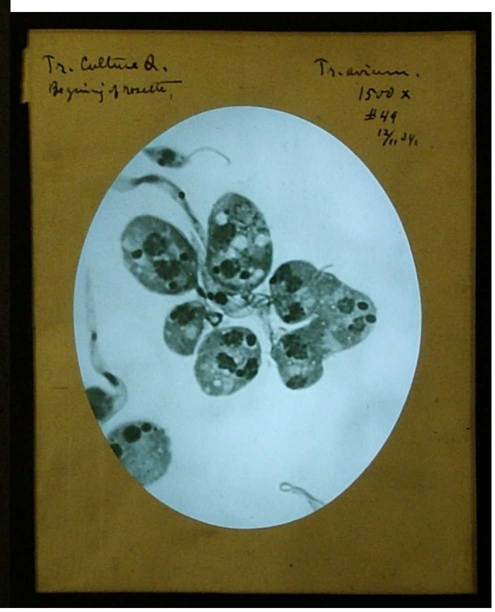

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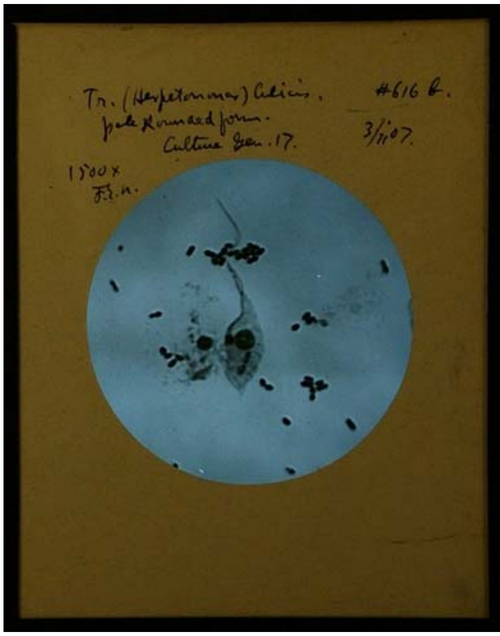
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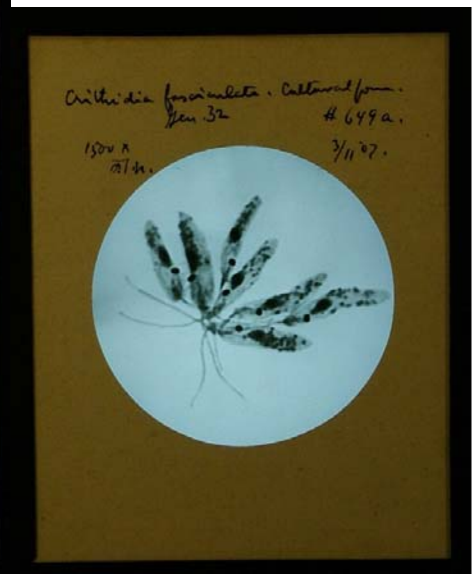
Crithidia fasciculata. Cultural form.
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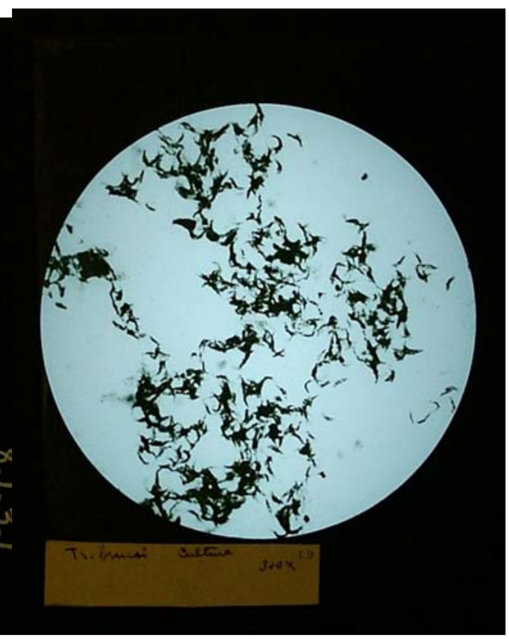
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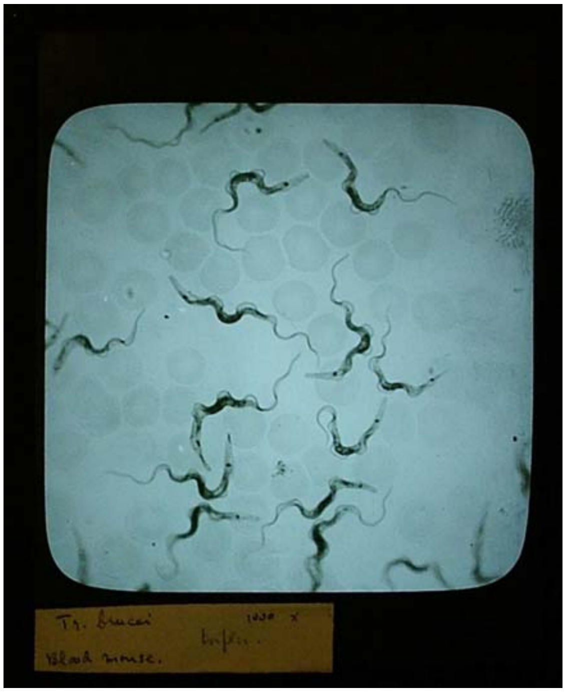

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Figure 2.5 A-F. Pictures of trypanosomes as they evolved over a 48 hour period of time in his culture system. Novy observed the morphological changes of the trypanosomes by observing the changes every 15 minutes. The pictures are taken through Novy's microscope and made into lantern slides that he used for his microbiology course at the medical school. Novy jotted information on the evolution of trypanosome forms in his own hand in the margins of the slides he used in his bacteriology course for a lecture on parasites. He described the changing morphology of the organisms in explicit terms as they evolved in his culture system over time.

Figure 2.5 A. Crithidia forms. This was an early oval form of the trypanosome organism. Novy described its wavy or undulating membrane extending from a whiplike structure called a flagellum (attached at the anterior end of the organism) to a small kinetoplast located anteriorly to the large nucleus located at the midpoint of the organism. He described a kinetoplast as a large basal granule of the undulating membrane flagellum.

Figure 2.5 B.Crithidia forms. The crithidial forms agglomerate over time, their flagella overlap and the organisms agglomerate into a circular or what Novy termed a 'rosette' pattern.

Figure 2.5 C & D. The mature crithidia (crithida fasciculate) begins to elongate and the kinetoplast begins to move toward the posterior end of the organism.

Figure 2.5 E. The mature crithidia form has now transformed into an immature trypanosome form. In the latter, the body is similar to the crithidial form, but more tubular, less flattened, more elongated and the kinetoplast is now located at the posterior end of the organism.

Figure 2.5 F. The mature trypanosome form. The organisms are now even more elongated, and the undulating membrane extends from the flagellum at the anterior end to the posterior end attached to the kinetoplast.

Figure 2.5 G. The mature trypanosome form from a blood smear. The mature trypanosomes are seen against the red blood cells in the background. Novy noted that the mature trypanosome is seen in the blood of humans as well as insect vectors. Novy correlated this form in the human blood with the forms in his culture system to correlate the dynamic changes in morphology in his culture system with the interaction of the organism as it changes with its host and its environment. (Courtesy of Bentley Library)

Novy methodically recorded detailed information about his experiments as he conducted them in laboratory notebooks. For most experiments performed, either he or his laboratory assistant entered into notebooks the design and the raw data from the experiment as well as the control. The notebooks he kept during his attempts to culture leishmania provide insight into his laboratory style. Novy's laboratory records reveal that before finding that leishmania organisms survived and could be carried into subsequent cultures, Novy made over one hundred cultures in his attempts to culture leishmania.[56] Novy postulated that the culture system was so inefficient that the culture selected one strain that could survive under artificial conditions out of innumerable strains that could not.[57] His diligence in pursuing the attempt to culture trypanosomes in the face of so many failures was a sign of what Ward MacNeal, his primary assistant during his experiments with protozoa, were to refer to throughout the years as the "dogged persistence of the chief."[58] According to MacNeal, Novy detailed his methods so methodically because he wanted to make sure that his results would be reproducible in the hands of other investigators.[59]

Having plotted the morphologic changes that occurred in leishmania species over time in his culture system, Novy used an innovative methodology to explore the causal relationship of these parasitic forms with human disease. He hypothesized that the promastigote, which he knew was present in the salivary gland of the sand fly (*Phlebotomus sp*), was the infective form that was then deposited into human blood as the sand fly bit humans.[60] Novy reasoned that his culture system provided a unique opportunity to empirically test his hypothesis by challenging dogs with an intraperitoneal injection of the promastigote form to determine whether the animal would develop disease.[61] Novy used dogs because he postulated that the human disease was of canine origin. In 1908, he used a specimen sent to him by Nicolle at Tunis that had been taken from the spleen of a sick child. He isolated a pure culture of the extracellular promastigote forms of *Leishmania infantum* from the specimen after 48 hours of incubation, then injected these forms intraperitoneally into the dog.[62] Fourteen days later, he sacrificed the animal and made smears of its spleen in order to observe whether the injected form had evolved into the amastigote form that appears in tissues of diseased animals.[63] Smears of preparations made from the spleen teemed with intracellular amastogote forms.[64] He concluded that the extracellular promastigotes were indeed the infective form as they matured into the intracellular, intrasplenic amastigotes in the dog. This finding confirmed his suspicion that the sand fly, which harbored the promastigotes in nature, was indeed the vector.

By producing leishmania infection in a dog, Novy used his dynamic system of observation to show not only evolving protozoal forms, but the behavior of these forms in their various animal hosts in nature. He showed that the promastigote is the infective form of Leishmaniasis.[65] Physicians and scientists marveled at how Novy's innovative experimental methodology allowed a greater understanding of the complex life cycle of parasites and which forms were infective for other animals. In a letter to Novy, William Welch said, "I congratulate you heartily for your original work demonstrating an experimental model with leishmania—it adds another laurel to your already splendid record of achievement in this field of investigation, which is a great credit to American medicine. We are all proud of you."[66] Welch understood the novelty of Novy's work--not only was Novy able to identify the changing morphology and behavior of organisms in the laboratory over time, he also correlated the changes he observed in the laboratory with the organism's behavior and mechanism of transmission as it adapted to its particular set of hosts in nature. His work led to a greater understanding of pathogenic protozoa, but it also was also clarifying the biology of protozoal behavior in nature.

Owing to the novel nature of his work on leishmania and trypanosomes, Novy was invited to deliver related lectures at a variety of venues. In these lectures, Novy adopted the attitude that protozoa and parasites had been neglected by too many early microbiologists.[67] In the early germ theory era, he argued, bacteria had been given what he referred to as an "almost exclusive role in the production of infectious disease."[68] Trypanosomes, he argued, attracted little attention largely because of the all-absorbing interest in the study of bacterial disease. Novy felt that bacteriologists should cast a wider gaze, and not restrict their vision to bacteria alone. For Novy, parasites were an ideal match to his interests, as they provided an opportunity to use a dynamic system of observation to observe and study the behavior of the changing morphologies he observed in his culture system as the organisms interacted with its various hosts.[69]

Novy may have felt that his tremendous interest in protozoa—pathogenic and non-pathogenic alike—placed him at the margins of microbiology at the time. After all, protozoal diseases had been noted as a discipline outside the mainstream of medicine, and one that has a tangential relationship with the germ theory. In the late 19th and early 20th century, parasitology was segregated from the modern field of bacteriology and institutionally separated from medical schools—it was taught in schools of tropical medicine, public health, and agriculture.[70] But Novy felt that the germ theory had made bacteria accessible to physicians and biologists, while leaving other fields of study, like parasitology, unavailable to physicians who sought to understand particular diseases. Novy objected to the marginalization of parasitology among microbiologists. He felt that those working with germ theory had been slow to use parasitology to gain insight into behavioral and adaptive changes of microbes in relation to their host over time, and had missed an opportunity to generalize models of parasitism to human disease.[71]

Perhaps sensing his own marginalization from microbiology, Novy argued that his field's indifference to protozoa and overemphasis on bacteria was unfortunate. Specifically, Novy argued that parasites were as important as bacteria in causing human disease. He noted, "pathogenic protozoa have arisen from an obscure to a commanding position by the side of the pathogenic bacteria."[72]To provide evidence for this point, he quoted studies by Bruce showing that trypanosomes were the cause of sleeping sickness, and studies by Ross on the parasitic cause of malaria. These two diseases, Novy noted, were responsible for a sizeable disease burden in human populations throughout the world.[73]

But Novy argued that the importance of protozoa went beyond identifying their role in human disease—their study was also essential in better understanding the ecology of the world and how protozoa were able to survive in nature. To illustrate this point, he described his own experiments with *T lewisi*, which he noted was universally distributed among white rats throughout the world, including barns in Ann Arbor. In fact, Novy sampled the blood of hundreds of rats caught in Ann Arbor barns and found that approximately five percent of rats had trypanosomes in their blood. Novy observed that these rats harbored the parasite without injurious effect and thus was able to argue that the animals serve as a reservoir for the parasite and are then able to supply the organism to the tsetse vector.[74]

Novy's interest in protozoa was not limited to their role in causing human disease; he was equally as curious about how to devise instruments and make dynamic observations to see how they behave in nature. In later years, he remained just as interested in trypanosomes that do not cause disease as those that do. By studying smears from tsetse flies and mosquitoes from Africa, Novy arrived at the conclusion that there were several trypanosomes in that region of Africa which had nothing to do with sleeping sickness.[75] He investigated differences among trypanosomes according to how the flagella originated from the anterior or posterior end of the parasite at certain stages of development, whether the anterior or posterior ends ever became sharp or not, or whether or not they contained a nuclear structure (a kinetoplast).[76] Thus, he also used these morphologic changes of the trypanosomes as they matured over time in his cultivation system for purposes of taxonomy.

Using dynamic observations in his innovative culture system, Novy was able to visualize the behavior of various protozoal forms as they developed over time. This contrasted to Bruce's and Koch's static observation of organisms from human specimens obtained in field studies. Novy then correlated changes in the structures of trypanosomes over time with their behavior in nature according to its host (humans) and vector (Glossina fly).[77] [Figure 2.6] Thus, by introducing an element of time into microbiology, he was able to gain insight into the appearance and maturation of these organisms in his laboratory. As a consequence, he also gained insight into their biological behavior in nature.

Figure 2.6. Picture of glossina morsitans, the tse tse fly that transmits trypanosome organisms. Novy correlated the changes in morphology in the culture system with the changes in morphology in nature as the organism matures in its vector, glossina morsitans (tse tse flay), and its host, the human. He postulated that the flattened, crithidial form resides in the salivary glands of the tse tse fly. These forms are deposited into human blood when the tse tse fly bites man, and in mammalian blood, the crithidial forms mature into trypanosome forms. When a fly bites a human and ingests trypanosomes, crithidia form in the gut of the fly.

Novy sought to extend the theme of using innovative methods to visualize new organisms in clinical specimens from field researchers throughout the world. He had become interested in devising a culture system to characterize the organism responsible for causing relapsing fever. He sought to isolate the etiological agents of *Spirocheta obermeieri* described by Otto Obermeier in 1870. Obermeir's attempts at artificial cultivation of the organism had failed. But one natural habitat of the organism was the blood of the rat, and it was customary at the time to maintain strains of the spirochetes in the laboratory by successive transfers to rats. From a colleague at Bellevue Hospital in New York City, Charles Morris, Novy obtained blood in 1905 from a patient who was suffering from relapsing fever, a condition in which fevers and muscle aches recur in a cyclic pattern.[78] Morris injected the patient's blood into a monkey, which then developed the disease. The blood of the monkey, when injected into rats, also led to the presence of spirochetes in the blood that was seen on a blood smear.[79] Morris sent to Novy a white rat inoculated with the blood of an infected rat.[80] Novy and his associate, R.E. Knapp injected the blood into rats and were able to carry the infection in successive passages through rats, thereby keeping the organism alive in another animal's body. Having satisfied his first step, Novy now proceeded with attempts to culture the organism he believed was responsible for the disease.

Novy's many hundreds of initial attempts to cultivate the spirochete on artificial media were unsuccessful.[81] He reasoned that the organism may be present in too small quantities to appear on cultivation by routine methods. He sought to invent new methods to concentrate the organism. Novy collaborated with Professor Floyd Bartell in the chemistry department to use a collodium sac to batch organisms in large enough concentration to allow them to be visualized. To do this, Novy made a sac holding 3 milliliters of uncoagulated blood in order to "trap" the organism in a large enough concentration. [Figure 2.7]

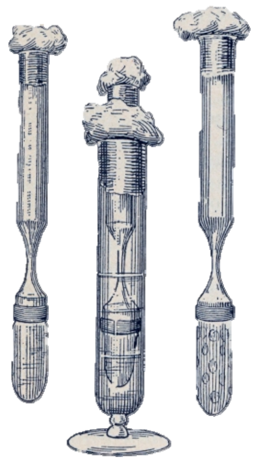


Figure 2.7. Collodium sac used to culture organisms that would not grow on routine agar media. Such organisms included spirochetes. This culture system attempted to grow organisms in the peritoneal cavity of an animal where nutrients are supplied and where the organisms are protected against phagocytic white blood cells. This was accomplished by enclosing bacteria in a sac, the walls of which were permeable to the waste products of germs and the 'nutrients' of peritoneal fluid. The tubes were 15 inches long and a width of a half of an inch. The opening was closed with collodium by touching cotton or cork with a solution. The sac is then inoculated with fluid attempted to be cultured, and is then placed in a peritoneal cavity of a guinea pig or a rabbit through an incision. The sac was then removed after remaining in the cavity for two to four weeks, and the contents stained.

This, when inoculated with blood from an infected rat, was placed in the peritoneal cavity of an uninfected one. When he removed the sac three days later, he reasoned it contained organisms in large enough concentrations to be cultivated artificially. He inoculated material from the blood-filled collodium sac into an artificial medium and he successfully isolated a colony of spirochete, which he then termed *Spirillium novii*.[82] Novy then took the spirochete and carried it through 20 passages in rats over 60 days. Thus, he had devised a technique that allowed him to isolate a spirochete from a person suffering from relapsing fever on artificial media, then inject it into experimental animals and subsequently isolate it in media.[83] [Figure 2.8] In 1907, after he published studies of his work on spirochetes, he acquired the nickname "Spi" from the students in his lab.[84] \

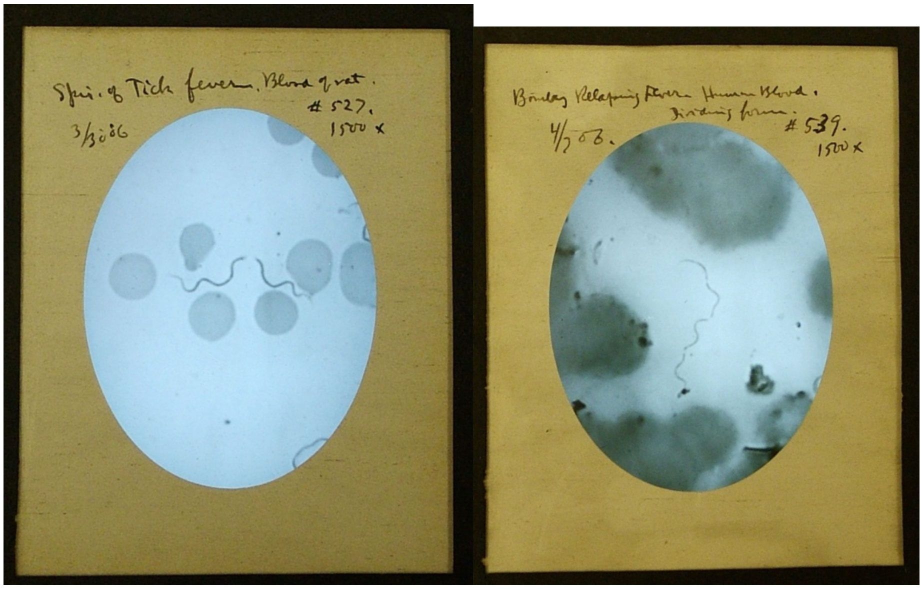


Figure 2.8. Stains of Spirillum novy. Organisms seen in blood smear from a rat (Left) and a blood smear from a human (right). Novy noted that the organisms are spiral shaped; they do not have flagella. (Courtesy of Bentley Library)

Not all of Novy's attempts to cultivate organisms were successful, nor did he publish all of his work. He labored for many years to devise an artificial culture system for malaria from specimens sent to him by researchers in the field, but he never succeeded in doing so.[85] He did not publish these attempts to culture malaria. He also tried to culture a microbe that caused fever, muscle aches, and headache from a human specimen sent to him by Howard Taylor Ricketts (1871–1910) from the Bitterroot Valley of Montana, but Novy's attempts failed. Novy attempted to culture the organism from collodium sacs, and tried new methods of filtering the blood with a variety of filters, but none of these attempts succeeded in isolating the microbe.[86] Again, he did not publish these experimental attempts. Novy did not address why he did not publish his attempts, or express concern at the lost opportunity to prevent others from repeating his failures. Victoria Harden mentioned Novy's correspondence about ticks as a vector, but she did not mention Novy's attempt to culture the organism in her history of Rocky Mountain Spotted Fever written in 1990.[87]

Despite the failures to isolate microbes from some clinical specimens, Novy remained committed to devising innovative techniques to help reveal the presence of microbes in clinical specimens. He was interested in visualizing what he termed "ultramicroscopic" organisms, such as the cause of rabies, that remained invisible with the use of conventional compound microscopes at the time.[88] Novy asked whether it was possible, in any way, or by any method, "to actually demonstrate such small things?"[89] The device that Novy recognized did not yet exist—what he termed the 'ultramicroscope'—would be what he needed to fulfill his desire to detect extremely small germs, or "ultrasomes: that were invisible under Novy's microscope.[90] Novy knew that these minute organisms, after passing through the walls of filters that retain the smallest of the "visible" organisms, may then cause infection when inoculated into a susceptible animal.[91] Novy believed that filtering these minute organisms offered the best chance to demonstrate their presence, as other methods, such as developing a stain, were not available.[92] Furthermore, attempts to centrifuge these organisms did not yield results, indicating they were, according to Novy, "extraordinarily minute" and very light weight.[93] Unable to classify the "ultrasomes", he began to refer to them as "filterable viruses" by 1911.[94]

Novy's interest in ultramicroscopic life led him to search for an ultramicroscopic organism as a cause of death in stock rats being used in the lab to carry the spirochetes of relapsing fever. But the storybook nature of the investigations that ensued caught the attention of the national and lay press.[95] In 1909, the passage strain of African relapsing fever spirochete, received by Novy from Robert Koch, was in danger of being lost. The rats in which the spirochete was being maintained were dying for unknown reasons. Novy's laboratory assistant, George Lutz, was challenged by Novy about whether Lutz was completing his animal-feeding duties correctly; but it became apparent that the deaths were not due to any change in feeding procedures. Moreover, bacteria could not be demonstrated in the dying rats. Novy postulated that a filterable virus that might be the cause of the rats' rapid death.[96]

Novy filtered the rat blood through a collodion filter and he demonstrated that the virus passed through filters. He then went on to examine the infectiousness of the filterable virus for rats. Novy first salvaged the Koch relapsing fever strain, which had been contaminated with the virus, by injecting the virus infected rat blood into healthy mice. He showed that a minimum of one hundred-billionth of one milliliter of infected rat blood, when injected into rats, would kill them. The infected rats frequently died in convulsions, which suggested to Novy an encephalitis. A reddish brown discharge around the eyes and nares was noticed and hematuria was observed. Novy reported in the Reports of the Michigan Academy of Science in 1910 his evidence of a "filterable agent" rather than a spirochete, bacteria, or trypanosome, was responsible for encephalitis on inoculation of filtered blood in experimental animals.[97]

Over the next eight years, Novy and his students, among whom was Paul de Kruif, performed further work on the nature of the filterable virus and its ability to engender immunity in rats. At the time, there were no cell-associated cultures that would allow the virus to be maintained in incubating agar plates. Therefore, to carry out these studies, Novy continued constant passage of the virus through rats. Specifically, he perpetuated the virus by inoculating rats then taking serum from them to inoculate others, and thus preserve a supply of the virus for his studies. Novy's assistants worked for years perpetuating the virus in rats, taking serum, inoculating, and re-inoculating. In fact, his laboratory assistants were charged every third day with taking blood from a batch of dying rodents and infecting healthy specimens. The routine, thought necessary to keep the virus alive, was a slow and painstaking process. Novy's assistants would take blood from an infected rat, inoculate another rat, and keep enough blood to seal in a tube. Such glycerin sealed tubes were refrigerated as a safety precaution in the event of difficulty with rat passage. The virus was maintained in this manner from 1909 to 1918.

But all work had to be stopped when the stock material containing the virus was unaccountably lost in 1918 when the rat passage failed. It appeared that the blood which was set aside in the tubes did not contain the original virus. The laboratory assistants' attempts to recover the virus from the current blood reserves failed, and the virus had apparently been lost. Novy attributed the lost tubes of virus to the serious inroads that World War I had made on his laboratory, which had become understaffed by 1918.[98] Novy opined that three workers had left his laboratory to join the service during WWI and he lamented that the "chance for maintaining research projects is practically nil."[99] The whereabouts of a basket of sealed tubes containing blood taken from infected rats in

1918 remained unknown, and Novy did not publish any of the findings of his experiments on the virus from 1910 to 1918 because he thought that others would not be able to check his findings as he could not locate the virus.[100] But all records and data of the rat virus experiments were meticulously kept in his unpublished laboratory notebooks, which he never discarded.

Novy longed to know what happened to the virus. As the years passed, he became increasingly sure that if the tubes were ever found, the virus would be dead. Novy was on alert constantly for any evidence in the literature of a spontaneously occurring virus, highly virulent for rats.[101] He stimulated his staff and students to search for such a virus in the rats being used for the passage of the relapsing fever spirochete. These and other efforts were of no avail. Meanwhile, the bacteriology department moved to the new East Medical Building and personnel changed. Novy retired, taking with him all consciousness of his virus. Like his attempts to culture malaria and an organism from the samples Ricketts sent to him, it looked as if another of Novy's undeveloped scientific projects was destined not to reach fruition.

The rat virus story, however, took a unique turn. Thirty-three years later it was discovered that the tubes containing the rat virus had not been lost, just misplaced. In the fall of 1951, an old laboratory was being cleaned in preparation for a move when workers found a set of dust-covered tubes that remained hermetically sealed with glycerin. These had undoubtedly once been kept in a refrigerator, but when discovered, they were in a cupboard at room temperature. Walter Nungester, who was then heading the bacteriology laboratory, speculated that the tubes had been stored at room temperature for a year, since the refrigerator room was closed in 1950 for repainting. Nungester noticed that labels on the sealed tubes were yellow with age and the writing obscure. But he recognized the writing on the labels as Novy's and wondered whether it was possible that these tubes contained the rat virus.

Novy was still alive at the age of 86 and living in Ann Arbor in his retirement. [Figure 2.9 A, B]. Consequently, Nungester was able to inquire with Novy about whether the virus was authentic. Novy read the labels on the tubes and confirmed that the blood had been drawn from virus-infected rats between 1914 and 1918. Novy then was able to find records in his meticulously kept laboratory logs verifying that the tubes had contained virus infected blood. The virus had been found, but only by farthest stretch of scientific imagination could the virus have survived. Nungester and Novy were intrigued by the potential significance of an affirmative answer. Medical theory in 1951 held that viruses do not survive indefinitely when stored. They were compelled to ask whether the basket of blood lurking in a laboratory for over three decades could have contained deadly blood. It seemed a fantastic question.

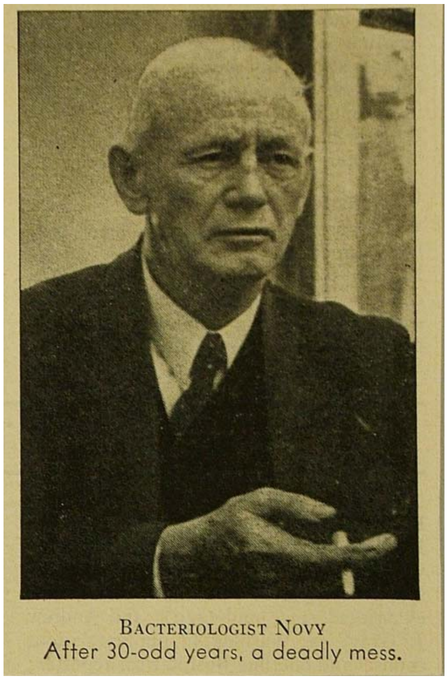


Figure 2.9. Novy Rat Virus. Novy in 1953 after returning to the laboratory from his retirement to investigate the rat virus.

Following the discovery of his long-misplaced samples, Novy came out of retirement to begin work again, but primarily in a supervisory capacity—personnel in Nungester's laboratory performed the experiments on his behalf. Nungester turned the tubes over to Russell Jordan, a graduate student, and asked him to find out what he could. But there was no way to extract the dried blood from the tubes, so Jordan first washed the tubes carefully in soap and cold water, immersed them in ethanol for one hour, then ground in a mortar into a fine powder, including glass, old blood, and even bits of the yellow labels.[102] A saline solution was added to the mixture, which enabled Jordan to extract blood samples from the ground glass. For a control, blood from healthy rats that had been stored for seven months was prepared in a similar fashion—washed, ground, and placed into a saline solution. After filtering and straining multiple times, the solution was injected intra-peritoneally into five lots of living rats. Although the virus may have lost some of its potency; the test solution still killed 75% of the rats in three days, compared with no deaths in the controls. Together with the observation that healthy rats died following injection of filtered blood from diseased rats, Jordan concluded that it was a virus and not other components of the tubes that caused death in the healthy mice.[103] Novy was astonished that not only had the virus been found, but that contrary to his prior expectations, it was still alive and still capable of killing rats after over 30 years of desiccation.

With the knowledge of a nearly a generation since Novy speculated about a viral cause for the mysterious death of his rats in 1909, Russell used an electron microscope to take pictures of the virus for his PhD dissertation.[104] Novy lived long enough to use the technology he had longed for since 1909--an "ultramicroscope"--to identify a filterable virus that his earlier conventional microscope could not visualize. At age 88, as the virus was again available, Novy went back and reviewed his original laboratory notes on the virus, methodically recorded from 1909 to 1918. Novy wrote a comprehensive report on the organism that he published in the *Journal of Infectious Diseases*.[105] Novy listed de Kruif as a co-author to acknowledge his earlier contributions. Novy reported that the virus was found to be potent when appropriate tests showed that, in spite of long storage and desiccation, the original virus in the tubes was still viable. He discovered that the virus, supposedly harmless shortly after its blood medium had died, was still deadly a third of a century later.

Novy was not able to name the virus in 1953. But based on properties of the virus that Novy described, there are some interesting clues that point to a particular virus based on what we know today. Novy described a highly stable virus--for over 30 years--that is resistant to extremes of temperature and pH, has a small size of 20 nanometers, is transmitted fecal-orally, and produces symptoms of encephalitis in rats.[106] Each of these features is consistent with a type of parvovirus called HER-1 (Hemorrhagic Encephalopathy of Rats) Killham rat virus, that was first described in 1970.[107] HER-1 Killham virus can also occur in rat colonies without causing symptoms.[108] This makes the continued transmission among a lot purchased from a breeder in Tennessee, such as Novy suspected in 1910, possible.

The true-tale of Novy's rat virus–involving serendipity, surprise, and the return of a famous scientist—captured the attention of lay audiences. It remains possible, in fact, that the selection of de Kruif as co-author may have indicated Novy's desire to dramatize the story even in the medical press. Nonetheless, Novy's reemergence from retirement and the remarkable circumstances were covered by the local and national press.[109] The University of Michigan medical school magazine, the Pharos, for example, remarked that Novy's ability to go back to notes forty years old and to reconstruct the story with great clarity indicated not only his keenness and vitality in old age, but also the lasting effectiveness of his simple and accurate method for recording data.[110] Esmond Long said of the episode, "Novy's last scientific article, which appeared in 1953 when Novy was nearly ninety years of age was one with a storybook background."[111] Novy did not invent the key technology he needed, but he did live long enough for others to develop it. In addition, the perseverance in finding the mysterious cause of the rats' deaths were not overcome by his old age. Nevertheless, following the completion of his rat virus work in 1953, Novy retired from the laboratory for the final time. [Figure 2.10]

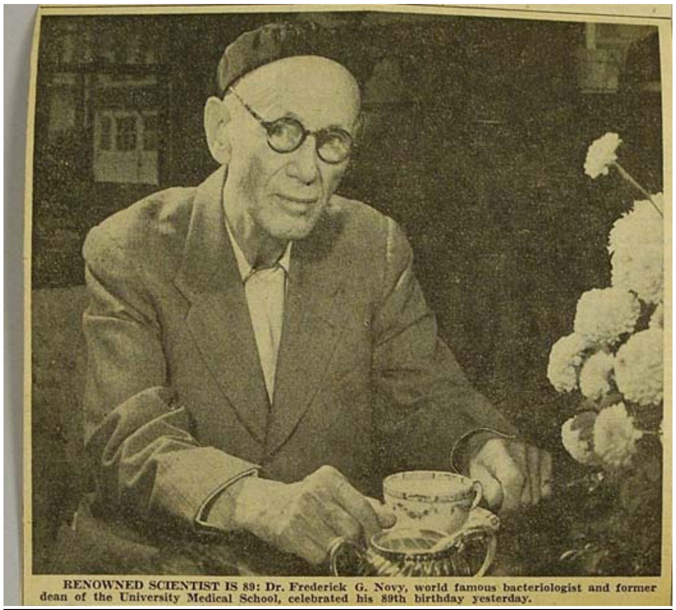


Figure 2.10. Novy in retirement in his home at Michigan in 1956 at age 92. He was photographed at home by the *Ann Arbor News* to accompany an article that commemorated his lifetime achievements. The reporter remarked on how his humility belied his recognition as a world famous bacteriologist. Novy died one year later in 1957.

Heterogeneisis

Novy used his innovative techniques of culturing trypanosomes and spirochetes to address a longstanding controversy among bacteriologists regarding the constancy of species versus the conversion of species (e.g., heterogeneisis). Those who adhered to the latter thought that some microbes could convert to one another, and those who believed in the former believed that microbial species were fixed and were not transformable. Fritz Schaudinn, the discoverer of the microbial cause of syphilis, was a prominent and respected bacteriologist who believed in the conversion of species. He argued that spirochetes and trypanosomes in the rat were in fact the same organism and they could switch from one form to another.[112] Novy, however, contested Schaudinn's claim and maintained that the two organisms were of entirely different species. Below, I provide a historic background regarding the debate about the constancy of species versus heterogeneisis, then show how Schaudinn and Novy approached the controversy and attempted to resolve it.

Historical controversy over conservation or conversion of species

When technology for the isolation and handling of specific organisms were being developed in the late 19th century, there was a lack of agreement about what germs were, how they caused disease, and how they came about.[113] Thinking about microorganisms and disease was new, and various theories regarding the biology of microbes and their relation to disease were beginning to be debated.[114] There were disputes regarding whether bacteria could appear spontaneously in nature, whether bacteria were necessary causes for disease, and, if so, if they were sufficient causes. In addition, different views of "germs" occupied scientists' and physicians' thoughts about disease causation for much the second half of the 19th century. In fact, a debate regarding the role played by a particular germ or the constitution of the individual in causing disease persisted well after Koch announced his identification of the tubercle bacillus in 1884.[115] A synthetic view acknowledging the role of both the germ and the body's constitution, called the "contingent contagionist" theory, enjoyed currency in Britain and in the United States well into the early 20th century.[116]

The universal conversion of species versus constancy of species controversy was one of several debates about germs and how they came about. The key issue debated was whether the various shapes, colors, and sizes of bacteria described by microscopists represented only one or more species that had an endless capacity to change morphology or whether these variations represented individual, fixed species of bacteria. Below, I will summarize the briefly summarize the arguments and evidence of each stance.

In the late 19th century, proponents of the theory of universal conversion of species, or heterogeneisis, maintained that there was one bacterium that was capable of undergoing infinite variation. Ernst Hallier (1831–1904) a professor of botany in Jena, based his idea of heterogeneisis in bacteria on the demonstration of polymorphism among certain fungi with budding spheres emanating from longer rod structures.[117] Hallier's main thesis was that the microscopic forms of bacteria are not in themselves genera and species, but are merely stages (Morphen) in the development of bacteria, and that the transformations are brought about through changes in medium, moisture, and variations in temperature.[118] From human specimens, he felt these different forms of bacteria represented the same species whose form varied according to changes in the environment.[119] Theodor Billroth (1829–1894) professor of surgery at the University of Zurich, agreed with Hallier.[120] Like Hallier, Billroth, thought bacteria were highly variable in appearance and that all of the different forms and colors on staining that could be seen under the microscope were different stages of one species.[121] Billroth argued that there was only one organism capable of undergoing infinite variation and that a conversion of one organism to another took place depending upon availability of certain nutrients or changes in environmental conditions—such as temperature and oxygen supply.[122]

Other 19th century investigators believed that all bacteria were variations of one and the same organism. Wilhelm Zopf and Carl von Naegeli believed that different stages of development, types of multiplication, the variety of size and form, and specific metabolic properties were not associated with distinct species types.[123] Like Hallier and Billroth, Zopf adhered to a pleomorphic doctrine of bacteria, which suggested that depending upon environmental circumstances cocci could change to bacilli or spirals.[124] Von Naegeli argued that different bacterial forms and shapes simply denote the developmental cycles that a single species of bacteria undergoes in its development.[125]

At a time when the concept of "species" was in flux and there was a lack of agreement about what germs were, some investigators contested the doctrine of heterogeneisis. In 1872, Ferdinand Cohn argued that the varying forms and shapes of bacteria, like plants or animals, represented distinct and different species.[126] He asserted the existence of specific organisms, constant in form and recognizable morphologically, and he argued that an individual species was conserved and did not change into one another. Cohn based his belief in the speciation of bacteria by observation of constant forms of bacteria and postulated a classification on the basis of morphology. Cohn was a botanist and, in 1875, the science of botany was based primarily of careful observation and taxonomic classification. In essence, Cohn the botanist argued that distinct species occurred in bacteria in the same sense that they occur in higher organisms such as plants.[127] Cohn admitted that there were varying morphological forms within a species, but he accounted for them by postulating a life history of the same organism.[128]

Cohn's classification was regarded as incorrect by several physicians and botanists who oppose the doctrine of the constancy of bacteria. The pleomorphism theory of Hallier and Billroth was accepted by Joseph Lister, (1827–1912) professor of surgery in Edinburgh; Ray Lankester (1847–1929), an English zoologist and director of Natural History Department of the British Museum; Theodor Klebs (1834–1913) professor of pathology in Berne; and Eugene Warming (1848–1924) professor of botany at the University of Copenhagen.[129] Warming, like Billroth, regarded bacteria as the simplest change in the development of a fungus.[130] By planting the spores from fungi he maintained that bacteria are produced. Further, Warming insisted that all attempts to obtain what the Germans called "pure cultures" must be abandoned as it was impossible to get an optically pure specimen from the environment. Lister, in 1873, described several morphological changes in bacteria under varying conditions of nutrition and refuted Cohn's classification system.[131] Lankester opposed the doctrine of the constancy of species through his studies of a bacterium he found in stagnant river water.[132] He postulated that the forms of this bacteria were inconsistent even though they were the same organism.[133]

Botanists Leo Cienkowski (1822–1887) and Wilhelm Zopf (1846–1909) accepted the inconsistency of bacterial forms.[134] Cienkowski felt that the change of one bacterial form into another was dependent on the environment and different conditions of nutrition.[135] Zopf's proposed the variability of bacteria as the bacteria underwent development.[136] Thus, these authors did not always mean the same thing when they used the term pleomorphism—some were referring to morphological inconstancy of bacteria under different conditions of nutrition, others used it to denote changes which some bacteria undergo in their development.

In the late 1870s, Robert Koch introduced new methods to isolate discrete bacterial colonies in pure form through the use of agar plate cultures. This led Koch to support the constancy of species. When Koch became convinced that each colony could arise from a single cell that had fallen on gelatin agar, he felt he had a method for the isolation of pure colonies.[137] Koch showed that different bacterial types bred true and he argued they could be considered separate species. After examining the morphology on the distinct colonies that grew on agar, he agreed with Cohn that bacteria could be divided into distinct species with typical characteristics, which are transmitted to the following generations when bacteria multiply. With the solid agar medium he developed, Koch felt he now had the technology to clarify the debate surrounding constancy versus conversion of species.[138] Koch's work during this time became a central tenet to the germ theory of medicine—that individual bacteria are responsible for causing distinct and separate diseases.

The demonstration of separate bacterial colonies resolved the issue for many scientists who already accepted that specific germs caused specific diseases. But through the late 1890s, the idea of universal conversion continued to be promoted by some physicians who opposed the germ theory of medicine. Adhering to the concept of universal conversion of species would undermine the notion that distinct organisms correspond with particular diseases and would provide a rational basis on which to reject the germ theory of medicine. Charles Kuhlman was a practicing physician in California who opposed the germ theory of medicine and was an adherent of universal conversion.[139] Kuhlman rejected Koch's claim that an individual germ could cause a particular disease because he believed that bacteria could not be catalogued according to species. He also rejected the germ theory on the grounds that germs had an incidental rather than a causal relationship to disease processes and that chemical products of bacteria, not the bacteria themselves, contributed to morbid pathology in tissues.[140]

Fritz Schaudinn was an early 20th century German investigator and zoologist who tried to reconcile the germ theory of medicine with the idea of the conversion of species. In 1905, the highly regarded bacteriologist co-discovered, with Erich Hoffmann, the causative agent of syphilis, *Spirochaeta pallida*. He sought to provide experimental evidence for his belief that microbes could convert to one another.[141] Schaudinn observed the blood of rats and postulated that the spirochetes and trypanosomes he viewed were expressions of different forms of the same organism.[142] He believed there was an alternation of growth of spirochetes in the blood of his owls, and that spirochetes changed into trypanosomes and vice versa. Schaudinn argued that microbes living inside of circulating white blood cells, or leucocytozoan, of the owl were a blood trypanosome.[143] As the leucocytozoan matured, he postulated, it formed in the stomach of the common mosquito, replicated, and then gave rise to spirochete progeny.[144] Once these spirochetes matured they converted back to trypanosomes.[145] Schaudinn believed in an interrelationship of spirochetes and trypanosomes.

Novy had been opposed to the theory of conversion of species even before Schaudinn published his arguments about spirochetes transforming into trypanosomes. In 1899, Novy wrote that the shape, size, staining characteristics, and variations in a bacterial colonies' ability to grow may depend on changes in the environment.[146] Novy argued that adherents of conversion of species were mistaken in attributing these changes to a new species. An individual bacterium, he argued, may be modified according to changes in the environment, giving rise to varieties, but as long as these varieties exist they still represent the original species. Novy substantiated his opinion by observing that the typical form and the typical species can always be reproduced by restoring the most favorable conditions of growth.

Schaudinn's publication spurred Novy to empirically test Schaudinn's hypothesis of constancy of species. Novy was to use his culture system of both trypanosomes and of spirochetes in an effort to dispel Schaudinn's notion of universal conversion of species.[147] From cultures of blood taken from owls, Novy methodically observed the maturation of trypanosome forms in a sequential fashion over a 48-hour period. If species converted, as Schaudinn claimed, Novy should directly observe it in his laboratory cultivation system. He examined the specimens himself every fifteen minutes, staying up all night to do so. He saw no changes of the type to which Schaudinn had referred. Thus, Novy concluded that what Schaudinn felt were spirochetes were actually stages in the life history of an intracellular trypanosome parasite, as he could observe the exact forms Schaudinn felt were spirochetes in the pure culture system of the trypanosome as it matured.[148] Novy felt that Schaudinn failed to appreciate this truth because Schaudinn did not have a culture system to observe the trypanosomes maturing and changing form dynamically over time.

To provide additional evidence against Schaudinn's claim, Novy then went back to investigate the owl blood more closely. Using staining and culture techniques, he found that the blood contained a dual infection with both trypanosomes and spirochetes. In his culture of spirochetes, he did not see any form resembling the leucocytozoan, which Schaudinn claimed became a spirochete. This finding bolstered his conclusion that one species was not converting into another. Novy saw no reason why two microorganisms could not be present at the same time in the same host. In his articles, Novy photographed a trypanosome approaching a red blood cell, entering it, then leaving this temporary housing—all the same species of trypanosome but with differing morphology.[149]

In a series of correspondences with Novy, Schaudinn at first remained unconvinced by Novy's findings and would not relinquish his belief that the intracellular stage of trypanosome, the leucocytozoan, gave rise to a host of spirochetes.[150] Novy remained steadfast in his argument that if the spirochete were a stage of a leucocytozoan, he should be able to see it grow in his culture system and to see the trypanosome change into a spirochete forms.[151] In an attempt to further disprove Schaudinn's paper, Novy examined samples from 800 additional birds during the next year.[152] He repeatedly stayed up all night, watching the growth of his cultures on fifteen minute intervals over a forty eight hour period to see if the trypanosomes changed to halteridia. He found that no change occurred. They always retained characteristic morphological features of trypanosomes (undulating membranes) and never those of spirochetes (helical forms). Although the words treponema and trypanosome are not etymologically related, one cannot discount the possibility that the verbal similarity of the words may have perpetuated Schaudinn's view.

In his papers on halteridia, Novy then made broad conclusions based on his data. Novy first reached his direct conclusion that the spirochete and the trypanosome were independent forms of life. But he then reached a more encompassing conclusion, stating that his findings argue against the alternation or the interchangeability of species.[153] He concluded by saying, "how readily erroneous conclusions may be drawn from otherwise simple facts."[154] Novy stated that Schaudinn failed to recognize these "simple facts" because his static observations at set time points did not allow him to recognize the trypanosome in its developing form.[155] Novy said that Schaudin's failure to observe the organisms sequentially as they matured over time—the neglect to incorporate the element of time in his methodology—led to his "erroneous conclusions."[156]

In letters to Robert Ross and to Schaudinn, Novy wrote that his intention was to use his dynamic culture system to refute Schaudinn's hypothesis and provide evidence against the theory of conversion of species.[157] In designing his experiments, Novy was motivated to resolve a hypothetical issue regarding the biological behavior of organisms in nature.[158] Although the issue at stake—specificity of microbial species, certainly did have practical implications, Novy, in his letters, never mentioned having a practical goal in mind. Novy was performing experiments to understand how organisms develop over time, and to find out where they come from. He felt that the most important discoveries in science came from investigating science for its own sake rather than making utility their guiding principle.[159] He never objected to his findings eventually having practical utility; he simply believed that a desire to seek truth in nature should be the sole motive for his experiments.[160] Perhaps it was for this reason that his colleagues considered his work to be "pure" or fundamental in nature.[161]

Using the methodology of chemistry to understand the behavior of microbes

Novy was interested in visualizing the behavior of organisms from the chemical viewpoint. His interests in this regard spanned from understanding what microbes do to survive in nature to exploring the fundamental mechanisms by which pathogenic organisms caused disease in humans. Regarding the latter, Novy's interests overlap with the 19th century germ worker Henle, who was interested in what bacteria did to cause disease.[162] Henle believed that it was not the presence of the germ itself caused disease, but that the germ did something to cause disease. Therefore, he believed that simply making the germ visible would not reveal the cause of the disease, but one must first see what the germ does in order to cause disease. Henle postulated that the "so far unseen bodies" produce disease by a process similar to putrifications and fermentations.[163] Thus, to Henle, visibility meant more than identifying the morphological characteristics of the bacterial organism. It also meant determining how the organism behaves in order to cause disease. To Henle, the trope of "visibility" was not limited to literally seeing an organism through the use of optic aids; it also applied to seeing how organism behaved in order to destroy what he termed "life's manifestations." But Henle could only speculate on these questions, as he lacked the tools to determine what he termed "the power of each one of these" to cause disease.[164]

Novy, like Henle, realized he would need to use technology other than optics in order to visualize how pathogenic bacteria behave and how they cause disease. As he said in 1902, "To cross the threshold of the cell, to unravel the changes which take place in the normal and in the diseased cell is the next task. In that work the microscope will no longer be of value since the changes will involve alterations of molecules and not of cells. It is to the chemist and the physicist that medicine and the broader biology must look for the solution of the ever recurring puzzle of life"[165] Novy's quote shows how he was turning towards the tools of chemistry to enable him to visualize their metabolism, respiration, and behavior that may or may not culminate in human disease. For Novy, understanding behavior of organisms entailed more than cultures, stains and microscopes—it involved using the instruments of chemistry to determine the chemical and gaseous products of bacteria. Through the viewpoint of a chemist, he visualized microbial metabolism and respiration in order to gain information about microbial survival in nature and production of clinical disease in humans.

In the early 1890s, Novy hypothesized that among the products of bacterial metabolism, one could discover substances of definable chemical composition, whose action may have no relation to the process of disease. To test his hypothesis, Novy chemically analyzed the liquid in the media freed from bacterial cells by filtration. Novy's discovery of certain free bases, which he termed a diamine, in the bacterial products of the hog cholera bacillus, led him to identify them as specifically active products of their metabolism. He identified them as nitrogenous products of organic nitrate substrate that the organism used for its nutrition by a process of nitrification. Novy postulated that these products of metabolism were simply a function of the organism surviving in nature and that that they were not toxic to bacteria's host.[166] To support this hypothesis, he injected the purified nitrogenous product into rats and observed no harmful effects. He then isolated a separate protein product produced by the microorganism by separating the diamine in the residue of the bacteria-free solution by using a differential gradient of mercuric chloride. He showed that the separate substance did have toxic effects when injected into rats.[167] Thus, Novy studied all chemical products of bacteria regardless of whether they harmed animals.

By the mid-1890s, Novy continued to use the tools of chemistry to differentiate bacterial products that could produce disease, and those that had no discernable effects on its host. He identified a number of ptomaines, intermediate products formed when bacteria degrade organic proteins to carbon dioxide, ammonia, and water. Based on his observation that ptomaines did not cause disease when injected into laboratory animals, Novy argued that ptomaines are transition products of putrefaction of proteins and are products of bacterial nutrition and metabolism.[168] He subsequently distinguished ptomaines from toxins that are synthesized and excreted by pathogenic organisms, such as the diphtheria bacillus, that result in human disease.[169] Novy dichotomized ptomaines and toxins according to whether they caused disease. He investigated and published on each—he did not restrict his concern to processes that relate bacterial products to disease production.

Later in his career Novy became interested in using chemical instruments to explore fundamental questions about whether the mechanisms underlying disease variability following infection may be related to microbial behavior. He became curious about the marked variability in clinical disease patterns that could ensue following infection with the tubercle bacillus. He wondered why some people who were infected with this organism have a rapidly progressive illness, where others were indolent, and others infected had no manifestations in disease at all?[170] He questioned whether the variations in disease may be due to changes in the behavior of the organism itself, perhaps in response to local environmental conditions within the host.

To test his theory about disease variation and microbial survival, Novy decided to devise chemical instruments to measure microbial respiration. He postulated that microbes not only metabolize chemicals in order to survive, they also exchange gas since "respiration is a fundamental characteristic of life".[171] He reasoned that all organisms produce and consume gas, including mycobacteria, protozoa and bacteria.[172] He noted that mycobacteria were known to be obligate aerobes, but nothing was known about the oxygen (O2) and carbon dioxide (CO2) tensions required for their optimal growth. He said, "Little or no attention is given to the gaseous product of cell activity…all living organisms and microorganisms are engaged in gas production"[173] Novy believed that microbiologists had neglected microbial respiration because of the high complexity of apparatus that would be required to measure gasses produced by microbes.[174] It is possible that WWI era work on gas gangrene may have also revived his student interests in microbial gas metabolism, although Novy never specifically mentioned this.

Novy wondered about the possible effect of increasing or decreasing tensions of oxygen or carbon dioxide upon the growth of these organisms.[175] Furthermore, he wondered whether variations in oxygen content in different host organs and tissues could account, in part, for the ability of the host to contain the growth of mycobacteria and result in slow growth of mycobacteria in certain circumstances.[176] In addition to determining gas exchange, Novy wanted to compare the composition of the gas phase under which microbes grow with the partial pressures of CO2 and O2 existing in the body of their animal host.[177] To do this, he sought to measure the much slower respiration of bacterial cultures over a period as long as 56 days.

To experimentally test for microbial respiration that may have been an essential component of survival, Novy resorted to methodologies of devising technology to measure gasses as he had learned during his chemistry training.[178] He devised equipment to measure the CO2 and O2 concentration of the gas produced by mycobacteria growing in an incubator in relation to the O2 content of the immediate environment. Novy devised a series of complex equipment to measure CO_2 production and O_2 consumption by mycobacteria.[179] [Figure 2.11] He constructed a differential manometer with one arm connected with a closed vessel in which the organisms grew in medium. The overall design sought to pay attention to the gas phase when Novy measured the growth and respiration of the tubercle bacillus. There were T tubes and stopcocks on the culture side so that gas could be sampled for analysis and the volume of gas given off or taken up by culture could be calculated by measuring the level of mercury in the manometer.[180] He measured O_2 and CO_2 over the culture, and because he was able to extract CO_2 from the culture medium, he found the CO_2 production. He was then able to determine "microbic respiration" by calculating respiratory quotient (RQ) defined as carbon dioxide (CO_2) production divided by oxygen (O_2) consumption.

Figure 2.11 A

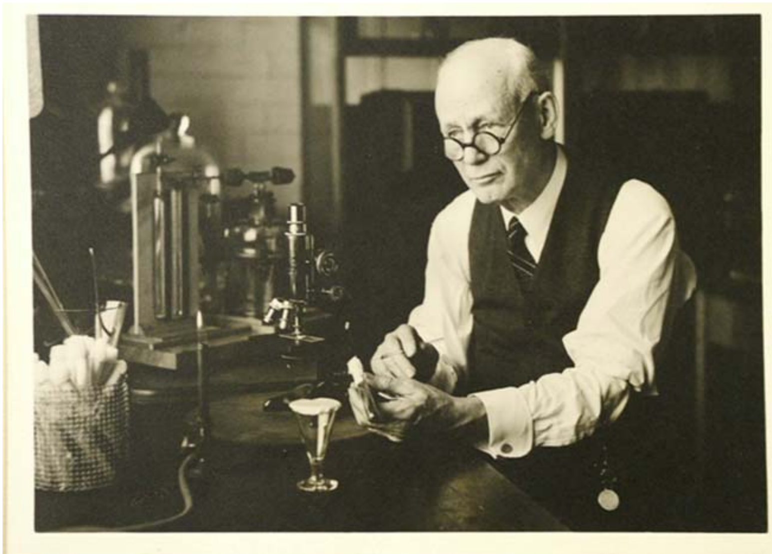


Figure 2.11 B

Figure 2.11 A & B. Microbic respiration. Figure 2.11 A: apparatus devised by Novy. Novy sought to measure the slow respiration of bacterial cultures over a period as long as sixty days. He postulated that all organisms produce gas, and sought to prove this with the slow growing mycobacteria.

Figure 2.11 A. Shows a differential manometer that Novy designed. One arm of a mercury-containing **U** tube was attached to a closed vessel whose volume was 100 milliliters. The other arm was connected with a closed vessel in which the organisms grew in a tube containing the culture growing on a slant. There were T tubes and stopcocks on the culture side so that gas over the culture was sampled for analysis. When the level of the mercury in the manometer was read the volume of gas given off or taken up by the culture was calculated. He used hischemistry training—a version of the Henderson-Haldane apparatus he had studied to measure oxygen, carbon dioxide, nitrogen, and hydrogen in the gas over the culture. Because he extracted carbon dioxide from the culture medium, he was able to determine the total carbon dioxide production. He calculated the respiratory quotient, RQ, for carbon dioxide production divided by oxygen consumption. Note the consistent theme of devising apparatus to measure gaseous products of his experiments, this one occurring forty years after his design of apparatus during his chemistry experiments in college.

Figure 2.11 B. Novy performed these experiments from 1923-1928. Novy in his laboratory in 1929 with his differential manometer in the background.

Novy and his students found that mycobacteria grew best in tubes that contained in higher oxygen contents, and that raising the oxygen content resulted in a higher respiratory quotient. He discovered that the optimal oxygen concentration of media for growth was high, as 50%, and that increasing carbon dioxide tension up to 20% did not inhibit growth. Novy then correlated his experimental findings with findings that occurred within animals. He concluded, "The slow multiplication of the tubercle bacillus in the body is explainable from the standpoint of growth in diminished O2 tension…A high supply of O2 under high tension…will probably enable the organism to grow slowly…The 'rest cure' and rich diet in checking the progress of the disease probably act by reducing to minimum the available O2 supply in the tissues."[181]

Novy's experimental results showed that the slow multiplication of the tubercular bacillus is correlated with low O2 consumption. Consequently, he reasoned, the variability in clinical disease patterns may be due to changes in microbial behavior based on the gas supply within the host tissue. Furthermore, he reasoned that the rest cure recommended by physicians may be explainable from the standpoint of reduced growth of mycobacteria in tissues with diminished O2 tension, even though he did not specifically refer to physiological studies of human tissues that supported his claim that rest or diet lowered tissue oxygen. His studies with Malcolm Soule (his graduate student, and later the chair of the bacteriology department) offered a biological basis for the "rest cure" and rich food diets, which doctors had been recommending to arrest the progression of tuberculosis. With his graduate students, Novy asked questions about how environmental and host factors alter microbial behavior, and together they performed experiments to understand the mechanisms by which therapies recommended in clinical practice may work. C.E.A. Winslow said about Novy's experiments, "Novy's work on microbic respiration was original, basic, and a fundamental contribution to bacterial physiology".[182]

A multitude of research projects

Several of Novy's graduate students wrote that he created an atmosphere that encouraged freedom to pursue topics according to the creative wishes of his many students.[183] This atmosphere attracted a variety of students with different interests, and Novy did not restrict the topics of their research pursuits. One former student, Max Marshall, who became a professor of bacteriology at University of California at San Francisco, wrote about how Novy encouraged him to "select and work on problems in basic science of (his) own choice", and how the "spirit of the environment" was centered around "forcing nature to give up its secret."[184] Consequently, many of the investigations that came from Novy's laboratory defy a common theme or may even seem disjointed. In the following paragraphs, I will outline this varied group of experiments.

Novy and his students investigated disinfection practices and germicidal agents.[185] He believed disinfection was an uncertain practice, as the optimal choice and concentration of disinfectant had not been adequately studied. His aim was to determine how to make the selection of disinfectant more rational than had previously been possible.[186] He incubated a variety of bacteria in several disinfecting solutions and created an *in vitro* system of identifying which solutions best killed the bacteria or stunted their growth.[187] He argued that disinfectants had specificity and allowed for the possibility that certain disinfectants could be tailored according to the epidemic and to the organism being disinfected.[188] Novy also searched for mechanisms of activity against various bacteria of commonly used disinfectants.[189] He showed that different germicides had varying activity against a particular organism and identified the concentration of germicide that was necessary to inhibit the growth of the different bacteria.[190]

Novy and his students also became interested in exploring the chemical basis of immune reactions. He found that a protein isolated from the nucleus, or nucleohiston, of thyroid cells taken from guinea pigs was not immunogenic and failed to protect the animals from intoxication with tetanus or diphtheria toxin.[191] While investigating immunity to trypanosomes, Novy became interested in investigating the problem of anaphylaxis.[192] Novy's interest in anaphylaxis was a consequence of studies funded by the Rockefeller Foundation to investigate whether could build up immunity to trypanosomes in animals in order to protect them.[193] Novy and his graduate student Paul de Kruif noted a sudden decline in temperature and circulatory collapse that led to death in some of the inoculated animals. It appeared to them that some specific poison was being induced in the blood.[194] The finding that the toxic substance could be generated by contact of rat serum with the trypanosomal antigen appeared to Novy and de Kruif as a lead for determining its nature and he investigated what it was about the trypanosome-host interaction that resulted in anaphylaxis.[195] They suspected the phenomenon of anaphylaxis was due to the globulin fraction of blood, but despite their continued attempts to discover the nature of the potent substance, de Kruif and Novy were unable to find a solution to anaphylaxis.

Representations in *Arrowsmith*

de Kruif had worked in Novy's laboratory principally on his anaphylaxis experiments for seven years from 1911 to 1918. de Kruif's first-hand impressions of Novy, his style and his experience in Novy's laboratory is evident in the detailed parallels between Novy's research program and the program of the fictional character Gottlieb in *Arrowsmith*. Martin's characterization of the fundamental nature of Gottlieb's research operation is reminiscent of Novy's; about Gottlieb, Martin said, "Gottlieb's work had been dealing with the foundations of life and death, and with the nature of infection."[196] de Kruif's depiction of Novy's curiosity to uncover truths that could not be interrupted by traditional daily habits, such as ending a day's work at evening, and his willingness to work in a solitary fashion throughout the night to satiate his curiosity, is reflected in Gottlieb. For example, in *Arrowsmith*, Martin said, "Gottlieb! Ideal of research! Never content with what seems true! Alone…working all night, getting to the bottom of things!"[197] Gottlieb's research topics were also similar to Novy's; Martin said, "Gottlieb was studying trypanosomes from a rat… An eight branched rosette..."[198] Martin also said of Novy, "He worked in the laboratories of Koch and Pasteur… and wrote vitriolic letters…He was analyzing the ptomaine theory of disease."[199]

de Kruif also worked with Novy on his rat virus experiments. But these experiments do not appear in *Arrowsmith*, perhaps because the experiments were thought to be terminated when the novel was written in 1925. But after the test tubes were unexpectedly found in 1951, de Kruif co-authored the scientific report with Novy that was published in *Journal of Infectious Diseases* in 1953. The scientific information in the paper was cogently presented—the thermal stability of the virus, infectivity experiments, and estimation of the size of the virus. The paper was intended for a straightforward scientific interpretation by the reader. But the inclusion of de Kruif as a co-author raises the possibility of alternate, literary meanings of Novy's continued participation in laboratory research in his old age. The paper may be saying that perseverance, especially when accompanied by meticulously kept laboratory records, cannot be overcome by old age. Given the similarities between the messages in the rat virus publication and the themes in *Arrowsmith*, de Kruif's 1953 scientific paper can be viewed as a sequel to the 1925 novel.

Conclusion

The historical literature has not systematically described the work done by late 19th century American bacteriologists who worked in medical school laboratories. In this chapter, I argue that Novy performed innovative work in his specialized laboratory space. Novy's colleagues considered his work pure, original, and basic and distinct from applied science.[200] In addition, Novy designed and conducted research programs that he himself considered "original investigations whereby the bounds of knowledge will be materially widened."[201]

Novy eschewed having the practical applications of his hygienic laboratory work as the principal function and purpose of his research agenda. The public health context of Novy's medical school bacteriology laboratory permitted investigations into what were more fundamental research problems that remained Novy's principal interest throughout his career. His research activities focused on technologic innovations that allowed him to "visualize" organisms on the cellular level and their behavior on the molecular level. He created new instruments and optical devises in his medical school laboratory to understand what organisms did to survive in nature. To investigate how pathogens caused disease in humans, Novy devised new microbiologic instruments to demonstrate the presence of pathogens (e.g., anaerobes, spirochetes, protozoa) in various clinical situations. He also devised chemical instruments in order to explore the metabolism of organisms in the course of their survival and ask whether respiration of microbes might be responsible for variations in disease activity in humans.

Novy's emphasis on technological innovation as a means of gaining new knowledge about microbes and their behavior had deep roots in the discipline of bacteriology. As mentioned in the introduction, the speculations of physicians throughout several centuries had to wait for the introduction of new technology to empirically test their hypotheses. To be empirically tested, the theories of 16^{th} century physician Fracastorius about the presence of germs had to wait for the invention of the 19^{th} century compound microscope, and the premises of the 19^{th} century pathologist Henle regarding individual germs causing disease had to wait for the invention of solid culture media to isolate individual organisms. Similarly, Novy's methodological and technological innovations permitted the empiric testing and recognition of the presence of obligate anaerobes, the changing morphologies of protozoa, the identification of the disease-causing morphological form, and the metabolism and gas production of microbes.

Novy focused on devising instruments as an objective means of finding truths in nature and reaching agreement among colleagues. To his students and colleagues, Novy was recognized for stressing the importance of repeating experiments in order to reproduce his findings prior to publication. In his scientific manuscripts, Novy was noted for his meticulous, detailed descriptions of his techniques and methods. In his letters to colleagues, he revealed that his intention was to describe his instruments and methodologies in explicit detail in order for other investigators to use them to verify his findings. In his letters to colleagues, Novy wrote that he would only consider a finding as valid or true if the experiments could be replicated in his own laboratory and also confirmed by other investigators working in independent laboratories. To Novy, scientific knowledge was never simply a matter of an isolated scientist like himself confronting nature. His insistence that a finding must not be considered a scientific truth until it has been reproduced within his laboratory and in the laboratory of others illustrates Steven Shapin's argument that scientific truths have a collective identity that are fundamentally a matter that involved trust and sharing of information among colleagues.[202]

Novy's reliance on instrumentation as an objective means of determining nature's truths also provided the potential to resolve scientific disputes. For example, Novy's use of his dynamic observation methodology to recognize the evolution of protozoal forms also enabled him to address a dispute about alternation of species. Novy's emphasis on instrumental objectivity as a means to ascertain truths and reach agreement was not new to late 19th century scientists. Lorraine Daston and Peter Galison, for example, argued that in the late 19th century, chemists and physicists sought to use mechanical innovation as an objective means to capture nature's structures in their purity and to obtain consensus about what they were.[203] Furthermore, Richard Holmes maintained that astronomers in this era refined telescopes to verify positions of distant celestial bodies and also to reach agreement among other astronomers about these structures.[204] Daston and Galison argued that the mechanical instruments devised by scientists during their period, with their qualitative measurements and abstractions, stood for authenticity in themselves. This minimized the willful subjectiveness of individual scientists who was manipulating them and facilitated consensus among scientists. But Bradford Keeney has argued that the attempt at structural objectivity could never really be achieved, since the ability to recognize what was in nature actually depended on one's particular training and not on any universally objective capacity of human understanding.[205] Keeney's point, that the scientist operating the mechanical instrument could not escape his own subjectivity when making observations and interpreting data, will emerge as a theme in chapter three.

The study of Novy's work adds to this literature by showing how a late 19th century medical researcher relied upon technological innovation as an objective means to gain insight into nature's truths and to resolve disputes among scientists. In the process, Novy introduced the element of time into the field of bacteriology. His experiments of dynamic observation sought to explain new basic biological aspects of microbial behavior—how germs themselves undergo morphologic changes as they mature. His novel experiments in challenging canines with protozoa allowed him to investigate the behavior of specific protozoal morphological forms and speculate about how protozoa brought about change in nature and disease in humans. His methodology of continuous, dynamic observation in a controlled laboratory setting signified a departure from traditional bacteriology, which had been involved with static observations of microbes after fixed periods of time. His new methodology enabled him show variation of form within a species, and to substantiate his hypothesis that there is constancy among species. By devising new, dynamic microbiological techniques to objectively evaluate the interactions of the organism with the host or environment over time, Novy attempted to apprehend nature's truths about the maturation of organisms in nature and to resolve basic controversies in microbiology.

Novy's experiments were not restricted to organisms that cause disease, but also nonpathogenic organisms, and how they lived, behaved, and matured in nature. Novy's colleagues never specified exactly what they meant when they referred to his work as pure, original, and basic. But when considering his investigations in aggregate, it is possible they were referring to a combination of factors—his motives to find truths in nature rather, his innovations in equipment and methods, and his discoveries that led to a greater understanding of bacterial behavior. Some of this work, including devising techniques to identify pathogens in clinical situations, is an extension of European germ theories of medicine. But it could be argued that his investigations of basic behavior of microbes, particularly non-pathogens, and their interaction with the environment are not clearly related to the causal relation of an organism to a disease that characterizes the germ theory of medicine.

Novy did not perform work in his medical school laboratory for his entire career. In 1901, in fact, he served as a Federal Commissioner appointed by the Surgeon General to investigate an infectious disease outbreak in San Francisco. In the following chapter, I will explore what type of work Novy did when he and his laboratory staff traveled away from their medical school setting. I will also address what the reactions to his bacteriological work in a public setting were—which groups contested his work and why.

CHAPTER 3

Outbreak Investigation in San Francisco 1901

Introduction: The 1900 San Francisco plague is well known to medical historians as a significant event where public health officials denied a diagnosis of plague on economic, political, social, and ideological grounds. To resolve the controversy, Surgeon General Walter Wyman appointed Novy to serve as bacteriologist of an independent federal commission to investigate whether plague was present. Wyman presumed that Novy's status as an eminent bacteriologist, his status that was independent of federal health service duties and perhaps his orientation towards the instrumental side of bacteriology would provide objective scientific evidence that would settle the dispute about whether plague was in San Francisco.

In this chapter, I explore how Novy used bacteriologic techniques to diagnose plague in San Francisco and concur with Joseph Kinyoun's conclusion. Novy satisfied Wyman's request to determine whether plague was present in the city. But in traveling to the site of an outbreak, he also found that disease differed from clinical and historical descriptions in individuals and in the broader population. On the basis of his bacteriological studies, Novy attempted to redefine plague by pointing out its variations, and, in the process, reinforce pre-bacteriological public health practices. But Novy could not explain why plague was behaving differently than it had been traditionally described according to characteristic clinical findings and devastating epidemiology.

Novy's use of the latest bacteriologic methods and techniques to identify the plague bacillus in diseased bodies and his agreement with Kinyoun did not provide the objective evidence necessary to convince local physicians and citizens that plague was present. Practicing physicians defined plague by a different set of objective criteria—clinical and epidemiologic. In the absence of these typical features, these physicians concluded that plague was not present in the city. Consequently, comprehensive anti-plague measures, including rat-control measures that were accepted as effective based on the knowledge of the spread of plague in 1901 were not implemented at the time the commissioners' conclusions were released. By 1903, however, further cases of plague had been reported by the local health department, and a trade embargo was threatened against the city unless comprehensive public health measures were implemented to stop the spread of plague. In 1903, the bacteriologic conclusions of scientists were acted upon once they resonated with the overall interests of the city, not because the evidence provided by the eminent bacteriologists such as Novy and Kinyoun enabled their diagnosis to prevail over conflicting views of practicing physicians and citizens of San Francisco.

In the absence of characteristic features that signified plague to physicians, Novy's bacteriological diagnosis did not persuade practicing physicians and citizens that plague was present. Practicing physicians used symptom-based criteria they understood as valid and objective to evaluate Novy's bacteriologic findings according to own training and interpretive framework. Consequently, the consensus that Wyman had hoped for or even expected by appointing Novy as the bacteriologist of the plague commission was not attained. Novy's word as a bacteriologist was not incontrovertible and his laboratory findings did not have authority to override opposing conceptions about the disease that were based on distinctive clinical and epidemiologic criteria and centuries of historical precedent.

Background

Medical historians have written about various aspects of the 1900 plague in San Francisco. Guenter Risse addressed the denial of Joseph Kinyoun's diagnosis of plague, asserting that the presence of plague had been thought to threaten the city's prosperity and led the Chinese to fear that Chinatown would be burned to the ground.[1] Risse also pointed out that practicing physicians mistrusted the methods of bacteriology, which were alien to them. Alan Kraut, Nyan Shah, Susan Craddock, and Howard Markel have addressed the public health response to plague and argued that public health measures instituted in 1900 were not value-neutral and were driven by anti-Chinese sentiments.[2] They have argued that specific practices such as cordoning off Chinatown excluded the unwanted Chinese race from white San Francisco society by separating them into a peripheral "plague" zone.[3] They also described rat control measures begun in 1903 based on the federal commissioners' 1901 conclusion that plague was present.[4]

This chapter builds upon the work of these historians by focusing on the activities of Novy as he traveled away from his medical school laboratory to San Francisco and his conclusions based on his bacteriological findings. After I explore the work Novy conducted during his travel to San Francisco, I then use the commissioners' investigation and the responses to their findings as a lens to view how Novy tried to reconcile his laboratory findings with the unusual clinical and epidemiological behavior of plague in the city. Novy's explanation had meaning for the new expertise of bacteriology in American medicine by reshaping traditional conceptions of disease and influencing pre-germ theory public health measures. I then explore the skepticism of Novy's findings that did not coincide with social and historical notions of the disease. Novy had trouble trying to make the world into a laboratory, as physicians and citizens were disinclined to institute comprehensive anti-plague measures for a diagnosis they considered dubious. I then address the conditions under which the word of the bacteriologists were eventually accepted and acted upon and conclude by addressing how the word of the new expert bacteriologists gained a voice in a democratic American society.

The 1900 San Francisco Outbreak

In 1899, United States Surgeon General Walter Wyman grew uneasy about the threat of a bubonic plague outbreak in San Francisco. Until that time, the mainland United States had been spared of plague.[5] But Wyman knew there had been recent reappearances of plague in Canton and Hong Kong (1894), Bombay (1896), Alexandria (1899) and Honolulu (1899).[6] As San Francisco was open to international commerce, he sensed that plague could spread from these locales through established trade routes to the city.[7] Like other areas where plague appeared, Wyman recognized that San Francisco had unhygienic, overcrowded tenements inhabited by recent migrants.[8] Thus, it seemed to Wyman that San Francisco, a product of the expansion of world trade and immigration, would be vulnerable to plague.

Anticipating that quarantine may be required, in June 1899 Wyman transferred Joseph Kinyoun from the federal Marine Hospital Service (MHS) in Washington to San Francisco to serve as the quarantine station officer.[9] Kinyoun was considered a prominent member of the MHS, heading the prestigious National Hygienic Laboratory in Washington, D.C. He was also an expert in the new science of bacteriology, having studied with Robert Koch in Germany. Shortly after arriving in San Francisco, Kinyoun remarked on the cavalier hygienic practices adopted by trading ships upon return from infected zones and shared Wyman's view that the city was vulnerable to plague.[10] He reasoned that plague-carrying rats could be introduced into San Francisco through cargo unloaded by trading ships, then make their way to unhygienic tenements in Chinatown.[11]

Wyman and Kinyoun's predictions materialized in March 1900 when Kinyoun concluded that plague was the cause of an outbreak of fever and glandular swelling among the Chinese population living in Chinatown. The first case was investigated on March 6, when F.P. Williams of the City Health Department conducted an autopsy on a 41-year-old Chinese man.[12] Given suspicions arising from his finding of inguinal swelling, Williams contacted the municipal bacteriologist, Dr. Wilfred Kellogg, who suspected plague upon microscopic inspection of a Gram's stain of fluid aspirated from the gland.[13] Kellogg then transported the specimen to the MHS bacteriological laboratory at the Angel Island quarantine station run by Kinyoun for further analysis. Using culture techniques and the animal inoculation experiments he learned in Germany, Kinyoun identified the plague bacterium, *Bacillus pestis,* as the cause of death.[14] He confidently asserted, "I as an officer of the Service, as well as my qualifications, was asked to confirm the diagnosis. This was done after the most searching examination wherein every demand of science was fulfilled."[15]

Notwithstanding his careful scientific methodology, some elected officials, business leaders and practicing physicians rejected Kinyoun's conclusion that plague was present. Politicians and businessmen feared that the presence of plague would diminish optimism and the growth of San Francisco, where the trade and tourism industries were thriving, since outbreaks of plague historically shut down trade in port cities.[16] In addition, practicing physicians protested Kinyoun's methods as unsubstantiated and his evidence unreliable.[17] As Russell Maulitz has argued, practicing physicians at this time had clinical concerns about the utility of laboratory science and the germ theory, and did not trust bacteriological techniques that were alien to them.[18] Some were uncomfortable with the implication that their experiential methods were no longer as reliable in diagnosis and of the potential of bacteriological diagnosis to replace clinical judgment. Moreover, they were anxious that laboratory science had the potential to shift the authority physicians had at the bedside to those of scientists in a laboratory. In the absence of a massive epidemic, which they had been taught was an invariable characteristic of plague, many San Francisco physicians felt Kinyoun must have erred in his diagnosis.[19]

Kinyoun's diagnosis also became a controversial public health issue among the Chinese population living in Chinatown. The presence of plague in indigent Chinese provided grounds for racially motivated public health practices, including cordoning off of Chinatown from San Francisco.[20] To counter such discrimination and liberate Chinatown from quarantine, the Chinese leaders and population denied Kinyoun's diagnosis, and concealed their sick and dying from public health officials.[21] Wong Wei, a representative of the Chinese Six Companies, a consortium of powerful merchants who mediated between Chinatown and the white municipal power structure, also protested the cordon on legal grounds.[22] Citing the 1899 burning of buildings in Honolulu's Chinatown, Wei argued that racial prejudice against Chinese immigrants made them scapegoats during plague outbreaks.[23] Judge William Morrow, who adjudicated the class-suit in federal court, agreed and ruled that quarantine discriminated against Chinese residents, depriving them of liberty and violated the equal protection clause of the Fourteenth Amendment of the Constitution. Judge Morrow issued an injunction against the quarantine.[24]

Once quarantine was deemed illegal, Henry Gage, Governor of California, sought a strategy other than containing the disease within Chinatown to avoid making San Francisco appear as a medically dangerous city. He chose to directly challenge Kinyoun's diagnosis by appointing to the State Board of Health only physicians who were willing to deny that plague was in the city and removing those who were not.[25] Gage appointed Winslow Anderson, a practicing surgeon in Los Angeles, whom Kinyoun claimed "supported pronouncements on public health made by the governor to whom he owed his position on the State Board."[26] Kinyoun characterized Anderson and Dr. Ernest Pillsbury, one of his appointees, "as practically nothing more or less than puppets to bob and do the bidding of their sire."[27] Pillsbury, corroborating Kinyoun's assertion that Gage removed all physicians from the State Board who reversed their decision on plague, stated that Gage "discharged me immediately from my post on the State Board of Health" when Pillsbury concluded that plague was present.[28] State Bacteriologist H. A. L. Ryfkogel, concurred and noted that when he himself “found plague germs, I lost my position and my back salary.”[29]

When Kinyoun realized that the outbreak showed no signs of abating, he advocated for sanitary measures directed at Chinatown. Some local newspapers, however, disagreed and argued that these costly measures would unnecessarily deplete city funds.[30] Landlords of Chinatown buildings, in addition, challenged what they thought was an arbitrary policy that might cost them large sums of money to improve property they already considered hygienically adequate.[31] They contended that their premises were perfectly sanitary, and believed that any information stating that San Francisco was a plague zone was erroneous as plague was said to be a devastating epidemic.[32] Other businesses remained concerned about a potential for economic loss to the community from a trade impasse, and the resulting decline in their own incomes.[33] Consequently, politicians and some businessmen continued to deny Kinyoun’s diagnosis of plague or ascribed it to marginalized Chinese inhabiting Chinatown. As Robert Barde has noted, this was reinforced by presumptions among non-Asians that plague occurred exclusively among Chinese because of genetic predisposition, poor nourishment, contemptible habits (e.g., gambling, opium smoking and prostitution), and residence in an unsanitary Chinese district.[34]

Despite opposition from skeptical politicians, anxious businessmen, dubious physicians, and concerned Chinese, Kinyoun remained unwavering. By August of 1900, he had confirmed 13 deaths due to plague in Chinatown.[35] Kinyoun lamented that “the State and City Boards of Health were not doing any effective work towards the suppressing of the disease.”[36] He coined the term “Kinyounism” as “a man who will carry out (what) he believes will help the people of San Francisco irrespective of the wish of the local people."[37] Kinyoun, who considered his objection to the prioritizing of business interests above duties to protect health by the majority morally justifiable, stated "it appears that the 'commercial interests' of San Francisco are more dear to the inhabitants than the preservation of human life."[38] Since politicians and citizens of San Francisco refused to implement measures to control the problem of plague as identified by his federal quarantine officer, Surgeon General Walter Wyman decided to opt for an assessment by experts who were not employed by the federal public health service or who did not have ties to local California interests.

The Independent, Federal Plague Commission

To provide an independent scientific assessment of Kinyoun's diagnosis and actions, Wyman assembled a commission in January 1901 consisting of prominent scientists who did not have political loyalties or involvement in government agencies.[39] Wyman selected three members whom he believed met his criteria: Simon Flexner, professor of pathology at University of Pennsylvania as director; Lewellys Barker, professor of pathology at University of Chicago as secretary; and Frederick Novy, associate professor of physiologic chemistry and bacteriology at the University of Michigan as bacteriologist. In his letter inviting Novy to be commission bacteriologist, Wyman was confident that the controversy surrounding Kinyoun's diagnosis would be resolved if eminent specialists who were independent of the federal or San Francisco health departments would personally visit San Francisco and obtain specimens from deceased bodies for plague.[40] [Figure 3.1]

Confidential

TREASURY DEPARTMENT
OFFICE OF THE
SUPERVISING SURGEON-GENERAL MARINE-HOSPITAL SERVICE

McE

Washington, Jan. 16, 1901.

Dr Frederick Novey,

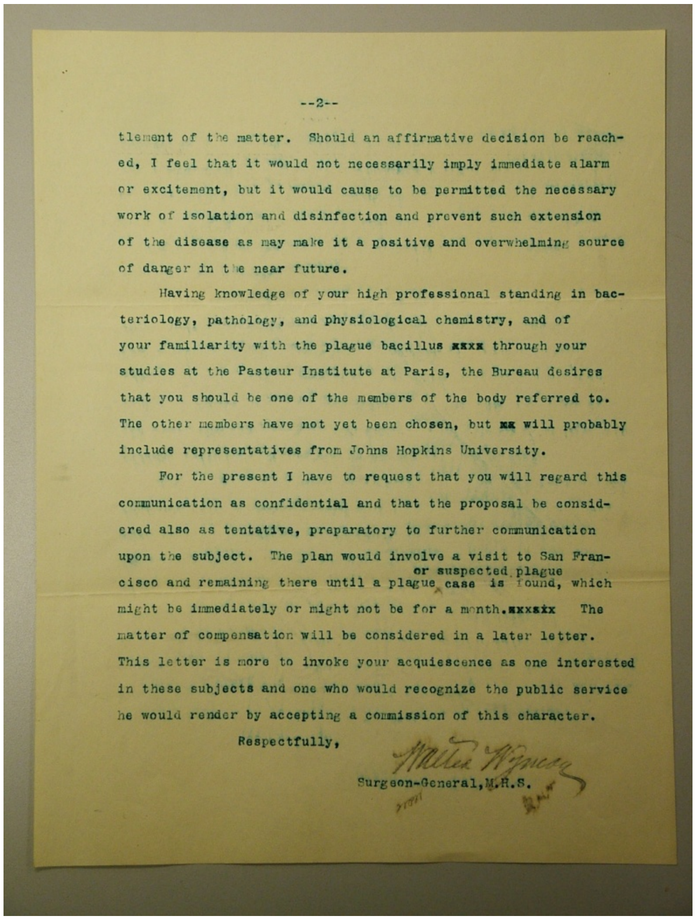
Associate Professor in Bacteriology and Pathology
and Professor of Physiological Chemistry,

University of Michigan, Ann Arbor, Mich.

Dear Sir:

You may have noticed in the medical journals the discussion that has been going on as to whether or not there have been, or are at present, cases of plague in San Francisco.

Based upon the reports of Surgeon J. J. Kinyoun, formerly Director of the Hygienic Laboratory of this Service, and upon examinations made in the Hygienic Laboratory here of specimens transmitted to the Bureau by Surgeon Kinyoun, the Bureau has not hesitated to give its affirmative statement in the official publication of the Bureau, namely the Public Health Reports. As not unfrequently happens, however, denials have been made, and it may become necessary in the interest of public health for the Treasury Department to call upon two or three eminent specialists to visit San Francisco and after examination of living or recently deceased patients suffering with supposed bubonic plague to give their decision as to diagnosis. It is felt that the findings of a body of this character, working entirely independently of the national or local experts at San Francisco, would result in a satisfactory set-



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tlement of the matter. Should an affirmative decision be reached, I feel that it would not necessarily imply immediate alarm or excitement, but it would cause to be permitted the necessary work of isolation and disinfection and prevent such extension of the disease as may make it a positive and overwhelming source of danger in the near future.

Having knowledge of your high professional standing in bacteriology, pathology, and physiological chemistry, and of your familiarity with the plague bacillus xxxx through your studies at the Pasteur Institute at Paris, the Bureau desires that you should be one of the members of the body referred to. The other members have not yet been chosen, but xx will probably include representatives from Johns Hopkins University.

For the present I have to request that you will regard this communication as confidential and that the proposal be considered also as tentative, preparatory to further communication upon the subject. The plan would involve a visit to San Francisco and remaining there until a plague or suspected plague case is found, which might be immediately or might not be for a month.xxxxxx The matter of compensation will be considered in a later letter. This letter is more to invoke your acquiescence as one interested in these subjects and one who would recognize the public service he would render by accepting a commission of this character.

Respectfully,

Walter Wyman

Surgeon-General, M.H.S.

Figure 3.1. Letter from Walter Wyman to Novy on January 14, 1901 inviting Novy to become bacteriologist for the federal commission. In the letter, Wyman highlighted the criteria he used to select the commission members: scientific expertise and independence from federal public health agencies. Wyman said, “Kinyoun feels that cases are plague. However, denials have been made, and it has become necessary in the interest of public health for the Treasury Department to call upon two to three eminent specialists to visit San Francisco and after examination of living or recently deceased patients suffering with supposed bubonic plague to give their decision as to diagnosis. It is felt that findings of this character, working entirely independently of the national or local experts at San Francisco, would result in a satisfactory settlement of the matter.”

Why was Novy interested in Wyman's invitation? As outlined in chapter two, Novy was a bacteriologist who performed independent, original research.[41] By 1900, he had demonstrated the presence of organisms in clinical specimens by devising new culture techniques.[42] He had applied the methods he learned in chemistry to microbiology in order to understand the metabolism of organisms.[43] Novy's major interest was in the "instrumental" side of bacteriology, as he developed various tools to understand the behavior of microorganisms that cause human disease.[44] Novy wrote that he was attracted by Wyman's invitation in 1901, in part, because he felt it would provide access to materials from humans, animals, or other sources that may not otherwise have been available to him within his medical school setting.[45] He had not yet reached the point in his career when investigators throughout the world shipped specimens to his laboratory, so he viewed going to San Francisco as an opportunity to extend the scope of his laboratory investigations to the site of an outbreak.[46]

Why did Wyman select Novy to serve as bacteriologist of the commission? Wyman selected Novy because of his scientific eminence and independence from affiliation with a federal health service.[47] In a letter inviting Novy to the commission, Wyman said, "Having knowledge of your high professional standing in bacteriology and physiological chemistry, the Bureau desires that you should be one of the members of the body referred to."[48] As Wyman explained to Flexner, "Novy has a world-wide reputation as an expert on bacteriology and has written several works upon bacteriology that are standard."[49] Wyman assumed that Novy's reputation as an expert bacteriologist and the independent status that his university base afforded him would render his opinion unassailable by those who had rejected Kinyoun's conclusion.

Wyman never explicitly explained why he believed that Novy's technical proclamations as an independent, unbiased expert of bacteriology could prevail over the voices of various dissenting factions in San Francisco. At this time, there were growing tensions between federal public health bureaus and local health departments, the latter of which viewed the MHS as meddlesome and a threat to local autonomy. [50] Perhaps Wyman felt that Novy's independent status would prevent him from being subject to the opposition from local citizens that Kinyoun experienced because of his U.S. Public Health affiliation. Wyman may also have felt that Novy's scientific frame of mind, committed to analyzing the concrete and to demanding rigorous inductions constituted universally valid principles that were more coherent and therefore more consensual than the arguments made by those who denied Kinyoun's diagnosis. If plague was the cause of the outbreak, perhaps Novy's word as an independent expert would lead to the implementation of satisfactory control measures without engendering dissent. Or so Wyman may have thought.

Novy's bacteriology, in actuality, was still medically controversial even within academia.[51] At Michigan, Dr. Heneage Gibbes, professor of pathology, was an opponent of the germ theory, and together with H. L. Obetz, dean of the homeopathic school, he tried unsuccessfully to appeal to the Board of Regents to eliminate Novy's position [see chapter 5]. Perhaps to defend his newly created position from attack by skeptics and to persuade potential donors of its value, Novy actively promoted the promise of bacteriology as a laboratory science in his writings and speeches.[52] He sought to persuade audiences that bacterial knowledge was both applicable and valuable to everyday practices of public health institutions, the clinic, and society.[53] He linked scientific bacteriological investigations carried out in well-equipped laboratories to the overall wellbeing of society.[54] Novy would draw upon arguments similar to those he utilized to consolidate his scientific base at Michigan as he strove to persuade businessmen in San Francisco of the value of the commissioner's investigations for the wellbeing of the city.

Activities of Novy and the Plague Commissioners

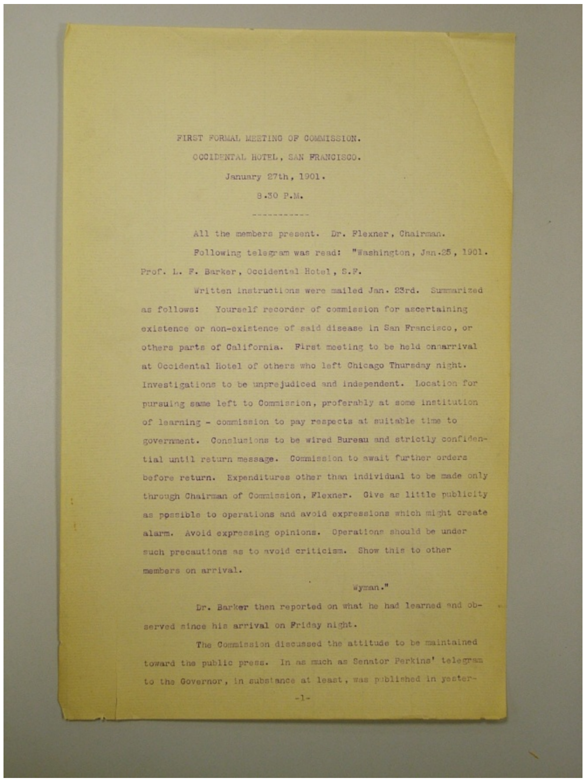
As Novy departed Ann Arbor by train for San Francisco on January 24, 1901, he began a series of daily letters to his wife, Grace Garwood Novy that he would continue until his return to Ann Arbor on March 6, 1901.[55] I use Novy's private letters to explore how he viewed his task and how he went about his investigation. Novy considered Grace a confidante, sharing his private impressions of his San Francisco experience with her. While an exploration of what Novy wrote to Grace in private does not provide a complete and unbiased account of what Novy really thought or did, it does provide access that is closer to his actual perceptions than manuscripts published in the medical literature alone would have allowed. In this sense, his private notes represent a less filtered vision of his thoughts than his formally published work.

As his train neared San Francisco, Novy confided in Grace that he had a difficult task in front of him—one that would likely require more than the sole application of his bacteriological expertise. On January 26, he said, "the commissioners have a delicate 'diplomatic' as well as scientific task ahead of us…the Gov [ernor] of California denies the existence of the disease in San Francisco. The press and people are unanimously against the idea that the plague exists here."[56]

Local newspapers had indeed begun to cast doubt on the credibility of the "expert" commissioners before their arrival. *The Chronicle*, on January 27, 1901, dismissed the scientific methods the commissioners used as misguided and irrelevant, and cast them not as independent assessors, but rather "federal" experts whose conclusions about plague could not be valid because they were unfamiliar with diseases that occurred locally in California.[57] Because geographic predilections for certain infections were well described at this time, the belief that local knowledge was essential for an accurate diagnosis of an infectious disease was not at all uncommon for this period.[58] Aware of the unfavorable local newspaper coverage, Novy became uneasy about whether his scientific findings would be contested if he were to find plague. Novy felt that the objection to Kinyoun went beyond his association with the MHS, and also involved a repudiation of any scientist whose findings threatened the prosperity of the city. On January 27, he wrote to Grace, "The newspapers maintain that [plague] not only does not exist but even that it has never existed. The moneyed interests are so vast that they will not consent to our scientific findings should it be positive. The newspapers feel that they must not be guided by bacteriological evidence. They will in the end lambaste us just as they have done to Kinyoun should we find plague."[59]

Governor Gage himself had also been calling the commissioners' scientific methods into question. *The Bulletin*, on January 21, 1901, reported that Gage was skeptical of the commissioners' "technologic knowledge" and disparaged their "university experience rather than practical experience."[60] His objection to bacteriologists who made claims of plague is not unexpected when one considers Gage's position as a lawyer who had represented several large trading industries whose profits could have been threatened by a diagnosis of a plague ridden city. According to historians Robert Somel and John Raimo, Gage's career indebtedness to the railroad and trade corporations, including the Southern Pacific Railroad, grew from their financial support when he ran for the Los Angeles City Attorney in 1881 and then Governor in 1898 on the Republican ticket.[61] Gage, in fact, had a record of acquiescing to political bosses as governor; he approved legislation supportive of the railroad and used a patronage system to reward friends and financial supporters with state office.[62] Moreover, since the railroad was identified with Chinese labor, blaming the Chinese for plague would hurt the railroad.

Novy entered an environment in San Francisco he had viewed as hostile even before his arrival on January 27, 1901. On that day, after unpacking their belongings in the Occidental Hotel, where Novy, Barker, and Flexner stayed throughout their mission, the commissioners met to review their explicit instructions from Wyman—to establish their own bacteriology laboratory in order to maintain independence, to meet with Governor Gage, to keep their investigation confidential and to send their report to the federal bureau and not for independent publication.[63] To gather information about the outbreak, they established daily commission "bureau" meetings held in room 56 in the hotel and recorded minutes of these meetings.[64] [Figure 3.2 A] At bureau meetings, the commissioners stated they "s[at] all morning and transact[ed] business negotiations on a daily basis with physicians from practice or City or State Health Boards, commercial leaders, or anyone else in the city with information on the outbreak."[65] The commissioners decided to meet with citizens from various sectors of the community to determine if anyone would be sympathetic to their investigation and whether they would be willing to facilitate it.



FIRST FORMAL MEETING OF COMMISSION.
OCCIDENTAL HOTEL, SAN FRANCISCO.
January 27th, 1901.
8.30 P.M.

All the members present. Dr. Flexner, Chairman.

Following telegram was read: "Washington, Jan.25, 1901.
Prof. L. F. Barker, Occidental Hotel, S.F.

Written instructions were mailed Jan. 23rd. Summarized as follows: Yourself recorder of commission for ascertaining existence or non-existence of said disease in San Francisco, or others parts of California. First meeting to be held on arrival at Occidental Hotel of others who left Chicago Thursday night. Investigations to be unprejudiced and independent. Location for pursuing same left to Commission, proferably at some institution of learning - commission to pay respects at suitable time to government. Conslusions to be wired Bureau and strictly confidential until return message. Commission to await further orders before return. Expenditures other than individual to be made only through Chairman of Commission, Flexner. Give as little publicity as possible to operations and avoid expressions which might create alarm. Avoid expressing opinions. Operations should be under such precautions as to avoid criticism. Show this to other members on arrival.

Wyman."

Dr. Barker then reported on what he had learned and observed since his arrival on Friday night.

The Commission discussed the attitude to be maintained toward the public press. In as much as Senator Perkins' telegram to the Governor, in substance at least, was published in yester-

-1-

Figure 3.2 A

<u>Figure 3.2 A.</u> Minutes from the Commissioners' first 'bureau' meeting on January 27, page 1. The commissioners' first order of business was to review the terms of their explicit instructions issued from Surgeon General Walter Wyman. In order to investigate whether plague was present, the commissioners were to establish their own laboratory and not use the US MHS laboratory at Angel Island in order to avoid any impression that their work was not entirely independent from that of Kinyoun's. They were to meet with Wyman, but to keep their findings confidential from him. Their work was not to be submitted for independent publication but to the Surgeon General for approval before the report could be released by the MHS for publication. Accomplishing the task in San Francisco according to Wyman's instructions would become a challenge for the commissioners.

On January 29, 1901, the commissioner "bureau" first met with representatives from the local board of health. The representatives agreed to help the commissioners identify cases by providing a police detective to accompany them during their rounds in Chinatown, secure a laboratory at the University of California for their investigations, help obtain rats from Chinatown by working with sewer men, and provide a bounty to hunters for captured dead rats.[66] Novy was relieved that he found the local board cooperative, as told Grace that "city officials will assist us in every possible manner. They are willing to find out the truth, whichever way it comes."[67]

On January 31, the commissioners next met with physicians to hear their views on plague. They found that some physicians had tenable reasons to believe that plague did not exist in the city.[68] For C. N. Ellinwood, professor of clinical surgery at Cooper Medical College, plague could not have existed because the epidemiologic pattern of the outbreak in San Francisco did not fit his notion of plague as a devastating scourge.[69] He also mistrusted bacteriology on the grounds that its relevance to clinical medicine was unproven, stating:

> "I do not believe we have had the plague in our city, because we have had no epidemic and the plague is well known to be a virulent epidemic disease. It is a mistake to associate the present described bacillus with that found in those historical epidemics which have been so destructive to human life. Bacteriologists have changed their views and findings in many instances, and it is not impossible that they find in this alleged plague, a disease which by intelligent precautions need not prove epidemic, nor in any way interfere with the commerce of our city, any more in the future than it has in the past. Bacteriology is too young yet, to

> declare positively what, without the evidence of contagion and epidemic characters, that this disease must close our Labor, and paralyze the commerce of our city...Epidemics of plague exist in many ports and different parts of the world, and we are by no means exempt from danger from the introduction of the disease here, and I believe that every rational precaution be taken to prevent its introduction and lodgment among us. I would urge to this end, most rigorous means for the destruction of filth, producing and disseminating pests viz: rats, vermin and fleas an also some system of personal cleanliness among the classes of people who are most in jeopardy…Rational measures of this kind would entail no restrictions on commerce and secure a sanitary condition, unfavorable for the development of any epidemic."[70]

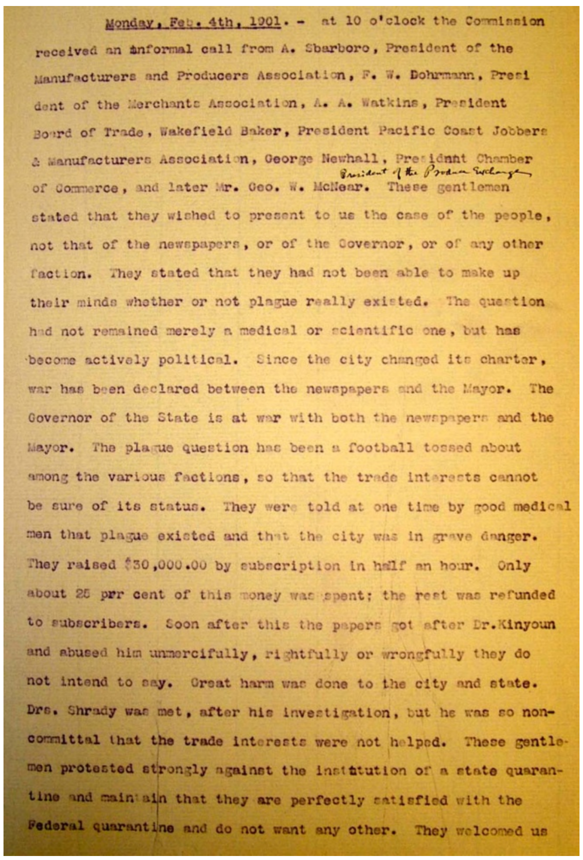
Ellinwood's quote shows that he believed the city was susceptible to plague, but that there was no good evidence that existed because the bacteriologic findings did not align with his understanding of the epidemic nature of the disease. Likewise, Levi C. Lane, professor of surgery at Cooper Medical College, felt the malady diagnosed as plague by Kinyoun could not be plague because it "had not spread like wildfire throughout San Francisco."[71] Alonzo Taylor, professor of pathology from the University of California, noted these sentiments extended beyond physicians. He said, "part of the failure to convince the public of the existence of plague in the city lay in the statement made that plague would spread like the wind and that unless rigid quarantine measures were maintained, the city would be devastated. All strict measures were withdrawn and no great outbreak occurred; hence discredit."[72] Novy felt that the physicians' rationale was perfectly sound—the San Francisco outbreak did not fit the historic pattern of plague, and there were certainly significant disagreements among bacteriologists.[73]

On February 1, the commissioners made their first visit to Chinatown to map out where the City Board had identified cases of plague.[74] At that visit, Novy observed the crowded nature and poor hygiene of residences of Chinatown, and wrote to Grace that "the squalor, 4 X 6 ft. rooms [that] were berths for 2–4 people" was typical for plague-ridden zones in general and was conducive for the spread of plague in San Francisco.[75] He also noted that the Chinese were concealing their ill and their dead, and lamented that the inability to access diseased Chinese bodies would paralyze his investigation. Furthermore, he was discouraged that the governor was promoting bills which, if passed by the State Assembly, would have made a report of plague as a cause of death by a physician a felony (Bill #559), made it illegal to handle the plague bacillus (Bill #557), and given the state board control over all contagious diseases (Bill #558).[76] Novy noted to Grace, "If the plague bills are passed, we will be at a standstill. The object of this whole thing of course would be to stop our work."[77] Novy was convinced these bills were proposed to halt his operation.

By February 3, Novy's initial hunch that the commissioners' task was going to require more than carrying out his scientific work had materialized. In addition to the potential for imprisonment and difficulty gaining access to bodies, he now was being shadowed by Gage's detectives and had no independent laboratory in which to carry out his bacteriologic work.[78] Novy learned that Gage had pressured Alonzo Taylor to recall permission to use his laboratory at the University of California. Novy noted to Grace:

> The Governor's hand is plain. He is wielding his power to interfere with our plans to establish an independent laboratory. He undoubtedly threatens to veto the University appropriations if our work be allowed to go on there. So the Commission now finds themselves without a proper laboratory or equipment. Your local peripatetic experts are going to have some trouble carrying out their work, but we'll get ahead of the honorable governor even if it takes us all summer to do so.[79]

How did Novy seek to go about "getting ahead of the governor?" He decided upon what he referred to as a "diplomatic mission—to meet with influential businessmen and give them a full hearing," then solicit their help in overcoming what he viewed as the governor's interference with the commissioners' scientific work.[80] On February 4, Novy, Barker, and Flexner met with those whom they deemed "representatives of the principal commercial interests of the city of San Francisco."[81] [Figure 3.2 B] When the businessmen explained that they had not been able to make up their minds whether or not plague really existed, Novy sought to convince them that the commissioners' investigation was not opposed to the representatives' business interests as Kinyoun had maintained.[82] Novy reasoned that some businessmen would support measures of any type if the commissioners could guarantee a quick end to the epidemic threat, and he tried to persuade the businessmen that they could attain a prompt return to trade if they would support the commissioners' investigation, regardless of their findings. Novy said, "If plague is not here, they saw the opprobrium would be removed. If plague is here, we proposed it will interest these gentlemen more than it can possibly interest anybody else. After discussion, they assured us that their interests most largely affected in the city and state were not antagonistic to our investigation. On the contrary, they would do everything in their power to facilitate our scientific mission. Of course, they hope that plague is not here, but they desire to know the truth."[83] Thus, Novy felt he could succeed in gaining access to diseased bodies because he could use persuasion to obtain the cooperation of the powerful businessmen.



Monday, Feb. 4th, 1901. - at 10 o'clock the Commission received an informal call from A. Sbarboro, President of the Manufacturers and Producers Association, F. W. Dohrmann, President of the Merchants Association, A. A. Watkins, President Board of Trade, Wakefield Baker, President Pacific Coast Jobbers & Manufacturers Association, George Newhall, President Chamber of Commerce, and later Mr. Geo. W. McNear, President of the Produce Exchange. These gentlemen stated that they wished to present to us the case of the people, not that of the newspapers, or of the Governor, or of any other faction. They stated that they had not been able to make up their minds whether or not plague really existed. The question had not remained merely a medical or scientific one, but has become actively political. Since the city changed its charter, war has been declared between the newspapers and the Mayor. The Governor of the State is at war with both the newspapers and the Mayor. The plague question has been a football tossed about among the various factions, so that the trade interests cannot be sure of its status. They were told at one time by good medical men that plague existed and that the city was in grave danger. They raised $30,000.00 by subscription in half an hour. Only about 25 prr cent of this money was spent; the rest was refunded to subscribers. Soon after this the papers got after Dr. Kinyoun and abused him unmercifully, rightfully or wrongfully they do not intend to say. Great harm was done to the city and state. Drs. Shrady was met, after his investigation, but he was so non-committal that the trade interests were not helped. These gentlemen protested strongly against the institution of a state quarantine and maintain that they are perfectly satisfied with the Federal quarantine and do not want any other. They welcomed us

Figure 3.2 B

Figure 3.2 B. Minutes from the Commissioners' meeting with representatives of commercial leaders of the city, February 4, p 1. The minutes from this day detail the list of prominent business representatives who attended the meeting. The meeting this day proved to be pivotal for the Commissioners as they realized that not all businessmen were against the notion that plague existed. This was to provide an opportunity for the commissioners to persuade the businessmen to cooperate with their investigation and enlist them as allies in helping to overcome what they viewed as obstacles Governor Gage created to interfere with their scientific investigation. The

> commission minutes state, "They (business leaders) stated they were unable to make up their minds whether or not plague really existed...The plague question has been a football tossed about among the various factions, so that the trade interests cannot be sure of its status. The businessmen were told at one time by good medical men that plague existed, and that the city was in grave danger. They raised 30 thousand dollars by subscription in half an hour. Only 25 per cent of this money was spent, the rest was refunded to subscribers. Soon after this the papers got after Dr. Kinyoun and abused him unmercifully, rightfully or wrongfully. Great harm was done to the city and state".

Novy did not presume that whatever authority his high scientific status may have afforded him would necessarily preempt business concerns. He wrote to Grace, "The business representatives were shown the necessity of opposing the governor's bills…They agreed to support us and send a big delegation to the Legislature to oppose Gage's bills. The business representatives suggested that they would gladly use their influence with the Chinese six companies in order that there may be no concealment of cases and that we may have every opportunity of examining the Chinese sick and dead."[84] Novy's comment shows that he sought to cooperate with the businessmen by persuading them that their interests were aligned with those of the commissioners.

Having gained access to diseased bodies, Novy now sought to find a means to obtain specimens from them. He accomplished the latter through a process of negotiation and compromise. During the February 4 bureau meeting, the commissioners noted that John Bennett, attorney for the Six Companies, was called at the request of the commercial entities.[85] Novy told Grace that Bennett came to offer the aid of the Six Companies to the commission in making its investigation, but divulged that the Chinese had become frightened during the excitement and concealed cases in order to avoid post mortem examinations.[86] Novy promised to limit his examination to an incision of diseased glands and enlarged spleens; this helped to respect a widely-held cultural wish to have bodies remain undisturbed after death in order to be transported to the deceased's native country for burial.[87] Novy noted that Bennett accepted Novy's proposal and advised the Six Companies to issue a proclamation ordering the Chinese to report any sick people as well as any dead and allow specimens to be obtained and sampled for plague. Novy said Bennett agreed to furnish them with guides or interpreters and to personally visit any of the Chinese cases, whose names Bennet would supply. With this help, Novy said the commissioners "would then be able to examine and obtain specimens for sampling from them."[88]

Novy became convinced he would be able to carry out his scientific mission now that he had gained the powerful businessmen as allies. On February 5, 1901, he wrote to Grace:

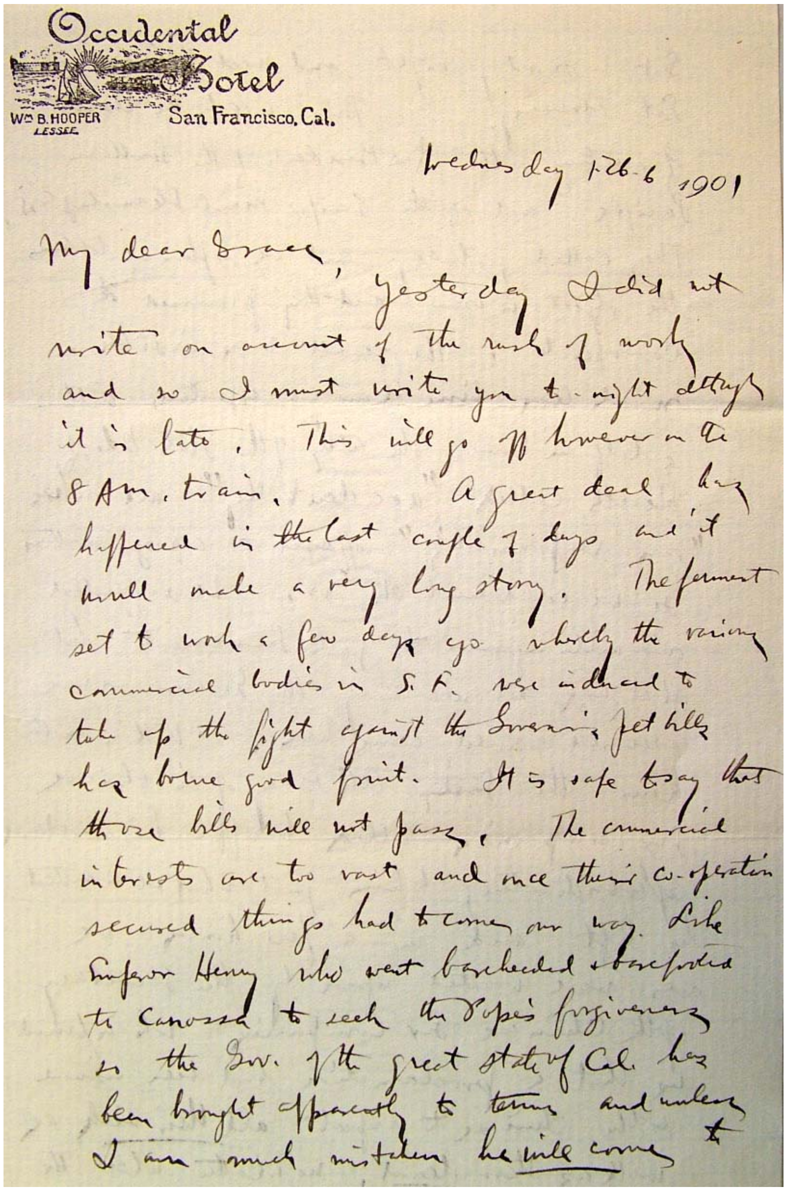
> This 'diplomatic work' will pay off. The business representatives were called yesterday and we explained to them the object in view and they promised to cooperate. The result was visible in much less time than we expected. Within an hour the attorney of the Chinese six companies called to offer his assistance. After indicating to the Six Companies attorney what we wanted he left and in a few hours we were waited upon by Wong Chung, the secretary of the Chinese six companies who informed us that a proclamation had been issued to the Chinese to report all their sick as well as their dead, no matter what the disease might be. He offered to conduct us to the bedside of all such cases and as this was just what we

> wanted, we of course accepted. We have gained the confidence of the Chinese and Chinatown is open to us through the agency of the six companies in a way that the police could not begin to open it for us.[89]

Novy's use of "expected" indicates the intentional nature of his "diplomatic work" and the agency he exhibited in surmounting the interference he believed he was encountering.

By February 5, the businessmen persuaded Colonel Mendel, a city official, to allow room 161 of the City Hall, previously used as a license office, to be converted to a microbiology laboratory with microscopes, slides, incubators, culture medium, and reagents.[90] This equipment was considerably less specialized than the highly sophisticated technology in Novy's medical school laboratory. Furthermore, the San Francisco laboratory was much smaller, only 20 X 20 feet. Nevertheless, the set-up in San Francisco was more than adequate for Novy's needs—to test specimens for the plague germ. As Novy confided to Grace, "the 'bureau' proved to be a great service by putting us into relation with the medical and business interests of the city. Through it a plan of work became easy to formulate. We learned how to gain access to the sick and dead Chinese, how to obtain a laboratory for our work, and how to proceed with our scientific mission without exciting the opposition and suspicion of those among whom we were to work."[91] Thus, he credited the "diplomatic mission" of the commission 'bureau' for enabling the scientific mission to be undertaken.

By stressing a "diplomatic mission," Novy acknowledged that an investigation restricted solely to science,—bacteriology, would not be a sufficient solution to determining whether plague was present in San Francisco. He reasoned that he first needed to address the ongoing beliefs of practicing physicians, businessmen, politicians, and the Chinese population; then attempt to obtain the cooperation of each group. The commissioners themselves became actors involved in a nexus of commercial trading interests, racial discrimination of the Chinese, and mistrust of scientific methods used by bacteriological experts. The commissioners found a means to negotiate the interests of influential businessmen, and the resulting alliance forged with them enabled the commissioners to convince other businessmen, politically appointed city officials and Chinese residents that they all had a shared interest in finding the cause of death through the application of Novy's technology. By February 5, the commissioners began their daily rounds of visits to Chinatown, gained access to ill Chinese residents and secured a suitable laboratory in which to carry out their bacteriological studies in City Hall. Now that they had access to diseased bodies and the assistance of interpreters, the commissioners noted that "rapid clinical examinations were made, and notes kept of the result…When patients were found who presented symptoms which were suggestive of plague, a careful examination was made."[92] Because the State Assembly had not met to vote on Gage's plague bills, the commissioners knew they could not be imprisoned if they found plague at that moment. Moreover, Novy became increasingly confident that the bills would not pass because, as he revealed to Grace on February 6, he had obtained the cooperation of the powerful commercial bodies as allies in the "fight against the governor's bills."[93] [Figure 3.3]



Occidental Hotel
Wm. B. HOOPER LESSEE San Francisco, Cal.

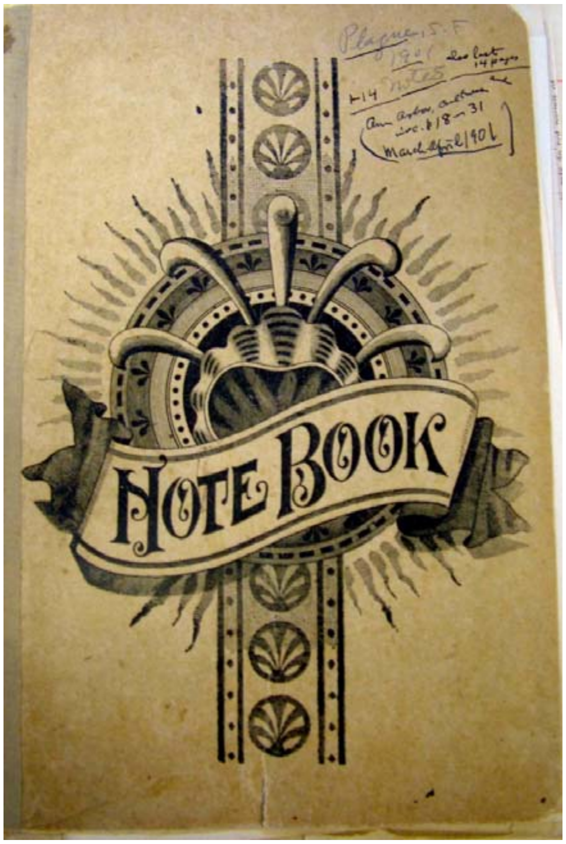
Wednesday Feb. 6 1901

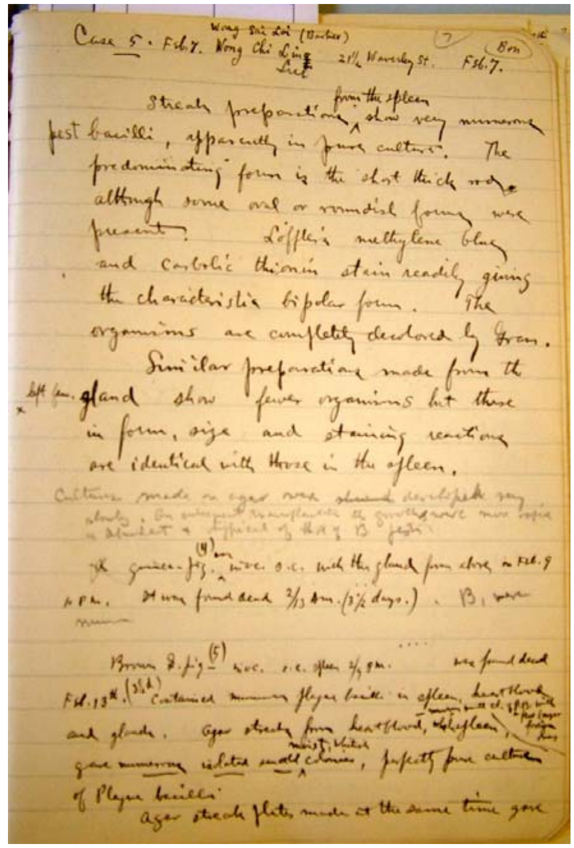
My dear Grace,
Yesterday I did not write on account of the rush of work and so I must write you to-night altho' it is late. This will go off however on the 8 A.M. train. A great deal has happened in the last couple of days and it would make a very long story. The ferment set to work a few days ago whereby the various commercial bodies in S.F. were induced to take up the fight against the Governor's pet bills has borne good fruit. It is safe to say that those bills will not pass. The commercial interests are too vast and once their co-operation secured things had to come our way. Like Emperor Henry who went bareheaded & barefooted to Canossa to seek the Pope's forgiveness so the Gov. of the great state of Cal. has been brought apparently to terms and unless I am much mistaken he will come to

Figure 3.3. Letter dated February 6, 1901 from Frederick Novy to his wife Grace; "My Dear Grace". On this day, Novy confided that the obstacles he believed the commissioners faced in carrying out their investigation could be overcome now that he had achieved the cooperation of the powerful businessmen. He acknowledged that he needed their support in order to defeat the governor's bills, thereby enabling him to carry out his scientific mission. He wrote to Grace, "The ferment set to work a few days ago when the various commercial bodies were induced to take up the fight against the governor's pet bills has bore good fruit. It is safe to say that those bills

will not pass. The commercial interests are too vast and once their cooperation secured things had to come our way". (Courtesy of the Bentley Historical Library)

On February 7, Novy found the first case of plague and recorded his methodology and results in the laboratory notebook he used throughout his San Francisco investigation.[94] [Figure 3.4 A] Using specimens obtained from blood and from the spleen on a 44-year-old Chinese man who died without buboes, Wong Chi Lin, Novy used methodology similar to Kinyoun's to isolate *Bacillus pestis*, inoculate a pure culture into a healthy guinea pig, and identify plague as the cause of death after identifying the organism in the diseased gland of the experimental animal.[95] [Figure 3.4 B] Novy remained vigilant about keeping his diagnosis confidential to comply with his orders from Wyman, but at the potential cost of public health.[96]




Case 5. Feb. 7. Wong Chi Ling 21½ Waverly St. Feb. 7.

Streak preparations from the spleen show very numerous pest bacilli, apparently in pure culture. The predominating form is the short thick rods although some oval or roundish forms were present. Löffler's methylene blue and carbolic thionin stain readily giving the characteristic bipolar form. The organisms are completely decolored by Gram.

Similar preparations made from the left ing. gland show fewer organisms but these in form, size and staining reaction are identical with those in the spleen.

Figure 3.4 A Figure 3.4 B

Figure 3.4. Laboratory notebook Novy recorded during the 1901 San Francisco plague investigation. Novy recorded the data of his microbiologic findings of specimens taken from ill or deceased Chinese persons in this notebook. He recorded notes from February 5, the date he obtained and began his bacteriologic testing of his first specimen, until February 16, when he completed his laboratory work on a specimen obtained from a patient on February 11. (Courtesy of the Bentley Historical Library)

3.4 A. Cover. Novy made entries into the first six pages of the notebook after arriving in San Francisco and prior to his first bacteriological examination. These pages include technical notes about the bacteriological features of the plague bacillus, as well as general notes about the clinical and epidemiological characteristics of plague outbreaks throughout history.

3.4 B. This page details the methods Novy used and the time course of identifying plague in an individual patient. From a specimen obtained from blood and from the spleen on a 44 year old Chinese man who died without buboes, Wong Chi Lin, Novy recorded that he observed typical bipolar organisms on the Loeffler's Methylene blue stain that were decolored by Gram's stain. The streak he refers to is a Methylene blue stain performed on the fluid aspirated from the spleen of Wong Chi Lin,on February 7. He incubated the fluid in agar media on Feb 7, and on Feb 9, cultures yielded characteristic translucent colonies of *B pestis* (plague colonies typically take 48 hours to grow, and Novy noted that the growth was "slow"). He inoculated a suspension of a colony from the agar subcutaneously into a guinea pig to fulfill Koch's postulates; the test animal died 2 days later on February 11 with evidence of an enlarged spleen. Novy made a diagnosis of plague on February 13 when he isolated *Bacillus pestis* from a culture of a specimen taken from the guinea pig spleen, thereby demonstrating "scientific proof" that plague was present by satisfying Koch's postulates (Courtesy of the Bentley Historical Library).

Meanwhile, following the commissioner's accord with business leaders, on February 12, the *Sacramento Bee* began to denounce the governor's bills for interfering with efforts to protect the health of the city.[97] Novy marveled that the unpopularity of the plague bills among businessmen did not sway Gage. Blocked in the legislature, the governor instead tried to avoid meeting with the commissioners, and therefore discredit them for making it appear as they had been disobeying Wyman's orders. Wyman had instructed the commissioners to meet with the governor soon after their arrival. Despite the governor's evasions, Novy jocularly reflected on their precarious position. Novy said to Grace, "Should the bills pass I have no doubt that we will be seriously interfered with. We are already planning about what kind of rooms they would furnish us at San Quentin the State Penitentiary. We really are enjoying things fully and the Governor's 'Opera Bouffe' furnishes us with a lot of amusement."[98] Evidently, Novy had some lingering concerns that his investigation could be halted if the bills were not defeated in the legislature even though he had the assistance of powerful businessmen.

Gage delayed meeting with the commissioners until February 16. By this date, the commissioners had identified plague in six persons.[99] During their meeting, Gage tried to convince the commissioners to disclose their findings, but Novy was not permitted to release any information about their investigations to anyone other than Wyman. Novy avoided being intimidated by what he regarded as the governor's imperious demeanor.[100] Novy wrote to Grace that when the commissioners did not divulge any information to Gage, the governor "obviously defeated in this tack, adopted a completely different tack."[101] Gage argued that the disease should, if present, decimate a population as did Black Death. Novy felt that Gage's skepticism had merit because the medical literature at the time characterized plague as a disease that could start off slowly but would invariably reach a state of a devastating epidemic within one year. Only one year beforehand, in 1900, Novy referred to "the pest" as a "relentless enemy" that spread like a "great title wave" that inevitably caused "frightful ravages throughout history."[102] Thus, in medical journals, Novy himself had defined plague according to its massive depopulations historically. But he knew that this outcome had not occurred in San Francisco, where the number of cases remained few for greater than one year. Novy addressed the atypical behavior of plague in San Francisco to Grace, saying, "The Gov [ernor] insisted that the disease had been in the area for 30 years and that it wasn't contagious. The ground he takes is that the disease is not epidemic, does not spread like wild fire, and therefore cannot be plague. On this legitimate point I think we showed his mistakes, that plague could exist without necessarily giving rise to an epidemic."[103]

Thus, Novy was aware of the discrepancy between the behavior of plague in San Francisco and plague historically. For the same reason that Novy had taken as valid the physicians' skepticism about the diagnosis of plague (which had been based on the grounds that the San Francisco outbreak was not behaving like a devastating epidemic), he similarly felt that Gage's objection on this basis was reasonable. Novy's attempt to reconcile the incongruous behavior of plague in San Francisco was to point out that his bacteriologic testing showed that plague need not decimate a population or destroy a town. Novy's use of the phrase "we showed his mistakes" implies he believed that Gage and perhaps physicians would be convinced by Novy's bacteriological diagnosis of plague and believes that variations of plague can occur. Novy was to underestimate the fact that for Gage, physicians, and some citizens of San Francisco, plague was defined by its epidemiologic, social and historic meanings--its massive depopulations, social disruptions, and interruption of commerce. To Gage and citizens of San Francisco, plague was a social and cultural phenomena that would become real when a disease reached an epidemic nature. This was not happening in San Francisco, and the isolation of the bacillus in a laboratory, whether by Kinyoun or Novy, would not be sufficient to convince Gage and certain citizens otherwise.

On February 17, following a heated discussion, the State Assembly defeated all plague bills.[104] The State Assembly did, nevertheless, appropriate $100,000 to be expended by the State Board, under the supervision of the governor, for the prevention and suppression of bubonic plague within the state.[105] Following the defeat of these bills, Novy noted Gage had softened his behavior towards the commissioners. Novy told Grace that Gage, with whom the commissioners met again, "was now pleasant and even apologized for his statements of the day before."[106] Now that funds had been appropriated for plague, Gage told the commissioners he would like to act to improve the health of those living in Chinatown. Novy explained to Grace that the commissioners "urged upon the Governor the necessity of prompt action [against plague] in order to regain the confidence of the other States. He seemed to accept our views and assured us that he would step in and clean up Chinatown. Things seem to move along in the right groove and if we succeed it will be a diplomatic triumph for the commission."[107] Novy seemed satisfied with the governor's promise to sanitize Chinatown.

While drafting their final report for Wyman, the commissioners entered a contentious exchange over the value of bacteriology with a physician practicing in California, Charles Kuhlman, at a California Medical Society meeting on February 21.[108] Kuhlman had previously published his views repudiating the germ theory and denying its relation to human disease on the basis that bacteriology was untested and impractical.[109] At the Medical Society meeting that day, Kuhlman denigrated the use of diphtheria antitoxin—a pivotal therapy for Novy and the commissioners as it symbolized the promise of bacteriology and provided tangible evidence of bacteriologic discoveries in the practical realm.[110] Barker and Flexner's retort to Kuhlman's argument and their defense of antitoxin did not subdue Kuhlman, who vehemently dismissed the commissioner's investigation on the grounds that bacteriology was bereft of clinical meaning.[111] He wrote, "Because the much vaunted bubonic government commission was utterly ignorant of the laws and teachings of clinical medicine, and consequently of the true relation of bacteria to disease processes, the knowledge of its members cannot be sufficient to properly weigh the evidence necessary to form correct conclusions in any matter appertaining to disease."[112] Kuhlman accused the commissioners of being "arrogant, artless youngsters" because they had not "engaged in the actual practice of medicine" and their knowledge was "limited to experiments performed in college laboratories."[113] Thus, Kuhlman argued that the commissioners lacked clinical experience and were therefore incapable of correlating their scientific findings with actual disease processes.

Why did Kuhlman's object to the role of the laboratory in medicine? Kuhlman was a practicing physician who deplored the hegemony of the laboratory and he reached for other ideals—the value of experience at the bedside. At the crux of Kuhlman's argument was the locus of where decisions would be made—in the clinic in communities or in the laboratories in colleges. Also at the heart of Kuhlman's argument was who would be making decisions. Kuhlman wanted decision making power in medicine to be held by practicing clinicians, where they could exert social power and moral authority at the bedside, rather than by laboratory researchers at the bench, since experiments could not influence patients. Furthermore, Kuhlman felt that the information produced through bacterial experimentation was esoteric and distant from the immediate problems of patient care; he did not feel it was relevant to the practice of medicine. He believed that clinical experience alone was sufficient to guide practice—it needed no fortification from the laboratory.

Kuhlman was exploring the sensitive issue of who gets to decide what counts as relevant evidence. He was constructing an argument to say that the non-local, laboratory scientists lack the necessary local knowledge and do not have the qualifications to make these decisions. The inexperienced, artless bacteriologists, unlike the local physicians, he argued, were not qualified to decide what counts as relevant clinical evidence because they had lost all touch with the physician's art. Consequently, he insisted, the federal commissioner's investigation provided no useful information for the city.

Kuhlman's choice of words fortifies his argument that the commissioners were prone to making a misdiagnosis that would have a negative impact on the lives and livelihood of the city. His reference to the commissioners as "youngsters" suggests he felt they lacked the patient care experience that could provide the vastly more trustworthy and truthful diagnosis than laboratory testing alone. His use of the word "limited" implies he disputed any notion that the new scientific knowledge coming from "college laboratories" was superior to the knowledge that came from clinical experience. Kuhlman's reference to them as "artless" suggests he believed the commissioners did not possess the capacity to correlate their bacteriological findings with clinical experience. And his use of the word "arrogant" shows that he believed that they held to a misleading and self-aggrandizing view that their scientific methods should have authority over more traditional experiential methods physicians used to arrive at truths. The university affiliated commissioners, according to Kuhlman, were isolated and cut-off from the practicing profession, both in the nature of their impractical laboratory work, and the kind of temperament that would take up such work—scientific, self-contained, and cold.

The Commissioners Report their Findings

The commissioners mailed their finalized, confidential 17-page report to Wyman on February 26. They found the plague bacillus in specimens taken from the carefully selected Chinese population that the commissioners selected to study—those with fevers, enlarged glands, or both. Their report detailed the methodology Novy used to isolate *Bacillus pestis* in specimens taken from six of thirteen people who presented symptoms which were suggestive of plague and concluded that plague was present "beyond possible doubt."[114] The commissioners maintained that the bacteriologic techniques they employed provided infallible evidence that plague was present, denoting "truth that is above question by those who are inexperienced."[115] In other words, their conclusion based on their exacting scientific techniques was irrefutable by those lacking bacteriological expertise, which, at the time, included most practicing physicians. The commissioners' report omitted any recommendation regarding anti-plague measures, as Wyman had not specifically requested that they do so. They were required to obtain the approval of their confidential report from Surgeon General Wyman prior to publication by the Treasury Department-US Marine Hospital Service.

On the train following their March 6 departure from San Francisco, Barker and Novy reflected on their experience as commissioners and wrote articles for the *American Journal of Medical Science* highlighting the pivotal role they felt bacteriological testing played in the diagnosis of plague.[116] In "The Clinical Aspects of Plague" published in September 1901, Barker argued that clinical recognition was not sufficient as the commissioners had shown there were cases with atypical presentations.[117] In "The Bacteriology of Plague," Novy noted that atypical presentations were not rare, as buboes were absent in two of the six cases in which he isolated plague. Noting that practicing physicians did not consider plague as a possible cause of death in these cases; he said, "it is often difficult under certain circumstances to make a diagnosis of plague, even post mortem, without bacteriological examination…. In the absence of primary buboes, the unskilled observer will miss practically every case, and even the practitioner who has had much experience with plague may be deceived."[118]

Novy contended that a bacteriologic examination is "indispensable" given the "manifold clinical features" of plague and recommended that once it has been established that "plague exists among the Asiatics of a town, every Asiatic who has fever should be suspected as a case of infection with plague until the disease is proven to be other than plague, and every dead body be treated as a plague cadaver until bacteriological examination of glands, lungs, and spleen, has proven the absence from the body of the *Bacillus pestis*. Only by such caution will it be possible to avoid missing actual plague cases."[119] Novy then tabulated the mortality from all causes among the Chinese population in San Francisco from 1897 to 1901, noting that the cumulative number of deaths remained stable at approximately 430 per year. He concluded that "at no time during the past four years has the mortality rate among the Chinese increased to such extent as to in itself cause alarm."[120] Plague in Chinatown, according to Novy, was not behaving as the "devastating epidemic illness" that had the "power to spread death and desolation" that Novy himself had described as "characteristic features of plague throughout history" in an article he had previously written.[121]

Novy was now explicitly proclaiming that plague was a disease for bacteriologists to define. This time, Novy's argument was more explicit, more forceful than the one he had articulated to Gage earlier. According to Novy, if there is disagreement between bacteriologists and clinicians about the diagnosis, bacteriologists have the right to decide the final word. And to Novy, why should bacteriologists get the privilege of deciding? He never explicitly stated, but it is likely he believed that his scientific methodology was more rigorous, valid, and legitimate than experiential methods used by clinicians. And why shouldn't his word carry authority? After all, he was an elite scientist with the top credentials of his day who had a powerful position at a major academic institution. He also wrote in a reputable journal. With his analytical methods and authoritative position, why shouldn't there be consensus among physicians and citizens of San Francisco when Novy reached a diagnosis about plague and its variations? Novy would attempt to redefine plague by pointing out its variations to the medical world, but he would find that his authority was not incontrovertible to the world at large. His message that plague was present in a non-epidemic form was not convincing to a population that had defined plague not by laboratory testing but by its epidemiological behavior and population decimation.

Just as it was in his medical school laboratory, the element of time remained a major focus for Novy's bacteriologic investigations in San Francisco. In his specialized bacteriology laboratory in the medical school, Novy had focused on the element of time in the experiments exploring the dynamic behavior and morphology of microbes. In San Francisco, his work again took into account the issue of temporality, but this time with regard to the effect of the microbe on the individual and the population. In San Francisco, he used his makeshift laboratory to investigate the variations in the severity of the clinical illness and vital statistics to determine whether there were deaths of an epidemic proportion. In medical journals, Novy concluded that the behavior of plague in the individual and the dynamics of the disease in the population differed from standard patterns of plague described in texts published at the time. But Novy could go no further than this, as he was unable to provide a biological explanation for why plague was behaving differently in San Francisco.

In a strictly medical sense, Novy's bacteriological conclusions represent an important moment for bacteriology in American medicine. By traveling to the site of the outbreak, Novy used his bacteriology laboratory to try to redefine traditional notions of "plague" by underscoring that plague in San Francisco was not behaving like the devastating epidemics throughout history. For many physicians and for Gage, plague had to be a formidable "epidemic" conjuring a dramatic iconography spreading rapidly and extensively, and causing massive depopulation, desolation of cities, and social disruption.[122] Consequently, throughout history, and to citizens and physicians in San Francisco in 1901, the possibility of plague had been apprehended with alarm.[123] Novy acknowledged that those viewpoints were rational and tenable. Nonetheless, on the basis of his laboratory testing, Novy argued that plague did not have to behave in this fashion by showing his microbiological evidence that the disease could also be present in a non-epidemic form, with the number of cases in San Francisco being few. In addition, Novy also argued that there were variations of the clinical signs physicians felt invariably accompanied the disease. Fever alone, in the absence of buboes and a rapid progression to death, he argued, could also represent plague.

Novy believed that the epidemiologic and clinical features of plague in San Francisco did not warrant the fear, social disorder and economic disruption that historically accompanied classic plague outbreaks.[124] He argued that there could be variations to the classic descriptions of plague that medical texts described as frightful ravages with rapid death and excessive mortality. Thus, by searching for and finding

Bacillus pestis, Novy's used his bacteriological evidence to attempt to redefine a disease that had previously been characterized exclusively by its dramatic epidemiology (population decimation), its clinical features (buboes), its consequences for society (economic disruption and social disorder) and the manner in which it was apprehended (terror).

The redefinition of plague by the bacteriologists also represents an important moment in the history of the germ theory of disease. Historians writing on the early history of the germ theory of disease have emphasized the efforts of researchers to prevent (e.g., through vaccination or disinfection) or control (e.g., antitoxin) infection.[125] Historians have also stressed the search of bacteriologists during the 1880s and 1890s to identify an array of disease producing organisms.[126] Lester King has added to this characterization by showing how bacteriology could shift the diagnostic framework of a specific disease such as tuberculosis away from a set of clinical findings towards specific pathological phenomena and microbiologic criteria.[127] Novy's investigation in San Francisco extends King's observations by showing how bacteriology attempted to redefine a disease in a manner that goes beyond the clinical, pathological, and microbiological realms. By demonstrating the plague bacillus in a town where there was no massive epidemic or buboes in all cases, Novy attempted to extend the entire basis for the definition of a disease that was previously known not only by its dramatic clinical features but also the iconography surrounding the frightening epidemiological criteria.

What followed, however, was not a process of reformulation and enlargement of the traditional imagery of a plague epidemic. The attempt by Novy to reduce the disease to a definition of germs was contested by the governor, physicians, and certain citizens who defined the disease in broader, social and historical terms and saw no good reason why they should turn a disease that was not behaving epidemically in their city into a diagnosis of plague.

<u>The Community's Response to The Commissioners' Findings</u>

The *Sacramento Bee* gained access to the commissioners' results prior to the drafting of the final report and, on February 15, wrote that plague was present in San Francisco.[128]It is unknown who leaked the news to the *Bee* and why. Gage was now aware that the commissioners had found plague. Unable to pass laws making a report of plague illegal, Gage attempted to suppress publication of the final report the commissioners submitted to Wyman. To accomplish this, Gage assembled a delegation of businessmen and newspapermen to travel to Washington to make a deal with the Surgeon General.[129]The delegation consisted of W.F. Herrin and John Young of the *Chronicle*; T.T. Williams of the *Examiner*; Freemont Older of the *Bulletin*; and Henry Scott of the Union Iron Works.[130] On March 6, Gage's delegation met with Wyman who then agreed upon the following arrangement:

> The report of the Federal Plague Commission on the conditions in San Francisco shall not be made public by the Marine Hospital Service, either in Washington or elsewhere. Nothing shall be made public by the MHS with reference to the existence of plague in California; all reports from its quarantine officers of the discovery of plague cases are to be suppressed, and all sources of information regarding plague in this state are to be cut off from the general public. The San

> Francisco newspapers that were represented at the conference with Governor Gage shall publish nothing whatever about plague in this state.[131]

In return for suppressing the findings, Gage's delegation promised to use his plague funds to disinfect and sanitize San Francisco.[132] In a letter to Dr. Joseph White, a MHS quarantine office who replaced Kinyoun, Wyman ordered that Gage's disinfection and sanitary measures "shall be conducted with the least possible interruption to commerce and the least possible excitation of alarm. All sanitation and disinfection shall be done as quietly and as free from publicity as possible. More aggressive measures would be taken if needed."[133] Wyman accepted Gage's offer in return for the implementation of sanitary measures.

The reasoning behind Wyman's about avoiding panic or employing "radical" control measures remains speculative. One may consider his concern in the context of his dual loyalties as Surgeon General and as an employee in the Department of the Treasury. At this time the MHS was a branch under the Department of the Treasury. Wyman's obligation to MHS as Surgeon General was to contain outbreaks, report all cases, and institute maximum anti-plague measures. But carrying out these obligations for the MHS could create a conflict with his responsibility to the Treasury Department to protect trade and commerce, as operations of business and commerce were the responsibility of this department until the creation of a separate Department of Commerce in 1904.[134] Wyman's duty to protect trade certainly meant safeguarding interstate commerce by properly handling outbreaks, but it could also have meant preventing anything that could jeopardize interstate trade, including excessive fear associated with rumors of a plague-ridden city. Thus, his decision to implement general sanitary measures without implementing more “radical” measures satisfied both obligations.

The agreement between Wyman and Gage’s delegation was leaked to the *Sacramento Bee*.[135] The source of the leak was again unknown. The *Bee* accused Wyman of violating federal law, the 1893 Acts of the 52nd Congress, which required the Surgeon General to publish all cases of communicable disease and of acting “at the instance of commercialism and against the health interests of the country...(by) suppressing information about plague.”[136] The *Occidental Medical Times*, the official organ of the state medical society, also denounced Wyman for being complicit with what they viewed as Gage’s unscrupulous tactics.[137] The Surgeon General, in the midst of this press coverage, approved the report of the Plague Commission, which was published in April 29, 1901 in the *Public Health Reports* in Washington and by the *Occidental Medical Times* in California.[138]

In actuality, Gage oversaw a marginal disinfection and sanitization program in Chinatown.[139] He earmarked only a small portion, $25,000 of the $100,000 budget appropriated for the job and cut costs in part by hiring too few workers and using insufficient amounts of disinfectants.”[140] Nonetheless, Gage’s sanitary measures, soon after implementation, received favorable coverage by some national newspapers. The *New York Times* reported that California was taking appropriate measures to respond to plague; The Times said that “the disease should not interfere with state commerce (because Gage’s sanitization program) is doing much good in wiping plague out of Chinatown.”[141] The *Washington Post* said “the work in cleaning Chinatown is progressing. The death rate in Chinatown has decreased greatly since the work of cleaning that district was commenced."[142] Medical journals also applauded Gage's efforts. The *Lancet*, for example, stated "the situation is now being treated in a frank and decided manner, so that no serious danger is apprehended."[143] Thus, Gage was credited for taking appropriate action even though he did not implement an effective sanitary campaign that he had promised the commissioners and Wyman.

Meanwhile, the local newspapers continued to dispute the validity of Novy's bacteriologic evidence in favor of evidence they felt was more valid—how plague was behaving locally in their city. In the absence of an epidemic, the press disagreed that experts in bacteriology could provide incontrovertible laboratory evidence that plague was present in the city. The *Chronicle* said, "Had there been any ground for the assumption that cases pronounced [by the commissioners] to be plague were the real thing, we should long since have had unmistakable evidence of the genuineness of the visitation in the shape of an epidemic. But there has been nothing even remotely suggesting such a thing."[144] The *Call* said, "At no time has there been evidence of anything in the way of a pestilence threatening the community."[145] The newspapers were saying there was no "evidence" of an epidemic catastrophe, so why should bacteriologists make the deaths in Chinatown into one? The Call argued that the definitive evidence about whether plague was present was the non-epidemic nature of the disease, not the bacteriological findings in the laboratory. The *Call* stated, "the public will not fail to note that there is something strange in a plague whose traces have to be looked for with a microscope."[146] The laboratory, the papers believed, could erroneously attribute a bacterial cause to a disease that was not infectious in nature, but the behavior of the disease in San Francisco—its non-infectious nature, provided the counter-evidence to convince them that plague was not present.

The press accused the commissioners of lacking the local knowledge of San Francisco that was necessary to judge whether plague was present. They resented the "federal" commissioners' intrusion into their local affairs, and they chastised them for being deficient in the practical knowledge that was necessary to properly assess whether plague was present. Papers such as the *Herald*, for example, proclaimed the "plague scare" propagated by the federal commissioners was harmful to the town and had to be gotten rid of.[147] To fortify their point that the federal commissioners were out of touch, the *Herald* depicted the commissioners wore "silk hats and kid gloves."[148] At the time these newspapers articles impugning the expertise of the commissioners were being published, Dr. Alonzo Taylor informed Novy that the report of the plague commission was being ignored in California.[149]

Novy, after his return to Ann Arbor on March 8, continued to resolve lingering issues about plague in San Francisco, but without success. On March 6, his last day in San Francisco, he wrote to Grace that he had shipped a box to his Ann Arbor home, then instructed her not to unpack the box pior to his arrival.[150] In that same letter, he instructed Grace to "telephone [Charles] Hare at the laboratory and ask him to have a lot of fresh media made up for me."[151] Novy clearly had shipped a sample of the plague bacillus he had isolated to his Ann Arbor home for one of his laboratory workers, Charles Hare, to begin cultivating in Novy's well-equipped medical school laboratory. Although Novy did not mention what were his experimental intentions, one can surmise, based on his zeal to discover truths about microbes that he was eager to explore why plague was not behaving epidemically in San Francisco. But his experiments were thwarted, as on April 8, Novy discovered that Hare developed acute pneumonic plague as a result of a laboratory accident. The organism had been introduced to Hare's mouth from the Novy sent from San Francisco through the use of a pipette, soiled finger or cigarette.[152] When the *Ann Arbor News* reported the event, they noted that the student body was "showing intense interest in the case."[153] But Novy maintained that "there is no cause for alarm" as "there is no possible danger of a spread of the disease."[154] Novy later noted there were no further cases of plague in Ann Arbor after he isolated Hare in the hospital, injected him with Yersin's anti-pest serum and disinfected his room with formaldehyde."[155] Hare survived, but Novy aborted further experiments with plague and never was able to provide a biologic basis for the variant behavior of plague in San Francisco.

From his Michigan laboratory, Novy made occasional comments about San Francisco plague throughout 1901. He remained steadfast that his bacteriological testing proved beyond any doubt that plague was present in San Francisco, but he said that there was no cause for alarm because it was not behaving epidemically and because sanitary measures were being undertaken in San Francisco. On May 15, 1901, Novy told the *Ann Arbor News* that "the disease is in San Francisco, and prompt measures are being taken to make sure it is stamped-out."[156] On October 9, in a speech delivered to the Milwaukee Medical Society, Novy said, "there is no danger of the spread of bubonic plague in this country…although plague still exists in San Francisco, it is confined to the Chinese quarter."[157] At no point did Novy address or acknowledge the fact that his bacteriological diagnosis was being ignored by elected officials and the press in San Francisco.

Gage, while implementing sanitary efforts in Chinatown, was able to maintain that plague was not in the city. He framed his sanitary efforts not as anti-plague measures of cases that existed in San Francisco, but as a precautionary measure against plague should it be introduced into the port city through international trade with a plague-ridden locale.[158] Sanitary measures were able adopted, he claimed, "more to prevent future catastrophe than from present alarm."[159]Although he had evidence to bolster his position that plague was not in the city--it was not behaving epidemically—he sought to bolster his case by directly disclaiming the federal commissioners' findings. He appointed his own hand-picked state plague commission.[160] Gage's Commission, headed by Dr. Randolph Hill, a practicing physician in Los Angeles who was not a bacteriologist, initiated their own investigation in April 1901. By June 1901, the *Los Angeles Herald* reported that Gage's state commission had performed 44 autopsies on Chinese bodies and found no cases of plague in San Francisco.[161] Joseph White, however, objected to Gage's Commission on the grounds that they were not qualified bacteriologists and used spurious findings to discredit the Federal Commission's methods.[162] Despite White's denunciation of what he felt were deceitful tactics, the state commissioners' challenge of the federal commissioners findings resonated with local newspapers.[163]

By October 1901, the opposition by the local press to Novy and the Federal Plague commissioners' investigation had fulminated. A *San Francisco Chronicle* article entitled "The Plague Fake" reported that Gage's State Commission had evaluated 145 deaths, and had not found plague in one body.[164] The article excoriated the federal commissioners as "unscrupulous, inept, and fraudulent" because they "fabricate (ed) plague results in order to obtain appropriations for their public health operations," and declared that they were:

> gross incompetents who have ventured to diagnose as bubonic plague a common disease, which is frequently met with in all Chinese communities…charlatans who deserve the reprobation of all decent citizens, and who must abandon their mischief making and criminal humbugging. No new cases have been found during the progress of the cleansing of Chinatown. There was never a genuine case found, and there will not be any if the precautions which prevented the 'bogus bacteriologists' repeating their infamies are continued.[165]

Another *Chronicle* editorial stated that no cases of plague existed when the "fakers were watched."[166] The paper faulted the commissioners for disregarding their orders by not calling upon the governor until after they had finished their investigation and causing irreversible damage to the economy of the state by performing incorrect examinations.[167] The *Chronicle* mistrusted the commissioners on the basis that they were isolated and removed from the local profession and dismissed the credibility of the commissioners' scientific findings, as had Kuhlman, because they were irrelevant.

In contrast to the unfavorable coverage by California press, scientific and medical publications defended the federal commissioners and warned that any attempt to deny plague was foolhardy and may worsen the spread of plague. *Science*, for example, attacked citizens and physicians who "belittle the reputation of these gentlemen as scientists," stating, "scientific methods…were in San Francisco disregarded and ridiculed…a sad commentary upon that portion of the medical profession which maintained the negative attitude. It must be insisted on that the existence of plague is a matter for scientific consideration, and not within the scope of the judgment of business men."[168] Moreover, by July 1901, the *Cleveland Medical Journal*, *Public Health Reports,* and *Occidental Medical Times* bemoaned the intrusion of California government on the medical investigation of plague and criticized all attempts to suppress reporting as a misguided cover-up that would eventually harm the public health of the state and nation.169[160] *Popular Science Monthly* also predicted that the spread would be exaggerated by attempts to deny its existence for commercial reasons.[170] By August, Kinyoun lamented that effective measures would not be taken until the epidemic worsened. He said, "no steps of a drastic nature, or perfect in result, will be undertaken until a sufficient number of cases of plague have occurred to cause consternation, fright, or panic."[171]

Some national newspapers and medical journals gradually began to question the findings of Gage's hand-picked plague commissioners and to criticize his sanitary efforts as unsubstantial and ineffective. As early as April 1901, newspapers including the *Philadelphia Inquirer* and the *Fort Worth Morning Register* deemed Gage's sanitary measures insufficiently funded and inadequate for preventing new cases of plague.[172] By mid-1901, medical journals acknowledged the continued spread of disease and called for more comprehensive measures to include rat control, along with improved general sanitation.[173] *Public Health Report* recorded an increase in the number of deaths due to plague in San Francisco from 21 in March to 38 in July 1901, and recommended sanitary measures combined with the extermination of rats and vermin.[174] In August 1901, the *Occidental Medical Times* concurred and advocated intensifying sanitary measures and adding rat control policies. The paper said, "the methods which have been permitted to be carried out in San Francisco are not those which are considered ample for the occasion."[175] In June 1902, *Medical News* attributed the rise in number of deaths due to plague, then reported at 71, to the pernicious effects of Gage's "cover-up" and his "marginal efforts" to disinfect Chinatown.[176]

How would citizens know who to believe—the state commissioners appointed by Gage or the federal commissioners appointed by Wyman? The *San Francisco Argonaut*, a semi-annual journal containing articles written by members of the San Francisco Historical Society, showed how one sector of society struggled to assess the arguments of the opposing sides. In an article published in December 1901, an *Argonaut* editorial stated, "based on conflicting results between Federal and State Commission, no conclusion about the presence of plague can be reached."[177] Since the Department of the Treasury did not back Kinyoun, or institute a trade embargo, the *Argonaut* felt there were insufficient grounds to declare San Francisco plague stricken.[178] Despite uncertainty in at least one sector of society, medical journals continued their pleas for initiating rat control measures to counteract the spread of plague. Were their appeals based on what was known about the epidemiology of plague at the time?

<u>Medical Knowledge of Plague at the time of the San Francisco Outbreak</u>

At the time of the San Francisco outbreak, medical texts and journals, and the general press, acknowledged that rats and fleas were the biologic variables responsible for the spread of plague. In 1897, Masanori Ogata conducted experiments where he transferred fleas taken from rats that had died of plague to healthy rats, which in turn developed plague. Ogata, posited that fleas, upon leaving their rat host, may transmit plague directly to man.[179] In 1898, Paul-Louis Simond showed that un-infected mice placed in the same cage with infected mice, but separated by wire so the mice could not touch each other, contracted plague through flea bites. Like Ogata, Simond attributed the infection of man to the fleas which had left the bodies of rats dead from plague.[180] That year, *Science* stated, "The part played by rats in dissemination of the plague has been elucidated, so that it might be said that the plague was really a rat disease."[181] In 1900, Surgeon General Wyman asserted that "rats and other vermin are the principal transmitters of plague…fleas by their bites infect other rats…and "the germ of plague is transported to patients by fleas."[182] In 1900, M.A. Loir, writing during an outbreak in Tunis, concluded that rat fleas are the main agent through which plague was transmitted to man, and James Anders' textbook of medicine agreed, stating "The rat is the carrier from house to house; fleas act as carriers of the contagion, particularly from rat to man.[183] In 1900, Dr. A Calmette, director of the Pasteur Institute in Lille concurred, writing that "the plague bacilli can be transported by fleas."[184] In April of 1901, the month that the commissioner's report was published, J. Ashburton Thompson, writing from an outbreak of plague in Sydney, Australia, wrote, "In its mode of spread, two hosts are requisite; one to diffuse the infection in place, the other to communicate it to man…they are the rat, and a suctorial parasite (the flea)."[185] In August 1901, Kinyoun agreed that "the infection from rat to man takes place through the intermediary of the flea."[186] Several medical textbooks, such as those published by Hermann Eichhorst and William Osler in 1900 and 1901 respectively, shared Anders', Loir's, Calmette's, Thompson's and Kinyoun's notions about the spread of plague, as did articles in *Journal of Hygiene, British Medical*

Journal and *Nature* in 1901, 1903 and 1907.[187] A periodical for general readership, *Current Literature* stated in 1900 "As vehicles for transmission of the plague, rats take the first place, and also the fleas which co-operate with the former in the diffusion of the disease in our species."[188]

By 1900, some medical and lay publications advocated eradication of rats and its attendant flea population as essential measures for handling plague. Wyman wrote in 1900, "The only defense against the danger which threatens us is to exterminate these animals (rats) as much as possible."[189] He elaborated on specific rat control measures, including providing a bounty for capturing and exterminating rats, sulphurizing the sewers, applying poison, and sanitary measures.[190] John Williamson, president of the San Francisco Board of Health, stated in May of 1900 that "a systematic destruction of rats in Chinatown was commenced (that)…resulted in the killing of rodents, which are recognized as being active agents in dissemination of plague."[191]The *Independent,* a journal that focused on politics and economics fully endorsed rat control as a key to preventing the dissemination of plague in 1900.[192] In June 1900, the *LA Times* advocated controlling the rat population as the "most feasible way" of ridding Chinatown of plague.[193] In 1902, Osler's Text stated, "A most important prophylactic measure relates to the destruction of rats, which are probably the chief agents in the distribution of the disease."[194]

Physicians who endorsed the new rat-flea epidemiology of plague in the early 1900s simultaneously advocated older general sanitary practices to control plague. In 1900, Wyman recommended elimination of rats, alongside broader sanitary measures, stating, "Buildings should be vacated for cleansing and disinfecting. Infected bedding, clothing, should be destroyed. An active campaign should be waged against rats and vermin."[195] In 1901, Eichhorst said, "It is important to exercise most scrupulous environmental, domestic and personal cleanliness and to insure the destruction of rats."[196] In 1902, Osler claimed that in addition to rat extermination, "hygienic measures should be carried out, including the most thorough disinfection."[197]In 1907, the *Journal of Hygiene* acknowledged that elimination of rats and fleas as well as general sanitation measures were required to handle a plague epidemic.[198]

Thus, medical texts and journals, though quick to accept the germ theory, did not relinquish older practices of sanitarians. The germ theory could support both general sanitary measures along with specific rat control measures. In the same way that scientists were arguing that parasitic diseases such as leishmaniasis or trypanosomiasis could not be apprehended without a knowledge of its vector and host in nature, bacteriologists such as Novy showed that plague could not be understood by focusing solely on the bacterial pathogen itself. It was a vector dependent disease that brought into consideration unhygienic environmental conditions that accommodated rats and fleas that then made humans vulnerable to infection. Consequently, for plague, older pre-germ theory, general sanitation and cleanliness practices remained a mainstay of the new approach to health even in the germ era. The practical application resulting from adherents of bacteriology and those who held to miasmatic theories shared commonality. The continuation of older sanitary practices into the germ era as demonstrated by the case of plague in 1901 is consistent with arguments made in other contexts by Nancy Tomes, Thomas Worboys, and Judith Leavitt that explore the various ways in which pre-germ practices persisted following the introduction of bacteriology.[199]

In the specific case of San Francisco plague, how did bacteriology affect the older public health approaches that persisted in the germ era? A Charles Chapin type of argument could be made—that a bacteriologic understanding of the environmental and ecological elements involved in the transmission of plague allowed public health authorities to act with greater discrimination, precision, and efficiency in environmental sanitation by modifying the older, general methods to specifically target rat and flea control. But in actuality, the same older broad environmental practices, including garbage elimination and cleaning of house walls and floors, received renewed justification with bacteriologic diagnosis, as it seemed evident to adherents of bacteriology that older, vigorous anti-filth measures would also enhance rat and flea control. Novy, for example, believed that filth did not cause plague, but furnished the conditions for spread of disease by providing an ecologic niche that could accommodate vermin.[200] Control of those conditions could be achieved by using the same practices advocated by earlier sanitarians coupled with newer rat control methods. Older sanitary measures, which focused on cleansed streets and homes, removed the filth and refuse that harbored rodents and their fleas. For plague, general sanitary measures were no longer informed strictly by miasmatic theory, they received support from the new theories of bacteriology. Thus, bacteriology provided an extension to traditional broad sanitary practices by advocating specific rat control measures. At the same time, bacteriology also provided a renewed justification for broad sanitary measures—it did not dislodge their utility in the control of plague.

<u>Acting upon the Commissioners' Conclusions—Adopting Specific Rat Control Measures</u>

Thus, for San Francisco plague in 1901, Wyman chose not to endorse the rat control measures he himself had acknowledged were needed for effective anti-plague programs. One can speculate as to why Wyman did not endorse these measures. At this time, medical texts identified elimination of rats as a public health response that was distinctive of plague.[201] Employing anti-rat measures, accordingly, could have been construed as acknowledging plague as the cause of the epidemic. But even medical texts acknowledged that plague had historically been accompanied by fear and panic.[202] There was no precedence for persuading citizens against responding to a plague outbreak with alarm, as advocated by those like Novy who approached the disease strictly from a bacteriologic perspective. More likely, conceding that San Francisco was a city marred with plague would have caused alarm, imperiled business and interrupted commerce.[203] By avoiding specific rat control measures and selecting general sanitation, Wyman abided by the March 6 agreement to avoid identifying the disease as plague. Avoiding rat control not only circumvented its expense and inconvenience, it also permitted state politicians to continue denying that plague had been present in the past or present.[204] Likewise, implementing general sanitary measures did not incriminate any particular infectious disease, as many other U.S. cities had adopted similar general hygienic measures at the time.[205] General sanitary measures had the added potential of bolstering the aesthetic image of San Francisco as a clean city, thereby fostering, not hindering, business and tourism. As Kinyoun remarked, "Every force was put into operation to keep the truth from being known, to protect the cherished schemes in increasing their material prosperity."[206]

By December of 1901, Gage's state commissioners had ceased performing their work, and they reported no cases of plague in San Francisco.[207] Meanwhile, the San Francisco Local Board of Health under the direction of W.H. Kellogg continued to test cases for plague and reported continued cases in the Occidental Medical Times by July, 1902.[208] Noting that cases of plague continued to occur in the summer of 1902, some medical authorities argued that Gage's sanitizing methods were not sufficient without also using rat control measures. But the quantitative increase in the epidemic did not constitute the "future development" Wyman stated would be needed to warrant the adoption of "more radical measures" and he did not recommend specific rat control measures at that time.[209]

What would it take for Wyman to consider implementing specific anti-plague measures? Some historians have maintained that the implementation of specific anti-plague measures had to await the understanding of the epidemiology and biology of plague, which was not appreciated at the time of the commissioners' investigation.[210] But this dissertation has shown that the role of rats and fleas in the transmission of plague to humans had been known prior to the time the commissioners' report in 1901. I posit that the delay in initiating specific rat control measures until 1903 was due to factors other than evolving medical knowledge about the biological variables of disease transmission. I argue that two major occurrences had concurrently arisen by the fall of 1902 that would influence the decision to initiate specific anti-rat measures in 1903. First, continued monitoring of cases by the local San Francisco Health Department showed that the disease spread beyond the borders of Chinatown, threatening the white community. Secondly, trade sanctions against San Francisco were threatened unless decisive action was taken. The convergence of these two issues, one social and the other financial, tipped the balance towards the adoption of specific rat control measures.

Throughout 1901, the disease was confined to the Chinese immigrant population living in Chinatown. Susan Craddock has described how public opinion considered the Chinese to be inferior and living in a spatially isolated, foreign zone away from white, middle class San Francisco. Local papers, such as the *San Francisco Bulletin*, reported plague had not had a significant epidemiologic impact on the city of San Francisco.[211] In March of 1901, newspapers such as the *Los Angeles Times* noted that the white city of San Francisco, not inclusive of Chinatown, had not been marred by plague and was therefore a safe place for businessmen to reside.[212] Other newspapers echoed this demographic and reiterated that there was no cause for alarm for citizens who lived in San Francisco, meaning white citizens who lived outside of Chinatown.[213] In July 1901, the *Occidental Medical Times* went so far as to predict that citizens would become motivated to employ specific plague measures only if the disease were to spread outside of Chinatown, and lamented, "Woe betide this community if it (the plague) ever invades the homes of the rich or of those who have outraged all honor and truth in their false groveling to preferment!"[214]

To some in 1900, including writers of *Scientific American*, it seemed acceptable to allow plague to fester in Chinatown, as long as the disease was contained within that domain.[215] But by September 1901, anxieties about the possibilities for the disease spreading beyond Chinatown became evident when the *Public Health* noted, "The disease involves mainly Chinese in Chinatown. Thus far only three whites have succumbed to the disease, but the disease has not become generally disseminated. The people at large have a legitimate interest in the manner of the work of eradication practiced in Chinatown, as the Chinese are migratory."[216] By mid-1902, Kinyoun speculated on how the lingering anxiety would play out. He said, "So long as the white population is not affected, no attention need be paid to the plague among the Chinese, until it becomes epidemic among the whites. Governor Gage has been reported as saying, 'It matters not how many Chinese are killed by Chinese, so long as the Chinese do not kill whites.'"[217]

By late 1902, these anxieties indeed materialized when the disease had spread beyond Chinatown to involve whites living throughout San Francisco. By December 1902, the total number of cases had increased to 91, and the number of deaths among whites had increased from three in July 1901, to six.[218] Moreover, white cases were now occurring outside of Chinatown, as four of the six white deaths from plague occurred in what the *Sacramento Bee* termed the "distant corners of San Francisco."[219] The fear of contamination of whites living throughout San Francisco by diseased Chinese living within Chinatown is evident in Dr. Williamson's comment, "The victims have been almost exclusively Chinese, but the white fatalities have increased. Chinatown is a menace to San Francisco."[220] But the fear is more explicitly expressed in the Denver *Colorado Republican* comment stating "The plague had been confined to the Chinese quarter. But there is now a constant danger that it will continue to spread into other parts of the city as white people as well as Chinese are now attacked."[221]

In early 1902, Novy commented on the new numbers of plague cases in San Francisco from his laboratory in Michigan, saying the disease "is slowly gathering headway."[222] Thus, he changed his earlier support of the handling of plague in San

Francisco and now began to accuse Gage's inadequate handling of the epidemic as placing at risk the spread of plague throughout the country. In January 1902, Novy caustically stated, "the whole country will someday reap the inevitable fruits of the plague culture nourished by the policy of the governor of California, for unless stamped out it will sooner or later suddenly expand over the whole country."[223] Novy, in a speech delivered on June 7, 1902, to the Lucas County Medical Society in Ohio, tempered his earlier remark, but reminded his audience that plague was still present in San Francisco. Novy said, "it is not in epidemic form, the number of new cases being few; but it still persists."[224] In a speech delivered to the Conference of Health Officials in Michigan on January 15, 1903, Novy first cited historical examples of how plague epidemics spread from city to city through trade. Noting that history, he then said, "I do not want to pose as an alarmist" but noted that "within the United States, a plague center in San Francisco is of greatest importance" because of its potential to spread to other parts of the country through trade.[225] He attributed the persistence of plague to the "state authorities strenuous denial of the existence of plague in the city of San Francisco" and stated "the destruction of rats is an essential measure and without this no real success can be attained."[226] The reason Novy changed his earlier viewpoint remains speculative. Perhaps in response to the repudiation of his findings in California, he was now clearly arguing that plague could spread from San Francisco throughout the nation unless definitive measures were taken to stop its spread.

News of the continued spread of plague throughout the city precipitated threats of economic sanctions against the state unless California implemented decisive measures to prevent its spread throughout the nation. The *Los Angeles Times* in November 1902 called for Gage and state health authorities to end “the nonsense about the matter and take the ‘most vigorous’ steps possible to stamp it out once and for all before it becomes a national concern.”[227] Delegates from the National Conference of State and Provincial Boards of Health of North America, held in New Haven, Connecticut on October 30, adopted a resolution to “censure the health authorities of San Francisco for their gross negligence of their official duty: the handling of bubonic plague. Delegates view with abhorrence the irretrievable disgrace of the present State board of health of California, and pronounce the plague situation in California a matter of grave national concern. San Francisco was negligent—while San Francisco was denying the existence of plague, new cases were developing.”[228] The *Washington Post* stated that, “Owing to the inability of the health authorities in the state to stamp out plague in San Francisco, the health authorities of some of the States are threatening to quarantine against California and are calling upon the Federal health authorities to take some decisive action towards stamping out the pest before it spreads to other coastal cities.”[229] National papers argued that an embargo on California trade be implemented unless decisive, comprehensive anti-plague measures including rat control were adopted to halt the spread of the epidemic.[230] The *Independent* echoed that measures undertaken by the California State Department of Health were ineffective and also advocated for rat control policies.[231]

Despite the mounting pressure to implement comprehensive measures to handle plague, those who had been denying the presence of plague did not give up doing so.[232] *The Chronicle* conceded that plague existed, but only in already “diseased” areas that were isolated from the “healthy” city.[233] Gage himself continued to deny the presence of plague, and even up until January 3, 1903, held that “there has never been and there is not now, any bubonic plague in San Francisco."[234] By this time, however, state newspapers including the *Los Angeles Times* had begun to excoriate the California governor for his denial of plague and what they deemed his inadequate anti-plague measures and deceitful tactics that permitted the unabated spread of plague.[235] The paper later claimed that there was a widespread sentiment among voters in the state that Gage's "foolish policy of suppressing the facts" led to damaging rumors about California throughout the country and threatened California's financial well-being.[236]In part for suppressing the facts and not acting decisively during plague outbreak, Gage failed to win the nomination of the Republican party for reelection in 1902.[237] Gage's opponent, George Pardee, a physician, successfully ran on a platform that included discrediting Gage's policies of suppressing plague and restoring to California prestige before the world.[238]

Shortly after the new Governor Pardee was inaugurated in January 1903, he initiated efforts to ward off the continued threat of quarantine against California.[239] He appointed Dr. Matthew Gardner, professor of legal Medicine at Cooper Medical College, as a member of the State Board and to represent California on January 19, 1903 at a special bubonic plague conference at the Department of Treasury in Washington, D.C. to determine whether economic sanctions should be instituted against California.[240] Delegates from the State Public Health officials of nineteen states at the conference called for effective state laws and city ordinances, the appropriation of ample funds for anti-plague measures in California, and a "proposal of a joint action in the way of a quarantine against California."[241] In response, Gardner proposed that San Francisco take immediate and vigorous action against plague.[242] Governor Pardee, who was also in attendance, promised delegates that he would implement Gardner's proposal by obtaining funds from the legislature and private sources to intensify existing sanitary activities and develop new rat control programs.[243] In return, the delegates agreed not to place an embargo on railroads leading out of California "if the state were to carry out effective action against plague as outlined by Pardee."[244] Novy, noting the above, wrote, "On January 19, 1903, a conference was held in Washington…with reference to the plague Situation in San Francisco. The result was that the State authorities were forced to take action and recede from their previous position."[245]

Within a week of the meeting at the Department of Treasury, representatives of commercial bodies within California met on January 27, 1903 to form a citizens committee.[246] The committee consisted of influential businessmen to work with the state government to take action to avert a trade embargo.[247] The 18 members of the committee resolved to "take such steps as might be necessary to satisfy the people from abroad regarding the condition of affairs in San Francisco."[248] The committee also resolved to take "Full measures against plague with the cooperation of the boards of public health of the city and the state, under the supervision of the MHS so that all fears of infection may be removed, the confidence of the boards of health of other states may be restored, and no injury however remote may result to the foreign and interstate commerce."[249]

By February 4, 1903, the citizens committee began to lobby for state government to take immediate and vigorous action to avoid financial ruin of the city.[250] Newspapers placed additional pressure on Pardee to adopt and fund full plague measures as recommended by San Francisco businessmen and the City and State Board.[251] Shortly afterwards, by February 11, Pardee initiated comprehensive anti-plague measures that were supported by funds from the state legislature with contributions from the citizens health committee to intensify sanitation and to control rats.[252] Thus, the biological factors thought to be responsible for the transmission of plague in 1903 played a role in the deliberations that led to the implementation of these anti-plague measures.

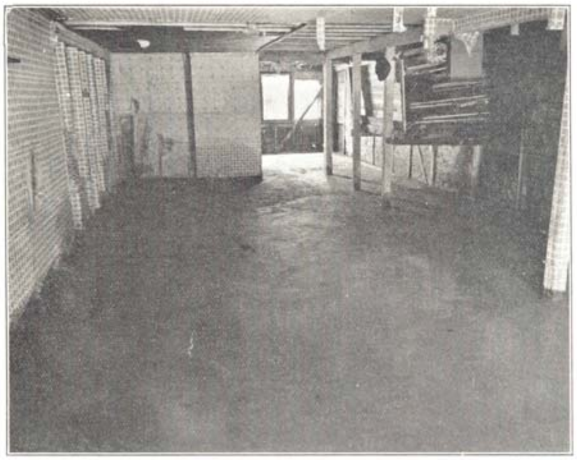
In February 1903, Dr. Rupert Blue of the MHS was the federal officer in charge of initiating a comprehensive anti-plague program that included practices of rat proofing, extermination, and sanitation that Wyman advocated in his 1900 manuscript.[253] Specific anti-rat measures that Blue oversaw included placing rat traps containing bread and cheese mixed with phosphorous poison in homes and stores and flushing sewers and streets with sulfur-containing solutions.[254] Chinatown was combed for infected rats by rat bounty hunters who were offered 25 cents for each captured rat submitted to the MHS laboratory for bacteriologic diagnosis.[255] Each week, the *Public Health Reports* recorded the number of rats with or without plague infection captured by the three men employed by the city board of health to systematically trap rats in Chinatown.[256] Aggressive measures used to destroy rat-containing homes included demolition and removal of wooden "excrescences" that enclosed bathrooms, kitchens, and sleeping quarters. These measures, which *Public Health Reports* called "radical measures for the eradication of the unsanitary nuisances in Chinatown," also included removal of decaying wooden balconies and porous wooden cellars and that were particularly suitable for harboring rats, and replacing them with hardened, rat-proof concrete basements.[257] [Figure 3.5 A-C] These measures were both sanitary and anti-rat in nature, since these decayed and unsanitary portions of Chinatown were thought to harbor rats. Enhanced sanitation and disinfection measures, including spraying carbolic acid and sulfur on the walls and sprinkling chlorinated lime in houses, were also employed.[258] Given the multifaceted nature of these measures, the state supplemented the existing corps of sanitary inspectors with reinforcements.[259]

Real Cleaning Up

Figure 3.5 A

What the Basement Gave up

Figure 3.5 B



SANITARY REQUIREMENTS SATISFIED

Figure 3.5 C

Figure 3.5. Photographs of intensive anti-plague measures implemented by Dr. Rupert Blue from February 1903-April 1905. (Photos from Citizens' Health Committee, *Eradicating Plague*, p.135)

Figure 3.5 A. Intensive Measures used to destroy rat homes included demolition and of wooden “excrescences” that enclosed bathrooms, kitchens, and sleeping quarters, decaying wooden balconies, and porous wooden cellars (circa 1903). The divan indicates that this particular excrescence was a living area. (Photo taken from *Eradicating Plague*, p.135)

Figure 3.5 B. Workmen destroying a rat focus beneath a boarded backyard, circa 1903. The wooden debris being raked into a pile for incineration was composed of rat nests and is laden with fleas. After demolition, the porous area where rats once lived was covered with concrete. (Photo from *Eradicating Plague*, p.95)

Figure 3.5 C. Concrete was layered over basements following demolition of porous wooden boarding to destroy rat abodes and make the basement rat proof. (Photo from Citizens' Health Committee, *Eradicating Plague*, p.137)

By March 1903, the press recognized and applauded the new comprehensive anti-plague activities and a trade embargo against California was averted.[260] Wyman received resolutions adopted by the Mercantile Joint Committee to take steps to secure the cooperation of the state and city boards under the supervision of the MHS.[261] The Surgeon General concluded that "the city and state were working in harmony."[262] Likewise, delegates from a conference of State and National Boards of Health (June 3, 1903) noted, "a hearty cooperation between city, state, and national health officers in endeavoring to stamp out the infection…There is now vigorous cleaning in Chinatown, and resolved that the fear of another attack was disappearing."[263] The delegates from the conference were satisfied that California had undertaken what they termed "vigorous anti-plague measures" and therefore determined that quarantine against California was not indicated.[264]

Blue reported tallies of his comprehensive rat control and intensified sanitation activities in weekly *Public Health Reports*.[265] From April through July 1903, no new human cases occurred, but when a relapse of two cases occurred in August 1903, Blue expanded his program throughout all of San Francisco. The new cases did not dampen the press's enthusiasm for the new anti-plague efforts, and the delegation of State Public Health officials from nineteen states did not call for quarantine against California.[266] When new cases recurred February of 1904, Blue improvised and expanded his rat poison formula to include a biological, *Bacillus typhimurium*, mixed with cornmeal.[267] With no further cases, Blue's vigorous anti-plague campaign was terminated in April of 1905.[268] The citizens committee then credited the intensive, comprehensive anti-plague program that they facilitated and financially supported with "building out" plague and averting a quarantine.[269]

But the quelling of the plague turned out to be just a temporary reprieve, as a second San Francisco plague outbreak occurred in 1907 following the 1906 earthquake.

During that outbreak, a comprehensive rat eradication campaign based on the measures used during 1903–1905 was implemented immediately.[270]The effort in 1907 was again facilitated by the citizens committee, which contained five of the same members that served on the committee during the first outbreak.[271] During the first outbreak, plague claimed 121 lives (an additional eight recovered). The victims were mainly Chinese but the tally also included 10 whites. Although disease involved all corners of the city, most cases were concentrated in a 20 block area of Chinatown. In January 1903, the *Los Angeles Times* stated, "If the plain truth were to have been admitted, and vigorous plague measures, including rat eradication, had been adopted previously, the disease would have been 'wiped out' a long time ago."[272]

Representations in *Arrowsmith*

There are several themes of Novy's San Francisco plague investigation—business interests vs. public health duties, and the adoption of effective public health measures when it suits the overall interests of the town—that are mirrored and fictionalized in *Arrowsmith*. In the novel, plague has spread throughout St. Hubert's, an island with trade routes to China, because the Surgeon General, Inchcape Jones, denied that plague had existed and failed to institute rat control measures in order to protect the island's flourishing tourism and trade business.[273]Jones said that rat control and quarantine would "frighten everyone…[and]…ruin the tourist and export business".[274] But when the plague became rampant throughout the island, Gustave Sondelius, a national public health official, argued that the economy would be threatened unless optimal anti-plague measures were urgently instituted. Lewis said that Sondelius argued that unless "rat-killing" were implemented, "the plague might cling in St. Hubert forever, so [the town] would no more have the amiable dollars of the tourists and the pleasures of smuggling.[275] Following Sondelius' argument, the town "immediately started rat killing."[276] Sondelius also sought to control the epidemic by administering Martin's untested bacteriologic discovery, a bacteriophage, to the entire population. Although Martin initially wished to have a control group to scientifically test whether cure was due to his phage, he eventually decided against withholding a potential cure after his wife, Leora, smoked a cigarette contaminated with plague germs and died.[277] Lewis likely patterned Leora's acquisition of the plague bacillus after the circumstances of Charles Hare, Novy's laboratory assistant.

In addition, the theme of mistrust of laboratory-based scientists like Novy and the commissioners by practicing physicians and citizens of San Francisco because the scientists lacked clinical experience is evident in *Arrowsmith*. Dr. Coughlin, a practicing physician in Leopolis, said about laboratory-based physicians, "A GP may not have a lot of letters after his name, but he sees a slew of mysterious things that he can't explain, and I swear I believe most of these damn alleged scientists could learn a whale of a lot from the plain country practitioners."[278]Furthermore, the perception of laboratory-based commissioners as detached researchers whose laboratory diagnoses had no clinical relevance is evident in another comment by Coughlin, "These laboratory fellows get delusions unless they have some practical practice to keep 'em well balanced."[279]

Conclusion

Working on site in San Francisco, Novy satisfied Wyman's obligation to find the cause of the outbreak by identifying the plague bacillus in deceased human bodies in

Chinatown. In order to identify the disease, Novy created a laboratory in the city. In this sense, Novy's laboratory investigation in San Francisco and his findings illustrate what Bruno Latour has referred to as turning the outside world into a laboratory—the business of traveling bacteriologists.[280] In the process, Novy detected a discrepancy between the traditional behavior of plague described in texts and its variant form in San Francisco. By detecting the bacillus in people who did not have the standard symptoms of plague, Novy did more than identify the cause of the outbreak. He was changing plague's identity from historically described patterns based on plague's clinical symptoms and epidemiologic behavior over centuries.

In the process of redefining plague, Novy encountered difficulties when he tried to reconstruct his laboratory and implement his methodology outside his home. Not only did he have trouble accessing disease bodies, but he also could not find a biologic explanation to account for the aberrant behavior of plague in San Francisco. Identifying the plague bacillus by bacteriologic means did not provide the objective evidence that could convince physicians and citizens that the disease was in the city and that there was a potential for an epidemic. While in San Francisco, and after returning to Michigan Novy was unable to reconcile his bacteriological definitions of disease not only with the absence of characteristic clinical features, but also the broader, cultural meanings of disease held by others. Consequently, physicians who were predisposed to defining disease by certain clinical and epidemiologic criteria that were not present did not believe Kinyoun's or Novy's microbiologic diagnosis of plague. As a consequence, the city did not adopt comprehensive anti-plague measures on the basis of Novy's diagnosis in 1901.

Novy encountered problems when attempting to use his bacteriological methods to redefine plague based on its cause rather than its symptoms or its specific epidemiologic character. By using "objective" bacteriologic evidence to claim that plague was present in clinical situations and epidemiological circumstances that did not classically represent plague to physicians, Novy was changing the identity of plague as a specific disease entity. Physicians were skeptical of Novy's bacteriological diagnosis because it did not fit their notion of plague. In the absence of a massive epidemic and its devastating social consequences, Novy's bacteriological findings did not provide the "objective" evidence to convince local physicians, politicians, the press, or certain citizens that plague was present in the city. To them, the presence of the germ without the characteristic symptoms was not sufficient to establish a diagnosis of plague. Their rejection of Novy's diagnosis was not an outright rejection of bacteriology, but rather their belief that bacteriology could not define disease in the absence of distinctive symptoms. They were unwilling to allow the bacteriology laboratory to be the instrument to transform the identity of a disease from being symptom-based to cause-based.

Historians have addressed how the discovery of disease-causing microbes had redefined various infectious diseases in the late 19th century. Evelynn Hammonds, for example, has described how New York City physicians in the 1890s were unwilling to accept the presence of the diphtheria bacilli in healthy throats as defining disease or the presence of the pseudodiphtheria bacillus in throats with pseudomembranes to mean the absence of disease.[281] Hammonds maintained that the use of the diagnostic kit for diphtheria introduced new problems for physicians, who protested against the usurpation of the role of diagnostician by the health department. In addition, Harry Solomon Caesar remarked how physicians were skeptical of a laboratory diagnosis of syphilis if it did not align with a person's exposure history or clinical findings.[282] Furthermore, Andrew Cunningham wrote about how physicians objected to the implications of cause-based rather than symptom-based definitions of infectious diseases for their clinical practice.[283] No longer was a disease constructed by means of symptoms; rather, it became the result of invasion by a particular microbe, Cunningham argued. Consequently, the patient's claim to be suffering from a particular disease could no longer be taken at face value; it had to be confirmed by means of laboratory testing.

The present chapter adds to this literature by providing further insight into problematic relationship between the laboratory identification of a germ to a disease witnessed by clinical observation. At issue in San Francisco was who got to decide whether plague was present, what criteria could be used, and how consensus could be reached. Wyman and Novy hoped that the use of precise methods and instruments would provide universally valid results and resolve the issue about plague's presence. But local physicians did not accept the ability of instruments operated by experts such as Novy or Kinyoun to objectively determine whether plague was present. The ability to reach agreement about whether plague was in San Francisco posed a problem because of different training of individuals addressing the issue about plague. Physicians read texts that told them to define plague by the identifying clinical and epidemiologic features that had invariably appeared in each historic outbreak. They assessed the situation and came up with an account that was objective according to the criteria in which they were trained. To accept the instrumental objectivity of Novy or Kinyoun required being steeped in another way of training one's objectivity to see the structures—colonies, stains and producing disease in guinea pigs—that the science of bacteriology required. By this logic, a bacteriologist and a practicing physician could look at the deaths in San Francisco and come up with a different structural account of the outbreak—all objectively according to their training. As discussed in chapter two, one's background and training influenced how one viewed the relationship between a bacteriologic diagnosis and a clinical diagnosis that did not match what the laboratory yielded.

In San Francisco, the consequence of physicians and citizens allowing plague to be defined by the laboratory when it did not conform to their traditional conception of disease was significant. Some businessmen and elected officials perceived that acknowledging plague would threaten the city's prosperity. In addition, Chinese immigrants feared punitive and discriminatory public health practices. Just as they had done with Kinyoun, elected government officials and certain business elite denied plague to prevent unnecessary panic and avoid a threat to economic prosperity. The commissioners' conclusion that plague was the cause of the outbreak was not accepted by practicing physicians not only because of the absence of extensive spread and buboes in all cases did not conform to their notion of plague, but also because they resented the intrusion of the bacteriologists whose laboratory-oriented methodology they mistrusted in their clinical domain. Moreover, implementing comprehensive rat control measures was viewed as yielding to the imposition of federal government controls by federal employees who did not have proper knowledge of the local environment. Consequently, comprehensive public health responses that included rat control measures were not initially adopted in 1901.

Historians including Risse, Craddock, and Shah have attributed the time interval between the issuing of the commissioner's 1901 report and the implementation of specific rat control measures in 1903 to evolving concepts and emerging consensus regarding the role of the rat and flea in the epidemiology of plague. But I have argued that the biological factors regarding the spread of plague were understood by 1901 and have proposed that the delay in implementing comprehensive public health measures were due to factors other than advancing scientific knowledge of plague. Specifically, I have argued that comprehensive public health measures were adopted in the context of contingent economic circumstances, politics, and race relations—to avoid further spread of disease beyond Chinatown to include whites, and to avert a threatened trade embargo. The 1901 San Francisco epidemic shows that during a time in American history when science occupied a powerful position in America, the bacteriologic findings of the university-based scientists were accepted and their conclusions acted upon only when they resonated with the overall financial, social, and political interests of the city.

Novy's field investigation also allows one to ask how science develops a voice in a democratic society. Novy's activities during his diplomatic mission suggest that he understood that the prestige of his scientific status did not mean that his bacteriologic word would supersede the views of others. He understood the arguments of those who adhered to traditional notions of plague and entered into debates with those who were skeptical of its presence in San Francisco. At their bureau meetings, he sought the cooperation of businessmen through persuasion and using negotiation in order to reach compromise. He also was willing to compromise so he could obtain crucial specimens from diseased bodies he needed to complete his scientific mission.

Despite the wishes of several actors in this narrative, including Wyman, Kinyoun, those writing for the journal *Science*, and later Novy himself, the powerful voices of eminent, disinterested bacteriologists would not preempt dissenting voices of other citizens, including practicing physicians, politicians, businessmen, and Chinese living in Chinatown. Nor would the proclamations of the highly respected scientists, Novy and Kinyoun, be considered the most authoritative source of disease interpretations in all places and at all times. Those who advocated scientifically-based measures to control disease spread (e.g., rat control) did not override the dissenting voices of those who did not see the need to implement such measures. Proposals on how to control plague and considerations of which measure to implement were contested among those who represented various economic, scientific, or social interests. Decisions that were eventually reached were contingent on the power, ideology, and pragmatic needs of a particular group in San Francisco at that time. In San Francisco in 1901, science was a powerful voice, but not the only voice.

After returning to Ann Arbor on March 6, 1901 after his six week trip as a federal commissioner in San Francisco, Novy did not become involved with any further investigations of outbreaks. He was to spend the remainder of his research career until 1933 performing experiments in his specialized laboratory located at the medical school. Chapter 2 described his elaborately equipped, physical laboratory space and the innovative investigations he carried out there during this period at Michigan. But the location of his laboratory at the medical school also provided him an opportunity to use his research activities as a foundation for medical education. The following chapter outlines the scope of his educational activities at the medical school.

CHAPTER 4

Making Medical Education Scientific

Introduction: Novy spent the majority of his long career performing scientific investigations in his medical school laboratory. There, he used the hygienic duties and his basic research operation as a platform to teach bacteriology to the university's medical students. In this chapter, I will explore Novy's goals in medical education as well as his educational activities. Novy's 1889 laboratory-based course in bacteriology was the first offered in America. What specifically did he teach those students? What was he trying to accomplish by teaching laboratory medicine to students who would spend their careers practicing medicine? Years later, how did he view his early efforts in instruction?

Novy wrote and lectured extensively about his views on the state of medical education in America when he began teaching at the medical school. In this chapter, I will examine what he intended to accomplish by introducing laboratory instruction into the medical curriculum. In particular, I will address how he perceived his efforts as having influenced the careers of medical students who were destined for practice as well as those destined for research. I will also discuss how he viewed his efforts as well as those of others as having changed the face of medical education in America.

Novy sought to foster in all students what he termed "spirit of research" or "spirit of science" in medicine. I will examine what Novy meant by using these terms. In particular, I will argue that Novy wanted to instill more than critical thinking and method for future researchers. The goal of his instruction to provide disciplined habits and a code of ethics based on shared duties and responsibilities for all medical students, including the majority who would enter private practice. Novy sought not only to instruct the mind, but also to mold the moral character and regulate the habits of students. Novy's educational intentions were far more expansive than medical historians have recognized for late 19th century medical educators. Although Novy's broad educational goals have not previously been described within the medical profession, they were, however, utilized by late 19th century chemists and physics who lectured to college students.

Medical Education in America and Michigan in the 1880s

Historians have written about the transformation American medical institutions underwent between the 1880s and the 1920s.Before this time, very few schools had university affiliations or were connected with teaching hospitals, most were proprietary institutions. Laboratory-based research was almost nonexistent.[1] Professors owned the schools not affiliated with a university and, operated them for profit. Small groups of medical practitioners taught part-time in these schools. The typical medical faculty in the post-Civil War era consisted of seven or eight instructors, all of whom tended to teach students in lecture halls in didactic settings.[2] It took two years to earn a medical degree, and each year was composed of two, four-month semesters. There were no formal admission criteria for medical schools at this time.[3]

In 1850, the medical school at the University of Michigan was opened and staffed by seven full-time faculty members.[4] Like most other American medical schools, it was a two-year school, but it differed from other schools in that each semester was six months long.[5] With the exception of anatomy, where demonstrations were provided on cadavers in the lecture halls, lectures were purely didactic and took place in large rooms. Like most other medical schools, there were no formal admission requirements.

By the 1880s, Michigan was among a handful of American medical schools that were beginning to expose students to "scientific" medicine. Scientific medicine in the late 19th century was seen as an array of medical practices rooted in experimental physiology, the chemical analysis of food and water, sanitary measures, and other areas.[6] Taking these activities into account, medical education at Michigan was becoming scientific in the 1880s. In 1882, for example, Henry Sewell taught a full two-term course in physiology to first-year students.[7] Sewell was able to illustrate his lectures with demonstrations, although he did not offer a laboratory course. Vaughan began to teach about the germ theory of disease in his 1881 course on sanitary science, which consisted of 20 lectures.[8] There was no laboratory component to this course, and there was no formal course dedicated to bacteriology.[9] To accommodate the addition of both physiology and a sanitary science course into the curriculum, in 1884 the University of Michigan extended the students' length of study from two to three years in order to earn a degree.

The insertion of an occasional lecture on bacteriology into the medical curriculum at Michigan, in the absence of an entire course dedicated to that topic, did not differ substantially from that of other medical schools in the 1880s.[10] In 1885, for example, Dr. H.C. Ernst gave occasional lectures on bacteriology in a course on medical hygiene at Harvard Medical School. In 1886, Theobald Smith began lectures on bacteriology in the medical department of what is now The George Washington University. George Homes gave more than one lecture on bacteriology during his course on hygiene at Chicago Medical School in 1888, and in 1889 Harold Pammel gave lectures in bacteriology at the Veterinary School of Iowa State.[11] Thus, in the 1880s, professors at various medical or veterinary schools did sporadically give lectures on bacteriology, but no full courses were offered and there were no laboratory components.

Novy believed medical education in America in colonial times and in the 19th century was terrible. He considered medical education in colonial times an apprentice system, and this was followed by a proliferation of proprietary colleges in the 19th century.[12] Novy was appalled by the "deplorable state of medical education in colonial America and in the 19th century."[13] He objected to commercial nature of private medical schools being run by "enterprising physicians who operated [them] for a profit in fees and the indirect profit that came from consultation with their ignorant graduates".[14] Novy ascribed the poor quality of medical students to the increasing number of medical schools, and he believed that the part-time faculty at commercial schools were unable to keep pace with the new scientific medical changes. He said, "With the increase in medical schools came a lowering of preliminary requirements to the point where no one was refused admission. Schools were graduating illiterate and incompetent men...without proper training."[15] Novy felt that two major forces that could "stem tide of deterioration in medical education" were to improve the quality of medical students by enforcing strict admission requirements, and to introduce laboratory science into the medical curriculum.[16]

In the late 1880s, a considerable proportion of students accepted into Michigan were unable to satisfactorily complete the coursework.[17] For example, the majority (117 of 123) of students admitted in 1889 were graduates of high school only, many of whom had diplomas from schools not certified by the University of Michigan Literary Department, which was charged with ensuring high school students met basic standards.[18] Furthermore, a sample of the 81 students from the Michigan class of 1892 shows that of thirteen of them (15 percent) were not recommended for graduation due to poor performance on tests, and nine others (11 percent) were either warned, placed on probation, or suspended.[19] To ensure that students admitted to the medical school were competent to understand the methodical, complex coursework in the sciences, Vaughan and Novy advocated that admission criteria to become more stringent. In the early 1890s, they proposed at faculty meetings to mandate an undergraduate degree and passing an entrance examination as criteria for admission. The regents approved these as mandatory criteria for admission to the medical school.[20]

Vaughan and Novy's educational reform efforts can be viewed from several perspectives. On the one hand, they could be interpreted as improving the quality of students and elevating medical education in general. At a time when students at commercial schools were learning about "humors" and "bleeding" as effective medical therapy, medical elite like Vaughan and Novy traveled to Europe to learn the "new" science—bacteriology. Vaughan returned to Michigan with reformist zeal to reform the curriculum by integrating laboratory work in the sciences, hire full time faculty, emphasize research, and, with Angell's support, closely associate the medical school with the entire university. Through these reforms, Vaughan became interested in reshaping the medical school into a center of advanced teaching and research.[21] The hiring of Novy as an assistant at the hygienic laboratory was a key component to Vaughan's overall educational reform strategy to establish medicine at Michigan as a branch of “higher learning” in the late 1880s well before Flexner’s Report on medical education in 1910. As a full-time Vaughan appointee working in a hygienic laboratory with a research component, Novy was positioned to develop a course devoted exclusively to microbiology that entailed a laboratory component--the first university course that was fully dedicated to bacteriology in this country.[22]

But Vaughan and Novy’s educational reform efforts can also be viewed from an alternate perspective. Advocating a modern pattern of medical education—four years of medical school following four years of college—barred most working class and poor people from the possibility of a medical education. At the time, only the affluent middle class were able to attend college and a college education was not required for admission to commercial or sectarian schools. When viewed from this perspective, Vaughan and Novy’s efforts could be considered elitist by turning allopathic medicine into a white, middle class, male occupation. It is important to acknowledge both perspectives as one examines Novy’s educational intentions.

Novy’s Microbiology Course at Michigan

Novy’s course was initially offered as a three-month elective in the fall semester of 1889. According to Novy, relatively few students initially took the course when it was first offered. [23] By 1890, the laboratory course became required for all students.[24] Titled, “Practical Bacteriology,” the intensive, four- hour laboratory class was offered five times a week for 12 weeks each semester to all first-year students.[25] The course was accompanied by a morning lecture in bacteriology. By the early 1890s at Michigan, bacteriology had assumed a dominating position in the second half of the first year of the student's curriculum—students were kept in class every afternoon, far beyond the time allotted, by the simple device of a quiz given at the end of the period.[26] By the early 1900s, bacteriology occupied a large portion of the curriculum at Michigan—384 hours.[27] This was almost twice as many hours more than other university-affiliated medical schools (Harvard, Pennsylvania, Columbia) during the same time period.[28]

The content of Novy's course in the 1890s is outlined in his two textbooks intended to accompany his laboratory course. In 1894, he published a 202-page text entitled *Directions for Laboratory Work in Bacteriology (for the use of the medical classes)*.[29] In 1899, Novy elaborated on his 1894 text and expanded it to a 563-page book called *Laboratory Work in Bacteriology*.[30] In each text, Novy emphasized both the cognitive as well as manual components of laboratory investigation. He highlighted critical thought and experimental design to test hypotheses, but he also stressed technical proficiency and proper use of laboratory instruments. Using classroom lectures to accompany his laboratory exercises, Novy patterned the structure of his course which combined principles and scientific theories with laboratory methodologies on the subjects he learned in Germany with Koch.[31] The content of Novy's course was derived from his duties in the sanitary laboratory and his independent research investigation. Regarding the former, students were trained in the methods of examination of air, soil, water, milk, and foods.[32] They were also taught how to count bacterial colonies and practices of sterilization and disinfection.

In his course, Novy first introduced students to the latest scientific techniques of the day. He familiarized students with the use of bacteriologic instruments including microscopes, solid culture plates, agar preparation, pipettes, incubators, sterilizers, animal inoculations, and some of his own innovative apparatus, including the Novy anaerobe jar. Novy then provided exercises to help students become familiar with laboratory techniques, including how to prepare and stain specimens, plate bacteria onto gelatin and potato agar plates, and incubate the plates using aerobic and anaerobic techniques.[33] He also taught students to prepare gelatin media, stain and culture microbes on agar plates, and inoculate guinea pigs with pure colonies.

In his course, Novy always encouraged active participation in learning. He worked to demystify the complex instruments in the laboratory and making them accessible to practitioners who would spend their time not in the laboratory, but at the bedside. Novy expressly omitted illustrations of the various microbes and of their cultural characteristics and provided an appropriate amount of blank pages for students to sketch from observation the form of each organism and the quality of their colonies on culture medium.[34] He taught how to perform postmortem examinations of guinea pigs in order to detect the presence of bacteria. Novy also included sections on the basic research techniques that he had personally developed, such as directions for cultivation of anaerobes, thus showing the relation between his course and the research investigation function of his hygienic laboratory. He taught students familiarity with the laboratory in order to make bacteriology relevant to their practice.

Once students demonstrated their capability in carrying out these techniques, they were then given the opportunity to think critically about determining the relationship of the microbes they had cultured to disease. They were provided unknown isolates and were asked how to determine whether the microbe was pathogenic or not, depending on whether they fulfilled Koch's postulates.[35] In the process, students were introduced to the rationale for a use of control in their experiments and the logic of experimental design to evaluate whether a microbe was a cause of disease.[36] Students were asked to identify pathogenic bacteria responsible for human diseases and taught how to differentiate the bacteria by morphological, cultural appearances from similar but harmless organisms.[37] They were taught how to identify microbes requiring special stains and agar, including tubercle bacilli. The content of Novy's course combined the cognitive with the technical aspects of bacteriology and laboratory experimentation. He taught technical proficiency of various instruments, how to recognize microbes, and the scientific method—the logic of experimental design epitomized by Koch's postulates.

Novy stated that among his major goals was to teach all students "the power to think and do," meaning experimental inquiry—the use of scientific methods, study design, use of controls, and active participation in the laboratory to test hypotheses--as a means of assessing and producing new knowledge.[38] For Novy, knowledge of the experimental laboratory methods gave students "power" to cancel or modify knowledge, rather than merely accept a fixed notion of knowledge in classrooms or recitation rooms. The value of laboratory courses to medical education was also later articulated by Abraham Flexner in 1910. Flexner stressed the importance of hands-on teaching in medical education—teaching all medical students the methods to solve problems, and to follow the logic of new medical information as it was reported in medical journals and later in medical texts.[39] John Dewey also recognized the importance of the hands-on teaching of critical thinking to students in a different arena—elementary education—as knowledge was not fixed but expanding and evolving, and young students would require this skill to adapt.[40] Thus, Novy's insistence on the process of embracing empiricism and laboratory experience as an avenue to obtaining new knowledge was consistent with those later articulated by Flexner and Dewey.

While emphasizing the scientific method, Novy also acknowledged the importance of the content of bacteriology. Teaching the principles, equipment, and techniques of bacteriology occupied much of his course. Novy believed the facts of bacteriology were useful to all students as a means of diagnosis for those diseases thought to be infectious in origin, for the successful performance of antiseptic operations, and for understanding of common hygienic measures for the prevention of communicable diseases.[41] For Novy's purposes, teaching the process of acquiring new information in the laboratory and teaching the specific content of bacteriology were not mutually exclusive.

Novy believed that the laboratory ought to play a critical role in medical education and in clinical medicine, and that all doctors needed to have scientific training and know the facts of bacteriology. But what evidence did he provide to show that all doctors should have scientific training? After all, medical practitioners, such as Charles Kuhlman, were concerned that the information laboratory scientists like Novy provided was irrelevant for practice. Novy never specifically addressed how understanding the laboratory methods he was teaching would help practitioners assess the validity of new information published in journals, or how doctors could use the methods or knowledge in their practices that Novy was teaching on a day to day basis. In the absence of being able to show this, the relevance of science to the practice of medicine was fair ground for dispute by Kuhlman or others.

Novy himself never contested the importance of clinical experience to medical education or to the practice of medicine. In fact, he paid considerable attention in his text and lectures to correlate his microbiologic findings with clinical information so that the two were complementary.[42] For Novy, it was not simply a matter of being in favor of laboratory medicine or clinical experience. He did not consider experimental design and method as incompatible with clinical medicine. He certainly embraced the ideals of laboratory medicine, but his was not an excessive belief in the laboratory at the expense of clinical experience.

Novy believed that bacteriology was only one of several laboratory-based scientific fields that were essential to include during their first year of education. Novy maintained that a particular cluster of scientific fields—anatomy, physiological chemistry, physiology, and pharmacology—were crucial to the first year curriculum.[43] Indeed, he had personally been involved in activities to support the accommodation of time-intensive, basic laboratory courses into the curriculum.[44] Novy, Vaughan, and others, in fact, advocated extending the length of medical school from three to four years.[45] As early as 1891, Novy and Vaughan campaigned at faculty meetings to make this extension.[46]

What was Novy's motivation to advocate for the placement of this group of laboratory-based courses, including bacteriology, in a dominant position in first-year medical education? As early as 1929 and throughout the 1930s, Novy would refer to this group of laboratory-based science courses as the "basic sciences".[47] In his writings in the 1890s and early 1900s, Novy wrote that by teaching this group of courses, instructors could instill a "spirit of research" in medicine or foster a "spirit of science" in all medical students. I will explore the broad meanings included in Novy's use of the term and how it went beyond teaching students critical thinking and the logic of scientific method that Ludmerer has addressed.[48] I will also address why Novy believed that fostering the "spirit" was of such crucial importance for medical students.

Spirit of Research in Medicine

In a speech delivered at the opening session of the Department of Medicine and Surgery on September 23, 1902, Novy outlined the meaning of the term "spirit of research" in medicine.[49] Novy had used the term in other venues, such as the preface to his 1899 textbook, where he used the term "spirit of science" in medicine.[50] Novy stated that "The spirit of scientific investigation, and not mere book reading, must be fostered in the student from the out start, since it is this that leads to progress in medicine and serves to distinguish the true physician from those bound down through blind faith, commercialism, or ignorance."[51]

In 1902, Novy taught the incoming first-year students that, to possess the spirit of science, one must first reject "blind faith" learning fostered by book reading and lecture courses that did not contain laboratories. Next, students must be motivated to search themselves for hidden truths in nature by performing disciplined, precise work in a laboratory. This work required more than adopting a rational scientific method. Novy insisted that this work be carried out diligently, and with persistence and plodding. He also warned students they must be able to endure criticism from traditionalists who resented questioning of authority. Finally, students must not be motivated by commercialism, a term he never precisely defined. By incorporating a code ethical conduct and disciplined habits, the spirit of science was more inclusive than training the mind alone. By teaching the mind, instilling disciplined habits, and imparting moral codes of behavior, Novy was molding the character of medical students to be citizens of a new culture and order that held above all else a freedom to think independently in their search for nature's truths.

Novy espoused that through laboratory-based science courses, students would learn the necessary facets of critical thinking—to doubt notions of fixed medical truths passed down in didactic lecture halls, to free themselves from blind faith in universal truths, and to think independently. Novy said that students must become involved in a "struggle for independence," for "emancipation from servile obedience to the writings of medical teachers."[52] Laboratory courses demanded that students actively participate in experimental inquiry in a laboratory setting—an "active process of searching for truths as they exist."[53] Through this process, Novy believed students would reside in a "republic of medicine…unfettered by dogma…by be(ing) bold to work with his own hands, the power to do work, and describe 'facts' as he found them through his experimentation."[54] All students who incorporated the spirit of research could become citizens in Novy's republic—a democratic regime that allowed all members the "power to work independently and to assess new scientific theories…to retain some and discard others."[55]Thus, through a disciplined process of doubt, critical thought and experimental inquiry, students would become worthy citizens of a new, rational culture of scientific medicine.

Novy asked all students to have faith in a science with fallible conceptions of knowledge and a tentative grasp of knowledge. Novy argued in 1902 that medical knowledge was in an evolutionary state and all medical students should be taught the logic and methodology to assess this knowledge as it grows and evolves.[56] Like Novy, Dewey's educational theories on acquiring knowledge in the elementary school, although in a different academic sphere, were also influenced by Dewey's recognition that knowledge is in flux.[57] Although there is no evidence about a direct intellectual collaboration between Novy and Dewey, they did know one another when Dewey was a faculty member at Michigan from 1884–1894. Dewey also held Novy's work in high regard, saying about Novy, "The lapse of many years since I was a colleague of his at the University of Michigan leaves the memories of former companionship undulled…I express my admiration of his personal qualities and his scientific and professional work."[58]

Novy asked students to believe in what they discovered through their own critical, rigorous assessment process, instead of "blindly" accepting what was told to them by their professor. With this charge, Novy deflated the idea of a medical professor as infallible. Furthermore, as Novy noted a "common bond that unite[d] teacher and student…the search for truth," he described a bond, a shared sense of purpose among like-minded but hierarchically dissimilar people.[59] Novy describes the common purpose not dispassionately, but emotively—as a "desire…a thirst, love, yearning…or zeal to unravel the mystery of life, seek the cause of things…[that] will expand the boundaries of knowledge and provide the means for prevention and cure." [60] Learned and intensely felt values about the usefulness of science in understanding nature and the harnessing of science for practical reasons structured the attitudes of Novy's students and teachers alike, and helped to deliver students from an older order--characterized by "blind faith" in fixed truths—to a new order where students had latitude to think independently and had the power to modify or cancel truths. Novy was the prophesizing a new religion that intended to have an ennobling, elevating influence on his “republic” not by teaching students fixed truths but by providing them with the tools to find truths in nature by themselves.

For Novy, instilling the spirit of science in students involved training the mind, providing a moral imperative, and disciplining daily habits. Novy taught students they have a “duty to doubt, to search for truths in nature; a determination to work hard, to produce something, and add to the common stock of knowledge” and need “courage to endure criticism.”[61] Novy also taught students they had “a noble motive to unravel the mystery of life ” and a “high purpose to think critically, work hard and describe things as you find them, not as they are supposed to be.”[62] By using the words “duty”, “noble motive”, and “high purpose”, Novy was conveying a sense of moral commitment to a disinterested search for truths in nature for the sake of pure knowledge. Novy’s commitment required action in the laboratory and he, in turn, asked all students to commit themselves to the cause he outlined without considering whatever self-interested courses of actions that may have been relevant previously--commercialism, or “blind faith” in didactic lectures. Novy insisted on disciplined hard work, determination, perseverance, plodding, accurate recording, and not rushing experimental results to press. In addition to warning students of sacrifice of immediate self-interest, he warned them not to be intimidated by ostracism and exclusion from traditionalists for questioning authority.[63]

Novy was intending to use laboratory science to do more than educate students, he was molding their character. He did more than discipline their minds with an intellectual regimen, he provided rules for moral conduct and insisted on disciplined daily habits of hard work. By regulating the behavior of students, Novy would mold them into noble men of science in a rational culture of medical science. Novy's goals of teaching laboratory science in medicine education are broader than Ludmerer had described for late 19th century medical educators in America. Ludmerer concentrated on researcher-educators teaching critical thinking and scientific methodology that was associated with learning by doing. Ludmerer did not address the intentions of medical educators to instill morals, habits, and an ethical conduct in students. Following the activities of an individual physician scientist such as Novy provides an additional dimension to the picture of the late 19th century researcher-educators that Ludmerer portrayed—to mold their characters as well as training their minds.

Novy's goal to mold the character of his students, however, was not new for late 19th century scientific education in America. His broad goals were similar to American chemists and physicists who were teaching laboratory science to their students. Owen Hannaway, for example, has shown how the goal of Ira Remsen, a late 19th century chemistry teacher at the Johns Hopkins University, was to build character of students.[64] In the late 1870s, Remsen sought to instill ethical values of an honest search for truth in nature, of the virtue of hard, thorough work, and of thoroughness and discipline in his students. In addition, Larry Owens has written on how the president of Johns Hopkins University, Daniel Gilman, viewed teaching laboratory science at Johns Hopkins in the 1870s not only to teach rigorous thinking but also to build students' character. Owens argued that the methods of instilling discipline of mind and habit provided a moral force within the modern university that served to prepare students for life.[65] Furthermore, H.A. Rowland, a late 19th century physics teacher at Johns Hopkins University, argued that American scientists ought to be motivated not by profit but by pure science to uncover truths in nature, and must have regulated, disciplined habits in the laboratory. [66] By disciplining students' minds, instilling a code of ethics, and instilling disciplined habits, Novy, like the chemist Remsen and the physicist Rowland, was building the character of medical students, had been doing in America. Thus, the broad nature of Novy's intentions of teaching laboratory science has precedence in scientific education in 19th century American universities, but it has not previously been recognized in medical education.

Novy's lecture on belief in the spirit of science as a means to expand knowledge was depicted in a religious framework. He taught students a system of belief—in the existence of "truths" in nature that could be apprehended through doubt coupled with the use of the scientific method.[67] Novy objected to "faith in words, blindness to reason and subservience to dogma" and rejected the idea of medical teachers as "high priests who hold keys to everything worth knowing" written in texts that contain "knowledge to perfection" and "truth itself."[68] He called for teachers to cease using "written words as a product of truth" and replace those words with "looking into the phenomenon of nature."[69] He said, historically, "spiritual truths that were learned by study of the *revealed* word and medical truths were sought for by studying what had been *revealed* in the writing of Hippocrates and Galen. Scriptures became *Bible* for all men, and works of Greek and Latin writers became the *Bible* for doctors."[70] Novy entreated students to have courage to oppose the "infallible" teachers and to "question authority or throw aside unless it be supported by demonstrable fact.[71] But Novy warned students that they must couple skepticism of blind faith with use of the scientific method and independent investigation; otherwise they were at risk of replacing one "dogma" with another.[72]

Here, Novy told students they should enter a medical profession dominated by a spirit composed of ideals and ethical codes, not by business concerns. Although Novy never defined what he meant by using the term "commercialism," there are several possibilities based on comments he made in his articles. Novy may have been referring to medical graduates mainly of proprietary schools whom he viewed as misguided because of their interest in seeking profit rather than truths in nature. In his other writings, Novy referred to the "worthless proprietary medical schools and medical sects" that produced "ignorant, immoral, and dangerous doctors" who were "swindlers" who prescribed "unverified nostrums" to "the unfortunate afflicted."[73] Novy's disdain for "average" doctors who earned their money by prescribing unproven, noxious agents to patients had been articulated by earlier 19th century elite doctors such as Oliver Wendell Holmes.[74] To Novy, a scientific approach, with its logic in thinking and rigor in method, which was absent in proprietary schools, provided a mechanism to verify its teaching and eliminate fraudulent, unscrupulous practices.[75] Novy may have been referring to the motivation of physicians to be professors for financial gain. For example, Novy stated that "proprietary medical schools were run by a group of doctors who cared as much about profits as medical education."[76] Finally, Novy may have been referring to researchers themselves who stood to make profits by commercializing their products. His silence regarding his own opportunities to commercialize products of his research, such as the chemical benzoyl acetyl with in vitro antiseptic properties, however, may not have meant he had a contempt for commercialism, but rather reflected his general preference to perform fundamental research rather than seek practical applications for his work.[77]

In 1902, Novy told his students that incorporating science in medical education was a potent factor in what would lead to the "upbuilding of medicine".[78] With the incorporation of the laboratory sciences—physiology, anatomy, pharmacology, physiological chemistry, and bacteriology—into the first year curriculum of university-affiliated regular schools, Novy said medical education would now be poised to eliminate "ignorance" of physicians and replace "superstitions" previously held by students who had "blind faith" in the words of their professors with "absolute facts" that could be verified through laboratory investigation and facility with the scientific method.[79] Novy believed that the once "disgraceful status of medical education" in the 1890s improved because of the "development of the medical sciences" in university-affiliated regular medical schools in the 1890s where full-time scientific-educator investigators could provide all students with a "rational and orderly method of understanding documentable realities within nature, accurate assessment of new medical knowledge, and legitimate therapies."[80]

The proliferation of the sciences in these university-affiliated regular schools, together with what Novy called "the exercise of the police laws of the state as reflected in the institution of licensing laws for physicians, led to the "extinction of undesirable medical colleges" including "proprietary schools and sectarian schools" where the "enterprising physician" and non-scientific teacher had perpetuated "ignorance" in medicine by "graduating illiterate and incompetent men."[81] Novy said "two forces that stemmed the tide of deterioration in medical education"—the introduction of basic sciences in the curriculum and the introduction of licensing laws for physicians—led to the "practical disappearance of worthless schools and old medical sects" and the "improvement in medical education."[82]

Thus, Novy had an evolutionary concept of medical education in America. He portrayed education as undergoing movement from the old apprentice system in colonial times, through the proprietary or didactic colleges and the to the university schools with scientific discipline as their cornerstone. Novy said, "Proprietary schools began to realize their inability to meet the increasing demands for better instruction in the basic sciences. They had to yield to the inexorable demands of progress and pass into oblivion."[83] By unifying medical education around science, Novy removed the understanding and treatment of diseases from non-regular physicians and regular physicians educated at proprietary medical schools, and placed that responsibility in the sphere of regulars at elite medical schools.

In addition, Novy was arguing that establishing science in a dominant position added a new dimension of rationality in medicine in the university-affiliated schools themselves. As he said, "the basic medical sciences were born in Europe, brought to this country and became the leaven which transformed medical education."[84] As bacteriology and the other laboratory-based medical sciences entered the curricula of what Novy called the "better medical schools..., the impact of these basic sciences on the old medical curriculum [in these schools] was irresistible."[85] As Novy said in 1935, "To provide instruction in these subjects meant the discard of the old didactic system…and the affiliation of the better schools by universities. The transplantation of medical sciences from Europe became complete, not only as regards to teaching, but also as regards productiveness through original research. It is no longer necessary to go abroad for fundamental medical training."[86] His comments on American education suggest a nationalistic pride, implying that through his efforts of himself and the efforts of others, the gap in science between America and Europe had dissipated and American students no longer needed to travel to Europe to study science. Referring to the incorporation of science in the medical curriculum, Novy said, "When America wakes up let Europe look to her laurels."[87]

The research agenda and changes in medical education curricula advocated by Novy and a small number of other American physicians served to advance medical school transformation. Michigan was a university-based medical school when Novy arrived, but his efforts with Vaughan bolstered the basic science facilities of the medical school and strengthened basic science as a foundation of medical education. In the late 19th century America when scientifically oriented medical institutions began to extend their basic science curriculums, smaller, proprietary medical institutions began to decline in number.[88] Consequently, American medical education transformed from one that occurred largely in proprietary institutions, to university-based centers with extensive basic-science facilities.[89] Didactic lessons added to laboratory instruction. Underlying these changes was the emerging ideal of medical education based upon experimental science, an ideal taken up by physicians such as Novy who had worked in the laboratories in Germany in the late 1880s, then returned to the States with a conviction that real research and learning took place only when students were active participants in the learning process.[90] This account of Novy's educational pursuits underscores how one academic leader in medicine embraced the ideal of learning by doing, critical thinking, and problem-solving, methods as John Dewey later advocated for use in elementary education.[91]

Novy's endeavors to make medical education scientific offered the promise of providing solid truths to a profession that was thought to be lacking in certainty and in need of reliable remedies. For these reasons, allopathic medicine occupied a lowly status in American culture in the late 19th century, allowing alternative systems of healing, including home therapies and eclectic practices to flourish.[92] The curriculum reform resulting from strengthening the basic sciences in American medical schools in the 1890s, together with efforts to educate post-graduate practitioners, lent a degree of respectability to a medical profession that was lacking prestige and authority at that time.[93]

There is an alternate way of looking at Novy's elevation of allopathic doctors to men of science who are beyond criticism or regulation. Laboratory science could be seen as a vehicle by which allopathic medicine achieved domination over its competitors—eclecticism, homeopathy, and the smaller, proprietary allopathic medical schools. The latter had proliferated and competed with the regular physicians, who in the mid-19th century could not claim to have any uniquely effective methods or special body of knowledge. But for the regulars, a special body of knowledge, laboratory science, became available in the late 19th century by elite doctors who returned from Europe after acquiring their special knowledge. Smaller, poorer proprietary schools or sectarian schools did not have this special body of knowledge, and could no longer compete with the larger, university-affiliated, scientifically based schools like Michigan, especially after they were unable to obtain Carnegie Corporation grants after the Flexner Ratings.[94]

When viewed in this way, Novy's efforts to incorporate science in medicine could be seen as hegemonistic and diminish competition from schools that could accommodate students other than white, middle-class men.

Novy attempted to teach critical thinking and laboratory training to postgraduates, as he believed this approach should be a lifelong process. He wrote articles aimed to instruct busy practitioners in the methodology of bacteriology.[95] He acknowledged that the new techniques of microscopes, stains, slides and incubators intimidated these practitioners. Novy wrote that knowledge of these techniques were invaluable to the practitioner for purposes of making an accurate diagnosis.[96] Novy believed practitioners were deterred from learning the new bacteriology because they thought the equipment was too expensive, they lacked the proper facility, they did not have sufficient training in science to understand how to perform the testing, and it simply took too much time to learn. Novy countered these concerns by maintaining that the core equipment was relatively inexpensive, that the set-up would occupy a small space in the office, and that the hours committed to study could be minimal.[97] Thus, in comparison with the microbiology course that he taught to medical students, Novy simplified and demystified the microbiological techniques he authored for the busy practitioner. Notwithstanding Novy's efforts, it remains speculative what impact these articles had on practitioners or whether any attempted to set up a small microbiology testing lab in their offices.

By emphasizing the relevance of bacteriology for all students, Novy's educational efforts suggest how his course may have differed from that of his European colleagues. In one sense, it could be argued that Novy's course was more egalitarian than his European colleagues. By offering his course to all medical students and making bacteriology relevant to clinical practice, Novy made his science more democratic, and perhaps more ‘American’ than his German professors, who restricted training in their laboratories for the most skilled students who were interested in becoming medical researchers themselves. Bacteriology courses were not taught in German medical schools in the late 19th century.[98] At that time, bacteriology was taught at a separate institute devoted to the discipline, to which one need apply and express a desire to perform medical research in order to enroll.[99] In contrast, the vast majority of the students who enrolled in Novy’s class did not aspire to academic research, but were to enter private practice.

Despite the fact that Novy stressed the clinical relevance of his bacteriology course, his emphasis on laboratory training still contrasted with courses given by most other Michigan medical school faculty at the time. Many of these faculty members had trained at schools where students were taught by didactic lectures based on clinical experience.[100] Novy did not advocate rejecting these formerly-employed teaching practices, and he never denied that they could be or ever had been of service.[101] He simply felt that didactic lectures delivered in auditoriums needed to be accompanied by hands-on laboratory experience.[102]

Novy’s intentions to teach medical students bacteriology and its techniques remained medically controversial at the University. Not every Michigan faculty member was supportive of Novy’s efforts to introduce bacteriology into the research agenda and medical school curricula. Dr. Heneage Gibbes, professor of pathology, was one faculty member who was troubled by the thought of Novy returning to Ann Arbor after studying in Koch’s laboratory. Gibbes was an opponent of the germ theory and voiced concerns about Novy using his experience abroad to develop a new course.[103] Gibbes began to plot strategies on how to eliminate Novy's course from the curriculum, and decided to team with H. L. Obetz, dean of the homeopathic school, to do so. The Homeopathic Medical College was established at the University of Michigan in 1875 as a result of the petitioning of the state legislature by practitioners of homeopathy in the state.[104] The legislature provided funds for two chairs in the homeopathic school and the school itself, which was separate from the medical school. But the relation between the two schools was always strained, with objection from the medical school over the state supported funding for the homeopathic school and chairs.[105] Obetz had been considering a strategy to amalgamate the two departments, perhaps in an effort to ward off any attempt by the allopathic physicians at Michigan to abolish the department of homeopathy.[106]

Gibbs and Obetz suggested a plan to the Board of Regents in 1895 to eliminate Novy's position—junior professor of hygiene and physiological chemistry.[107] This petition had followed Novy's introduction of germ theory to the curriculum. The plan included a merging of the two medical schools (allopathic and homeopathic), with the justification that it would reduce salaries and staff from the department of medicine and surgery.[108] But Dr. Herman Kiefer, chairman of the medical committee and a regent of the University was not in agreement with the reorganization plan. Kiefer argued that the proposals reduced not costs but the quality of the medical and educational scientific research programs.[109] Keifer argued that "our professors should be educated scientific physicians and teachers just as our officials should be honest American citizens," and he made a counter-motion to abolish Gibbes' pathology position.[110] After some consideration, a new professor of pathology was appointed, and Kiefer successfully lobbied to maintain Novy's position.[111] The two schools remained separate, and the chair of pathology at Michigan was temporarily abolished in 1895 and the department was placed in charge of George Dock, professor of medicine.[112]

Novy's appeal for the integration of laboratory science in medical education and instilling the ideals of science in medical students are fictionalized in *Arrowsmith*. Novy's contempt for didacticism is evident in the book's comment on Martin, "In the study of the profession to which he had looked forward to all his life, he saw no clear path to Truth but a thousand paths to a thousand truths far-off and doubtful."[113] Novy's disdain for commercialism and his need for an ideal in medicine are reflected in Martin's comments towards his fellow medical students, "These darn students, they aren't trying to learn science; they're simply learning a trade. They just want to get the knowledge that'll enable them to cash in. They don't talk about saving lives but about losing cases—losing dollars…It's dreadful the way people don't have ideals about their work."[114] Martin regards the Gottlieb ideal as a means to rectify the need to verify medical teaching and to counter commercialism in medicine. About Gottlieb, Martin said, "I do know what a man like Max Gottlieb means. He's got the right method, and all these other hams of profs, they're simply witch doctors. [Gottlieb's] just being in a lab is a prayer…you [classmates] are the kind that keep medicine nothing but guess-work diagnosis, and here you have [Gottlieb]….Do you see where [Gottlieb] leaves all these detail-grubbing doctors buzzing in the manure heap, just as much as he does the commercial docs."[115]

Novy's insistence on careful methodology and meticulous technique in the laboratory is also evident in *Arrowsmith*. For example, Martin says of Gottlieb, "He had fingers of a pianist above the keys… [Gottlieb taught] technique is the beginning of all science, the least known thing in science."[116] Novy's emphasis on the use of logical scientific method is also reflected in Martin's comment of Gottlieb, "When a physician boasted of his successes with this drug or that electric cabinet, Gottlieb always snorted, "Where was your control? How many cases did you have under identical conditions?"[117]

Novy's portrayal of laboratory science as having an uplifting power to reformulate and create new knowledge through its active inquiry into unknowns is evident in *Arrowsmith*. Gottlieb advises Martin, "Observe what you observe, and if it does violence to all the nice correct views of science—out they go!..find out the Why, the underneath principle."[118] With Gottlieb's advice in mind and heart, Martin is disposed toward the laboratory to fight his way to a higher level of existence; Lewis writes, "If Martin had given up Gottlieb-worship and his *yearning* for the laboratory as his sanctuary, if he had resolved to be a practical and wealth-mastering doctor, yet something of Gottlieb's spirit remained. He wanted to look behind details and impressive-sounding lists of technical terms for the causes of things, for general rules which might reduce the chaos of disorder and contradictory symptoms to the orderliness of chemistry."[119] The novel becomes a romantic quest for Martin to fulfill his inclination toward "the thrill of uncharted discoveries, the quest below the surface and beyond the moment, the search for fundamental laws which the scientist…exalts above temporary healing as the religious exalts the nature and terrible glory of God above pleasant daily virtues"[120]

Conclusion

In his bacteriology course, Novy tried to convince students to share his belief in the utility of laboratory-based science in their careers—whether that was practice or independent investigation. As an expert in bacteriology, Novy was armed with special knowledge and technique, and he ventured to instruct his students in the mysteries of his specialized instruments, methods, and technical language of his field. His instruction enabled students to apprehend the particular facts of bacteriology, which he believed were relevant to clinical practice. But he also provided students with the tools to understand the methods of science. In his course, he instilled critical thinking as he believed his students would need an understanding of the logic of science to assess new information produced in journals and texts. In his laboratory-based microbiology course; questions of methodology and experiment became as important as the content of a course.

Historians writing on medical education in the late 19^{th} century have emphasized aspects of teaching critical thinking and scientific methodology to students. Kenneth Ludmerer, Thomas Bonner, and Edward Rothstein have focused on the changing pedagogical style of teaching during this period whereby the role of the student changed from that of a passive observer to active participant in the learning process. These historians maintained that the emphasis of teacher-investigators was on instilling techniques of acquiring and evaluating information rather than providing facts. Professors taught experimental methods, use of rigorous controls, and skills that would enable their students to assess new knowledge as it was produced. These historians have characterized medical education during this period as a progressive one that was meant to allow students to take responsibility for their own medical education.

Novy's educational activities add another dimension to portrayal of medical education of this period by historians like Ludmerer, Bonner, and Rothstein. By teaching laboratory-based courses that included bacteriology, Novy maintained that the investigator-educator should impart a "spirit of science" in all first year medical students.

To Novy, this “spirit” was broader than training the agility of students’ minds in scientific methodology and content—it was designed to mold their character and regulate their behavior according to shared beliefs, disciplined habits and a moral code. Students were taught they had a duty to perform “pure” research that was motivated by a desire to find hidden truths in nature, not for practical application or for commercial gain. Students were also instructed in the virtue of precise, thorough, hard work. Novy felt that by fostering a spirit of science, students would be delivered from “ignorance and commercialism” and become worthy citizens in a new order, a rational “republic” where they could carry out experimental inquiry in a laboratory setting.

Although Novy’s broad educational goals have not been described in the context of late 19th century medical education, similar goals had been laid out by science professors outside of the medical setting during this period. Ira Remsen, professor of chemistry at Johns Hopkins University, taught his students an anti-commercialist, pure science ideal and he sought to mold the moral character of his students in order to prepare them for their duties as citizens of science. Similarly, H.A.Rowland, professor of physics at Johns Hopkins in the 1880s, taught the morals of the pure science ideal and also encouraged promising students to choose a career in science rather than one in which they would obtain commercial gain. Thus, Novy’s broad educational message that included a moral imperative as well as an intention to teach mental discipline, although not previously described in the context of medical education, was not new in late 19th century American science.

Through the integration of laboratory-based courses in medical education, Novy believed that an older order in which students deferentially received fixed knowledge through “blind faith” in a lecture hall would be replaced with a new order. In this new order, Novy’s students including de Kruif and the fictional character Martin Arrowsmith he created with Sinclair Lewis, would independently participate in a laboratory ritual that would provide them with the “power” to cancel and modify knowledge. His students had independence and freedom of experimental inquiry, they were not bound to perform experiments whose purpose was the display of an old order or law. The autonomous student who was free to choose topics of investigation and conduct of their experiments resembled the German ideal of scientific research.

But Novy’s version of the “scientific spirit” was more democratic than the German ideal, as Novy aimed to teach independent thinking to all medical students, not only the talented few who were destined for a research career. He intended to provide all students with more than the methodology they would need to search for solid truths in nature; he also wanted to instill in them the discipline they would need to do so. By training the minds and molding the character of all students, Novy believed that the addition of laboratory-based science courses would simultaneously elevate the quality of medical instruction, medicine in general, and would uplift the character of all students.

Novy believed that his efforts towards making medical education scientific made higher standards feasible for medical education and medicine in general. He intended to accomplish this through his participation in educational reforms to raise the caliber of students admitted and extend the basic science curriculum to impart hands on-experience and critical thinking to all medical students. He believed that teaching such methodology was important to all physicians. In the next chapter, I will explore how a group of Novy’s students, including those who were practitioners, received his intentions and goals to train their minds in scientific method and instill in them the “spirit of science”.

CHAPTER 5

Experience of Students

Introduction: Throughout his long career at the University of Michigan, Novy had extensive contact with medical students and aspiring researchers in his laboratory. In the previous chapter, we reviewed Novy's stated goals in teaching: to foster a "spirit of science" in all students regardless of whether they were to become practitioners or independent investigators. But how did students and researchers receive Novy's intentions? What did students think important about what they learned from Novy? How did they see Novy's ideas as having influenced them? What meanings did they attribute to Novy's work, and how do their perceptions of Novy compare with Novy's own stated goals?

Historians who have written on the introduction of laboratory science in medical education in the late 19th and early 20th century have not included the experience of students who took courses in bacteriology, anatomy, physiology, or pharmacology. Consequently, these historians have been unable to provide information about how students during this historic period viewed learning about laboratory science. Did those destined to become practitioners view laboratory science courses as a positive experience, and, if so, which aspects of their experience, their professor, or both did they value highly? In this chapter, I will attempt to address these questions. Specifically, I will examine the experience of Novy's students and the researchers he trained by exploring the notes and letters they wrote to Novy later in his life. Many of Novy's students wrote to him about their experience in his classroom and laboratory course. The students elaborated on the ways in which they saw his ideas influence them throughout their careers, as practitioners or as medical researchers. There is an inherent selection bias in this method, as the letter-writing students represent a self-selecting sample of the total population of students who took Novy's courses. Because the voices of students who did not write to him cannot be included, this chapter will not claim to portray a complete picture of Novy's students' experience as a whole. Nonetheless, one can employ the letters to explore how this group viewed Novy's instruction overall, and his emphasis on the "spirit" and principles of basic science in particular. I will ask what Novy represented to these students, then explore why they may have valued him so acutely.

The student experience

In addition to making bacteriology relevant for students who were headed for private practice, Novy also became a leader of a new breed of physicians—academic medical researchers who did not practice medicine. In this section, I will evaluate the experience of both students who chose a career of practice and those who eventually obtained one of a growing number of positions in academic medicine. Many former medical students wrote to Novy about what he and his teaching of bacteriology meant to them as a student and then as a practitioner or researcher. I have chosen letters from students which I felt best encapsulated the sentiments expressed by the group of similar, archived letters from Novy's students. In all, there are letters from 117 students to Novy written from 1909 to 1931; forty-six of the letters came from researchers and 71 were from practitioners. Thus, the 117 archived letters represent a fraction of the total number of students who took Novy's mandatory course (estimate 2,321 students based on the number of graduating students during this period). The majority of letters were written in 1929 to Novy by request from Novy's former student, Malcolm Soule, and presented to Novy on the occasion of his 65th birthday. The voices of the students address the ideal of science that Novy represented to them, and they articulate the meanings of this ideal to them throughout their careers—either as a practitioner or as a researcher.

The idealization of Novy and laboratory science in medicine

In the early 20th century there were few therapies available to clinicians as the result of bacteriological research (e.g., diphtheria anti-toxin and serum, anti-tetanus serum, antiseptic surgery). They were not likely to have been applicable to the bulk of routine illnesses that a practicing physician encountered on a day-to-day basis. The tools Novy offered practitioners probably did not substantially change the way they practiced medicine. However, these practitioners were willing to embrace what Novy symbolized for them—the use of laboratory methods to search for pure truths in nature.

During this period, David Sugar was one such practitioner who assimilated the ideal of laboratory medicine that Novy represented to him. A former student of Novy and a medical practitioner in Detroit, Sugar wrote his recollections about Novy in the *Detroit Medical News*:

> Every medical student seeks the man who symbolizes his dream of a scientist and teacher. To us, Novy was that realization…he is the servant of truth. His love of truth dominates…his life in the laboratory. A dreamer who did things, a teacher

> with the divine spark...A teaching Novy. A research Novy. An idealist, an exemplification of the nobility of ideals. And human. The greatest dramatic presentation we saw was not on the stage. The greatest sermon we heard was not from the pulpit…All these were one in Novy's lecture. If greatness be measured in terms of medical teaching, Novy was the greatest teacher we had. With reverence in his voice, with the zeal of a religious leader, Novy taught about his science to thousands of students the world over. His work flames on and on. His is the fire eternal of science in medicine…Never since have we been pervaded with idealism such as emanated from and surrounded that man...In the laboratory, Novy taught us humility—He taught us technique. And he preached, the truth, the truth.[1]

Sugar had faith that Novy's use of specialized methods and refined techniques would lead to underlying truths in nature. For Sugar, these truths need not have utility, as Sugar did not mention prevention, cures or practical results. For Sugar, a search for truths in and by itself was the scientific ideal that Novy symbolized. Sugar had faith that the pure search for truth itself, conducted with the zeal of a skillful scientist like Novy, was noble. Sugar also acknowledged that Novy's contribution was accomplished by "doing" work in a laboratory setting.

Lewis Knapp, a practitioner from Monroe Michigan and a former student of Novy, wrote to Novy about the potential of laboratory science to benefit humanity. Knapp wrote,

> I want to extend to you my sincerest congratulation on your achievements in the realm of science and medicine. The results of your labors have been far reaching in striving towards mitigating the ills of mankind. Your untiring and unselfish devotion to science and your students; your critical approach and your indomitable will in surmounting all obstacles to work on discovering the causes of so many ills that have afflicted mankind has rightly won for you the honored recognition of being one of the greatest bacteriologists, professors in our medical profession, and benefactors of humanity.[2]

Knapp wrote that Novy's science discovered the causes of disease, but he does not mention cures. As Knapp's discourse on "mitigating" ills and being a "benefactor" of humanity does not explicitly denote prevention or cures, he may simply have been referring to the ability of laboratory science to allow physicians to provide more accurate prognoses or perhaps to the physician's supportive sympathetic role.

A letter from Thomas Cooley, a practicing surgeon and former student of Novy's, addresses the meaning of Novy's ideal of science to him in practice. Cooley wrote the following about his experience:

> I admired you as a teacher, as did all of my classmates. No man in the University has made a more lasting impression upon his students, or is held in greater reverence. The debt we owe to the masters at whose feet it has been our fortune to sit is not the bare facts they have taught us; but by the impression made upon us by their example of high ideals of science. The influence of the great schools has always come more from the degree to which their students have absorbed such ideals and exemplified them in

the communities where they have lived and practiced than from any mere academic influence. There is none to whom we owe more for the inspiration we have had for high aims and honest effort than to you yourself. You are not eternal, but your teachings are for they are carried over the whole world by your students and their students who gained faith that your science was our only salvation to find truths. I measure your age by your original contributions and the disciples whom you have created."[3]

Cooley was eager to embrace Novy as the ideal of science as an avenue to discover truths in and by themselves, not necessarily because of practical applications.

The letters from all three students show that the values that Novy instilled in them were important in creating an ideal to emulate, as they became practitioners of medicine. The students had faith in the ideal he embodied: a life devoted to the search for underlying truths that would benefit mankind—simply because they were true. In conjunction with the pursuit of this ideal, Novy helped to create a role for laboratory science in medical education and, ultimately, medical practice. As will be discussed below, all three letters use words such as sermon, pulpit, zeal, eternal ideals, faith, and disciples that project Novy as the prophet of a new religion: a religion of science that was based on finding not revealed truths, but truths in nature. They suggest that even supposedly "practical-minded" clinical practitioners could share the appeal of "pure" knowledge, that truth was holy and that Novy had made them disciples of a True Faith.[4]

I cannot exclude the possibility that some practitioners may indeed have based their enthusiasm for laboratory methods on a faith it would produce practical therapies for diseases. For example, Charles Georg, a practitioner in Monroe, Michigan, may have been referring to this when he said to Novy, "Your work…has added to human knowledge in ways which have led to the alleviation of human suffering."[5] Georg certainly had faith that Novy, and other specially-trained leaders of scientific disciplines in possession of refined techniques, would provide knowledge to alleviate suffering. But Georg may not have meant that this knowledge would necessarily translate into providing more therapies than what was already available to him. He may have meant that knowledge in itself may have provided information that would be useful for purposes of prognosis.

One practitioner, John Dodson addressed his view on the influences Novy had on medical education. Dodson believed that Novy's efforts helped to contribute to an advance in the standards and methods of medical education in the U.S. Of this advance, Dodson wrote:

> [It had] beginnings in the late 1880s at the time when Novy, entered upon his career as a teacher of one of the fundamental medical sciences in the Medical Department. It was realized that in a science fundamental to medicine, effective training and instruction of students could be given only by one who was devoting his attention exclusively to research and teaching in his chosen branch… The purpose of the medical curriculum is not merely to supply information to the student, but to develop and train his faculties to the end that he become a keen, exact observer of medical phenomena within the laboratory…The most potent methods is the investigator who is seeking knowledge of the unknown as pursued, first, in the laboratories of the fundamental sciences of chemistry, anatomy and

> bacteriology, and later in the clinical branches. The most conspicuous of the recent advances in medical pedagogy has been the substitution, for the older methods of empiricism and the rule of thumb, of the plan of first hand observation of facts by the student and the development of his powers of independent thinking. To this kind of medical instruction the science of bacteriology lends itself especially well. Doctor Novy, one of the outstanding investigators and teachers in this field, was one of the pioneers in bringing about these changes in the methods of medical education and has been an important contributor to their wonderful development.[6]

Dodson's letter illustrates the ways in which Novy's activities and methodologies in public health, research investigation and education coincided with and reflected the dominant beliefs and objectives of the Progressive period in early 20th century America. It underscores the crucial role that educators such as Novy played in the progressive transformation of American medical education—to teach not just facts, but the value of independent thinking to all students.

Practitioners wrote that they admired Novy's intentions, which they considered as selfless. Fred Taylor, a practitioner in Michigan, wrote to Novy that he admired Novy's "virtue" which he described as a "motivation…singularly free from the economic or mercenary element…In a period when the scientist is tempted to sell his birthright for a mess of pottage—I have thought of you as one to whom this particular temptation makes no appeal…You have been responsive to those motives which best befit the scholar, namely: an insatiable appetite to seek the truth and teach it, and a pride in maintaining the highest standards of workmanship."[7] Taylor is likely alluding to the fact that Novy did not seek profit from his discoveries during a period of commercialization of scientific products for medical purposes. Taylor's perceptions of Novy—a yearning for truth and not commercialism—match Novy's own stated goals. By referring to Novy's qualities as "virtues," Taylor was writing about Novy in a moral framework.

The letters that articulate an emulation of Novy's scientific ideal as a motivation for students to gravitate toward his teachings do not dismiss a more self-interested motive for a young practicing physician's acceptance of Novy's teachings. Their motivations were likely more complex than those linked to the ideal of scientific medicine alone. For example, they may have felt that scientific training would provide them with skills that the older generation of practitioners did not possess, possibly giving them an advantage in competition for patients. Possessing novel and potent approaches to patient care may have, in fact, provided a competitive advantage in what was an unregulated and competitive marketplace for patients among established practitioners and alternative healers. Regardless of these considerations, the letters do provide a different angle of vision regarding why the students were attracted to Novy's science.

Some students who then became medical researchers also reflected on their experience and felt compelled to express what Novy meant to them. Such was the case with the practitioners, Novy represented an ideal that the researchers emulated—a search for truths in nature. Earl McKinley was a former student who emulated these research ideals and articulated them to Novy on his 65th birthday. McKinley, who became a medical researcher at the San Juan School of Tropical Medicine, Puerto Rico, wrote to Novy on June 26, 1929:

The first day I entered your class as a student I well remember autoclaving culture media until midnight that day. I thought that was one of the hardest days' work I had ever done…After working under you I later learned that is such a thing as working for the love of pure scientific investigation and that it was this spirit, inculcated by you into all the members of the department, which accounted for the brilliantly lighted laboratories until the small hours of the night. Later some of your old students were to experience the discipline of the army during the world war…None of us thought very much of army discipline after our experience on the second floor of the old medical building. But there was a distinct difference. The discipline we had been schooled in had taught us to do the thing right for the sake of the thing—not because of rules, restrictions on topics of investigation, and regulations. In fact we had few of these. I can't recall any except to…be skeptical…think critically and do the experiments promptly, accurately, efficiently, honestly and well. A word of reproof from you was enough to cause any of us to shake in our boots and one of my happiest memories is that I never received such a word from you although I know that many times I deserved it. To us you were 'the chief' and in the background there was always a spirit throughout the department of loyalty, esteem, affection and an intense desire 'to do the thing right. Because of this spirit you always supported us to choose and pursue research questions that most intrigued us. All of the staff knew this and we always felt we had a friend in the little cloister off the main laboratory…Time passed, and the students are now scattered in different parts of the world. We all carried away with us a series of fundamental scientific lessons you had selflessly

> given us. We had intensive training in pure bacteriology and physiological chemistry, minute and careful instruction in technique and method, we had been taught a genuine humiliation toward fundamental science, a love of it for its own sake, and some of us had gained even more from you—an encouragement, inspiration and aspiration to continue in the field and make seeking truths our life's work. …Once independent and on our way we felt honor bound to make a mark of an original contribution to deserve your confidence. These are a very inadequate expression of what you mean to us can be placed in words. But there are things which cannot be expressed in language, things which can only be felt. All your students feel these things."[8]

McKinley acknowledges the "spirit" of science that Novy "inculcated" in his students, a perception that matches Novy's own stated goals. Like the practitioners, McKinley held Novy as the ideal of a scientist, and he had faith in performing "pure" science for its own sake—finding truths in nature without necessarily thinking of its practical value. McKinley also elaborated on the broader meanings of the spirit similar to those Novy had included in his teachings, including Novy's efforts to mold character by establishing ethical codes and disciplined work habits. McKinley noted the value in doubting, thinking critically, and using orderly, specialized methods and techniques to apprehend occult truths in nature. His quote also reveals the self-sacrificing discipline of hard work and obedience to laboratory procedures, sometimes required all night work necessary to carry out scientific investigation. Furthermore, a bond between Novy and his aspiring students was felt, it was forged by a shared duty of a disinterested search for truth through rigorous laboratory procedures and long, hard hours of work. McKinley did not work in the laboratory because he was told to; he joined because he was inspired to become a participant in a community of expert evaluators who promoted above all else, inquiry and professional methods. Novy provided the guidance and the freedom for these investigators to become “independent” and to make “original” contributions in bacteriology—ones that focused on the discovery of the fundamental behavior of organisms and not necessarily the control of the pathogen—and shape the boundaries of knowledge. And Novy was present to provide this guidance; he was not distracted by personal fame or material reward.[9]

McKinley’s account shows that Novy instilled in his students a reverence for original investigation and skepticism for the received teachings of the traditional medical environment. His insistence on the laboratory as a source of new knowledge served as a source of inspiration for students like McKinley. Novy’s brand of science also served as a basis for their identity and for their work. The established reverence for original investigation allowed Novy to create an environment in which he could find achievement within his own specialty. He was on top of a rising group of technocrats like McKinley who represented a new order, based on its own terms and its own logic. This was one way that researchers such as Novy helped to establish disciplines such as bacteriology—through the creation of a group of scholars and academic entrepreneurs, enthusiastic in their motivation and confident in their special knowledge and technical expertise.[10] [Figure 5.1 A-C] As discussed in chapter six, the cultivation of a group of adherents also enabled scientists like Novy to establish bacteriology as a discipline of medical science.


Figure 5.1 A

Figure 5.1 B

Figure 5.1 C

Figures 5.1 A-C. Novy in group photos with his laboratory workers. The three pictures from separate times show Novy surrounded by a cadre students in his laboratory.

Figure 5.1 A. Novy posing outside his laboratory building with his laboratory staff in 1916. His students from Left to right are: Paul De Kruif, Charles Behrens, George Hermann, and an unknown. The scholars went on to become academic entrepreneurs of their own; de Kruif became a medical writer; Behrens became a Professor of Microbiology at the University of Illinois, and Hermann a Professor of Microbiology at Tulane University.

Figure 5.1 B. Members of Novy's Laboratory shown standing in an undated photograph; the names of the students are not given in this photo. As in figure A, the students expressions and posture show their pride to be associated with Novy and their confidence in the special knowledge and expertise they have gained by their experience.

Figure 5.1 C. Members of Novy laboratory, 1917. This is the only picture showing women in his laboratory. In Novy's papers, there is no mention of graduate students who trained with him. Nor are there letters addressed from Novy to women training in bacteriology. However, there were three women in medical school in 1917; it is possible that the photo included female medical students, or female laboratory technicians.

At the time Novy was operating, bacteriologic tools were just beginning to be defined and revised, and Novy was at the forefront of this movement. At this moment, McKinley's letter shows there was an excitement surrounding the promise of studying with a master technician who had the expertise to use these specialized tools and to devise new methods to find truths that would ultimately benefit mankind. There was a sense of passion and thrill that surrounded studying with whom his students referred to as "the chief" or "master."[11] [Figure 5.2 A-B] His students had faith in the progress of science to explore unsolved problems and they believed that Novy was the one to provide the methods and tools to guide them. McKinley and others objected to what they perceived as the traditional passive learning of medical knowledge by rote.

Figure 5.2 A


Figure 5.2 B

Figure 5.2 A & B. Novy the master scientist and mentor as he appeared to students training under him as they sought his scientific advice. Novy is sitting in his office adjacent to his laboratory. This is how he appeared to students who approached him after their experiments to review their work with him. This is also the office where Novy wrote and edited his manuscripts by hand.

Figure 5.2 A, Novy's pose with legs crossed and raised chin makes him appear austere, strict, and perhaps formidable to a student seeking his advice. His imposing posture may have intimidated students and coaxed them to make sure they had done their work as diligently as possible before approaching him.

Figure 5.2 B. But a different shot at the same moment gives a different impression. This pose is more informal, and Novy's more relaxed posture an widespread hands makes him appear as if he is welcoming a laboratory worker in need of assistance or advice. Students, in fact, described Novy's demeanor as solemn, but also kind as well. (Courtesy of Bentley Historical Library)

Other student researchers wrote to Novy about their perceptions of the spirit of research and how Novy embodied the ideal of scientific investigation to them. One such student, Charles Behrens, from Tulane University, wrote to Novy

> "You follow great principles, e.g.., that doubt and not faith is the beginning of wisdom in science; that skeptical judgment helps to reach the truth; that the fundamental requisite of scientific observation is accuracy…Here…lies the secret of your influence; under the guidance of these principles you have produced work that lives on because it is helpful to other investigators, helpful in hypotheses, in methods, selection of controls, and in observations…I regard you as the master scientist."[12]

To Behrens, Novy represented a force capable of replacing the passive reception of knowledge delivered in lecture halls with a culture of critical thinking and empirical testing of hypothesis in the laboratory. Students like Behrens and McKinley had faith that science remained the ideal vehicle for promoting critical inquiry, expert methods and accuracy. They believed that Novy "influenced" their work by providing them with guidance in critical thinking (creating hypotheses), technique (methods and observations) and in stressing "accuracy". Novy's work "lived on" in the independent investigations of other scientists, who in turn sought to establish valid truths of their own in medicine. Through this process, his students embraced the attributes of a biomedical culture that Novy symbolized to them—adventure, rational thinking, and objective methods.

McKinley and Behrens elaborated on the Novy ideal. But why was this consideration so important for Novy and for his students? For his students and for himself, freedom from the constraint of utility was a pivotal issue in Novy's experimental motives. He operated under the principle that the most creative and possibly even the most important discoveries in science come from experiments whose guiding principle is not utility, but rather from investigations of science for its own sake. Ultimately, the products of these experiments could have practical application, as a scientist cannot foresee what may be someday the practical application of laboratory discoveries, no matter how remote from practical utility they may seem at the time of experimentation. But for Novy and his students, the application should not be part of the experimental design, and should be considered only after the results as any *a priori* considerations of practicalities could only constrain the scientific experimental design.

Novy was successful in cultivating students like McKinley and Behrens into biomedicine, where Novy fostered the scientific spirit and gave his students the right amount of guidance to master science's rigorous methods. Novy fully supported junior researchers, and his relish for investigating new hypotheses and the encouragement he gave to his researchers provided the structure and independence for them to carry on their own work and relate their work to others. His reputation and his willingness to give student researchers latitude to pursue their own work attracted promising students to his laboratory. As McKinley's notes indicate, there were no rules in Novy's lab other than to do the experiments properly. McKinley approved of the way his mentor nurtured students—by picking talented students and giving them the freedom and resources to work in their own way.[13] To sustain independent students, Novy provided a permissive environment in his laboratory. He did not require a common theme for research topics, but he gave his students critical advice, sometimes harshly, when indicated. Novy's laboratory had an atmosphere of freedom, which McKinley contrasted to the military. Perhaps this permissive environment accounted for the broad range of research projects carried out in Novy's laboratory, which lacked a unifying theme [see chapter 1].

Students such as McKinley sought Novy's intellectual guidance, but his recommendations for what his researchers should pursue were not highly structured. Students investigated a range of topics including variability of disease, chemical metabolism of microbes, the dynamic behavior of organisms over time, and host responses including immunity.[14] A community of science supporters coalesced around his laboratory-based version of scientific medicine, with a balanced emphasis on instruction of scientific methodology on one hand, and license to pursue topics of their choosing on the other. In this atmosphere, students were provided the necessary tools to forge independence in their respective careers. Consequently, over time, Novy's activities consolidated the support of followers of scientific medicine. Novy's broad range of activities did not lead his students to evaporate; they condensed around him as they went on to perform independent research in his department or their own institutions.

One student, Paul de Kruif, used his experience to collaborate with Sinclair Lewis to write a fictional work about what Novy symbolized to his students.[15] In de Kruif's memoir, *The Sweeping Wind*, he wrote how he patterned Gottlieb after Novy.[16] de Kruif recalled how he was inspired by Novy, whom he called his "microbe-hunter, truth-seeker master…[my] austere, growling, kindly chief…[who]…didn't allow the littlest of lies in his simple spirit of science."[17] de Kruif's sentiments towards Novy are evident in Martin's views towards Gottlieb in *Arrowsmith*. In that novel, Martin described the "tyrannical honesty of Gottliebism, from the unswerving quest for causes which, as it drove through layer below layer, seemed even farther from the bottommost principles, from the intolerable strain of learning day by day how much he did not know."[18]Martin emulated the Gottlieb style of science: "a wide-ranging, sniffling, snuffling, undignified, unself-dramatizing curiosity, and it drove him on...When he was at his bench he did not have grandiose aspirations but there was the sniffling, snuffling beagle."[19] In his memoirs and through the depiction of Gottlieb by Martin, de Kruif indicated how he was inspired by Novy's spirit of truth seeking, his honesty and his self-discipline.

Novy's preaching of an all-inclusive notion of the ideal of science, which included an opposition to commercialism, is carried forward in *Arrowsmith*. In that novel, Lewis objected to the "businesslike" culture of medicine in the early 20th century. Instead of being a profession that promoted discovery on the scientific side and healing on the clinical side, Lewis objected to a medical profession that had become business-like, including the commercialization of products of discovery and promotion of therapies by doctors who did not know whether they were helpful. Lewis felt commercialism was widespread in medicine, and criticized it in the clinical domain (Rouncefield Clinic), public health departments (Nautilus), and research (McGurk Institute). Lewis viewed laboratory science as the ideal that could transform the medical profession from a trade that sold goods to unsuspecting patients to a profession that beheld verifiable truths.

Strains of Religion

Novy often exemplified the increasing secularization of late 19th century America.20[19] A son of devout Catholic Czech immigrants, he turned to the material world and devoted his life to scientific endeavors. His major interest was in exploring a world of purely natural laws rather than one in which there was divine intervention. The students' reception of Novy's campaign for laboratory medicine, as evidenced by their letters, can be viewed in the material context of this time period. Each of Novy's letter-writing students refused to give up a quest for truths, although like Novy, they veered towards seeking scientific truths rather than spiritual truths. As cited above, for example, Cooley wrote that Novy's students had faith that his "science was our only salvation to find truths".

Student adherents of scientific medicine drew on strains of religion in their belief in Novy's laboratory science. Students no longer able to seek reflection and refuse solely in religion turned for sustenance to a faith in scientific progress. The letters from students show they had a hearty belief that science would uncover hidden truths in nature that would benefit mankind. Their faith in an incessantly progressive science became a theology of its own, as it functioned to hold up a religious confidence that eventual salvation would be attained through a natural process of discovery of hidden truths. They were assured of the beneficence of their work for society because they believed it widened the existing boundaries of knowledge and ameliorated human suffering. Novy's students could be considered pilgrims searching for salvation in scientific truths.

Novy's students described their experience with him in religious terms. Their use of religious language underscores that their faith in the material works of science and its attendant progress had its roots in religious beliefs. In writing about Novy, his students construct a narrative that projects him as the incarnation of the spirit of science. They worshipped Novy's broad range of educational and his scientific activities, and they had faith that these activities would provide beneficial rewards to the wellbeing of the public. Nevertheless, the students portray Novy himself in an ambiguous fashion. They depict him as a cold, rational technocrat who possessed a unique knowledge and had mastered the use of specialized tools. However, he is also illustrated in a romantic fashion, as being a seeker of truth. Novy is portrayed as a sacralized being, in possession of a divine spark, who enlists students as disciples through the inspiration of their minds and hearts by Novy's Holy "spirit of science." Adherents join the new religion because they believe in the spirit of science preached by the prophet Novy, not because they are instructed to do so by a set of codified, institutionalized rules. The students' spirituality is evident in the depiction of Novy's work habits—pious, monk-like and carried out in a secluded laboratory. Furthermore, as Novy brandished his potent tools for the benefit of mankind, his teachings, as a consequence of his devoted student disciples, became eternal.

The religious tones of students who wrote letters cited above are evident. David Sugar, for example, wrote about Novy possessing a "divine spark" and having the "zeal of a religious leader". Cooley refers to Novy's "inspirational" teachings as being "eternal" and of Novy's "disciples." McKinley writes about Novy mystically, stating that

Novy's meaning cannot be expressed in words but only felt. Knapp wrote about Novy's "devotion" to science and his beneficence to humanity. Former student A. C. Furstenberg, who subsequently became dean of the University of Michigan Medical School, wrote to Novy, "We had gained faith and settled down to the job of learning bacteriology convinced that our only salvation lay in a diligent effort. The inspirations we gained from you in those days have left a grateful memory with us all…You stand before us, touched with the immortal spark serenely pursuing unknown paths for the welfare of mankind."[21] de Kruif described a "feeling" he was unable to describe in words and noted that Novy "worked in solitude" and "possessed an immortal spark."[22]Another student, B.T.Terry, lauded him for "revealing" an "epiphany" of science that had guided them in their subsequent careers.[23]Another, Campbell Bonner, said he had "made himself a part of the machinery of creation."[24] W.C.Hoad said he was "happy to have a part in the general hallelujah chorus of your former students and disciples."[25]

Viewing Novy's teaching from the student perspective allows one to appreciate an additional facet—a religious dimension—to Novy's intention to mold their character through their mind, morals, and habits. The student letters connote a religious devotion of Novy as the incarnation of a faithful scientist pursuing his calling in isolation and without distraction from material temptations as he stressed the need for rigorous technique, full concentration, and absence of diversions. The students described the monetary sacrifices he made in his scientific career, and they commented on his devotion, humility, and dedication to his work. Students venerated Novy as the self-sacrificing scientist who was not motivated to work for financial gain or reputation, but rather for the inspiration of performing science for its own sake.[26] Former student George Herrmann, who then became professor of microbiology at Tulane University, for example, wrote, “I have held you as the true ideal of a pure scientist. Your staff has a hero worship along with them; you are in the true heroic mold. The inspiration and stimulation came to me then (when I was) as a student of yours. The hope of increased salary, better teaching facilities, academic honors, added administrative power and position never tempted you to forsake your principles and I shall always honor you for it.”[27] The students admired his willingness to share data with other scientists for the benefit of the scientific community. Taking into consideration the qualities of selflessness and devotion, in combination with Novy’s special skills and knowledge, students such as David Sugar invoked a concept of immortality. [Figure 5.3 A-C]


Figure 5.3 A


Figure 5.3 B


Figure 5.3 C

Figure 5.3 A-C. Novy as he appeared to students in the laboratory and in the classroom. To his students, Novy represented an ideal for a search for solid truths in nature, a search that began in his laboratory and was relayed to students both in his hands-on laboratory course and in the classroom. Regardless of whether they were destined for research or for clinical practice, students had faith that his special technical knowledge and innovations offered a certain route to uncovering these otherwise occult truths in nature.

Figure 5.3 A. Novy standing in his laboratory bench, with his instruments by his side, 1929.

Figure 5.3 B. Novy was known for his diligence at his research bench. He is shown in 1921, working on the metabolism of anaerobic bacteria. He is sitting by his instruments and his microscope.

Figure 5.3 C. Novy lecturing in the classroom. 1914.

Novy's students also viewed his works as a pinnacle of excellence towards which they strived. His supplicants strove towards the goal of scientific perfection that Novy symbolized to them. But Novy's scientific skills ultimately proved elusive, as his students gradually came to terms with a realization that they could never reach the apogee of scientific mastery that Novy represented. But it was this through the process of extension that his students found reward. They credited Novy for compelling them to stretch themselves to the utmost as Novy's mastery served as a yardstick against which they could measure the success of their own scientific pursuits. de Kruif wrote "You will want only the truest expression of what you—my first and only master—have meant to me. I shall try hard, but I will never be as good a truth hunter as you tried to teach me to be."[28] [Figure 5.4] R. Jones, former student and Professor of Bacteriology at University of Wisconsin, expressed similar sentiments of his relationship with what he viewed as the divine Novy, "In the most refined methods of research we still follow you. Your forty years of truth making in fundamental medical science is an inspiration to those who struggle with hope but know they can never attain your height".[29]

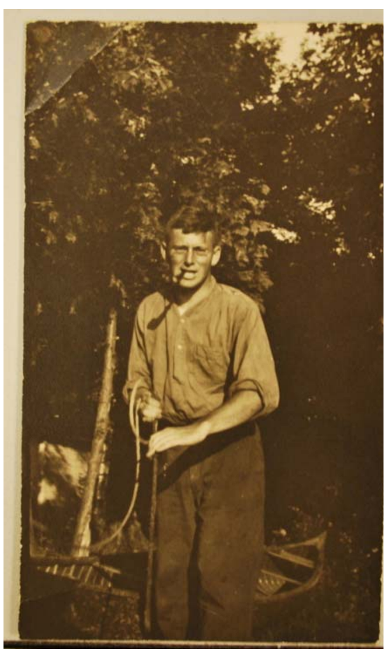


Figure 5.4. Paul deKruif. deKruif wrote his sentiments to Novy while on a camping and canoeing vacation in Marquette, Michigan. deKruif repeatedly wrote to Novy that he

represented the paragon of a truth hunter that deKruif strove for but never quite attain. Students like deKruif were drawn towards Novy and his brand of laboratory science. Sinclair Lewis collaborated with deKruif and fictionalized the attraction students had towards Novy in his novel *Arrowsmith*.

The students' veneration of Novy as a prophet of a new religion is captured in Lewis' novel *Arrowsmith* that he wrote in collaboration with de Kruif.[30] In *Arrowsmith*, Gottlieb, like Novy, is a prophet of a new religion based on a belief in truth as holy. In *Arrowsmith*, Gottlieb preaches about the religion of a scientist, "the scientist is intensely religious—he is so religious that he will not accept quarter truths because they are an insult to his faith. [A scientist] wants that everything should be subject to inexorable laws. He is opposed to…preachers who talk their fables. He speaks…[harshly]…of the doctors that want to snatch our science before it is tested and rush around hoping they heal people; he hates guess-scientists who know only one text book and how to lecture to nincompoops all so popular. He alone knows how [little] he knows."[31] But Martin knew it is not an easy task to be a disciple of Gottlieb's science, as it required selflessness and self-discipline. Martin, who possessed the curiosity needed for scientific investigation, did not inherently possess these attributes. To seek assistance in obtaining them, he "prayed the prayer of a scientist…God give me the freedom from haste, a quiet and relentless anger against all pretense and all work left slack and unfinished. God give me a restlessness whereby I may [not] sleep…till my observed results equal my calculated results."[32]

Novy's teachings about doubt, truth seeking, likelihood to be ostracized by traditionalists, and self-sacrifice are portrayed in *Arrowsmith*. Martin admires Gottlieb because he symbolizes "pure research; seeking the truth, unhampered by commercialism or fame seeking, getting to the bottom, and ignoring consequences and practical issues."[33] Martin also said, "Gottlieb's gods are the cynics, the destroyers—Diderot and Voltaire…men that had more fun destroying other people's theories than creating their own."[34] About Gottlieb, Martin said, "not once did he fail to be hated by his colleagues, who called him diabolist, killjoy, pessimist, destructive critic, flippant, intellectual snob."[35] Like Novy's students, Martin referred to the "cool ascetic hours working in the lab late at night…alone, absorbed" in the monk-like sanctuary that was Gottlieb's laboratory."[36] Martin's girlfriend, says of Gottlieb, "…think how much more money…a successful doctor has than one of these scientists that just putter and don't know what's going on in the world…somebody pointed out Max Gottlieb the other day, and he had on a dreadful old suit..."[37] Martin elaborated on Gottlieb's self-sacrifices, "While medical quacks, manufacturers of patent medicines, chewing-gum salesmen lived in large houses, Gottlieb dwelt in a cramped cottage whose paint was peeling and rode to his laboratory on a squeaky bicycle."[38]

As Martin Pernick has maintained, writers such as Sinclair Lewis preached the scientific method as a spiritual and moral replacement for traditional religions.[39] Pernick pointed out that the objectivity of science made it the best source of moral and spiritual values. For some doctors, the scientific method became the foundation of a new objectively true religion, an "intellectual gospel" in which the laws of nature were morally binding laws—ethical imperatives.[40] For example, at the Race Betterment Conference in 1928, Adred Scott Warthin argued that traditional religion with its concept of forgiveness of sin could damage humankind by perpetuating the transmission of social diseases through changes in the hereditary “germ plasm.”[41] He also discouraged marrying for romantic love and encouraged those contemplating marriage to check fully into their ancestral backgrounds to avoid the transmittal of inheritable disease to future generations. Warthin believed the only means to physical betterment and long life came through eugenics. Other physicians, including Harry Haiselden also disagreed with faiths he considered to be based on outdated tradition, and he based his advocacy of the moral and spiritual authority of eugenics on this premise.[42]

Humanizing Novy

Novy’s students and colleagues were clearly in a willing mood to construct Novy as an ideal of perfection towards which they could aspire.[43] They elevated him to the status of a divine figure and what some students considered a “paragon” of a scientist and a ”pioneer” in his field.[44] Their high regard for Novy as a scientist was based on his professional behavior—the code of ethics that guided his science and his insistence on using exacting and precise methods.[45] These idealized traits revolve around Novy’s skills and his behavior while at work.

Novy’s day-to-day practice—in the laboratory, the classroom, or at the podium at meetings, also involved social interactions with students, colleagues, and lay citizens. The daily, personal interactions he had during long laboratory sessions each afternoon, or performing research made their own type of impression on students and colleagues. Novy’s personal mannerisms and interpersonal conduct may not be directly related to his academic activities, but they were an inseparable component of the construction of Novy not only as an idealized scientist, but also one who was human, real and imperfect. To understand this construction of Novy in a mode of realism rather than idealism, it is important to consider how students, colleagues, and the lay public viewed his day-to-day personality traits. I will address some of the personal characteristics that served to humanize the idealized construction of the scientist.

Novy's students commented on many of his personal idiosyncrasies. They described him as being intolerant of carelessness.[46] Students mentioned that he disapproved of what he felt was the tendency of others to rush to publish, the tendency of editors to shortcut bibliographies because of publication costs, and the occasional author's downright neglect to refer to earlier work was met with sharp disapproval.[47] Novy's students and associates noted that his uncompromising lectures on certain principles, such as his insistence on precision and exacting methodology, and his industry and logic in teaching, earned him a reputation as a strict disciplinarian.[48] Some remarked on his harsh critiques of their written work. Paul de Kruif, for example, noted in his memoirs how Novy "rip[ed] my…scientific reports to bits! In his precise, minute handwriting he wrote "bosh" and "twaddle" and "rot" on the margin. He growled that every one of my conclusions was unjustified, exaggerated, untenable. Then he sat down by me and said, 'Let's start over.'" According to de Kruif, Novy thought that every scientific worker should be his own task master and most severe critic.[49] These characteristics were fictionalized in the scientifically uncompromising Dr. Gottlieb in Sinclair Lewis' *Arrowsmith.* For example, Martin described Gottlieb's papers as being "exquisitely finished, all easily reduplicated and checked by the doubtfulest critics."[50] In addition, Martin described Gottlieb's "tall, lean, dark aloofness."[51]

Novy's students remembered a generous interest, which lay behind his sharp comments. He occasionally used stern reproaches for those demonstrating suboptimal technique, but he resorted to a wit to lessen the pain of his caustic criticisms.[52] Nungester remember that Novy was likely to deliver a volley of contempt, phrased in choice bits of what he called “the King’s English,” in order to show his displeasure for a student’s careless work.[53] On the other hand, students noted that he frequently revealed his sparkling wit and good humor.[54] Nungester wrote that Novy’s keen sense of humor showed in his eyes, which came as a welcome antidote for the sting his sharp tongue inflicted on students who exercised poor judgment or misdirected activities. Nungester then commented, “this I know,” indicating that he himself had at times been the object of Novy’s disapproval.[55]

Some have enjoyed writing about Novy’s foibles. Students commented that Novy had scarcely any interest in nonscientific and social activities.[56] He had a habit of paying his house bills in person rather than by mail, and took this opportunity to visit and chat briefly with Ann Arbor citizens. Ordinarily, he was constantly absorbed in his work and after dinner would go directly to his lab, working at least until midnight and frequently until two or three o’clock in the morning.[57]Although Novy was known to wear the same suit of clothes until threadbare, and it mattered little to him whether the coat, vest, or trousers matched, he would wear only tailor-made clothes, and it was important that every buttonhole be made by hand and pass his exacting scrutiny. On Sundays and holidays he wore a brightly colored vest or tie. [Figure 5.5 A-B]

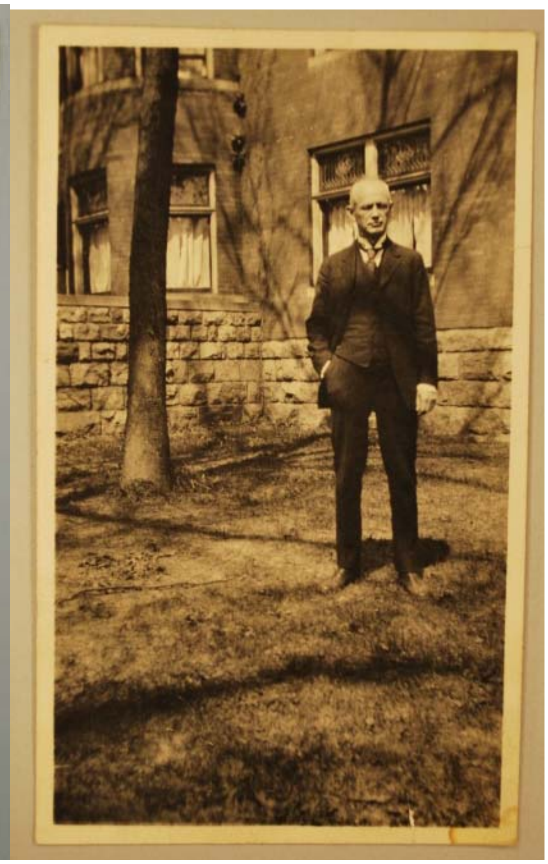


Figure 5.5 A Figure 5.5 B

Figure 5.5 A & B. Novy standing outside of his Laboratory.

Figure 5.5 A. Novy showing his preference for well-worn clothes that did not match.

Figure 5.5 B. On occasions, he would wear suits that would match. (Courtesy of Bentley Historical Library)

Novy's students were amused by his idiosyncrasies. Some remarked upon his unique gesticulations, the manipulation of his long fingers, and other mannerisms that were carried out in silence.[58] His students also recalled his tall, conspicuous appearance while walking to work or riding his bicycle, or in the amphitheater, where he would often wind one leg around the other while lecturing. His writing was eloquent, and his speech was quiet and deliberate. Students found it fascinating to listen to him enunciate every syllable and bite off every word.[59] Novy's modesty was also legendary, as exemplified by a correspondence with Milton Rosenau, the dean of the Harvard School of Public Health. Rosenau wrote to ask for a signed picture for Novy to hang prominently among a group of celebrated scientists in Rosenau's office.[60] Novy apologetically declined Rosenau's offer on the grounds that he didn't have an extra picture of himself and that he had not sat for one in years.[61]

Novy was portrayed as a man so absorbed in his work that he was oblivious to the quotidian aspects of daily life. In attempting to capture his mannerisms, an article written about Novy by the *Michigan Daily*, entitled "University Professors, their eccentricities and their everyday life" reported, "This tall, lean man wore a threadbare suit, an old cap, a low, turned down collar and a simple black tie. His study, in which he worked every night until long after midnight, was a small dingy room next to the roof."[62] The image of Novy as an eccentric scientist absorbed in the quest of truth searching was depicted in in the *Ann Arbor News*. The article stated, "Novy is so absorbed in research that he probably hasn't found time to learn much about himself. He is tireless when delving into the mysteries of bacteria; he is persistent, relentless. Something that is sure to bring on gruffness is for a student to excuse an error by saying 'I think'—Novy will pound the desk and exclaim vehemently, 'Don't think—know'."[63] The article then said, "He is said to be the limit in thoroughness as a teacher. He'll never let a student give up. One must keep at a thing until he masters it. That is Novy's way."[64] These idiosyncratic personal qualities—his obliviousness to routine human rhythms and activities, his all-consuming absorption with experimentation, and the high standards he demanded of others supply an imperfect, real dimension to the idealized image of Novy his students constructed.

<u>Novy received by lay audiences</u>

Novy lectured to the lay public to share his scientific ideal. The public response to these attempts remains unknown, as there are no records to identify how various sectors of society received his lectures. However, an article was published in 1901 in the *Michigan Daily* by a, presumably, non-medical student. The student had visited Novy's laboratory and expressed a fascination with germs, but also his fear in visiting a laboratory in which danger could potentially lurk in invisible germs stored in flasks.[65] The following is excerpted from the article:

> The lab…is of special interest because it is gruesome as it is fascinating. It is here that deadly and repulsive diseases are experimented with, studied, instructions given to students, and progress made given out for the benefit of the world at large. Novy has made important discoveries which have attracted attention of the medical world, and he is teaching bacteriology to regular classes now and more students are now becoming proficient in this branch of medical work than any other institution in America. As interesting as the discovery of germs themselves, or perhaps even greater, is the discovery of the anti-toxins, serums and other disease arresters. As yet this feature of the work is only in its infancy…So sure is the cure and so productive of good results that the once dreaded diphtheria is no longer feared where anti-toxin is to be had. In one little room of the lab there are enough deadly germs, and there are enough bottled epidemics to bring devastation to the whole continent. Novy said, as he uncorked a tube containing diphtheritic germs and placed a small dab of the culture upon the glass and then placed it under a powerful microscope 'Just look at this.' The curious little germs, magnified a few thousand times and colored so as to bring them prominently into

view, were plainly seen and could be easily studied. Then changing the slides, just as a stereopticon artist might affix a new screen, he showed another glass containing tubercles, and these were followed by an exposure of those busy little things which get into the blood and cause lock jaw. There was a difference in form of all of them, as easily discernable and distinguishable by an expert as human faces are to an ordinary observer.'[66]

The writer of this article was enthralled by the expertise that laboratory scientists possessed which enabled them to make visible, identify, and safely handle safely an array of minute germs that could cause colossal devastation. The writer also revered the power that scientists like Novy held to control lethal diseases. The article explicitly expresses a faith that finding a few cures offers the hope that the same methods will produce even more cures. The stated faith is unique to the non-medical author of the article; the quoted medical practitioners imply this hope without specifically stating it. The article also shows the excitement surrounding the recognition that bacterial research, as carried out by scientists such as Novy, had already provided tangible benefits for society by controlling at least one killer disease—diphtheria. Consequently, the lay writer promoted a progressive story of bacteriology and laboratory medicine, as had Novy. The story did not rely on the promise of science alone, but on results.

Conclusion

Historians writing about American medical education in the late 19th century have not explored the experience of students who took laboratory oriented science courses. Ludmerer, Bonner, and Rothstein have identified the intentions of researcher-educators to teach critical thinking and the scientific methodology, but they have not examined the voices of students who took these courses. They have not explored what students, including those that were destined for practice, thought was important about what they learned in these courses. The present chapter adds to the medical literature by examining how students received Novy's intentions and how they saw Novy's ideas as having influenced them.

In this chapter, I have argued that the ideals that Novy represented had significance not only for students within the confines of university walls, but also for practicing physicians in the community. Both practitioners and researchers had a shared appeal of learning laboratory science. They also believed in the ideal of performing research for science's sake—that pure knowledge and truth alone would benefit mankind. Their enthusiasm for laboratory methods was bolstered by a faith that more reliable remedies would become available than had been possible in earlier eras when less certain, experiential methods were employed.

Clearly, Novy's students, practitioners and researchers alike, had a positive view about what they learned from Novy. But what specifically did his students view as positive about their experience? Do their comments shed any light on why every medical student must have extensive laboratory experience, not only in bacteriology, but also in anatomy, physiology and pharmacology? Did the student letters reveal what they learned that made them a better physician? Did they feel that their education in laboratory science made them a better problem-solver, more likely to look for the origins and not just the surface manifestations of disease? The students who wrote to Novy did not address these specific issues. Nonetheless, an examination of their language sheds some insight into what it was about their educational experience and what it was about Novy himself that they valued so highly—their belief that his search for pure knowledge and truth alone would benefit mankind.

Novy's science, like religion was a belief system for his students. For his students, practitioners and researchers alike, Novy's science was a new religion, with a belief not in the written word as a means to apprehend the revealed word, but in doubt as a means to find occult truths in nature. Students who embraced Novy's instruction had faith that truths could be accessed, first through skepticism and then through the application of special knowledge, then rigorous, painstaking scientific rituals, which they learned, albeit imperfectly, from their devout, selfless, and skillful master. They had faith in the promise of science to expand the boundaries of knowledge and to benefit mankind. They project Novy as a divine being who enlists students as disciples through the inspiration of their minds and hearts--Novy's Holy "spirit of science." Novy was the prophet of this new religion with an ethical imperative to seek truths through hard work and self-sacrifice, rather than pursuit of profit. His student-disciples joined the new religion because they were inspired by Novy's "spirit", not because they were required to do so by a set of codified, institutionalized rules equated with the military. In this sense, their letters reveal a religious facet to Novy's "spirit of science".

The students' letters were written during a time when religious beliefs were challenged by science, and faith in religion was carried over to faith in science. The acceptance of the existence of truths of nature took place during a period of upheaval in the late 19th century—a time when people retreated and turned towards science for a belief in solid truths. The students' embrace of Novy's ideals of science over his long career reflect a particular blend of several dominant themes and philosophical modes in late 19th century America. Novy's optimistic portrayal of bacteriology resonated with the Victorian belief in the progress of science. But his linkage of scientific research to the welfare of mankind struck a chord with utilitarianism.

One cannot infer, however, that all students who took Novy's course share the uniformly positive assessment of Novy that are conveyed in notes from students who wrote to him. These notes represent the impressions of a fraction of the students who studied with Novy. One can only speculate what these other students thought. It is possible some considered his science irrelevant to their practice, his course too time-consuming and an unfortunate diversion from more relevant topics, his insistence on thoroughness too tedious for their purposes, or his intolerance for error to be abrasive. While acknowledging that the voices of all his students cannot be heard, one can nonetheless consider the meanings that the students who wrote to him derived from his work.

As the expert scientist who had sought to replace traditional, subjective, experiential methods with precise, objective, systematic ones, Novy's activities resonated with the dominant theme of progressivism in early 20th century American culture. Novy was operating during a historical moment when science held a powerful position in society. There was a belief that the techniques and methods of science were tools, which if used by a qualified expert, could yield truths that existed in nature and provide innumerable practical benefits to mankind. Students had faith that a technocratic expert like Novy, using precise tools and methods, could create a more reliable, more truthful profession than the older, ad hoc experiential methods of an earlier era. The transformative potential of laboratory science to provide verifiable truths to a culture that was lacking certainty and credibility was fictionalized in *Arrowsmith*.

By making scientific medicine relevant for all students, Novy was able to create something novel: an enduring basic discipline in bacteriology within a medical school setting. In the following chapter, I will consider the meanings of Novy's educational and research activities had for the new science—the growing field of bacteriology.

CHAPTER 6

Defining Bacteriology as a Discipline in its Early Years

Introduction: Novy's early work coincided with the efforts made by some early bacteriologists in America to define their field as an autonomous scientific field. They argued that bacteriology had long been considered a handmaiden to pathology. In this chapter, first I will first explore how bacteriologists created their argument for a separate science. In particular, I will explore the ideologies articulated by presidents of a newly-formed society, the American Society of Bacteriologists, and the rhetoric they employed as they were creating their new field into a distinct specialty and explaining it to others. I will also explore the possible reasons that compelled them to fashion their field into a separate science.

The society meetings, although important in constructing bacteriology as a separate field, only took place on a yearly basis. In order to explore the importance of activities that took place more frequently, I will address the norms established by bacteriology researchers such as Novy that served to self-regulate behavior within the profession. Letters written by students to Novy, addressed in chapter five, show the ethical codes to which his students found meaning. In this chapter, I will address how these codes and behavioral norms were important in constructing the distinct identity of bacteriologists in relation to other fields. The norms and values researchers like Novy articulated were adhered to by members of the profession and therefore became distinctive characteristics of professional behavior and identity.

In this chapter, I will address why the differentiation between bacteriology and pathology may have been important to bacteriologists as their discipline gradually became defined. I will also examine the circumstances under which the bacteriologists stressed how their field differed from others, and address the circumstances under which this distinction was downplayed. In order to examine these questions, I will first review some of the key literature on professionalization and specialization that will serve as a background to the examination of the yearly presidential addresses and the behavioral norms that served to create an identity for the new science of bacteriology.

Professionalization and Specialization

Early literature on professionalization and specialization emphasized definitions of the structures that characterize professions. In 1933, Carr-Saunders described professions as organized bodies of experts who applied esoteric knowledge to particular cases.[1] Certain structures, including departments, societies, licensing, and boards, are put into place and characterize these professions. Through other structures, such as journals and meetings, experts then apply esoteric knowledge to particular cases. In 1964, Millerson also included a code of ethics as part of the structure of professions, which assumed an unselfish and collegial nature of professions.[2]By 1970, Friedson, however, questioned the assumption of the selfless nature of the structures within professions and argued that corporate dominance was the hallmark of professionalism.[3] Berlant in 1975 attributed the structures of professionalism directly to the goals of economic monopoly.[4]

Larson in 1977 emphasized the consequences of professionalism for the status and power of the profession, and the neglect of social concerns by both the legal and medical profession.[5]

Thus, the literature that addressed the structures of professions ascribed motives for constructing them, which vary from selflessness to self-interest. The literature also points to key structural elements of professions: its groups, controls, and worksites. Groups, for example, may simply be organized around professional membership, but they may also have lobbying or informational functions. Membership is controlled by the credentials required for a practioner to enter the specialty—including types of schools that train them, the work required to enter the organization, the examinations that test them, the licenses that identify them, and the ethics codes they are presumed to obey. Practitioners operate in worksites according to the profession, varying from the classroom or library (education) to the hospital (physician) or laboratory.

In 1976, Bledstein explored professionalism at the individual level rather than the structural level. Professionalism, he argued was a matter of individual choices and institutional action taken to enable them.[6] The importance of professionalism lay in building channels for individual achievement.[7] He traced how mid-Victorians appreciated the value of a career composed of membership in professional scientific associations with distinguished titles. In the 1880s, for example, scientific societies were formed (e.g., chemistry, geology, and mathematics) that bolstered the self-certainty of the specialist who defined professional boundaries so they were indisputable to others. Science was the spirit which could unite workers in a particular area into a harmonious organization as each specialty emphasized the unique identity of their subject, their distinct qualities, language, and research.[8] This scientific particularization furthered their control over the discipline, making it difficult for an outsider to attempt to pass judgment on their field.[9] To Bledstein, professionalism meant a culture—a set of learned values which structured the attitudes and responses of the professional and the lay public.

In 1982, Paul Starr addressed the issue of professional autonomy in the particular setting of medicine.[10] In the case of medicine, practitioners attempted to develop professional autonomy to fight off efforts at coordination and nationalization of health care service and regulation of professional autonomy. The growth of technology raised new questions regarding who would control and profit from the new kinds of work that were being created. As hospital, clinics and laboratories grew, doctors wanted to use hospitals and laboratories without being an employee of those institutions. Doctors, as professionals, wanted to maintain autonomy but not lose control.

In 1988, Andrew Abbott examined the distinguishing characteristics of a profession. He looked beyond structures and argued that it is an abstract body of knowledge on which the occupation bases its claims for the exclusive right to control work activities.[11] A knowledge system governed by abstractions, he argued, can redefine the problems and tasks of a profession and defend them against interlopers. For Abbott, the actual work is just as important as the structure of work to a profession. Abbott looked at the tasks of a profession, the work content that is defined as the core of the profession, and he defined a jurisdiction to be a link between a profession and its work. Abbott argued that occupations define their jurisdiction by the right to control the provision of particular services and activities. To make his argument, he paid attention to inter-professional competition and besting rival professions. Thus, Abbott claims that professions created their own boundaries through the use of abstract knowledge that legitimated their claims of controlling particular work activities.

In the 1990s, Bruce Kimball and Samuel Haber published studies on professions that differed from Abbott's study of abstract knowledge and professional institutions. In 1992, Kimball examined law and medicine in late 19th century America.[12] He viewed these professions as having an elite social status with distinctive characteristics—self-regulation instead of marketplace and governmental control, social authority based on technical competence, and institutional norms and values that place service to others above self-interest. In Kimball's view, individual professionals are motivated to adhere to professional norms and values because self-regulation enables the professions to provide rewards to those who adhere to them. In 1991, Haber examined the same professions from the mid-18th century to the late 19th century in America. He agreed with the key elements of professional norms and ethical codes in professions, and also maintained that professional ideologies and rhetoric are important components of professional behavior that explain a profession to others and influence their reactions to professional activities.[13] Both studies are consistent with the approach formulated in 1954 by Talcott Parsons, who proposed that self-regulation based on norms and technical expertise are key elements of professional identity.[14]

Below, I will outline the various facets that were instrumental in constructing bacteriology as an autonomous field. I will outline the ideologies these American bacteriologists articulated and the rhetoric they employed at the turn of the 20th century as they were in the process of making their field into a distinct specialty. In addition, I will also examine the behavioral norms and ethical codes that were operative on a day-to-day basis that were important in constructing a distinct professional identity of bacteriologists.

In the late 1890s, a cadre of American bacteriologists became interested organizing their field. The first stated mission of the charter members of this circle of bacteriologists, who called their organization the American Society of Bacteriology, was to “embrace a common interest irrespective of the particular field of study” and “to advance bacteriology as a pure science.”[15] These bacteriologists included William Sedgwick, professor of public health at the Massachusetts Institute of Technology, A.C.Abbott, professor of hygiene and bacteriology at the University of Pennsylvania, Herbert W Conn, professor of biology at Wesleyan University, and Frederick Novy. The early founders dedicated their society to promote bacteriology as a “fundamental” discipline.[16] They resolved to cultivate bacteriology not for practical applications but as a science with a mission to understand basic knowledge of microbes.[17] The society was formed in 1899, and Novy became its fifth president in 1904.

Each president, who was elected for a one year-term, gave a yearly keynote address promoting their vision for how their field should become united and autonomous. I will select addresses made by presidents from 1899 to 1935, whose themes are representative of those given by other presidents during this period. The presidents argued that bacteriology had its own distinctive ideology, methods, instruments and language that permitted a unique ability to apprehend truths in nature. They used a distinctive rhetoric to propose that the criteria to become independent is a science’s unique ability to understand nature, and bacteriology had met this criterion.[18]

William Sedgwick gave the inaugural presidential address at the first annual meeting of the Society in the auditorium at Johns Hopkins Hospital on December 27, 1900.[19] In his speech, entitled "The Origin, Scope, and Significance of Bacteriology," he argued that bacteriology, like astronomy and physiology, deserved the status of a "distinct scientific discipline."[20] Because of its unique ideas and methods that allowed an understanding of the behavior of bacteria and the vital role they play in nature, bacteriology led to a rational understanding of a range of natural phenomena--fermentation, putrefaction, and organic decomposition—that had previously been attributed to supernatural causes. Other fields of science, he maintained, had done the same—astronomy, physiology, and geology, and this was what conferred independent status to these sciences. Thus, because bacteriology could explain previously unaccounted for natural phenomena, it deserved a status of a separate scientific field.[21]

Sedgwick argued that bacteriology "had its beginning as a pure science at the hands of physiologist, Schwann, and later in medical men (Lister, Koch) who, through their researches provided practical results for human welfare."[22] What did Sedgwick mean by "pure" science? He was referring to the discoveries that led to a rational understanding of "unseen bacterial activity" that then accounted for changes of "fundamental importance" in nature.[23] Sedgwick said bacteriology's "distinguishing characteristics" were its ideas, methods and discoveries that give it a unique ability to understand the vital significance of the behavior of microbes:

> Without their activity, the habitable world would become one vast charnel-house because there would be no adequate agency for mineralizing dead matter. We begin to realize the enormous importance of the part which they play in the

> economy of nature…[Bacteria have a] welcome unseen activity in removing from view dead animal bodies, dead leafage, worn out tree trunks, and waste matter…Bacteria therefore have a ‘fundamental importance in nature.’[24]

Sedgwick argued that bacteriology had a capacity to account for important changes in the natural world. He said of bacteriology “its most important contribution is the area of philosophical significance…in explaining hitherto mysterious natural phenomena—spoilage of fruits and their juices, putrefaction and decay of rotting organic matter, manure applied to land vanishing, epidemic plagues and pestilences sweeping over earth that man could not explain or fight.”[25] Because of bacteria’s “causative participation in such universal…important processes in nature”, bacteriologists are in a unique position to “understand the scope and significance of the culturable microbes” and therefore nature itself.[26]

Sedgwick related the work, methods and accomplishments of bacteriology to other branches of science that were independent. He linked bacteriology’s disclosure of “invisible” microscopic forms and the significance of their activities to that of Copernicus, who used telescopes to plot the changing positions of celestial bodies and therefore explain planetary motions on a rational basis; and Newton, who explained motion of objects in the natural world on a rational basis. Sedgwick believed that astronomy and physics earned the status of independent sciences because of the unique ideas and methods explained previously unexplained phenomena in nature in rational terms. Likewise, he concluded, bacteriology should be considered an autonomous field of science for the same reason. Sedgwick made the statement: The scrutiny of bacteriology has given to us a comprehension of the underworld similar to that which astronomy has given us of the heavens. It has disproved ideas such as spontaneous generation, which has proven to have been a medieval idea faded out by bacteriology, just as chemistry has faded out medieval ideas of alchemy and the transmutation of elements. Science dispels supernatural explanations of change in the world, and provides a natural rather than a supernatural explanation for them. These medieval ideas of magic, thanks to sciences such as bacteriology and chemistry, have 'disappeared from science.' Bacteriology has replaced myth with fact.[27]

Bacteriologists, like astronomers, he argued, had the capacity to use their unique instruments to test ideas about how microbial behavior caused changing natural phenomena and therefore supernatural explanations with rational explanations. Bacteriology, Sedgwick claimed, fulfilled the criteria that other fields of science had already met to be called autonomous and therefore had a legitimate basis to be designated an independent scientific field.

Subsequent presidents would elaborate on the foundation for bacteriology as an autonomous field based on its ideas and work that Sedgwick laid out in his inaugural address to the society. In 1917, Leo Rettger, Professor of Bacteriology at Yale University, called bacteriology "our new science and "a separate science among other sciences."[28] Other presidents also implemented structures of the field as it evolved. In addition to forming an organized body of experts with membership in the society, these structures included establishing prerequisites to control who entered the society, including publication of at least one article in a peer-reviewed journal.[29] Winslow, in 1914 felt that the practical application of bacteriology was fragmenting their field into disparate spheres--industrial, agricultural, hygienic, and pathological. Winslow believed an emphasis on pure or fundamental science would bring together the enlarging and growing number of divisions within their field.[30]

In 1931, J. Howard Brown, professor of bacteriology at Johns Hopkins Medical School gave a lecture requesting that members of the society perform experiments with the "pure" intention to find fundamental truths about microbes rather than have practicality be the experimental motive.[31] Brown argued that bacteriologists should have "pure" motivation like the scientific investigator referred to in a passage from H. L. Mencken he quoted:

> …the scientific investigator, one of the greatest [noblest] men in the human race, is moved by insatiable, unquenchable curiosity—to uncover the secret and find out what has not been found out before. His prototype is not the liberator releasing slaves, the good Samaritan lifting up the fallen, but the dog sniffing tremendously at an infinite series of rat holes.[32]

Brown warned members of the danger in allowing any other motive to enter into scientific research other than the disinterested discovery of truth. Brown maintained:

> The *pure motive* of those who sniff at rat holes is curiosity and the fun of doing it. Their reward is curiosity satisfied. Their social justification is that experience has shown that this motive most effectually excludes prejudice and most successfully contributes to a body of truth which enables man to make adjustments of internal to external relations.[33]

Brown warned members against targeting experiments solely towards practical applications. He argued that a humane desire or industrial need may indicate where research is needed, but during the design of the project, progress of the experimentation or interpretation of data, such desires are best forgotten.

Although fruitful applications of bacteriologists' work were acceptable to Brown, he felt it should not be the guiding principle of research. Rather, his main intention was to investigate science for its own sake and make novel contributions that represented an advance of their science. By insisting that utility should be absent from experimental design, he reinforced a code of ethics to the society. Brown was concerned about excluding practicality from experimental design because he did not want the notion of application to interfere with the integrity of the scientific process or dampen the enthusiasm of the scientist. But he may have also felt that the notion of utility could constrain potentially important research programs. He may have found some practices in the applied realm to be unnecessarily restrictive in the questions they were able to pose and the nature of the experiments they could conduct.

Brown argued that a purely biological approach to research is necessary because it too could someday yield practical applications even if that was not the immediate aim in carrying out the research. He outlined some fundamental discoveries that eventually had practical ramifications, even though these applications may have seemed remote to the investigators at the time they were conducting their "basic" research investigations. For example, the microorganisms that bring about chemical changes such as fermentation and putrefaction were a biological discovery that made practical bacteriology possible. Because it is impossible to foresee the potential future utility of any fundamental discovery in a laboratory, focusing on "pure" research would not diminish the practical products of bacteriological research.

Brown maintained that his plea for pure research was not a radical new movement, but was in fact a revival of an earlier phase of bacteriology that had focused on purely biological interest in bacteria rather than practical application. Regarding spontaneous generation, he cited researchers such as Lazzaro Spallanzani (1729–1799), an Italian naturalist and Pasteur (1822–1895) who designed experiments to show how organisms propagate from one another and refuted a longstanding theory on abiogenesis.[34] Though spontaneous generation had been considered fundamental, it also turned out to have applications that the investigators studying the process may not have foreseen. For example, the development of sterilization methods, designed to solve the spontaneous generation controversy, were found to have practical applications in medicine despite that there was no evidence that Pasteur developed these methods for those purposes.[35] In addition, Theodor Schwann (1810–1882), a German physiologist, studied putrification and fermentation to understand the process of growth of organisms that use organic substances as food and therefore result in organic decay and alcoholic fermentation.[36] But fermentation also has commercial applications, not only in the wine industry, but also for industries related to packaging and storing food for future use.

Brown claimed that this early period of bacteriology was overtaken in the late 19th century when microbe hunters searched for specific organisms as the cause of disease and means of overcoming infection.[37] He lamented that this period of too exclusive devotion to practical results was self-limiting in bacteriology. He claimed it lacked innovation and was concerned with the application of old knowledge and technique. But he was heartened by what he called the “modern bacteriology period,” when researchers embraced chemistry and biology to broaden the foundation of bacteriology. With this era, Brown argued, bacteriology reclaimed the original interest in studying the behavior of bacteria. He claimed that the American Society of Bacteriologists represented the resurgence of a "pure research", thereby reinforcing this trend as an ethical code of their organization.[38] Specifically, Brown claimed there more emphasis on basic microbial biology, including microbic respiration, growth phases, metabolism of bacteria and their chemical products, the existence of life cycles, and of filterable forms of bacteria. Without mentioning names of individual researchers, the topics he chose to illustrate as biological research matches Novy's research agenda.

Presidents of the society elaborated in their speeches and writings how their field had been subordinate to other fields. In 1917 Rettger claimed that for too long bacteriology had been subservient to pathology.[39] He argued that bacteriology should become an autonomous field, as it had developed its own fundamental scientific program that explained "nature's secrets". Rettger stated:

> Bacteriology has recreated pathology, but has been the victim of paternalism by those sciences which it has come to redeem…To pathology it has been holding itself *in bondage*…Like a young man who has grown to a state of independence, bacteriology also must emerge from its *servile state*…Its foundation is as scientific as those of any other branch of knowledge and by *learning nature's secret* in so far as it is revealed is as truly a scientific inquiry as the most profound investigation into the structure of the protein molecule. To those in quest of *basic scientific* pursuits, its discoveries are of profound interest…bacterial classification, variation, cell growth and metabolism, the response of microbes to

> stimuli, organic synthesis and decay. The very problems of life's origin and of death belong as much to the realm of bacteriology as any other science.[40]

Rettger argued that bacteriology deserved to be an autonomous field because of the fundamental importance of its discoveries. Although Rettger did not specifically refer to the work of any one particular microbiologist, the topics of "basic" bacteriological investigations he described—biological classification, variation, cell growth and metabolism—is consistent with the many of Novy's own investigations.

How did Sedgwick, Brown, and Rettger try to construct bacteriology as a separate scientific field? Their argument that bacteriology had unique ideas, methods, instruments, and tasks is consistent with Abbott's idea of how professions distinguish themselves. In the early 20th century, this group of scientists defined their professional "jurisdiction" as their ability to yield discoveries about microbial behavior that led to a rational explanation of vital phenomena in nature that other scientific fields could not apprehend. As Mansfield Clark, professor of bacteriology at Johns Hopkins University and president of the Society argued in 1933, bacteriology was a specific science because it allowed a biological "investigation into natural phenomena that is specific to our own science."[41] Furthermore, the presidents of the society also developed structures of their profession, including an organized body of experts, control over who could become members, and a code of ethics that encouraged a pure scientific intent when designing experiments. By stressing a "pure" motive to understand bacterial behavior, presidents also tried to unify members of an organization that risked fragmentation by its applications in differing areas. Brown said, "There is no scientific society in which the membership represents a greater diversity of interest than does the membership in our society…But diversity of interest does not necessarily imply diversity of motive."[42] Brown's idea about using a common motive to unify individual workers into a distinct harmonious organization is consistent with Bledstein's argument of developing a culture of professionalism.

What other motives may have compelled bacteriologists to claim that bacteriology was subordinate to pathology and to argue for their own separate field? Self-interested motives, as mentioned by Friedson and Berlant, may have been involved. One possibility, although never directly stated in the presidents' addresses, is that creating a specialty in bacteriology could have helped to establish an independent institutional base, as well as a powerful professional status, for bacteriology. Constructing such a base may have freed bacteriologists from performing duties they might otherwise have had to perform if they held appointments in other departments. The distinction may also have bolstered the bacteriologists' ability to focus on their research and assure lasting opportunities for their students following graduation. Additionally, it may have given them control over the increasing complexity of laboratory equipment that accompanied the growth of technology. Although there is no evidence of a direct relation between the American Society of Bacteriology and the growth of new bacteriology departments, there were a growing number of presidents of the society who were also chairs of newly created bacteriology departments in their respective institutions from 1899 to 1915.[43]

The ideologies and abstract knowledge articulated by the presidents at the yearly American Society of Bacteriology meetings were important elements in the construction of bacteriology as an independent specialty. As Haber and Kimball have pointed out, other characteristics are important in constructing professional identity and status that differentiate a field from others, including professional norms and codes of behavior.

These norms and codes, unlike presidential addresses at annual meetings, are exhibited on a day-to-day basis. The letters that students wrote to Novy outlined in chapter five provide insight into the norms and codes to which students adhered. Below, I will summarize some of the key norms and behaviors these letters reveal insofar as they relate to the construction of bacteriology as a separate field.

The letters from Novy's students show that they were willing to self-regulate their behavior according to the norms and values that Novy's articulated in his "spirit of science." As expressed in the student notes, these norms included doubting the received word and a duty above all else to perform "pure" science for its own sake—a disinterested search for truth without necessarily thinking of its practical value or self-interest (e.g., fame or material reward). This process required elements of self-sacrificing discipline and obedience to orderly, specialized methods and rigorous laboratory procedures that involved long, hard hours of work, sometimes lasting all night long. The norms also involved open-mindedness, and sharing methods with colleagues in order to validate experimental findings.

Bacteriologists' daily hard work in the laboratory combined with a shared moral commitment to a search for truth formed the fabric of a distinct culture of scientific bacteriology. Members elected to join the culture of science because they were inspired to become a participant in a community of expert evaluators who promoted above all else, a reverence for original investigation, skepticism for the received teachings of the traditional medical environment, inquiry and professional methods. In his own institution, Novy provided the guidance and the freedom for these bacteriologists to become "independent" investigators. With his students, Novy shared his knowledge about special technology that allowed them to strive on a daily basis to discover the fundamental behavior of organisms and not necessarily the control of a pathogen. As their letters indicate, their dedication to work in the laboratory not for personal profit but rather to shape the boundaries of knowledge formed the ethical code that provided unity and cohesiveness in their profession.

Novy writes about the dual nature of bacteriology

At Michigan, Novy worked to establish an institutional base for bacteriology. He was appointed the first professor in 1902 and became head of a newly created department of bacteriology (later to be called microbiology in 1937) that had its own budget and was separate from pathology.[44] By 1907, Novy's research laboratory was no longer affiliated with the hygienic laboratory at the State Health Department, which moved its location to Lansing, Michigan in that year. By emphasizing how bacteriology was separate from pathology, those who helped construct the discipline demarcated their own domain.

When Novy sought funding to establish and maintain his laboratory, he stressed the practical applications of bacteriology in controlling pathogenic bacteria in humans. In so doing, he highlighted the relationship of bacteria to human disease, and of bacteriology to pathology. He promoted a linear story of innovation: a fundamental science leading to an applied science that had social consequences. Novy used progressive, historical narratives to articulate the value of his experimental work to society and possibly to defend against the attempts of anti-bacteriologists and anti-vivisectionists to curtail bacteriologic experimentation.[45] In a speech Novy delivered to state legislators who provided funding for his space at the hygienic laboratory, his equipment, and reagents, Novy stated:

> …no one discovery redounds more to the credit of the last quarter of the 19th century than the recognition that [communicable disease] is due to lower forms of life. The unknown cause of disease has become known, the invisible foe has been rendered visible, and hitherto invincible enemy has been met and forced to yield on his own ground. Scarcely a score of years has passed by since the first germ was demonstrated to be the cause of a disease, and yet what triumphs have been accomplished in that short space of time. Preventive medicine has been furnished a rational basis in its struggle against the spread of human disease. In curative medicine a new era was marked by Pasteur's work on hydrophobia, and the more recent work on antitoxins. Only a few weeks ago, the French Academy of Sciences divided a standing prize for the cure of diphtheria between Behring and Roux. More than prize money, the gratitude of the world belongs to these devoted, disinterested and persevering investigators in experimental medicine. This is humanitarian work in its highest and noblest sense and should forever silence the harpings of those zoophiles that look upon the use of animals for experimentation as a blot upon our civilization. The discovery of antitoxin as a cure for diphtheria was not an accident, but the logical sequence of patient, prolonged, systematic investigation extending over many years. Its value was demonstrated in the laboratory long before it was applied to man. It is within a laboratory that the cause of a disease is ascertained and it is from the laboratory

> that our curative and preventive methods must come. In no other way is this possible, as the records of centuries that have rolled by abundantly testify.[46]

In this linear narrative, Novy selects the facts of history and of biography in such a fashion as to give the impression of a necessary sequence and causal relationship. He constructs a useful history of the germ theory delivered to an audience who provided funding for his laboratory.[47] He addressed how his laboratory may benefit society, then placed this in the context of the accomplishments of other notable 19th century inventions.[48] He wrote:

> Within a comparably short period of time, perhaps 15 years, the field of knowledge has been enlarged by a new science—bacteriology…Without the recognition of the extraordinary significance of these organisms this sudden and remarkable evolution of the science would be impossible. We may not inaptly compare, so far as development is concerned, bacteriology with electricity. Electricity had been known for more than a century, but it required an Edison and a Bell to develop its practical side just as bacteriology required a Pasteur and a Koch. It is well known what electricity has done, but is it known what has been accomplished through bacteriology?"[49]

Novy then pointed out how the laboratory produced practical products such as antitoxins for diphtheria. Thus, to the state legislators of Michigan, who provided funds to support his laboratory, Novy highlighted practical aspects of the laboratory in the context of controlling human disease.

Novy extended his linear argument of pure science leading to applied science, with social consequences by bluntly concluding that it the state's responsibility to fund the hygienic laboratory. He stated:

> …the germ theory is a thing of the past. A theory ceases to be a theory when facts have been accumulated and proofs furnished. This has been done with a large number of infectious diseases. Today, the bacteriologist has already entered upon the cure of infectious diseases and even now two diseases have been robbed largely of their dreaded character (tetanus and diphtheria). It is the duty of the state to ensure protection of its citizens, not only from accident or violence, but disease as well.[50]

Novy, when addressing audiences who provided financial support for his laboratory, argued that science had a legitimate place in a medical and public health setting. He maintained that laboratory science protected citizens against disease, and it was the state's duty to fund this type of laboratory in order to provide protection of its citizens against harm, just as it was the duty of the state to support a police department to protect citizens against crime.[51] When it suited his purposes, Novy stressed the linkages between bacteriology and pathology.

Bacteriologists like Novy acknowledged the dual nature of their discipline. Bacteriology, in actuality, had both fundamental and practical elements and these elements were not always easy to disentangle. Nevertheless, the particular nature bacteriologists chose to emphasize at any given moment depended upon their purpose. When building bacteriology as a distinct discipline, they invoked the fundamental side of their discipline and emphasized ruptures with other disciplines. When advocating for funding of their laboratory, they emphasized the connections between bacteriology and pathology. Although the composite picture of bacteriology from their constructions may seem fragmented, the picture becomes cohesive when considered in the context of the purpose for which the histories were written by bacteriologists like Novy. It was the dual nature of bacteriology that allowed bacteriologists like Novy to choose to highlight either the applied or theoretical nature of their science, according to how it suited their most pressing concerns.

Conclusion

By the late 1890s in America, a cadre of bacteriological researchers began to construct bacteriology as an autonomous biological science rather than an auxiliary to other fields. The presidents of the society provided an ethical rationale for becoming an autonomous specialty—to establish a unified identify and enforce standardized codes of excellence in carrying out experimentation. But they were also likely motivated by self-interest—for prestige, to establish a base in their respective institutions, or obtain funding. Novy and other founding members of the Society, in fact, were appointed heads of newly formed, autonomous bacteriology departments in their respective academic institutions.

The Society founded by the cadre of early bacteriologists served a dual purpose in constructing bacteriology as autonomous field. It provided the structures to create their specialty and it served as an instrument by which bacteriologists could project their work and discoveries as unique. To make their argument, bacteriologists used a particular rhetoric that first distinguished between applied and fundamental sciences. Bacteriology was a fundamental science, they argued, because it had its own ideology and its distinct technical competence and set of tools to investigate how bacteria behave and cause change in nature. Next, they compared their own developing field to others, and maintained that bacteriology ought to be an independent science, much like astronomy, zoology or botany. Just as these fields were considered distinct, bacteriologists claimed that their own unique tools and tasks that enabled them to explain certain natural phenomena that other fields could not apprehend. Their creation of their specialty by claiming their own ideology is an illustration of Abbott's argument that professions are defined by their abstract base of knowledge. Bacteriologists used this ideology, along with the distinctive work they claimed to do and the discoveries about nature they claimed to make to create their jurisdiction in relation to other branches of science.

The ideologies and rhetoric of the presidents of the American Society of Bacteriology at yearly meetings were important elements in constructing bacteriology as an independent specialty. But these types of arguments, as important as Abbott has claimed were important in the creation of professions and specialties, were articulated in "special event" type of occasions and not articulated on a day-to-day basis. As Haber and Kimball have pointed out, other distinctive characteristics of professions, such as institutional norms and values, self-regulate behavior on a day-to-day basis that characterizes professions. In this regard, the letters from Novy's students demonstrate how members of the profession were motivated to adhere to a code of ethics in accord with Novy's "spirit of science." These norms included skepticism of the received word and an obligation to perform "pure" science for its own sake in a disinterested fashion.

They also made a pledge to share their results with others, to obey specialized methods and rigorous, arduous laboratory procedures.

This chapter adds to the ideas of Abbott, Kimball, and Haber by showing how individual researchers such as Novy established disciplines such as bacteriology. They were able to help create these disciplines with the help of the ideologies articulated at national meetings on special occasions. These groups of scholars and academic entrepreneurs, enthusiastic in their motivation and confident in their special knowledge and technical expertise also helped to create their disciplines by adhering to ethical codes and norms on an everyday basis. Novy's insistence on the laboratory as a source of new knowledge served as a source of inspiration for students. Novy's brand of science also served as a basis for their identity and for their work. The established reverence for original investigation allowed Novy to create an environment in which he could find achievement within his own specialty. He helped to cultivate a rising group of academic entrepreneurs who possessed distinct technical competences who represented a new order, based on its own code of ethics, norms, and ideology.

The technical competence that Novy both insisted upon and symbolized to his students served as a distinctive characteristic of his specialized field. At the time Novy was operating, bacteriologic tools were just beginning to be defined and revised, and Novy was at the forefront of this movement. At this moment, Novy's students were excited about the promise of studying with a master technician who had the expertise to use these specialized tools and to devise new, specialized methods to find truths that would ultimately benefit mankind. There was a sense of passion and thrill that surrounded studying with "the chief" or "master," as his students referred to Novy. His students had believed that science could yield new knowledge and they had faith that Novy's expert knowledge and the technical virtuosity would help them to apprehend nature's occult mysteries.

With the autonomous status of bacteriology being promoted by the society's presidents, and with institutional norms and a code of ethics that regulated behavior on a more day-to-day basis, scientists such as Novy carried out his own special research and educational activities in bacteriology departments in their own academic institutions. At Michigan, we have explored how Novy examined the fundamental scientific issues of bacteriology (chapter two) and established bacteriology as a distinct course in the medical school curriculum (chapter four). In his bacteriology department, he was able to promote a group of scholars and academic entrepreneurs who were confident in their specialized knowledge and technical expertise (chapter five). Through these activities, Novy was able to maintain a lasting base for himself, his student bacteriologists, and his department in his institution. In chapter seven, I will explore the ways in which Novy made a scientific career for himself in medicine.

CHAPTER 7

Making a Scientific Career in Medicine

Introduction: Novy's professional achievements were atypical for his day in that he succeeded in making a living as a physician-scientist without practicing medicine. Initially appointed as an assistant in the hygienic laboratory in 1888, then a full-time junior faculty member in 1891, he became professor and chief of the department of bacteriology that he helped to establish in 1902. When he retired from the lab in 1933, the department had expanded to four faculty members who were former students of Novy's: Malcolm Soule (microbic respiration), Harold Roehm (immunology to pneumococcus), W.G Nungester (bacterial metabolism), and A.C.Furstenberg (anaerobic bacteria).[1]

Novy was a 19th century American academic entrepreneur—the poor son of Czech immigrants who achieved employment in an enterprise to which he aspired. The story of American entrepreneurialism in the 19th century has traditionally been told in the context of an industrial American capitalist framework. Andrew Carnegie was one example of a poor immigrant who, due to his ingenuity and diligence, became a wealthy industrialist in a field and business he helped to create. Carnegie, through hard work and imagination, progressed from labor to the comfort of his own wealth.[2] Carnegie's success ideal, based on an individual working hard and striving for success and with his philanthropic obligation to the public, had implications for all of society in addition to his individual financial reward. Novy's story is a variation of the traditional 19th century theme of American entrepreneurism—a middle-class version in which Novy achieved success in a profession he helped to create through his own hard work and perseverance. He did not amass wealth, but his work, like Carnegie's, had implications for the benefit of a larger community. Like Carnegie, he found achievement in an operation that persisted after his death and his work provided employment for many.

This present chapter explores how Novy was able to create a full-time laboratory research position in medicine during a time when opportunities to obtain governmental funding for science were beginning to become available. Novy was able to obtain funding from the state to carry out practical work for the hygienic laboratory. Nonetheless, when addressing audiences responsible for funding his operation, Novy did not hesitate to show how he valued pure, fundamental research and the autonomy of the scientist above other goals and priorities. In this chapter, I will address the rhetoric Novy used and the ideology he employed to justify his independent position and pure research mission. In doing so, Novy expected to be exempt from the usual rules of government accountability.

In this chapter, I will also address how Novy's decision to remain at Michigan throughout his long research career was an active choice on his part to decline offers from competing institutions. To some extent, his professional life as it matured was due to Novy's capacity to make choices among the alternatives that were available to him and impose them on his surroundings. But contingent factors also played a role in how his career evolved. Following Novy's footsteps throughout his career provides an opportunity to examine these questions of agency and contingency that concerned his professional life. I will address these questions with regard to how he first established his career and how he maintained his position over a long span of time.

Making his scientific career in medicine

Novy actively pursued his career path during his early years. As an amateur scientist, for example, he worked after school to earn money to buy experimental equipment. At college, he took independent study courses in chemistry where he designed equipment and methods that provided a foundation for his subsequent independent research career in bacteriology. But there were also elements of contingency as his career unfolded. He re-entered graduate school in 1887, for example, because he was unable to find a chemistry job in industry. Furthermore, the motivation behind his choice to enter medicine was never explicitly stated in his letters. Becoming a physician was not an aspiration he had in high school or even college—during that time, he wanted only to become a chemist. His interest in medicine may have been sparked by the educational opportunities available to him at Michigan where professors like William Prescott taught physiological chemistry at the medical school as well as chemistry at the college. One can speculate that Novy's interest in medicine was a by-product of this trend, as Prescott may have interested Novy in the medical aspects of physiological chemistry.

Novy selected and put into place the components he needed to succeed in his aim to be an independent researcher. He filled a position in bacteriology that he and Vaughan helped to create—one that enabled him to work full time in research without practicing medicine. In order to create this position, he delivered his specialized argument about bacteriology to audiences, including the state legislature, who funded his research operation. At the time Novy was making his arguments in the late 1880s, a few governmental funding sources had recently become available to scientists. For example, the Morrill Acts of 1862 and 1890 granted federally controlled land to states to endow land grant colleges whose mission was to teach science and engineering.[3] In addition, the Hatch Act of 1887 extended federal funding to scientists who worked in Agricultural Experiment stations affiliated with the land grant colleges who had college-teaching assignments as well as station duties in entomology, horticulture, or poultry husbandry.[4] Funding from the latter source, according to Charles Rosenberg, played a role in the careers of individual scientists and also provided a secure level of support for state universities.

During a time when governmental funding for scientists was in its nascency, Vaughan and Novy sought to obtain funding from the state legislature to support the Michigan Hygienic Laboratory. To the state legislature, Vaughan and Novy argued that their primary function was to perform fundamental, basic microbiology research investigations. Novy said the primary purpose of the laboratory was "the fundamental, basic demand for knowledge of hidden facts which bore upon microbes…the first object of the hygienic institute is to carry on basic, original investigations whereby the bounds of knowledge will be widened."[5] To the same audience, Novy also argued that the "duty of the hygienic laboratory…[was to]…search for truths…[in order to]…uncover the cause of things."[6] In his speeches to legislative audiences, Novy also emphasized the necessity of the autonomous role of the laboratory investigator to choose the topic and scope of research investigations. Novy argued that the accumulation of new knowledge required the independence of the investigator. Novy said that new knowledge was "not an accident [but rather] the result of logical sequence of patient, prolonged, systematic investigations selected by medical researchers."[7] Thus, Novy constructed an argument for performing pure, fundamental science, and he emphasized the autonomy of the researcher.

Novy accepted governmental funding for his laboratory, but he never mentioned any obligation of accountability to the responsible government funding agencies. Absent from his speeches or letters was any information about reporting the results of his experiments to responsible funding agencies. Even though Novy never explicitly addressed accountability to the state government, Novy, as reviewed in chapter six, constructed a progressive narrative where he selected facts of history in such a fashion as to give the impression that the "pure" scientific work of laboratory researchers would produce discoveries that could at some future point provide a practical benefit, including the means for prevention and cure. Thus, the legislature may have been able to infer from Novy's speeches that funding his fundamental research could yield a practical benefit, even though there was no formal system put into place to account for Novy's research activities.

Novy was instrumental in establishing bacteriology as an independent department in his own institution. His ability to attract students, serve as an idealized mentor for them, and establish a structure in which they found achievement in their activities, allowed him to build an enduring bacteriology department. After over forty years of active research, he curtailed his experimental activities and assumed administrative duties as dean of the Medical School in 1933. He retired two years later at 70 years in 1935.[8] [Figure 7.1]

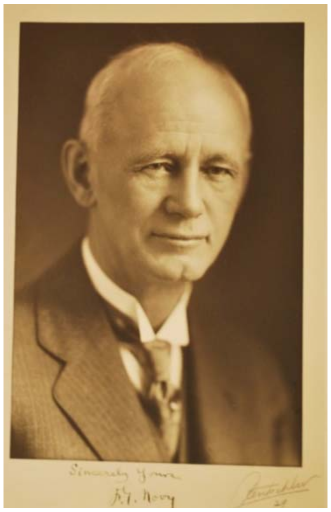


Figure 7.1. Novy in a posed Portrait, 1933 at age 68, at the time he retired from his laboratory and began his two year tenure as dean.

Novy was successful in achieving his aspirations—he performed medical research full time without practicing medicine. Novy's was the academic leader of an intellectual enterprise for an extensive period of time. His long stay at one institution, however, was not a passive affair—it was the result of an active choice. With his high regard among scientists, he was recruited by several institutions. But he chose to remain at Michigan to work in an academic environment he considered rewarding. I examine one offer and how he evaluated it to gain insight into which elements of his research program and Michigan were most meaningful to him, and how personal considerations influenced his decisions.

In May 1901, a group of prominent medical researchers assembled in Washington D.C. to discuss the possibilities of establishing a new medical research institution.[9] The group consisted of Professors William Welch (professor of pathology at Johns Hopkins University in Baltimore), T. Mitchell Prudden (professor of pathology in the College of Physicians and Surgeons of Columbia University in New York), Christian Herter (physician and clinical pathologist in New York), Hermann Biggs, Simon Flexner, and

Theobald Smith.[10] They read a letter from the American businessman and philanthropist John D. Rockefeller, Jr.[11] Rockefeller informed the prominent researchers that his father, John D. Rockefeller Sr. would provide funds to create an institute for medical research of $20,000 per year for ten years, and requested the doctors to serve on a committee that would manage the fund and carry out its goals.[12] Subsequently, Rockefeller decided he could make one million dollars available for the next ten years for buildings and operations.[13]

The group of men named the organization the Rockefeller Institute for Medical Research and they designated themselves as its board of directors. Flexner later agreed to become the director of the institute on July 1, 1903. The certificate of Incorporation of the Institute declared that the purpose of the corporation was medical research with special reference to the "prevention and treatment of disease." The Institute's focus was explicitly specified in a detailed report of its activities for 1902, "while the study of lower animals is highly important from their bearing upon the understanding of many forms of human disease, the intimate relation with the problems of human disease should not for a moment be lost sight of."[14] Thus, the original objective of the Institute was a practical one, to conduct investigations in the nature and cause of disease and the method of its prevention and treatment, and to make knowledge relating to these various subjects available for the protection of the health of the public, and the improved treatment of disease and injury.

The Rockefeller Institute for Medical Research was incorporated under the laws of the state of New York and was established in 1901. From 1901 to 1904, the $20,000 per year pledge of the institute was applied only in the form of grants to support the work of investigators in different parts of the world. In 1904, anticipating the completion of its own laboratory, the institute leased a building, formerly a part of the Nursery and Child's Hospital at 127 East Fiftieth Street. Here the first investigations conducted by the institute were begun, under the direction of Simon Flexner. In October 1902, Rockefeller gave a site for the larger institute, the cost of which was about $40,000. The new building was under construction for four years and opened on May 11, 1906. Later that year, the work of the institute was established on a permanent basis with a gift from Rockefeller of $250,000.[15] By 1907, the Rockefeller Institute –with abundant funding, well-equipped, large laboratories in a newly constructed building and a group of the most prestigious medical researchers serving on the Board of Directors—was considered by many researchers to have been the premiere research institute in America at the time.[16]

By 1907, Simon Flexner, then the director of the Rockefeller Institute in New York City, sought to recruit prominent researchers to head various departments within the institute. For the position of director of bacteriology, Flexner turned to his fellow commissioner from the San Francisco plague investigation in 1901, Novy. Flexner stated that he had a high regard for the diligence and ingenuity Novy displayed when he served as bacteriologist of the commission.[17] He also admired Novy's research accomplishments, particularly the innovative techniques Novy devised to visualize disease causing organisms.[18] In spring of 1907, Flexner offered Novy a position as the director of research at the Institute.

The position must have been tempting to Novy. From his perspective, a well-equipped, expansive laboratory funded on an ongoing basis by one of the country's wealthiest philanthropists in an institute with the most prominent medical researchers in the country must have been an attractive proposition. After all, Novy had been based at a state-affiliated institution where he and Vaughan had lobbied to build and fund a laboratory.[19] At Rockefeller, Novy would have been able to move into the finest research facility in the country, one whose operations were fully funded on perpetual basis. If he accepted Flexner's offer, Novy would have been able to give his undivided attention to his research program, while working in the most premium research laboratory in the country and also not have to seek funding for his facility on a continued basis.

Novy may have also considered Flexner's offer attractive for personal reasons. The Rockefeller position would have increased Novy's salary at a rate of twice of that he was receiving at Michigan: his salary at Michigan in 1907 was $3,500 per year; he was offered $7,500 per year, from Rockefeller. To give a longitudinal perspective of his salary at Michigan, in 1887 it was $200 per year, and in 1921 it was $7,500 per year, and in 1932, it reached $8,500 per year. Such a raise in salary in 1907 must have been tempting for Novy, who at the time had five children, two of whom were about to enter college. Novy knew allure that working at Rockefeller meant a greater salary, a superbly equipped laboratory, and a leadership position at a prestigious research institute. Despite these attractions, a series of correspondences with Flexner discloses the factors that influenced Novy's ultimate choice to remain at Michigan.

Novy felt that the position at Rockefeller would derail him from pursuing what he called the "pure" laboratory scientific endeavors that he was accustomed to pursuing at Michigan. In addition, he wished to avoid getting bogged down with the "red tape" attached to an administrative position within a research institute as large as the Rockefeller.[20] He felt that he would have less control over the direction of his research agenda than he had at a university because he believed that at Rockefeller, he would need to justify whether his research programs had relevance for therapeutics. Novy was fearful that this requirement would impair the quality of his science he was accustomed to performing in academics by restricting his selection of research topics, limit his choice of experiments, and force him to publish his material before the results had been validated through experiments that met his exacting standards.[21] He feared the job would take him away from association with young students and ideas, and that the position would not give him the freedom to choose and pursue the fundamental research topics he was accustomed to pursuing in academics.[22] The latter was of particular concern to Novy because he did not wish to abandon the latitude that his scientific research program had provided him.[23]

At Michigan, Novy had been receiving independent funding from Rockefeller to perform research at his Michigan laboratory since 1902. William Welch, then head of the board of directors at the Institute, wrote to Novy in 1901 inviting him to apply for a grant.[24] Welch explained to Novy that Rockefeller was targeting research with a practical application in mind. He said, the "money is to go into the prevention of treatment of disease. The decision was made to make use of existing labs for this purpose, rather than start a new lab. Work that has come from Pasteur in making vaccines and Koch in searching for treatment of disease indicates the general scope of the research that is desired."[25] Welch informed Novy about the annual sum of $20,000 that would be used to fund laboratory research of this practical nature, and he asked Novy to propose a subject for study, and then funding could be granted accordingly after review by a committee consisting of Herman Biggs, Theobald Smith, Simon Flexner, and Welch.[26]

In response to Welch's invitation, Novy submitted a one page proposal to develop an animal model in the hopes of developing a vaccine for trypanosomiasis.[27] The Institute awarded Novy $1,000 per year as they deemed that his proposal was aligned with the goal of the Institute.[28] By the time Novy was invited to take a job at Rockefeller in 1907, his efforts to devise a means for securing immunity to trypanosomes in a rat model had not yielded a positive result.[29] Nevertheless, Novy continued this line of research, and he submitted a one-page progress report to the institution each year. He continued to receive ongoing funding in the sum of $1,000 per year to further this project.[30] But Novy sometimes showed impatience at the administrative rules of the Rockefeller.[31] For example, he informed the administrators of Rockefeller he felt he had not always received his funding in a timely manner.[32] On another occasion, he petitioned the board because he had applied for funding for two $500 grants and only received funding for one of them.[33]

On May 17, 1907, Flexner wrote to Novy offering Novy a position at the Rockefeller Institute.[34] On May 23, Novy responded to Flexner saying that he had given the matter some thought, and then Novy expressed his reservations about the Rockefeller offer. Although he conceded that his Michigan salary was small, Novy wrote that things "on the whole are satisfactory at Michigan," including raising a family. He then voiced concerns about accepting a position at Rockefeller—whether that might entail giving up freedom of investigation to pursue science for science's sake, as he had been accustomed to at Michigan. He insisted that the position would need to be '"free from restraints in the matter of the nature of my experiments and publications."[35] Novy also had reservations about losing the autonomy he possessed by running the bacteriology department at a university affiliated medical school, and the bureaucratic obstacles he may encounter at an institution the size of Rockefeller. To Flexner, Novy wrote:

> The salary at Michigan is small, but I enjoy absolute independence in the scope and conduct of my research and as the head of the department, I am not answerable to any other than Faculty and regents. Having lived under these conditions, I cannot consider a subordinate position to find myself checked by rules, orders and red tape. The position at Rockefeller would need to have to be one of about the same independence as here and that it would carry ample provision for conduct of research wherever deemed expedient and be free from any restraints, expressed or implied, in the matter of the nature of my experiments, publications, etc."[36]

Novy was hesitant to leave academics because he was reluctant to relinquish what he valued most highly: a complete lack of restrictions on the selection of research topics and the freedom to choose and design experiments. Novy then went on to say even if all conditions were satisfactory, he would still have some hesitation about what he described as transplanting the family from country to city life. He had settled in country life, and asked Flexner to address what the advantages of city life over country life might be.

In two subsequent letters, Flexner addressed Novy's concerns and tried to persuade him to come to Rockefeller. On May 27, Flexner stated that he would be able to "offer [Novy] whatever [Novy] want[s]."[37] Flexner himself had been a faculty member at a medical school prior to accepting his position at Rockefeller, having been a professor of pathology at the University of Pennsylvania. He used this personal experience in academics to identify with Novy's concerns and validate them, but also to ensure him that he would not have any restraints if he were to come to Rockefeller. In a reply to Novy, Flexner wrote:

> There are no conditions of status and work mentioned that the institute cannot afford you in the fullest measure. I know what is the liberty which a university affords its higher staff and I believe that less than that in any scientific institution would not only be intolerable but also utterly unwise. I would like to go over with you the project which has been forming itself in my mind and see how it strikes you.[38]

Flexner tried to persuade Novy that there he would have the freedom he desired to conduct the experiments of his choice at Rockefeller. To convince Novy of this, Flexner maintained that he did not have a "specific plan" for Novy, but a general one—to offer what he called "the greatest promise of fruitfulness in research."[39] Flexner was hoping that his word about a flexible atmosphere at Rockefeller would carry weight with Novy—after all, Flexner had considered the same issues about sacrifice of academic freedom as he moved from academics to a research institute. Flexner hoped that his word and advice would resonate with Novy.

Flexner traveled to Ann Arbor to visit with Novy to discuss any lingering reservations. Novy left no account of this meeting, but after Flexner returned to New York, Flexner again wrote to Novy.[40] In the letter, Flexner bluntly told Novy he would have the largest, best-equipped laboratory possible in New York, and he would have a higher salary as well. Flexner assured Novy that he would also have a well-trained staff.

Flexner wrote, "I sincerely hope that you will decide to come to the institute where I can assure you everything possible will be done to advance your work and interests."[41] He offered Novy a chance for a permanent appointment and an opportunity to run the research department.

After considering Flexner's offer for one month, on July 3, 1907, Novy declined the Rockefeller position. In a letter to Flexner, Novy acknowledged that he had "endeavored to look at [the offer] from all sides."[42] Novy conceded that the facilities and salary were preferable at Rockefeller, saying that he "fully realized the advantages associated with…the position." He admitted that the University of Michigan officials "realize[ed that] they cannot compete with the institute either in facilities or in the salary." He then admitted, "it was not expected that [university officials] influence my decision, it was wholly a matter for me to decide one way or another." In making this distinction, Novy did not mention the issue that had previously troubled him—the possible loss of absolute freedom of his research program and the opportunity to pursue the research topic of his choice for both him and the promising students who worked under him to pursue. Flexner spent such effort trying to persuade Novy that he would have unmitigated freedom to pursue his own topic of research that this topic had become the focus of Flexner's efforts to attract Novy to Rockefeller.

But in his final response to Flexner's offer, Novy suddenly shifted the focus away from the issue academic freedom to the topic of his preference for bringing up his children in rural Ann Arbor. Novy wrote:

> Your letter of the 23rd acquainting me with the action of the board and formally offering me an appointment in the staff of the institute while very gratifying in itself brought me face to face with the question of removal which I have endeavored to look at from all sides. Everything considered, I feel that it would be unwise to make the change. The university authorities while anxious that I should stay…could not influence my decision. But there is an aspect which after all must be [a] factor and that concerns the best interests of the family (particularly the children).It was wholly a matter for me to decide one way or the other and I much regret that I cannot bring myself at this point in time to meet your sincere wishes and accept the position tendered to you through you by the board.[43]

Thus, the actual reason Novy declined the Rockefeller Institute offer remains speculation. It is very possible that Novy believed he would have be offered the freedom to select his experiments at Rockefeller and that he would not be overburdened with administrative tasks. But it is also possible that he did not believe he would have to target the selection of his experiments according to practical application rather than doing science for science's sake. Novy in his initial response to Flexner stated that the Rockefeller offer would have to be "free from any restraints, expressed or *implied* in the nature of his experiments. Despite Flexner's attempts to convince him otherwise, it is possible Novy felt that there was something implicit about Rockefeller's restricting the nature of his academic pursuits. If so, what may have led Novy to harbor this concern despite his meetings with Flexner?

In order to receive ongoing funding from Rockefeller for the research carried out at Michigan, Novy needed to target his research for practical matters. As Welch wrote to

Novy requesting an application for funding, “making vaccines and searching for treatment of disease (was) the general scope of the research that is desired.”[44] To receive Rockefeller funding, Novy had to write grants to ensure his intentions were aligned with the practical goals of the committee. Novy was not required to go through a similar process of having his experiments approved before he could begin them at his own academic base. At Michigan, he carried out whatever experiments he wished to perform regardless of whatever practical application they may or may not have. Performing experimentation for science’s sake had been of crucial importance to Novy throughout his career. This freedom was evident in vast expanse of topics he chose to investigate throughout his career that were not motivated by practical application, the large number of techniques he innovated, and the number of investigations he performed that were never published to make organisms and their behavior visible to others—not only those organisms that were involved in diseases in humans. Michigan, as he admitted, gave him ample leeway to investigate the topics of his choice, and he was certainly weary about losing this latitude if he relocated to another institution—even if this possibility was only implicit.

Although Novy never elaborated on what he meant by not getting involved in ”red tape,” it is possible he was referring to the need to obtain approval from a committee in order to pursue a particular line of research, as had been a requirement for him to receive his grant funding from Rockefeller. If indeed he declined the offer on the basis of lack of freedom of experimentation or concern about becoming bogged down with “red tape,” it is possible that he used his family simply as a more convenient explanation in declining the offer. Novy may have reasoned that Flexner would not have any avenue to put forth a counter offer if Novy invoked his family as a reason to decline the Rockefeller offer. Furthermore, in decisions Novy made at other points in his career (e.g., deciding whether to study in Europe, or to choose a career path in which a high salary was not available), he did not bring family matters into consideration. It seems questionable whether Novy would have based the Rockefeller offer on the needs of his family.

Although these possibilities remain speculative, the correspondences with Flexner show the facets of his work that Novy valued highly—the freedom to carry out experiments without practical application in mind. In 1912, five years after he declined the Institute's offer, Novy's Rockefeller-funded program to develop a trypanosome vaccine failed to yield any positive results.[45] Furthermore, Novy never submitted the Rockefeller funded work on developing immunity to trypanosomes for publication.[46] Perhaps sensing that the Rockefeller may have wished to withdraw his funding, Novy addressed the board of scientific directors in 1912.[47] In his letter, Novy provided his rationale for Rockefeller to provide continued support—because his work may at some day lead to protection of infection in animals, then in man, even though it had yet to yield such a result after 10 years of effort. In 1913, Flexner wrote to Novy, informing him that board of science decided to withdraw Rockefeller's yearly $1,000 of funding to Novy.[48]

Novy also considered an invitation to head the newly formed Department of Bacteriology at Northwestern Medical School. On February 18, 1909, he received a recruitment letter from Robert Gait, Professor of Pathology. The letter stated that Northwestern and its "benevolent patron, Mr. James A Patten, would grant, without hesitation or condition, every wish you might have your own way."[49] On February 21, Novy wrote to Gait:

> This university [Michigan] has been so liberal with me in granting complete control in selecting the course of my research program that I can hardly put myself in the position of considering a change. Owing to the long years of service here and the generally satisfactory conditions, I do not feel that I can consider the position with which you have honored me.[50]

Just as he had done with Rockefeller, Novy weighed the various factors that had meaning for him at Michigan and he saw no good reason to leave for Northwestern.[51] At Michigan, Novy valued the freedom to select the "course" of his research program and provide guidance to promising young students who were eager to work under his supervision.

Paul de Kruif was one such student who worked in Novy's laboratory from 1911 until 1918.[52] One year after he obtained his doctorate in 1916, de Kruif entered the military during the First World War.[53] During his army service, de Kruif characterized Novy as "a 'pure' scientist; never rushing to print, lashing his sharp tongue out with a few selected words at the student who was guilty of sloppy work, and possessing disdain for publishing one's results too early instead of verifying with repeat experimentation."[54] When de Kruif returned to Michigan in 1918, he had decided to accept a position at the Rockefeller Institute. Years later, when recounting this decision, de Kruif characterized Novy's laboratory as a disciplined, scientific "shrine" that upheld "honesty and accuracy", whereas he portrayed "mistakes frequently made" in the Rockefeller laboratory that was too consumed with "sensational scientific events".[55]

Novy's concern about the potential for a research institute's allegiance to practicality to constrain independent, "pure", methodical experimental conduct is a theme that is evident in *Arrowsmith*. de Kruif and Lewis pattered the McGurk Institute after the Rockefeller. There is no direct evidence that de Kruif told Lewis about Novy's offer from Rockefeller or Northwestern, or that de Kruif was recounting Novy's sentiments towards Rockefeller rather than his own. Nevertheless, de Kruif and Lewis dramatize the potential of the practical orientation of research institutions like Rockefeller to threaten the integrity of "pure" university-based research.

In *Arrowsmith*, Martin is offered a position at McGurk and accepts in part because of the high salary, $10,000 per year.[56] While at Mc Gurk, Martin continues to practice the pure brand of science Gottlieb taught him. About Gottlieb's brand of science, Martin said, "When he was at his bench he did not have grandiose aspirations but there was the sniffling, snuffling beagle…Before him, supreme joy of the investigator, new mountain-passes of work opened, and in him was new power".[57] But the Institute became intolerant of Martin's Gottlieb-like brand of science. A Dewitt Tubbs, Mc Gurk's director, said to Martin, "you have been working brilliantly, but without a complete vision of broader humanity…(you are)…merely plugging along doing individual work".[58] Also, Major Holobird, said, "We'll have extended your work to practical proofs…There's no limit to the honors that'll come to you…acclaim by scientific societies…prizes… a ripping place in society."[59] Martin, who perceived the "horror of the shrieking bawdy thing called success, with its demand that he give up quiet work," came to regret his decision to join the Institute.[60] Gottlieb, who became critical of Mc Gurk's rushing results to print too quickly without verifying them, said to Martin, "You let a doctor try it before you finished your research? You want fake reports of cures to get into the newspapers, to be telegraphed about places? You want to be a miracle man and not a scientist?"[61]

Eventually, Martin becomes alienated from McGurk's intolerance to the pure science ideal—working independently and diligently, often throughout the night in search of truths and not necessarily cures. Lewis romanticizes the urge for scientific independence by having Martin leave Mc Gurk with a colleague, Terry Wickett, to pursue his "ideal of science" in rural Vermont. In Vermont, Martin and Terry strive to achieve their true calling by "perform(ing) science in isolation, devotion…without trying to solve anything for anybody but ourselves."[62]

The image of Novy as a well-known, autonomous scientist who works in solitude late at night and is therefore unrecognized by the public is consistent with the image of the isolated laboratory researcher iconized in *Arrowsmith*. The portrayal of the scientist who discovers happiness and adventure while alone in his sanctuary, the laboratory, enforces the moral quality of his behavior. Consequently, solitude and retreat become the companions of true scientists as they seek truths in their shrines of science. Novy's life encapsulates this image of the late Victorian laboratory researcher. In his elaborately equipped physical space, his medical school laboratory, Novy happily and independently searches for truths in solitude. In this technologically intricate shrine where, as ascetic as any monk, Novy lived only for his science. He eschews involvement in any activity—laboratory work in the field or private practice that would divert his absorption in the laboratory. Although a scientist like Novy was known by experts within his field, his discoveries were unknown by the general public. Similarly, Lewis depicts a scientist like Gottlieb as an independent, solitary person who works alone in the laboratory and whose works are unknown in general. In the novel, when Martin wanders from his straight “arrow” path (e.g., when working in the clinic or public health department), he becomes forlorn without the seclusion of his laboratory work.

The portrayal of a scientist as an independent figure is both romanticized and exaggerated by the closure of *Arrowsmith*. Martin eventually listens to Gottlieb who explains that Martin would be fortunate if he is not successful because success, as defined by research institutions like McGurk, ruins the scientist. To resolve his conflict, Martin moves from the city to the woods with his colleague from the McGurk Institute, Terry Wickett. There, they create a laboratory of their own and achieve a salvation in their retreat to the woods as Martin finally embraces the power of independence of the scientist. Through this retreat, Martin is able to embrace the spirit of science and his inner calling and flee from the social and commercial department heads that he believes have hindered his true scientific work. Alone, isolated, and independent are the images of the laboratory scientists searching for truths, unencumbered by the restrictions of practicality that institutions like the McGurk place on them.

Novy’s own reluctance to accept the position at Rockefeller is mirrored in *Arrowsmith*. Lewis contrasts the image of Gottlieb as a pure scientist against the so-called successful McGurk researchers Tubbs and Holabird who Martin calls “men of measured merriment”. Martin believes that their accomplishments are measured because their reward is derived from social status and business profit. The McGurk men have achieved the success and wealth that society covets yet they are antithetical to Martin’s search for truth as they rush to print, and their work is guided by practical application.[63] For Martin, the successes of the “men of measured merriment” tempt him from his true calling, but they have the potential to contaminate the “purity” of the spirit of science that he learned from his teacher, Gottlieb.

Novy’s long academic Career at Michigan

Novy received recognition from his peers for the research and educational activities he carried out during his many years at Michigan.[64] He gave keynote addresses at national and international meetings, published 151 manuscripts in peer-reviewed medical and scientific journals, and wrote two authoritative texts that were considered to be the standard in bacteriology.[65] Furthermore, he was elected to leadership positions in prominent professional organizations, including the Michigan Academy of Science (President 1910) and the Society of American Bacteriologists (President 1905). He also received prestigious honors, including election to the Institute of Medicine in America, and Chevalier, Legion d’honneur in France.[66]

It is possible that Novy chose to remain in his position at Michigan not only to engage in laboratory science with minimal distractions and restraints on his experimentation, but also because he felt that such a position gave him the greatest opportunity to influence students, other physicians and scientists, and the general public on the value of laboratory science and its microbiological representations to medicine and society.[67] In a lecture delivered to medical students at the University of Michigan in 1908, he stated his linear views on the influence of laboratory spirit of science on medicine:

> In recounting the evolution of the modern laboratory spirit in medicine...the onward and upward evolution in search of truth has left the old school, the old

> medicine, far behind in its shadowy past. In its place we have the new school, the new medicine based on the solid rock of experimental research. It is this scientific medicine of today which strives to unravel the mystery of life, seeks for the causes of things as well as the means of prevention and cure."[68]

From his prestigious position, Novy preached throughout the years that laboratory science had the potential to offer certainty to a medical profession that he felt was in need of truth.[69]

Conclusion

Novy was an academic entrepreneur, a son of immigrant parents who succeeded in his aspirations to become a full-time, laboratory-based medical researcher in bacteriology at a time when such positions were being created. The stories of late 19th century entrepreneurs have been told in the more familiar context of industrialists. But showing how Novy, a middle class, professional, made a scientific career in medicine casts another contour to the more familiar picture of entrepreneurism.

This chapter shows how a medical researcher like Novy depicted medical science in the course of justifying his claim for a special relationship with the state government for support of the hygienic laboratory. Novy was making his arguments at a time when a few federal grants for scientists, such as the land-grant colleges and agricultural science stations, had been established. However, as D.S. Greenberg has pointed out, it was a time well before large-scale federal grants for medical researchers first became available after the Second World War.[70] To those who funded his laboratory in the late 19th century, Novy promoted an ideology of medical science to be pursued for science's sake. He did not emphasize the pursuit of bacteriology as a means of solving a material problem; it was to be pursued simply because of the truth—which was what science was thought to be uniquely about—was noble in itself, and because it was laudable to expand knowledge. Interestingly enough, to those funding his practical hygienic laboratory, Novy was not emphasizing the eventual utility of his work. Instead, he stressed that scientific knowledge was valuable in its own right. However, he freely recalled in his linear narratives that scientific knowledge did in fact frequently produce practical benefits in the long run.

To those funding his activities, Novy was portraying bacteriology as an autonomous activity that required no outside surveillance and with a mission to search for fundamental truths. Novy's portrayal of science was formulated in the course of Novy's dealings with governmental funding for his hygienic laboratory. Normally, as historian Michael Mulkay points out, the receipt of governmental funds by a medical researcher entails acceptance of the principles of accountability; that is, government controls the distribution of funds and decides to what extent these funds have been appropriately used.[71] An account of Novy, however, depicts a different scenario—Novy as a 19th century medical researcher avoided the application of the principle of accountability to his hygienic laboratory activities. With his historical account of scientific advancements resulting from fundamental laboratory, Novy created an argument to give the impression that government regulation from the outside was unnecessary for scientists to continue with their work. Similar to conceptions of intellectual independence and academic freedom he had seen in Germany, Novy created a historical narrative that implied that scientists, when they proceed according to their own judgements and values, produce valid knowledge.

Historians have addressed what late 19th century American physicians and would-be researchers did after they returned to America after studying science in Germany. Kenneth Ludmerer noted that most Americans who returned from Europe practiced medicine as full-time research positions were sparse in number.[72] Thomas Bonner echoed this sentiment, claiming that research positions were available within a handful of universities.[73] Because the university schools had to compete with practical training schools for students, Bonner claimed that even the elite medical schools had to provide a larger amount of practical professional training than their German counterparts. This meant that even in elite medical schools, full-time research positions were few in number. William Rothstein claimed that by and large, American physicians returning from Europe did not find full time research jobs in American medical schools, and most used part-time teaching positions at medical schools only as a stepping stone for future clinical chairs. [74]

The present chapter adds to the medical literature by showing how an aspiring medical researcher first established and then sustained a full-time career in medical research. Novy and Vaughan clearly set out their priorities of performing fundamental, pure research without governmental interference in the context of public health service from the beginning. At a time when most aspiring researchers were unable to obtain full time university positions, and when opportunities for government support was newly available, Novy casted his field in a particular fashion in an attempt to justify their special relationship with government—to obtain funding, have the freedom to choose experiments, but not to have accountability by the funding governmental source. In the late 19th century, when few full-time research positions were available, Charles Rosenberg maintained that in the years of austere academic budgets, almost any position was a good one.[75] Thus, when taken in context of the historic moment, Novy's ability to attain his goal as a full-time medical researcher was noteworthy.

The ideology Novy adopted in his addressing funding agencies is consistent with the relationships social scientitss have claimed that 19th century American scientists outside of medicine had with government. George Daniels maintained that in the late 19th century, the pursuit of truth was valued highly by American scientists (chemists and physicists in particular) and the independence of the scientific community was a prerequisite for the attainment of this value.[76] Daniels claimed that the practical applications of pure science became increasingly evident by the late 19th century, it was no longer necessary for chemists and physicists to emphasize the eventual utility of their work. Furthermore, he claimed that as the scientific community became increasingly professionalized, its members came to believe that only qualified scientists could understand scientific investigation and increasingly wanted to exclude non-scientists from making decisions about the course of science. Thus, Daniels argued that the search for pure knowledge and independence buttressed the attempts of scientists to claim the right to create new knowledge with the help of public funds, but without outside interference.[77]

In the late 19th century, social scientists such as Daniels maintained that chemists and physicists began to argue that society should support but not govern science. A study of Novy adds to this literature by showing how a medical researcher was also in a unique position of receiving governmental support without being subject to the usual rules of accountability. During this period, not only chemists and physicists, but also medical researchers self-regulated themselves with social values as individualism, disinterestedness, and sharing; and that these values could only be maintained if scientists were left free from outside regulation.

How did Novy sustain a scientific life in medicine? His decision to remain at Michigan was a conscious choice to continue working in an academic environment of his own making, one which provided a suitable environment in which he could carry out his intellectual research operation in the deliberate, methodical way he considered rewarding. With high regard for the permissive research environment of his academic institution as a means to provide verifiable discoveries, he rejected an offer to be the director of research at the Rockefeller Institution because of potential restraints it would pose on the conduct of his research. Throughout the long years he remained in his academic position at Michigan, Novy successfully institutionalized his conception of experimental aims that were unfettered by practicality, experimental design that was disinterested, and methodology that was rigorous. His ability to attract students, serve as an idealized mentor for them, articulate a “spirit” of science in which he believed, and establish a structure in which his students found achievement in their activities allowed him to create a culture of scientific medicine and build an enduring bacteriology department at Michigan.

In turn, one of Novy’s students, Paul de Kruif, worked with Sinclair Lewis to write about Novy’s spirit of science in *Arrowsmith*. Just as was the case with Novy, research institutes like McGurk were not a suitable environment for pure research because of restraints on the conduct of research due practicality. But in the novel, de

Kruif and Lewis addressed larger themes about the meanings that Novy's spirit of science had for both medicine and for American society.

CONCLUSION

This dissertation depicts an image of late 19th and early 20th century American bacteriology that differs from its traditional portrayal by medical historians. This dissertation argues that during a time when historians noted bacteriology had veered towards becoming an applied science, Frederick Novy, an American bacteriologist working in a medical school setting, had given store to pursuing scientific knowledge above and beyond anything else. Novy stressed the "virtue" of performing laboratory experiments to pursue scientific truths "for their own sake" and without making utility a commanding imperative in his experimental design. It was not necessarily the spectacular therapies that emerged, but rather the use of novel instruments used to objectively pursue "pure" truths itself that were the highlight of the work in Novy's laboratory. Taking the overarching themes of the pure science ideal and instrumental objectivity as a starting point, I will now address five major points developed in this dissertation that are built upon them.

First, Novy introduced something new to bacteriology: a method of dynamic observation as an objective means to visualize organisms and apprehend their behavior in nature. Through his instrumental and methodological innovations, he introduced an element of time that allowed him to go beyond the stasis that had characterized conventional bacteriological methodology. Prior to Novy's work, bacteriology had utilized systems with predetermined, fixed observational time periods. But the traditional system did not permit the cultivation or visualization of microbes whose morphology was constantly changing. The innovative techniques that Novy devised to cultivate protozoal organisms and the novel dynamic observational methodology he introduced allowed him to visualize individual protozoal forms as they matured over time.

Novy went beyond description of changing morphology—he sought to correlate particular structural forms with their respective behavior. Using an innovative animal challenge experiment, Novy was able to identify the precise morphologic form that was responsible for causing animal infection. He verified his hypothesis by showing that the "infective" form he used to inoculate an experimental animal matured into the "pathological" form that he visualized in a diseased organ of the animal. Novy's experiments were performed with protozoa that were non-pathogenic in humans. They were not carried out with any practical intention of providing human cures, but rather to provide a greater understanding of the biology of protozoa as they adapted to various hosts. On the basis of these experiments, Novy's colleagues considered him as a "basic" or "pure" scientist whose investigations provided a greater understanding of microbes and their behavior in nature.

In his private letters and publications, Novy shared precise descriptions of his novel dynamic observational methodologies with his scientific colleagues. As a consequence, it became possible for Novy's peers to use his techniques and methods to conduct experiments about protozoal behavior in their own laboratories without Novy's direct presence. Through this process, several investigators were able to reproduce his findings and "objectively" visualize the evolving protozoal forms for themselves. By sharing information about his specialized techniques and instruments, Novy showed that science was not a matter of an isolated scientist confronting nature. His emphasis on sharing techniques illustrates Shapin's argument that truth is a "social institution" whose collective identity is fundamentally a matter of trust among scientists.[1] His communications about methodology and technique in his protozoal experiments and other projects allowed colleagues and students to "visualize" microbes on the cellular level and evaluate how organisms survived in nature by detecting the molecular products of their metabolism and their respiration.

Novy's focus on instrumental objectivity provided more than a means for a community of scientists to understand nature—it also permitted a possibility for them to reach agreement about nature's truths. Indeed, in the setting of controversies, such as the alternation of species and teaching bacteriology to medical students in the setting of a faculty member who disputed the germ theory, Novy relied upon his specialized instrumentation as an objective means to resolve disputes. In the late 19th century, laboratory science, with its specialized technology and analytical inductive methodology offered the hope to use universally valid principles that were more consensual than older, traditional-based methods. Novy's reliance on instrumental objectivity illustrates, as Daston and Gallison have pointed out, how laboratory science offered the promise to be objective, free of prejudice and to resolve conflicts among scientists.[2]

But Novy's rigorous bacteriological techniques and methods could not provide the objective evidence that was needed to obtain agreement in all circumstances. In the situation of an outbreak in San Francisco in 1901, for example, the new science of bacteriology did not have authority to prevail over traditional ways to account for natural phenomena. In 1901, Kinyoun's and Novy's bacteriological findings were unable to convince the citizens and physicians of San Francisco that plague was present or compel the community to take action against plague. They defined plague not by bacteriological laboratory studies but according to their own objective criteria—the clinical manifestations and the massive epidemic behavior—in accord with their training and prior understanding of plague. For these physicians, the isolation of a bacillus in the laboratory in the absence of typical clinical and epidemiological features did not mean that plague was in the city.

In reality, despite the use of precise instruments and logical methodology used by an expert like Novy, consensus in San Francisco remained an elusive goal in 1901. Physicians, bacteriologists, and public health officials had distinct ways of interpreting bacteriological results that differed according to their training. Each professional brought their distinct ways of understanding and interpreting bacteriological findings according to their training. Each had biases and prejudices from which they could not escape. Thus, laboratory science, with its rational methodology, could not entirely banish bias or conflict among these professions during this historic moment. Indeed, the inability of science to eliminate individual prejudice became noticeably evident later in the twentieth century, when science was used to legitimate ideological fanaticism and scientific rationality was deployed in pursuit of barbarous ends. For example, popular eugenics in the early twentieth century ultimately resulted in the practice of genocide in the Second World War. Later in the twentieth century, the prospect of scientific rationality to be normative ideal for society became subject to reexamination.

Secondly, with regard to medical education, the broad scope of Novy's educational goals outlined in this dissertation differs from those traditionally attributed to late 19th century physicians by medical historians. Novy's educational objectives were more expansive than those outlined by Kenneth Ludmerer, who concentrated on efforts by late 19th and early 20th century to train students' minds in cognitive thinking and scientific methodology.[3] Ludmerer did not address the teaching of morals to students. But Novy's emphasis on seeking "pure" truths above competing interests and instilling disciplined habits in his students clearly involved an ethical imperative. In his laboratory-based bacteriology course, Novy intended to build students' characters as well as train their minds. He attempted to instill morals in all medical students, not only those who were destined for medical research. The letters Novy received from students—even those who were practitioners—acknowledged the virtue of his instruction in laboratory instruments and methodology to seek for pure truths in nature, even though his results may not have been useful to them in a practical sense.

The inclusion of morals in Novy's instruction underscored a Victorian notion that medical science demanded of its practitioners a personal character that was perhaps more noble than was required by other occupations. Novy instilled in his students a belief that the future of medicine appeared limitless, but he tried to mold their character so they possessed the diligence and disciplined work habits to expand the body of knowledge. Novy included a strict code of ethics directing students towards discoveries of truths and away from "commercialism." Moreover, the inclusion of methods and habits suggested that the actual participation in scientific work in the laboratory could refine the student's moral sensibility. Novy promoted the ideology that truth could be apprehended only through a formulaic process beginning with faith in doubt, development of a logical hypothesis, the use of specialized instruments and precise methods of science in the laboratory, and the sharing of both methods and findings with other scientists. The ritual of doing disciplined, hard work in the laboratory reinforced desirable moral traits. For Novy, it was more than the principles of science that were ennobling; the practice itself, done diligently, was purifying. For Novy, the labor of the laboratory had a moral efficacy that could discipline the student's habits.

Third, Novy's emphasis on morals reveals how he helped to institutionalize the new scientific activity of bacteriology in an established profession like medicine—by attaching it to traditional Victorian values and ideals. These Victorian values included a certainty that truths exist and could be ascertained through a logical, precise process. The Victorians had a belief in progress and their ideal of character was based on a notion of the self as controlled by morals and discipline.[4] They valued hard work and the virtue of selflessness above self-interest. Novy, by aligning the values of the science he was promoting with Victorian values, was easing, whether intentionally or not, the transition into "making medicine scientific". Novy's "pure" science with its disciplined, controlled hard work, its search for truths, its moral code of selflessness, its denigration of self-interest and commercialism, and its belief in progress, legitimated the new activity of bacteriology in medicine by aligning it with dominant late Victorian confidence and values.

Advocating pure science—to be done for the love of science alone without any practical implication—was no easy task for Novy given his institutional duties and responsibilities in late 19th century American medicine. Novy, in actuality, had a practical responsibility to the state and the mission of medicine was essentially a pragmatic one—healing. In this context, Novy and a cadre of other physicians were promoting change by attempting to incorporate the new activity of science in medicine. To accomplish this change, Novy was not rejecting the past in order to celebrate the new science. He was reconciling as best he could the values of an earlier period with the ideals of a new era. He was promoting a new order but he did not sever an attachment to familiar Victorian values and ideals.

In his letters and speeches, Novy's choice of vocabulary aligned his activities with established Victorian values. In his letters to other scientists, Novy justified his insistence on delaying publication until his experiments could be repeated on the grounds that he needed to "verify" his findings in order to publish high quality work. This would ensure the smooth development of scientific knowledge. He therefore legitimated his activity by aligning it with the Victorian value of certitude. But Novy's habit of delaying publication could also be interpreted as an example of scientific secrecy that could impede the advance of science by withholding timely publishing of results and preventing competing groups from undertaking supplementary work. The fact that Novy's activity could be interpreted either as certitude or secrecy argues against Robert Merton's assumption that there is one set of norms that underlie scientific activities.[5] It supports I.I. Mitroff's argument that multiple sets of norms can be operative among the structures of science.[6] Novy's selection of words illustrates Michael Mulkay's point that scientists tend to select their vocabulary from a repertoire of accounts to serve their interests—in Novy's case, legitimizing his new activity by aligning it with traditional Victorian values and.[7]

Novy also aligned the new scientific activity with its rationalized vision of the world with the Victorian ideals of morality and religion. These ideals are demonstrable in the ways that Novy's students had belief in the self-sacrificing "spirit of science" that he embodied. As Novy fostered an ideal of pure science in students, a group of student disciples were created who had faith that they would expand the boundaries of knowledge through their steadfast devotion to the spirit that was preached by their prophet Dr. Novy. Novy and his students had faith their unwavering dedication to the belief that search for pure truth above any competing motives by using specialized instruments in the laboratory and sharing methods with other investigators was able to elevate the medical profession above all others not by making it scientific and therefore more certain, but also by giving it an uplifting spirit. The students' faith in Novy's spirit of science illustrates that religion and science are both belief systems and are not opposing forces. His students, including Paul de Kruif, who collaborated with Sinclair Lewis to write *Arrowsmith* based on his experience with Novy, wanted to show that the medical scientist not only conformed to Victorian ideals and values but was an exemplar of them, more so than other disciplines such as business and law.

Fourth, with regards to the significance of Novy's story to American culture, the students' view of Novy and his activities were instrumental in creating a storybook image of a heroic medical researcher in American society. In *Arrowsmith*, de Kruif's and Lewis' portrayal of Max Gottlieb, Martin Arrowsmith's university teacher and lifelong master who was patterned after Novy, served to create the iconography of the noble, selfless, autonomous, pure laboratory researcher.[8] The novel had wide appeal in America, and it popularized a new type of hero, the medical scientist, as a disinterested, relentless seekers not of profit but of nature's truths.[9] To see how pervasive this exalted view of a scientist was in American society, Margaret Mead and Rhoda Metraux selected a sample of high school students in the early 1960s. The students depicted medical scientists as objective, dedicated men and women who work not for money and fame or self-glory but for truth and the benefit of mankind.[10] In a study of American college students, David Beardsley and Donald O'Dowd reached similar conclusions.[11] These favorable accounts demonstrate that American students in the 1960s had an ennobled image of a medical scientist as a loyal truth searcher. In part due to the literary representations in *Arrowsmith*, the elevating "purity" of the medical scientist's conduct became rooted in American thought.[12]

Sinclair Lewis believed that *Arrowsmith's* usage of scientific values and preoccupation with "pure" science reflected the attitudes of Novy's student Paul de Kruif.[13] Lewis also believed that de Kruif formulated the scientist's philosophy based on his experience with Novy, then contributed it to the character Max Gottlieb. One of Gottlieb's principal messages to his student Martin is that of respect for the purity of science and the need to protect it from misuse by "the doctors who want to use therapeutic methods they do not understand" and want to "snatch our science before it is tested and rush around hoping they heal people."[14] Gottlieb also taught Martin that a medical researcher's disciplined laboratory ritual was a key means of apprehending nature's occult truths. In uncovering these mysteries, the scientist honored a commitment to work devoutly and diligently in the laboratory in order to represent nature with fidelity. Thus, *Arrowsmith* is a moral tale: every step in Arrowsmith's life brings him closer to final redemption of his material temptations through his devotion to an ideal towards which he could aspire—"pure" science and its prophet Gottlieb.[15]

Arrowsmith served as an inspiration to a generation of young science students to study medicine.[16] Students reading the novel identified with Martin's curiosity for science and truth, which were the virtues that Max Gottlieb both represents to him and recognizes in him.[17] In the novel, Martin was disappointed with the uncertainty of experiential medicine and searched for a resonant truth and righteousness. Martin was disposed to find a level of existence higher than those around him—his path to a transformed culture was scientific medicine. For Martin, laboratory science offered a possibility of elevating medicine from what he believed was a vague, unsubstantial endeavor to a legitimate field in pursuit of truths that can be verified using precise instruments and standardized methods. Martin's faith in the potential of science to save the medical profession from imprecision by offering an "objective" path to underlying truths-in-nature parallels Novy's students' devotion to this ideal.

Novy's preaching of an all-inclusive notion of the ideal of science, which included a moral opposition to self-interest and commercialism, is abundantly evident in *Arrowsmith*. In the novel, Lewis objected to the "business-like" culture of many facets of early 20th century American medicine. Instead of being a profession that promoted discovery on the scientific side and healing on the clinical side, Lewis objected to a medical profession that had become business-like, most noticeably in the commercialization of products of discovery and promotion of therapies by doctors who did not know whether they were helpful. Moreover, Lewis derided the pervasiveness of commercialism in the clinical domain (Rouncefield Clinic), public health departments (Nautilus), and research (McGurk Institute). But Lewis offered laboratory science as the ideal solution that could transform the medical profession from a trade that sold goods to unsuspecting patients to a profession that beheld verifiable truths. It was only in the life of the pure, independent scientist, not in the businesslike culture of medicine, that Martin discovered a vocation in which his spiritual endowments could find meaningful expression.

The portrayal of the medical scientist as a heroic, autonomous figure is both romanticized and exaggerated by the closure of *Arrowsmith*. Martin eventually listens to Gottlieb who explains to Martin he would be fortunate if he is not successful because success, as defined by research institutions like McGurk, ruins the scientist. To resolve his conflict, Martin moves from the city to the woods with his colleague from the McGurk Institute, Terry Wickett. There, they create a laboratory of their own and achieve a salvation in their retreat to the woods as Martin finally embraces the power of independence of the scientist. Through this retreat, Martin is able to embrace the spirit of science and his inner calling and flee from the social and commercial department heads that he believes have hindered his true scientific work. Alone, isolated, and independent are the images of the laboratory scientists searching for truths, unencumbered by the restrictions of practicality that institutions like the McGurk place on them.

To Lewis, the core of heroism lay in the extent to which an individual was able to extricate himself from the confining, commercial pressures of American society. To de Kruif and Lewis, it was the social necessity of the medical profession that tied its practitioners to the emergencies of everyday life, to compromise and commercialism. A practicing physician as able as he may be could never transcend social relationships which formed the fabric of his professional existence. In contrast to the practitioner, the medical scientist, as evidenced by Martin Arrowsmith and Terry Wickett, was able to disengage himself from American society in his truth searching pilgrimage. Consequently, the medical researcher was capable of creativity, greatness and nobility—

qualities that for Lewis could not exist in American society. For these reasons, Lewis found it natural to accept the pure medical scientist's vocation as a higher one than the practitioner or other professions.

The romantic, storybook image of the medical researcher—noble, selfless, autonomous, independent, honest—can be appreciated by examining *Arrowsmith* in relation to Lewis' other novels. In *Babbitt* and *Elmer Gantry,* Lewis portrayed an American culture that was bereft of a resonant truth. In these novels, he offers nothing other than a depiction of vacuous, commonplace individuals in business and religion and a mercenary American soul. His novels express a general discouragement with a society that was lacking an ideal, whether it is precision and reliability in medicine, scrupulousness in business, or spirituality in religion. Unlike *Elmer Gantry* and *Babbitt*, both commentaries on the shallowness of early 20th century society that lacks spirituality, Lewis offers a positive alternative in *Arrowsmith*—the work of noble, selfless, scientifically sharing laboratory scientists who pursue truths in nature and who are morally superior to other professions. Lewis offered a laboratory science that was patterned in part after Novy's own operation as a potential salvation for a vague and imprecise medical culture that was lacking certainty by searching for these truths. Lewis implies that laboratory science confers the medical profession privilege, power, and perhaps an authority because science provides medicine with a transformative capacity lacking in other professions. Thus, unlike Lewis' other novels where he offers solely a portrayal of an empty, mercenary American culture, in *Arrowsmith,* he conveys a positive alternative—laboratory science as a potential salvation for an imprecise medical profession.

Fifth, the account of Novy in this dissertation shows how an aspiring investigator made a scientific life in medicine in late 19th century America. During this period when government funding sources became newly available, Novy and Vaughan sought and obtained state funding for their hygienic laboratory.[18] Despite the practical responsibilities of their hygienic laboratory, Novy professed the pure scientific research ideal—that science should be done for science's sake—and the ethical standards of his profession to share information with others rather than self-interest as his primary goals. Novy was depicting science as ethical and self-regulating when attempting to create and legitimize his research activities with the government. Science has an ethical standard, he argued, that requires no outside surveillance. Novy was resisting the usual government controls of pure science and he implied that pure science should be free from outside regulation. Novy claimed that science had a right to federal support and funding but without interference, constraint, or regulations.

Novy cast his field in a particular ideological fashion to justify a special relationship with government—to obtain funding, have freedom to choose experiments, but not accountability. Although the particular ideology Novy adopted in his addressing the state has been associated not with medical investigators, it was held by scientists in other fields during this period. Chemists and physicists in the late 19th century, for example, proposed the pursuit of truth as the ultimate value and the independence of the scientific community as prerequisites for the attainment of this value.[19] As the practical applications of pure science became evident as the century progressed, it was no longer necessary for scientists to emphasize the eventual utility of their work. Consequently, the search for pure knowledge and independence buttressed the attempts of scientists to claim the right to extend certified knowledge with the help of public funds, but without outside interference.[20] Scientists claimed they were self-regulated by values such as individualism and sharing that could only be maintained if scientists were left free from outside regulation. Novy's arguments to obtain funding for his medical research operation resonate with those made by scientists in late 19th century America.

Throughout Novy's career, the autonomy to pursue and maintain his version of "pure science" without any scientific constraints remained of highest concern to him. Novy could not consider losing his independence to choose experiments, irrespective of whether his work led to publication or yielded a clinical application. Novy was operating at a time when practical-minded institutes like the Rockefeller were established to perform research with practical implications. Novy declined an invitation to head bacteriological research because he felt that he would have less control over the direction of his experimentations at a research institute because he believed that at an institute, he would need to justify whether his investigations had relevance for therapeutics. He was fearful that this requirement would impair the independence of his science by restricting his selection of research topics, limit his choice of experiments, and force him to publish his material before his results had been validated through further experiments.

The vision of laboratory science in medicine espoused by late 19th century basic investigators like Novy helped to establish the contours of the biomedical system as it presently remains. Today, major medical centers equipped with suitable laboratory space prosper by receiving sizeable percentages of federal grants from their basic science faculty. The basic sciences are still taught to all medical students while debates about the relevance of the subject matter persist.[21] But other parts of the Novy spirit seem outdated, including the idealized view of the medical researcher as behaving more ethically than other professions.[22] There are several possible reasons for this moral portrayal of the medical scientist to no longer seem relevant. In the late 19th century, creating a moral view of the medical scientist was an initial way of justifying medical science with a dominant, central value in Victorian American society.[23] However, as G.N. Gilbert argues, when an activity like medical science becomes successful, then one no longer has to justify it in the same manner it was initially legitimized.[24] As the new activity becomes incorporated into the structure of the institution in its own right, it becomes the central value.[25] Furthermore, the plea for medical researchers to be autonomous and not accountable for federal funds they receive is no longer operative today.[26] Finally, the rhetoric of the pure science ideal is no longer applicable, as federal funding agencies today prefer to fund applications that stress the potential practical applicability of their basic research.[27]

As this paper has argued, the plea for pure science made by scientists like Novy may have had several meanings and served several purposes in late 19th century America. Among these meanings and purposes include a true intellectual interest in microbial biology rather than obvious utility, a means to justify and legitimize the new activity of medical research, an ideology to solidify the field of bacteriology as a separate discipline, and an ethical imperative that served to mold characters of a cadre of students. One of Novy's students, Paul de Kruif, used his experience with Novy to utilize the pure science ideal as a foundation for the construction of the storybook image of a medical scientist as a hero in American culture. Martin Arrowsmith's relentless search for truth and his absolute devotion to science have undoubtedly inspired many people to research careers in medicine since the novel's publication in 1925.[28]

The moral achievements of Martin Arrowsmith as he overcome his material temptations and reached a deepened understanding of the pure scientific ideal, however, may no longer be relevant to young medical students today. Given the realities of scientists' conduct, the noble, moral image of the medical scientists may no longer seem applicable. For example, the image of the medical scientist as selfless may no longer seem pertinent given occurrences of scientists who have engaged in public priority disputes over credit for scientific discoveries.[29] In addition, the portrayal of the medical scientist as honest and sharing accurate information with other scientists may not seem appropriate in today's times given instances of fraudulent research.[30] In addition, the significant amount of time that medical researchers in today's medical environment must spend writing grants in order to receive federal funding may lead some aspiring researchers to view entering a medical research career with reservation if not cynicism. Notwithstanding these considerations, the unconditional passion for discovery exhibited by the medical scientists that Lewis based on de Kruif's description of Novy in his 1925 novel may still serve as a source of inspiration to aspiring medical researchers today.

Despite the image of Novy as an original, moral, and even heroic bacteriologist as fictionalized by his student and celebrated by peer scientists, his name is little recognized today. One can speculate why in histories of microbiology and medicine Novy is given polite but cursory mention, unlike the names of Koch or Pasteur. Perhaps historians have focused on these well-known researchers who professed to have "founded" a new science. Novy, unlike these researchers, was not as intimately involved in the creation of his own myth to the degree that Gerald Grison has claimed that Pasteur sought recognition in the history books. Novy promoted the value of bacteriology for medicine and for society, but his orientation towards fundamental research may have lacked the sensation that surrounded more well-known endeavors. Consequently, his fundamental work, although forming the basis for a popular fictional work, was not publicly recognized and did not have consequences, as did Pasteur's research, that were vital to the nation.

Nevertheless, this dissertation on Novy's research and his teaching activities shows that late 19th and early 20th century American bacteriology was not exclusively a period of practical applications that was derivative of European work. Novy's original microbiologic investigations, his focus on technological innovation, and his ideal of the "pure" medical researcher's quest for truth had far ranging consequences for medical education, the profession of medicine, the creation of bacteriology as a separate field, and for American culture.

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67. Hammonds, *Childhood's Deadly Scourge* (n. 5).
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85. Ibid., pp. 296-299.
86. Ibid., pp. 296-299; Chapin, Charles V., *The Sources and Modes of Infection* (New York: John Wiley & Sons, 1910) pp. 12-31.
87. Rosen, *A History of Public Health* (n. 1) p. 318.
88. See: ibid., p. 308. Rosen noted that quarantine regulations were modified in the light of bacteriological discoveries—by establishing the incubation period in a given disease, the number of days required for quarantine could be set more exactly.
89. See: Duffy, *The Sanitarians* (n. 2) pp. 205-206. Biggs, according to Duffy, maintained that laboratory testing to make a positive diagnosis of all reported cases of diphtheria would be cheaper than disinfecting and quarantining the homes of all suspected cases. See also: Winslow, CEA, *The Conquest of epidemic disease: a chapter in the history of ideas*, (Madison: The University of Wisconsin Press, 1943) p. 411.
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91. Kramer, "The germ theory and the early public health program in the United States," (n. 1) pp. 233-247.
92. Ibid., pp. 233-247.

93. Smith, "The History of Public Health, 1871-1921," (n. 71) pp. 1-15.
94. Ibid., pp. 1-15.
95. Tomes argued that the interest in science and the development of bacteriology laboratories in public health departments did not necessarily mean that bacteriology "narrowed" public health department activities. See: Tomes, Nancy, "The private side of public health: sanitary science, domestic hygiene, and the germ theory, 1870-1900," *Bulletin of the History of Medicine* 64 (1990): 509-539.
96. Ibid., pp. 509-539.
97. Rosenkrantz, *Public Health and the State: Changing Views in Massachusetts, 1842–1936* (n. 28) pp. 123-127.
98. Fee contended that the powerful new bacteriological methods of identifying disease through the microscope drew attention away from the larger and more diffuse problems of water supplies, street cleaning, housing reform, and the living conditions of the poor. See: Fee, *Disease & Discovery: A History of the Johns Hopkins School of Hygiene and Public Health, 1916–1939* (n. 28).
99. Leavitt explored the history of the public health movement in Milwaukee, as well as the public health responses to typhoid carriers. She points out that broader conceptions of public health that require an understanding of economics and politics remain important, not just practices that are based almost exclusively on the biological sciences. See: Leavitt, *The Healthiest City: Milwaukee and the Politics of Health Reform* (n. 31); see also: Leavitt, Judith Walzer, "Typhoid Mary Strikes Back: Bacteriological Theory and Practice in Early 20th Century Public Health," in *Sickness & Health in America. Readings in the History of Medicine and Public Health* (Madison, University of Wisconsin Press, 1978) pp. 555-572.
100. See: McKeown, Thomas and R.G. Record, "Reasons for the decline in mortality in England and Wales during the nineteenth century," *Population Study* 16 (July 1962): 275-297; McKeown concluded that the major influence on declining death rates was the rising standard of living, the most significant feature of which was the improvement in diet.
101. McKeown, Thomas, *The Modern Rise of Population* (San Francisco: Academic Press, 1976) pp. 128-142.
102. See: Condran, Gretchen, Henry Williams, and Rose Cheney, "The Decline in Mortality in Philadelphia from 1870 to 1930: The Role of Municipal Services," in *Sickness and Health in America. Readings in the History of Medicine and Public Health* (Madison: University of Wisconsin Press, 1978) pp. 453-465. Condran argues that typhoid fever was eliminated by water filtration, and childhood diarrhea decreased by improvement in the quality of milk.
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105. Ibid., pp. 184-189.
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121. Rosen, *A History of Public Health* (n. 1) pp. 305-37.
122. Ibid., pp. 312-314.
123. Hoffman, Frederick L., "American mortality progress during the last half century," in *A Half Century of Public Health*, ed. M. P. Ravenel (New York: American Public Health Association, 1921) pp. 95–117.
124. Winslow, "Some leaders and landmarks in the history of microbiology," (n. 118) pp. 99-114.
125. Burrill reproduced disease by inoculating pears with pure bacteria isolated from diseased pears. See: Burrill, Thomas J., "Pear and apple Tree blight," *Transaction of Illinois State Horticultural Society* (New Series) 14 (1880): 157-67.
126. Smith and Kilbourne found that Texas fever was caused by protozoa, *Pyrosoma bigemmum*, which lived in red blood cells; they believed the disease was spread by cattle ticks. It was transmitted by the cattle tick, *Boophilus bovis*; See: Dolman, Claude E. and Richard J. Wolfe, *Suppressing the Diseases of Animals and Man: Theobald Smith, Microbiologist*, (Boston: Boston Medical Library in The Francis A. Countway Library of Medicine and the Harvard University Press, 2003) p. 691.
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131. Bulloch, *The History of Bacteriology* (n. 4); Winslow, "Some leaders and landmarks in the history of microbiology," (n. 118) pp. 99-114.
132. See: Borus, Daniel, *Twentieth Century Multiplicity: American Thought and Culture, 1900-1920* (New York, Rowman & Littlefield Publishers Inc., 2009) pp. 208-211; Borus discusses the powerful position that science occupied in American society during the early 20th century.
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138. See: Rosenberg, Caroll Smith, *Disorderly Conduct: Visions of Gender in Victorian America* (New York: Oxford University Press, 1985); Rosenberg discusses the possibilities of intellectual life in Victorian America and the anxiety this created in men.
139. See: Wiebe, *The Search for Order, 1877-1920* (n.133) pp. 44-75; See Chapter 3, ‘Chris in Communities’ Wiebe argued that there was a breakdown of the isolation of people and organic, rural communities prevailing in the latter part of the 19th century and the replacement of this isolation by institutional and bureaucratic centralization in every aspect of life.
140. See: ibid., pp. 67-75; Wiebe argued that the old “ethical” values were being replaced in the 1890s by impersonal “bureaucratic” ones—an increase in communications, voluntary associations, and inter-group relations.
141. See: Chambers, John, *The Tyranny of Change. America in the Progressive Era, 1890-1920* (New Brunswick, New Jersey: Rutgers University Press, 1992) p. 276; Chambers traces how progressives were concerned with how to preserve democracy in an age of industrialization that concentrated great power in the hands of new industrial elites. These progressives, he argues, were dissatisfied with the results of unrestricted individualism and the unregulated marketplace that underlay the depression of the 1890s and led to labor disputes during that period.

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146. See: Stevenson, *The Victorian Homefront:American Thought & Culture, 1860-1880* (n. 143) pp. 148-149; Stevenson discusses the optimistic Victorian view that society could be known through its facts, and that society was improving as a result of knowledge of those facts.
147. See: Borus, Daniel, *Twentieth Century Multiplicity: American Thought and Culture, 1900-1920* (n. 135) pp. 208-211; Borus discusses the powerful position that science occupied in American society during the early 20th century.
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Chapter 1
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2. Ibid., p. 78.
3. Duffy, John, *The Sanitarians* (Chicago: University of Illinois Press, 1990) pp. 205-206.
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8. *Fifth Annual Report of the Secretary of the State of Michigan.* Lansing, 1877.
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61. See: ibid. Novy studied at West Division High School in Chicago. Novy studied history under Dr. Samuel Willard, M.D., a veteran of the Civil War. Novy Papers, “High school history notes," 1881.
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65. See: Novy, "High school history notes," (n. 59). De la Fontaine claimed he had discovered the element samarium.
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67. See: ibid. Novy was eventually placed in charge of the circulation desk on Sundays.
68. See: ibid. Novy’s notes state he purchased an R and J Beck microscope, a highly regarded and expensive microscope of English make, for sixty dollars
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71. See: Novy, "High school chemistry notes," (n. 59). He roamed Chicago's south side collecting specimens of water from various ponds for study under his microscope.
72. See: ibid., The Club was located on Wabash Avenue.
73. Gould, "Frederick George Novy, microbiologist, 1864-1957," (n. 64), pp. 297-309.
74. See: Novy, "Autobiographical Notes" (n. 55). Novy was encouraged to use the microscope to find forms of microscopic life that previously was not thought to exist in that environment.
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79. Reuben, *The Making of the Modern University* (37) p. 363.
80. See: Novy, Frederick, "University of Michigan Student Notebooks," 1881, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy took two foreign language courses during his freshman year: French and German.
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96. Spalding, V.M., Frederick Novy "Recommendation Letter," 1886, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

97. See: Novy, "Autobiographical Notes" (n. 55). In his notes, Novy stated he was interested in finding a research position, and that he decided against teaching high school chemistry. One could infer that he decided against this position because it did not provide ample opportunity for research.
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110. See: ibid. Novy noted: "Lectures do not permit students an opportunity to inquire about causes and there are no laboratory exercises designed for their investigation."
111. Novy also asked, "Would symptoms improve without therapy? Would different treatment provide superior results?" See: Novy, "Medical student notes," (n. 104) 1889.
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123. See: ibid. The first of these courses was also taken by William Welch of Hopkins in 1885 and Mitchell Pruden of Columbia.
124. Ibid. The date of the entry is not present.
125. Novy, “The Hygienic Institute at Berlin” (n. 119).
126. Ibid., p. 427.
127. See: Novy, "Diary of the Hygiene Institute, Berlin," (n. 122). Novy made several subsequent trips to Europe. He studied at the University of Prague, in 1890, and at the Pasteur Institute in Paris in 1894. See also: Novy "The Hygienic Laboratory," (n. 19), pp. 242-244.
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137. Mall, Franklin P., “Wilhelm His: His relation to institutions of learning,” *American Journal of Anatomy* 4 (1905) p. 141.
138. Frederick Novy to Grace Novy, 5 September 1890, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
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140. See: Frederick Novy to Grace Novy, 1888, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). See also: Novy, “Grace Novy” (n. 138). Novy’s granddaughter, Dorothy Wilson, who knew and lived with Novy during a period during the 1930s, stated that her “grandfather was purely a laboratory man right from the start; he was never a clinical man”. Author interview with Dorothy Wilson, October 29, 2009.

141. See: Frederick Novy to Dr. William Johnson, 5 September, 1890, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Johnson, a member of the Michigan State Health Department, invited Novy to rejoin the department. Novy responded that he was unable to do so because of his full time involvement in scientific research.
142. Lewis, *Arrowsmith* (n.112) p. 199.
143. Novy, "Autobiographical Notes" (n. 55).
144. Bonner, T. N., "The German model of training physicians in the United States, 1870-1914: how closely was it followed?" *Bulletin of the History Medicine* 64 (1990): 18-34; Ludmerer, Kenneth M., *Learning to Heal: the development of American medical education* (Baltimore: Johns Hopkins University Press, 1996) pp. 62-119.
145. Ibid., pp. 62-119.
146. Ibid., pp. 67-70.
147. Frederick Novy to Emile Roux, 18 July, 1896, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
148. Frederick Novy to Grace Novy, 9 August, 1894, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
149. Crenner, Christopher, *Private practice in the early twentieth-century medical office of Dr. Richard Cabot* (Baltimore: The Johns Hopkins University Press, 2005) pp. 7-22.
150. Lewis, *Arrowsmith* (n.112) p. 121.
151. See: Novy, "Grace Novy" (n. 148). In this letter, Novy mentioned that “the salary is higher for doctors in private practice than in the medical school.”
152. Ludmerer, *Learning to Heal: the development of American medical education* (n.144) p. 126.
153. Vaughan, "First quarterly report, Michigan state laboratory of hygiene," (n. 48), pp. 2-11, 20-23.
154. Novy, F. G., "Analysis of fluid with which to make fraudulent milk," *State Board of Health, Michigan* XCVIII (1892) p. 20.
155. See: ibid. Novy found that one sample, for example, contained solids (44%), common salt (13%), invert sugar (14%) and cane sugar (16%) and salicylic acid.
156. Ibid.
157. Novy, F. G.,"What is ice-cream poisoning?"*Pharmaceutische Rundschau* 5 (1887): 152-3.
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159. Vaughan, Victor, *A Doctor's Memories* (Indianapolis: The Bobbs-Merrill Company, 1926).
160. See: Novy, "Analysis of fluid with which to make fraudulent milk," (n. 154). Novy analyzed milk and showed that it was found to contain Salicylic acid 44%, common salt 13%, cane sugar 16%.
161. *Twentieth Annual Report of the Secretary of the State of Michigan*. Lansing, 1892, pp. 69-81.
162. Vaughan, Victor, "Work done in the laboratory of hygiene," in *Public Health Reports, Nineteenth Annual Report of the Secretary of the State of Michigan.* Lansing 1891, pp. 104-121.
163. Ibid., p. 115.

164. *Twenty fifth Annual Report of the Secretary of the State of Michigan* (n. 47) p. 87.
165. Vaughan and F. G. Novy, "Experimental studies on the causation of typhoid fever with special reference to the outbreak at Iron Mountain, Mich.," (n. 48) pp. 2-11.
166. Novy, F.G., "The Hygienic Laboratory," (n. 19) pp. 242-244.
167. Ibid., pp. 242–244.
168. See: ibid., pp. 242-244. Novy said, "Epidemic diseases received only such consideration as could be obtained from a purely epidemiologic standpoint."
169. Vaughan, "Work done in the laboratory of hygiene," in *Public Health Reports, Nineteenth Annual Report of the Secretary of the State of Michigan.* Lansing, 1891 (n. 162) pp. 272-278.
170. Novy, F. G. and Victor Vaughan eds, *Poison producing bacillus found in cheese and ice cream* (Lansing: 1896) pp. 5-9.
171. Vaughan, "Work done in the laboratory of hygiene," (n. 162) p. 72.
172. Vaughan, "First quarterly report, Michigan state laboratory of hygiene," (n. 48) p. 2-11, 20-23.
173. Ibid., pp. 2–11, 20–23.
174. *Twenty fifth Annual Report of the Secretary of the State of Michigan* (n.48) pp. 144-148.
175. Ibid., p. 149
176. Ibid., p. 151.
177. Novy, "The Hygienic Laboratory," (n. 19) pp. 242-244.
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179. Ibid., p. 243.
180. Ibid., pp. 245-7.
181. Ibid., p. 251.
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rights to patents arising from their work to the WARF, which then attempted to license the technology. Proceeds were shared by the university and the inventing faculty member.
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194. Bonner, T.N., "The German Model of Training Physicians," (n. 130).

Chapter 2
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4. Novy specified the equipment that was in his laboratory in the 1890s in two publications. The first was his 1899 textbook. See: F. G. Novy, *Laboratory Work in Bacteriology* (Ann Arbor: George Wahr, 1899). The second was an article he wrote in 1904; See also: Novy, F.G. "Bacteriological Technique," *Reference Handbook of The Medical Sciences* 8 (1904): 370-404.
5. Novy, F.G., *Directions for Laboratory Work in Bacteriology* (Ann Arbor: George Wahr, 1894) p. 209, frontispiece.
6. Novy, *Laboratory Work in Bacteriology* (n. 4) p. 563, frontispiece and 76 figs.
7. Novy, *Directions for Laboratory Work in Bacteriology* (n.5) p. 1.
8. Novy, *Laboratory Work in Bacteriology* (n. 4) pp. 267-271.
9. Novy, F.G., "A new anaerobic bacillus of malignant oedema," *Trans. Pan-Am. M. Congress* 1 (1893) p. 49.
10. See: Novy, F. G., "The immunizing power of nucleohiston and of histon," *Journal of Experimental Medicine* 1 (1896): 693-716. Later in the 20th century, nuclei's were referred to as nucleic acids.
11. Ibid., pp. 693-693.
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16. Novy, *Laboratory Work in Bacteriology* (n. 4) p. 563, frontispiece and 76 figs.
17. William Welch to Frederick Novy, 12 August, 1899, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
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25. See: Gradmann, Christoph, *Laboratory Disease* trans. Elborg Forster (Baltimore: The Johns Hopkins University Press, 2009) pp. 223-244. Gradmann discusses Koch's travels to Lake Victoria and descriptions of trypanosomes and surra.
26. Novy and Ward J. MacNeal, "On the cultivation of *Trypanosoma lewisi* " (n. 18) pp. 549-577.
27. Ibid., pp. 549–577.
28. Novy, F. G., "The artificial cultivation of trypanosomes (parasites of man and animals)," *Proc. 4th Gen. Confer. Health Officers, Michigan* (1904): 104-112.
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30. Novy, "The artificial cultivation of trypanosomes (parasites of man and animals)," (n. 28) pp. 104-112.
31. Novy, "Laboratory Notebooks," (n. 29).
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35. Novy, F. G. and Ward J. MacNeal, "The cultivation of *Trypanosoma brucei*. Preliminary note," *J. A. M. A.* 41 (1903): 1266-1268; Novy, "The artificial cultivation of trypanosomes (parasites of man and animals)," (n. 28) pp. 104-112.
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37. Novy, "The artificial cultivation of trypanosomes (parasites of man and animals)," (n. 28) pp. 104-112.
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48. Novy, Frederick, "Laboratory Notebooks," Box 5 and 6, 1903-1927, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
49. Novy, F. G., and Ward J. MacNeal, "On the cultivation of *Trypanosoma brucei*.," *Journal of Infectious Disease* 1 (1904): 1-30.
50. See: Novy, F.G., and Ward J. MacNeal, "On the cultivation of *Trypanosoma evansi*," *Report of the Michigan Academy of Sciences* 6 (1904). He kept the organism growing for 280 generations, transplanting it once every week, until the culture died.
51. Charles Nicolle to Frederick Novy, 1904, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
52. Novy, Frederick, "Laboratory Notebooks," Box 4 and 5, n.d., Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
53. Novy, F. G., "Successful canine infection with cultures of *Leishmanie infantum* (Ch. Nicolle)," *J. A. M. A.* 51 (1908): 1423-1424.
54. Novy noted that the promastigote forms occurred in the sandfly whereas the amastogote forms occurred in humans. See: Novy, F.G., "Leishman-Donovan bodies," *The Physician and Surgeon* 32 (1910): 369-372.
55. Novy. "On the cultivation of *Trypanosoma evansi*," (n. 50) pp. 6-8.

56. F.G. Novy Papers, "Laboratory Notebooks"," Notebooks 20-21, 1907-1908.
57. F.G. Novy Papers, "Laboratory Notebooks"," Notebooks 21-23, 1907-1908.
58. F.G. Novy Papers, Ward J. MacNeal, "Letter from MacNeal to Novy," 1929.
59. F.G. Novy Papers, Ward J. MacNeal, "Dear Doctor Novy," February 27, 1907.
60. Novy, "Successful canine infection with cultures of *Leishmanie infantum* (Ch. Nicolle)" (n. 53) p. 1423.
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72. Novy, "Trypanosomes," (n. 67).
73. Ibid., pp. 1-3.
74. Novy and Ward J. MacNeal, "On the cultivation of *Trypanosoma lewisi* " (n. 18) pp. 575-577.
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76. Novy, Frederick, "On Trypanosomes.Harvey," *Society Lectures* 1 (1906): 33-72.
77. Novy, Frederick, "On Mosquito Trypanosomes," *Science* 23 (1906): 206-207.
78. See: Charles Morris to Frederick Novy, 2 November, 1905, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Charles Morris, a pathologist at Bellevue Hospital, sent Novy the citrated blood of a white rat infected with blood from a patient with a spirochateal infection.
79. Ibid.
80. See: ibid. Morris did not comment in his letter whether he believed there was a risk to the public of shipping infected vectors. This silence suggests that Morris and Novy may have believed that accidents were rare if handling was done appropriately, or that if a mishap occurred, then it was an inevitable consequence of science being carried out.
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86. Novy, "Laboratory Notebooks" (n. 32).
87. Harden, Victoria, *Rocky Mountain Spotted Fever: History of a Twentieth Century Disease* (Baltimore: Johns Hopkins University Press, 1990) pp 1-375.
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89. Ibid., pp. 179-186.
90. Ibid., pp. 186-192.
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92. See: Novy, "Ultramicroscopic organisms," (n. 88) pp. 179-186. He says caution is needed not to make false calls about organisms.
93. Ibid., pp. 179-186.
94. Ibid., pp. 188.
95. See: "Lost and Found (Rat Virus)," *Time Magazine* LXI No. 6 (February 2, 1953). The magazine dramatized the story, and referred to it as, "truth is stranger than fiction' and a sequel to a mystery story.
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97. Novy, "A New Filterable Virus," (n. 91) p. 17.
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99. Ibid.
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109. "Lost and Found (Rat Virus)," (n. 95); "Deadly virus being studied by famous bacteriologist," *The Sun* (Jan 25, 1953); "A Virus survives oblivion," *The Michigan Alumnus* LIX (1953): 285-288; "University researcher's very name means medicine," *Ann Arbor News* (Dec. 10, 1953) p. 1; "Virus lost in UM laboratory for 30 years discovered.," *Detroit Times*, January 25, 1953. See also: Nungester, "Recovery of the Novy Rat Virus," *University of Michigan Medical Bulletin* (n. 96) pp. 55-58.
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111. Novy, F.G., W. A. Perkins, R. Chambers and P. H. de Kruif, "The Rat Virus," (n. 102), pp. 111-123; Nungester, "Recovery of the Novy Rat Virus," (n. 96) pp. 55-58.
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120. See: ibid., p.87.Ford refers to Theodor Billroth and F. Ehrlich, *Untersuchungen über die Vegetationsformen Coccobacteria septica und den Antheil, welchen sie an der Entstenhung und Verbreitung der accidentellen Wunderkrankheiten haben*, (Berlin: 1874).
121. See: ibid., p.89.Ford refers to Billroth and F. Ehrlich, *Untersuchungen über die Vegetationsformen Coccobacteria septica und den Antheil, welchen sie an der Entstenhung und Verbreitung der accidentellen Wunderkrankheiten haben*, (n. 120); See also: Bulloch, *The History of Bacteriology* (n.117).
122. See: Ford, *Bacteriology*, p.89. Ford refers to Billroth and F. Ehrlich, *Untersuchungen über die Vegetationsformen Coccobacteria septica und den Antheil,*

welchen sie an der Entstenhung und Verbreitung der accidentellen Wunderkrankheiten haben (n. 120).
123. See: Bulloch, *The History of Bacteriology* (n. 117) p. 201; Bulloch refers to W. Zopf, *Zur Morphologie der Spaltpflanzen, Spaltpilze und Spaltalgen*, (Leipz: 1882); C. Von Nageli, *Gattungen einzelliger Algen, physiologisch und systematisch bearbeitet* (Zurich: 1849) p. 85.
124. See: ibid., p. 202. Bulloch refers to W. Zopf, *Die Spaltpilze, nach dem neuesten Standpunkte bearbeitet* (Breslau: 1885) p.63.
125. See: ibid, p. 202. Bulloch refers to Von Nageli, *Gattungen einzelliger Algen, physiologisch und systematisch bearbeitet* (n. 123) pp.85-89.
126. Cohn, F., "Organismen in der Pockenlymphe," *Arch. f. path. Anat., etc.* (1872): 229-238 in Broch, *Milestones in Microbiology* translated by Thomas Broch. p. 210.
127. Bulloch, *The History of Bacteriology* (n.117) p. 198; Bulloch refers to F. Cohn, "Untersuchungen über Bacterien. II," *Beiträge zur Biologie der Pflanzen* Bd I (1875): 141-207.
128. See: ibid,, p. 200. Bulloch notes that in Cohn's first system for classifying bacteria, Cohn proposed a scheme with four groups: (I) Sphaerobacteria (sphere-shaped), *Micrococcus*; (II) Microbacteria (rod-like), *Bacterium*; (III) Desmobacteria (filamentous), including *Bacillus* and *Vibrio*; and (IV) Spirobacteria (screw-like bacteria), including *Spirillum* and *Spirochaeta*.
129. Lister, Joseph, "A further contribution to the natural history of bacteria and the germ theory of fermentative changes," *Quart. J. Microscopy. Sc.*, NS (1873): 380-408; see also: Lankster, E. Ray, "On a peach-coloured bacterium—Bacterium rubescens, N. S. ," *Quart. J. Microscopy. Sc.* NS (1873): 408-425; See also: E. Klebs, "Beiträge zur Kenntniss der Micrococcen," *Arch. f. exp. Path. u. Pharmakol.* I (1873): 31-64; See also: Warming, Eugene, "Om nogle ved Danmarks Kyster levende Bakterier," *Vidensk. Meddelelser fra den naturhistoriske Forening i Kjøbenhavn* (1875): 307-420.
130. Bulloch, *The History of Bacteriology*, (n.117) p. 201. Bulloch refers to Warming, "Om nogle ved Danmarks Kyster levende Bakterier," *Vidensk. Meddelelser fra den naturhistoriske Forening i Kjøbenhavn* (1875): 307-420.
131. Lister, "A further contribution to the natural history of bacteria and the germ theory of fermentative changes," (n. 129) pp. 380-408; Lankster, "On a peach-coloured bacterium—Bacterium rubescens" (n. 129) pp. 408-425.
132. Lankster, E. Ray, "Note on Bacterium rubescens and Clathrocystis roseopersicina," *Quart. J. Microscopy. Sc.* NS (1876): 278-283; Lankster, E. Ray, "The Pleomorphism of the Schizophyta," *Quart. J. Microscopy. Sc.* NS (1885–6): 499-505; Bulloch, *The History of Bacteriology* (n. 117).
133. See: Lankster, "On a peach-coloured bacterium—Bacterium rubescens, N. S. ," *Quart. J. Microscopy. Sc.* (n. 129) pp. 408-425; Lankester postulated that a peach colored bacterium, *Bacterium rubescens*, showed a number of forms or form species that were all genetically connected as they all contained a definite coloring matter that he called ‘bacteria-purpurin.
134. See: Bulloch, *The History of Bacteriology* (n. 117) p. 201; Bulloch refers to L. Cienkowski, "Zur Morphologie der Bacterien," *Mém. de l'Acad. impér. d. sc. de St. Pétersbourg 7e sér* (1877); See: Zopf, *Zur Morphologie der Spaltpflanzen, Spaltpilze und Spaltalgen* (n. 123) pp.184-192.

135. Ibid., p. 201; Bulloch refers to Cienkowski, "Zur Morphologie der Bacterien," *Mém. de l'Acad. impér. d. sc. de St. Pétersbourg 7e sér* (1877) p.193.
136. See: ibid, p. 203. Bulloch refers to Zopf, *Die Spaltpilze, nach dem neuesten Standpunkte bearbeitet* (Breslau: 1885).
137. Koch, Robert, "Die Aetiologie der Milzbrand-Krankheit, begründet auf die Entwicklungesgeschichte des Bacillus Anthracis," *Beiträge zur Biologie der Pflanzen*, 2 (1876): 277-310 translated by Thomas Broch. In Broch, *Milestones in Microbiology* p.89.
138. Koch, Robert, "Die Ätiologie der Tuberkulose," *Berliner Klinischen Wochenschrift*, (1882): 221-230 translated by Thomas Broch. In: Broch, *Milestones in Microbiology*. pp.110-118.
139. Kuhlman, Charles G., "The microscope as a guide in medicine," *St. Louis Med. Journal* LXX (1896): 201-209.
140. Ibid, pp. 201-209.
141. Frederick Novy to Fritz Schaudinn, 4 February, 1905, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
142. See: "Dr. Schaudinn's work on blood parasites " *British Medical Journal* 1 (1905): 442-444. This article summarizes Schaudinn's argument and refers to his publication: Schaudinn, "Generations-und Wirtswechsel bei Trypanosoma und Spirochaete," *Arbeiten aus dem Kaiserlichen Gesundheitsamte* (n. 91).
143. See: ibid., p. 443. Schaudinn believed that spirochetes and trypanosomes are of the same species.
144. Schaudinn, "Generations-und Wirtswechsel bei Trypanosoma und Spirochaete," *Arbeiten aus dem Kaiserlichen Gesundheitsamte* XX (1904).
145. Frederick Novy to Ronald Ross, 25 September, 1905, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
146. Novy, *Laboratory Work in Bacteriology* (n. 4).
147. Novy, “Fritz Schaudinn” (n. 141).
148. Novy, F.G.. ”The Role of Protozoa in Pathology” *Proceedings of the Pathological Society of Philadelphia* (1907): 15-17.
149. Novy, "The role of protozoa in pathology," (n. 24) pp. 15-19; Novy, "On trypanosomes,” (n. 67) pp. 1–10, 124–127.
150. Fritz Schaudinn to Frederick Novy, 3 March, 1905, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
151. Frederick Novy to Fritz Schaudinn, 18 March, 1905, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
152. Novy, "Laboratory Notebooks,” (n. 56).
153. Novy, "Trypanosomes,"(n. 67).
154. Novy, F.G., "The Trypanosomes of Tsetse Flies," *Journal of Infectious Diseases* III (1906): 394-411.
155. Novy, Frederick G., “Recent Achievements in Parasitology,” *Report of the Michigan Academy of Science* 13 (1911) p. 25.
156. Ibid., p. 24.
157. Frederick Novy to Ronald Ross, 25 February, 1906, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Novy, “Fritz Schaudinn," (n. 141).
158. Novy, "The role of protozoa in pathology," (n. 24) p. 1-27.

159. Ibid.
160. See: Novy, F.G., *Spirit of Research in Medicine* (1902). Novy wrote that the principal component of the spirit o f research or science in medicine was purely to discover truths in nature.
161. J. Kinyoun to Frederick Novy, 4 April, 1908, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Ronald Ross to Frederick Novy, 4, April, 1908, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Ronald Ross to Frederick Novy, 13 February, 1906, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
162. Henle, J., "Von den Miasmen und Contagien und von den Miasmatisch contagiösen Krankheiten," *Pathologische Untersuchungen* (Berlin: August Hirschwald Verlag, 1840) pp. 1–82.
163. See: ibid. Henle referred to Schwann's work in bacteria causing putrifications. See: Theodore Schwann, "Vorläufige Mitteheilung, betreffend Versuche über die Weingährung und Fäulnis," *Annalen der Physik und Chemie* 41 (1837): 184-193.
164. Henle, J., "Von den Miasmen und Contagien und von den Miasmatisch contagiösen Krankheiten," (n. 162) pp. 1–82.
165. Novy, *The Spirit of Research in Medicine*, (n. 160) p.14.
166. Novy, F.G., "The toxic products of the hog cholera bacillus," *Med. News* 57 (1890): 231-237.
167. Novy then showed that an immunological response could be built up in rats repeatedly injected with small amounts of the protein. See: ibid., pp. 231-237.
168. Novy, Frederick, "Ptomaines " no date, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
169. Novy, F.G., "Cell Chemistry," *Intercollegiate Medical Journal* 2 (1898): 129-140
170. Novy, F.G. and H.M. Soule. "Microbic Respiration.II. Respiration of the Tubercle Bacillus," *Journal of Infectious Diseases* 36 (1925): 168-70.
171. Novy, F.G., M.H. Soule, "Some Observations on the Gas Exchange of the Bovine Tubercle Bacillus," *Contributions to Medical Science* (dedicated to Aldred Scott Warthin 1927) pp 13-14.
172. Novy, F. G., H. R. Roehm and M. H. Soule, "Microbic respiration. I. The compensation manometer and other means for study of microbic respiration," *Journal of Infectious Diseases* 36 (1925): 109-167.
173. Novy, F.G., "Respiration of Microorganisms," *Journal of Laboratory and Clinical Medicine* 17 (1932): 731-733.
174. Novy, F.G. and Malcolm Soule, "Some observations on the Gas Exchange of the Bovine Tubercle Bacillus," *Contributions to Medical Science* (1927) p. 18.
175. Ibid., pp. 13-18.
176. Novy, F.G., "Respiration of Microorganisms," *Journal of Laboratory and Clinical Medicine* 17 (1932): 731-733.
177. Novy, F. G., H. R. Roehm and M. H. Soule, "Microbic respiration. I. The compensation manometer and other means for study of microbic respiration," *Journal of Infectious Diseases* 36 (1925): 109-115.
178. Novy, F.G. and M. H. Soule, "Microbic Respiration and the Tubercle Bacillus," *Journal of Infectious Diseases* 36 (1925): 168-232.
179. Ibid., pp.168-72.

180. Novy, F. G., H. R. Roehm and M. H. Soule, "Microbic respiration. I. The compensation manometer and other means for study of microbic respiration," *Journal of Infectious Diseases* 36 (1925): 109-118
181. Novy, F.G. and H.M. Soule. “Microbic Respiration.II. Respiration of the Tubercle Bacillus,” *Journal of Infectious Diseases* 36 (1925) p. 124.
182. Winslow, C.E.A., "Some leaders and landmarks in the history of microbiology," *Journal of Bacteriology* 2 (1950) p. 107.
183. Max Marshall to Frederick Novy, 24 October, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Earl McKinley to Frederick Novy, 26 June, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
184. Ibid.
185. Novy, F. G., "Disinfection of rooms," *Teachers' Sanitary Bulletin* 1 (1898): 17-35.
186. Novy said he also wanted to explore how different disinfectants worked to kill bacteria. See: ibid., pp. 17-35.
187. The solutions he used to incubate bacteria included mercury chloride, formaldehyde, and sulphur dioxide, at varying concentrations and temperatures. See: ibid., pp. 17-35.
188. See: ibid., pp. 17-35. Novy developed a method for testing the biological activity of agents used for the purpose of fumigation against an array of bacteria. He used sulfur at various concentrations to see what will inhibit the growth of various organisms (Streptococcus, tuberculosis, glanders, cholera, etc).
189. Novy wanted to see whether formaldehyde affected the soluble ferments, or enzymes of bacteria. See: Bliss, C. L., and F. G. Novy, "Action of formaldehyde of enzymes and on certain proteids," *Journal of Experimental Medicine* IV (1899): 4, 47-80.
190. Novy examined how germicides worked, and he again focused on enzymes of bacteria to investigate the chemical mechanism of certain germicides. See: Freer, Paul C. and F. G. Novy, "On the formation, decomposition and germicidal action of benzoyl acetyl and diacetyl peroxides," *Am. Chem. J.* 27 (1902): 161-192.
191. Novy, Frederick "The immunizing power of nucleohiston and of histon," *Journal of Experimental Medicine* (n. 10) pp. 693-716.
192. Anaphylaxis was a phenomenon described by the French physiologist Charles Richet in 1907. Richet had described that circulatory collapse and temperature alteration occurred in animals that had a small injection of a protein, or antigen, to which the animal had already been exposed. See: Richet, C., "De l'anaphylaxie en general et de l'anaphylaxie par la mytilo-congestine en particulier," *Annals de l'Institute Pasteur* xxi (1907): 497-524.
193. Novy, F. G., and P. H. de Kruif, "II. Agar anaphylatoxin: Guinea pig serum," *Journal of Infectious Disease* 20 (1917): 536-565.
194. Ibid., 536-565; Novy, F. G. and P. H. de Kruif, "III. Agar anaphylatoxin: Rabbit serum " *Journal of Infectious Disease* 20 (1917): 566-588.
195. Ibid., pp. 566-588; See: Novy, F. G. and P. H. de Kruif, "IV. Agar anaphylatoxin: Rat serum," *Journal of Infectious Disease* 20 (1917): 589-617. He performed chemical studies indicated that anaphylatoxin production was not the result of protein cleavage, but indicated that changes of the fibrinogen proteins of the blood were concerned.
196. Lewis, Sinclair, *Arrowsmith* (New York: Signet, 1925) p. 19.
197. Ibid., p. 22.

198. Ibid., p. 37
199. Ibid., p. 121
200. William Welch to Frederick Novy, 1 October, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); John Abel to Frederick Novy, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); See: Frederick Gay to Frederick Novy, 8 November, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Frederick Gay was a bacteriologist at Columbia University Medical School.
201. Novy, F.G., "The Hygienic Laboratory," *The Michigan Alumnus* 6 (1900): 242 244.
202. Shapin, Steven, “Who was Robert Boyle? Creation and Presentation of an Experimental Identity,” in *A Social History of Truth* Shapin ed. (Chicago: Chicago University Press, 1994).
203. Daston, Lorraine and Peter Galison, *Objectivity* (New York: Zone Books, 2010).
204. Holmes, Richard, *The Age of Wonder: How the Romantic Generation Discovered the Beauty and Terror of Science* (New York: Pantheon Books, 2008).
205. Keeney, Bradford, *Aesthetics of change* (New York: Guilford, 1983).

Chapter 3

1. Risse, Guenter B., "The Politics of Fear: Bubonic Plague in San Francisco, California, 1900," *New countries and old medicine: proceedings of an international conference on the history of medicine and health, Auckland, New Zealand, 1994,* Linda Bryder and Derek A. Dow eds. (Auckland Pyramid Press, 1995) pp. 1-18. Other authors who wrote about San Francisco plague have also commented on how rumors of plague could cripple commerce; See: Shah, Nyan, *Contagious Divides: Epidemics and Race in San Francisco’s Chinatown* (Berkeley: U of California Press, 2001) p. 124; See: Chase, Marilyn, *The Barbary Plague: The Black Death in Victorian San Francisco* (New York: Random House, 2003) p. 4.
2. Craddock, Susan, Nyan Shah, Alan Kraut, and Howard Markel have each argued that the occurrence of plague in Chinese buttressed preexisting anti-Chinese sentiments and provided grounds for discriminatory health practices; See: Kraut, Alan M., *Silent Travelers: Germs, Genes, and the "Immigrant Menace"* (Baltimore: Johns Hopkins University Press, 1994) pp. 83, 86; Craddock, Susan, *City of Plagues: Disease, Poverty and Deviance in San Francisco* (Minneapolis: University of Minnesota Press, 2000) pp. 128, 135; See also: Shah, Nyan, *Contagious Divides: Epidemics and Race in San Francisco’s Chinatown* (Berkeley: U of California Press, 2001) pp. 121,132; Markel, Howard, *When Germs Travel: Six Major Epidemics That Have Invaded America Since 1900 and the Fears They Have Unleashed* (New York: Pantheon Books, 2004) p. 65.
3. See: Shah, *Contagious Divides* (n. 2) p. 11. As Barde notes, Shah ties the San Francisco plague to the social construction of race and citizenship; See: Barde, Robert, “Plague in San Francisco: An Essay Review,” *Journal of the History of Medicine and Allied Sciences* 59; 3 (2004): 467; See also: Craddock, *City of Plagues* (n. 2) p. 143. Craddock argues that the quarantine was a tool to reinforce the boundary between the normal white and the deviant Chinese.
4. See: Kraut, *Silent Travelers* (n. 2) p. 96; See also: Craddock, *City of Plagues* (n. 2) p. 137; Like Kraut, Craddock notes that attention shifted to catching rats in 1903, p. 138;

see also: Chase, *Barbary Plague* (n. 1) p. 81; Chase describes the rat control program implemented in 1903, p. 125; see also: Markel, *When Germs Travel* (n. 2) p. 75. Markel mentions that the commission confirmed that plague did exist in San Francisco in 1901, then mentions the rat control program implemented during the second plague epidemic in 1907, p. 76; see also: Risse, Gunter, "A Long Pull, A Strong Pull, and All Together: San Francisco and Bubonic Plague, 1907-8," *Bulletin History of Medicine* 66 (1992): 265-268. Risse describes the specific rat control measures implemented in 1903; see also: Shah, *Contagious Divides* (n. 2) p. 145; Shah reports on the plague commissioners' findings of plague in 1901 and the public health measures of rat control in 1903, p. 148.
5. Barde, Robert, "Prelude to plague," *Journal of History Medicine* 58 (2003) p. 157.
6. Walter Wyman wrote of the 1894 pandemic appearing in multiple locales in two separate reviews he wrote on plague: Walter Wyman, "The Black Plague", *North American Review* 164; 4 (1897) and his 1900 monograph on plague: Walter Wyman, *The Bubonic Plague* (Washington: Government Printing Office, 1900). For an overview of the spread of the third plague pandemic in 1894 along trade routes, see Myron Echenberg, "Pestis Redux: The Initial Years of the Third Bubonic Plague Pandemic 1894-1901," *Journal World History* 13; 2 (2002): 429-449.
7. Wyman voiced his concern for the potential for spread of plague to US shores in two articles. See: ibid., p. 9; Wyman wrote that plague could be spread along trade routes by steamships from Honolulu to San Francisco and other ports in the US through trade routes. See also: "The Black Plague", *North American Review* 164; 4 (1897) p. 441.
8; See: Wyman, "The Black Plague" (n. 6) pp. 448-452 and Wyman, *The Bubonic Plague* (n. 7) pp. 9, 41; For a thorough discussion of the social and material conditions of Chinatown in San Francisco, including the crowding of Chinese in unhygienic buildings during the 1900 plague outbreak. See: Kraut, Alan M., *Silent Travelers: Germs, Genes, and the "Immigrant Menace"* (Baltimore: Johns Hopkins University Press, 1994) pp. 84-86.
9. Kinyoun, Joseph, "My Dear Senator: from Kinyoun,", 24 January, 1901, Ms. C 464, Box 1, Joseph J Kinyoun Manuscript Collection (History of Medicine Division, *National Library of Medicine*, Bethesda, MD).
10. Kinyoun, Joseph, "Dear Doctor Bailhache" 9 August, 1900, Ms. C 464, Box 1, Joseph J Kinyoun Manuscript Collection (History of Medicine Division, *National Library of Medicine*, Bethesda, MD).
11. See: Kinyoun, Joseph, "Dear Doctor Bailhache," 5 June, 1901, Ms. C 464, Box 1, Joseph J Kinyoun Manuscript Collection (History of Medicine Division, *National Library of Medicine*, Bethesda, MD). In this letter, Kinyoun said, "It seemed probable that the disease could have gained entrance to San Francisco by means of the [trading ship] 'Australia', whereby rats could have been infected and…sick rats escaped and got into the sewers and thence up into Chinatown, where they gained entrance to the houses of the Chinese."
12. See: Chase *The Barbary Plague: The Black Death in Victorian San Francisco* (n. 1) p. 51; Chase describes how an autopsy was a required examination of all dead Chinese who had not been under care of a white physician.
13. "Minutes from Meeting of Commission, Occidental Hotel," January 28, 1901, Box 4, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

14. See: Kinyoun, *"Dear Dr. Bailhache"* (n. 11) p. 32-40. Kinyoun's method of identifying plague was inoculating the glandular fluid taken from the diseased person onto solid agar media, then detecting small, transparent colonies of the pure organism following two days of incubation. He then injected healthy test animals with pure organisms isolated from one of these colonies and satisfied Koch's scientific criteria of bacteriological proof by identifying the plague bacteria from a guinea pig that had developed an enlarged gland.
15. See: Kinyoun, *"Dear Doctor Bailhache"* (n. 11) p. 40. Kinyoun had followed the rigorous scientific process of fulfilling Koch's criteria of bacteriologic proof in order to establish the diagnosis of plague.
16. Risse, Guenter B., "The Politics of Fear: Bubonic Plague in San Francisco, California, 1900," *New countries and old medicine: proceedings of an international conference on the history of medicine and health, Auckland, New Zealand, 1994*, Linda Bryder and Derek A. Dow eds. (Auckland Pyramid Press, 1995) pp. 9-10; see: Chase, *The Barbary Plague* (n. 1) pp. 4; 31-36.
17. The skepticism of Kinyoun's methods by practicing physicians in San Francisco, who considered bacteriology untrustworthy and inferior to the observation of symptoms at the bedside, is described in both Risse, *Politics of Fear* (n. 16) pp. 10, 11 and in Chase, *The Barbary Plague* (n. 1) p. 46.
18. See: Maulitz, Russell, "Physician versus Bacteriologist: The Ideology of Science in Clinical Medicine," T*he Therapeutic Revolution: Essays in the Social History of American Medicine*, eds. M. J. Vogel and C. E. Rosenberg (Philadelphia: University of Pennsylvania Press, 1979) pp. 99-108. Maulitz argues that medical practitioners in general during this time were resistant to the germ theory and feared the increasing turn from clinician to laboratory technician. Maulitz did not specifically write about physicians in San Francisco during the 1900 plague outbreak.
19. "Minutes from Meeting of Commission, Occidental Hotel" (n. 13).
20. Susan Craddock, Nyan Shah, Alan Kraut, and Howard Markel outlined the discriminatory health practices against Chinese implemented in San Francisco. See: Craddock, *City of Plagues* (n. 2) p. 128; Shah, *Contagious Divides* (n. 2) p. 121; Kraut, *Silent Travelers*, (n. 2) p. 83 and Markel, *When Germs Travel* (n. 2) p. 65; see also: Barde "Prelude to plague," (n. 5) p. 160; Bard argues that these discriminatory practices underscored how bacteriological discoveries had "changed the language of scapegoating, not the target."
21. Risse, *Politics of Fear* (n. 16) pp. 9-10; Chase, *The Barbary Plague* (n. 1) pp. 45-50.
22. Chase, *The Barbary Plague* (n. 1) p. 61.
23. See: ibid. For a complete account of the burning of buildings in Chinatown as a public health measure to control the plague outbreak in Honolulu; See: Mohr, James C., *Plague and Fire: Battling Black Death and the 1900 Burning of Honolulu's Chinatown* (New York: Oxford University Press, 2005).
24. McClain, Charles, "Of Medicine, Race, and American Law: The Bubonic Plague Outbreak of 1900," *Law & Soc Inquiry* 13 (1988) p. 447.
25. Kellogg and Kinyoun each wrote that Gage appointed members to the state board who denied Kinyoun's diagnosis. See: W. H. Kellogg, "Present Status of Plague, with Historical Review" *American Journal of Public Health* 10 (1920): 835-844. See also

Kinyoun, "Dear Doctor Bailhache" (n.11) p. 52. Kinyoun claimed that Gage “made a deliberate attempt to pack the board with those of his particular ilk.

26. See: Kinyoun, "Dear Doctor Bailhache,"(n. 11). Kinyoun claimed that Winslow Anderson, editor and owner of the *Pacific Medical Journal*, and one of his appointees, Dr. Ernest Pillsbury, reported that there never had been plague in San Francisco. Kinyoun claimed that Anderson was paid $25 for every postmortem by the Chinese and $10 per day by the state. Pillsbury, “made his own bacteriologic investigation” of a specimen isolated from a Chinese man that Dr. Alphonse Taylor, pathologist at University of California, had claimed died of plague. Anderson was paid on a per diem basis by the state, and additional payments by the Chinese Six Companies for each autopsy performed.

27. See: Kinyoun, "Dear Doctor Bailhache" (n. 11) p. 47. Kinyoun wrote that one of Anderson’s “selected ‘lieutenants”, Pillsbury, “made his own investigations” in his private laboratory in his own residence and determined the bacterium Kellogg thought was plague was in fact chicken cholera.

28. "Minutes from Meeting of Commission, Pillsbury interview by Commissioners,” Box 4, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

29. “Minutes from Meeting of Commission.” Ryfkogel interview by Commissioners, Box 4, February 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

30. See: "Eradicating Plague from San Francisco," *Report of the Citizens' Health Committee* (San Francisco: 1909) p. 30; The book states that the San Francisco *Chronicle*, *Call* and *Examiner* were supporters of Governor Gage’s attempts to suppress plague in 1900 and wrote that control measures were unnecessary because the disease never existed.

31. Ibid., p. 32.

32. See: ibid., p. 30. Landlords contended that their premises were adequately sanitary because the plumbing was vented. They, like practicing physicians, doubted plague in the absence of an extensive epidemic.

33. Risse, *Politics of Fear* (n. 16).

34. See: Barde, “Prelude to Plague” (n. 5) p. 160. Barde explained how non-Asians attributed the small number of plague cases among Westerners living in plague ridden cities not only to genetic superiority, but also to environmental factors that included proper nutrition (avoiding exclusively rice containing diets), proper habits and hygiene.

35. Kinyoun, “My Dear Senator” (n. 9).

36. Kinyoun, “Dear Dr. Bailhache” (n. 11) p. 24.

37. See: ibid., p. 49. Although Kinyoun never actually alluded to Ibsen, “Kinyounism” bore similarities to the dilemma of the fictional physician Dr. Thomas Stockmann in Henrik Ibsen’s 1882 play *Enemy of the People*. Kinyoun, like Stockmann, considered himself morally justified because he objected to the materialism of the majority. In Ibsen's play, Stockmann identified contaminated spas in a coastal town, and then refused to subordinate himself to the community, who were unwilling to publicly acknowledge and address the problem because it could mean financial ruin for the town. Convinced his discovery would have helped the town, Stockmann pressed for changes to be made to the baths, but citizens turned on him.

38. Ibid., p. 68.
39. See: Walter Wyman to Frederick Novy, 14 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); in this confidential letter, Wyman invited Novy to join the commission.
40. Frederick Novy to Walter Wyman, 16 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
41. See: Frederick Novy to Grace Novy, 4 February, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). His major career goal after being hired by Vaughan was to pursue medical research in bacteriology; see also: Novy, F.G., "Bacteriology in its Relations to Public Health," *Teacher's Sanitary Bulletin* 3 (1900): 59-66.
42. Long, Esmond R., "Frederick G. Novy and Some Origins of American Bacteriology," *Transactions & Studies of the College of Physicians of Philadelphia* 26 (1957) p. 34.
43. Novy, F. G., "Bacterial Toxins and Anti-Toxins," *Med Surg Reporter* LXXIV (1896): 351-360.
44. Winslow, C. E.A, “Some leaders and landmarks in the history of microbiology”, *Bacteriology Reviews* 14 (1950): 99-114.
45. Novy, F.G., "Personal San Francisco Plague Notebook," Box 4, p. 1 – 3, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
46. Ibid., p. 2.
47. Horace Davenport, *Not Just any Medical School* (Ann Arbor: 1999) p. 45. Davenport maintains Novy's course, “Practical Bacteriology”, was a course that was renown by bacteriologists throughout the world.
48. Novy, “Walter Wyman” (n. 40) p. 1.
49. Simon Flexner to Walter Wyman, 23 January, 1901, Box 4, p. 2,Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
50. See: Risse, *Politics of Fear* (n. 16) pp. 3-4. Risse outlines how the authority of federal health departments was contested by state and local authorities. The cooperation between MHS personnel and state and municipal authorities failed to materialize. See also: Risse, *A Long Pull*, (n. 4) p. 261.
51. Nungester, W. J., “Frederick George Novy 1864-1957," *Journal of Bacteriology* 74 (1957): 545-547; Shaw, Wilfred B., *The University of Michigan, an Encyclopedic Survey, Part V*, (Ann Arbor: 1951) pp. 773-808, 821-827.
52. See: Novy, F. G., "Practical Benefits of Bacteriology," *First Report of the Michigan Academy of Science* (December 26, 1894) pp. 14-18. In 1894, Novy compared the benefits of electricity with those of bacteriology.
53. Novy, "Bacterial Toxins and Anti-Toxins" (n. 43) pp. 351-360.
54. Novy, F.G., "Germs, What they are and how they Produce Disease," *Teacher's Sanitary Bulletin* 1 (1898): 1-12.
55. See: Frederick Novy to Grace Novy, 1901, Box 3, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy wrote to his wife Grace on a daily basis (with the exception of February 5) from his departure January 24 until his return on March 6.
56. See: Frederick Novy to Grace Novy, 26 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy claimed that the

governor and others insinuated that the germ had been planted in the bodies by Kinyoun to bolster up his reputation and secure financial assistance for the MHS laboratory in Angel Island.
57. See: "Federal Commission Experts," *San Francisco Chronicle* (January 27). In this article, the *Chronicle* stated, “The three ‘experts’ will decide the matter wholly on the so-called bacteriological proofs which have been so freely handed out by Kinyoun. Instead, they should be furnished with evidence from the practical side of the case, as there will be no lack of data from which a decision based on actual conditions may be rendered.”
58. Physicians at this time described geographic predilections for particular infections. See: Cabot, Richard C., “The three long-continued fevers of New England,” *The Boston Medical and Surgical Journal* 157 (1907): 281-285; Cabot states that typhoid should be thought of as a cause of prolonged fever, but only in environments where the disease is prevalent. See also: Flint, Timothy, “Diseases, Mississippi Valley; Florida, Alabama, Missouri, Illinois, Ohio,” *The History and Geography of the Mississippi Valley* (1834): 35-40, 199-201, 223-225, 298-299, 407-408. In this publication, Flint describes the association of certain diseases, such as malaria, with particular geographic locations.
59. Frederick Novy to Grace Novy, 27 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
60. "Governor on the Plague Commission," *San Francisco Bulletin* (January 31, 1901).
61. See: Sobel, Robert and John Raimo eds, *Biographical Directory of the Governors of the United States 1789-1978* (Westport, CT: Meckler Publishing, 1978). The authors state that the Gage administration was “rife with partisan politics” and how the Southern Pacific “political machine” tried unsuccessfully to force its candidate for US Senator through the legislature.
62. Ibid.
63. "Minutes from Meeting of Commission, Occidental Hotel”, Box 4, January 27, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
64. See: ibid. The Commissioners held daily Bureau meetings from January 27 through February 4, then again on February 16. The commissioners kept recorded minutes from these meetings, and this paper uses the unpublished minutes from the Commissioners’ bureau meetings as a source throughout this paper.
65. See: ibid. The commissioners contacted the press to invite commercial leaders or physicians to confer with them.
66. “Minutes from Meeting of Commission,” January 29, 1901, p. 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
67. Frederick Novy to Grace Novy, 29 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
68. See: “Minutes from Meeting of Commission,” Box 4, January 31, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Eight of the eleven physicians interviewed believed plague did not exist in the city.
69. See: ibid. For titles and affiliations of physicians; see: McClung, L. and K. Meyer, “Beginnings of Bacteriology in California” *Bacteriological Reviews* 38 (1974): 251-271.
70. Ibid.
71. See: “Minutes from Meeting of Commission, Interview with Dr. Levi Lane,” Box 4, January 31, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Lane said the malady in San Francisco existed for the past 20

years, so clearly could not be plague. The disease was subacute, not acute, according to Lane, and therefore did not fit the clinical pattern of plague he had read about.
72. “Minutes from Meeting of Commission, Interview with Dr. Alonzo Taylor,” January 31, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
73. Frederick Novy to Grace Novy, 31 January, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
74. “Minutes from Meeting of Commission, Occidental Hotel," February 1, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
75. See: Frederick Novy to Grace Novy, 1 February, 1901, Box 3, pp. 1-7, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy said, "The detective would get them through the door but the people wouldn’t talk or answer questions.”
76. Frederick Novy to Grace Novy, 4 February, 1901, p. 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
77. Ibid.
78. See: Frederick Novy to Grace Novy, 3 February, 1901, pp. 1-8, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy recounted to Grace how he had traveled to Chinatown at 11PM on the previous night to investigate a suspicious case, shadowed by Gage’s detectives.
79. See: Novy, “Grace Novy” (n. 76). Novy wrote to Grace, “circumstances over which Taylor had no control forced him to recall the permission to use the pathology laboratory in the Medical Building at the U of California”.
80. Ibid.
81. See: “Minutes from commissioner's meeting," February 4, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). The men with whom the commissioners met included A. A. Watkine, President of the Board of Trade, George McNear, President of the Produce Exchange, R. P. Schwerin of the Pacific Mail Steamship Co., Mr. Stubbs of the Southern Pacific Railway Co., Pacific Mail Steamship, members of Mercantile Association, F. W. Dohrmann, President of the Manufacturers and Producers Association, Wakefield Baker, President of the Pacific Coast Jobbers’ and Manufacturers Association, and George Newhall, President of the Chamber of Commerce.
82. See: Novy, “Grace Novy” (n. 41) p. 3. Of note, some of the business representatives, including those of the Mercantile Association and the Southern Pacific Railway, are identical to those Kinyoun had claimed had “fixed the presses.” See also: Kinyoun, “Dear Dr. Bailhache” (n. 11) p. 47. In this letter, Kinyoun claimed that the Mercantile association and Southern Pacific Railway had fixed the press against the notion that plague was in San Francisco.
83. Novy, “Grace Novy” (n. 76).
84. Ibid.
85. “Minutes from Meeting of Commission," (n. 81).
86. Novy, “Grace Novy” (n. 76).
87. “Minutes from Meeting of Commission,” (n. 81).
88. Novy, “Grace Novy” (n. 76).

89. Frederick Novy to Grace Novy, 5 February, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
90. “Minutes from Meeting of Commission,” February 5, 1901, p. 14, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
91. Novy, “Grace Novy" (n. 89) p. 16.
92. “Minutes from Meeting of Commission,” (n. 90).
93. Frederick Novy to Grace Novy, 6 February, 1901, Box 4, pp. 1-14, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
94. See: Novy, Frederick, “Laboratory Notebook, Plague, San Francisco,” Box 4, pp. 1-14, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Novy jotted results of his microbiologic findings of specimens taken from ill or deceased Chinese persons in his laboratory notebook. He recorded the results of his laboratory work from February 5, 1901, the date he examined his first specimen, until February 16, when he completed his lab work on a specimen taken from a patient on February 16. The first 5 pages of the notebook contain various notes on plague and impressions of his work in San Francisco.
95. Ibid., p. 5.
96. See: Frederick Novy to Grace Novy, 16 February, 1901, pp. 1-8, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). In his letters to Grace from this day and afterwards, he did not to disclose his findings to her.
97. See: "Plague Day in Assembly," *San Francisco Bee* (February 13, 1901). The article stated, “Gage is trying to strong-arm the legislature to pass his bills.
98. Frederick Novy to Grace Novy, 13 February, 1901, pp. 1-5, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
99. “Minutes from Meeting of Commission,” February 16, 1901, p. 19, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
100. Novy, “Grace Novy” (n. 96).
101. Novy, “Grace Novy” (n. 96).
102. See: Novy, F. G., “The Bubonic Plague,” *Popular Science Monthly* 57 (1900): 576-578. See also: Novy, “Grace Novy” (n. 96). Novy commented to Grace that doctors had been taught that plague was a devastating epidemic. This is consistent with medical publications about plague Wyman had written in 1901. See also: Wyman, “The Black Plague”, (n. 6) p. 441.
103. Novy, “Grace Novy” (n. 96).
104. See: "Plague Day in Assembly. Fight Over Gage's Bills Consumes Morning Session,” *Sacramento Bee* (February 18, 1901); see also: “Plague Situation”, *Occidental Medical Times* Vol. XV. No 4, p. 134. The *Occidental Medical Times* noted that members of the legislature who opposed the bills were “converted to the truth, vigorously antagonizing the governor, upholding with a firm hand the position of scientific medicine.”
105. Ibid.
106. Frederick Novy to Grace Novy, 18 February, 1901, pp. 1-4, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
107. Ibid.
108. Frederick Novy to Grace Novy, 23 February, 1901, pp. 1-4, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

109. See: Kuhlman, Charles G., "The Microscope as a Guide in Medicine," *St. Louis Med J* LXX (1896): 201-209. Kuhlman questioned the basic assumption of bacteriologists as to whether disease entities could be tied to the taxonomy of bacterial species. He asked, "Oh, what's in a name and description? Are medical men in this age mere children to accept such vagueness as their scientific standards in etiology?"
110. See: "Proceedings of the San Francisco County Medical Society, Monthly Meeting, February 21," *Occidental Medical Times* XV; 4 (April 1901) p. 139. Kuhlman reasoned that the purported value of diphtheria antitoxin was due to "higher rates of tracheal intubation" in people who received anti-toxin compared to those who did not. Kuhlman argued that a reduction of mortality was incorrectly attributed to antitoxin rather than intubation, a procedure he believed would have been lifesaving in itself.
111. See: Kuhlman, Charles G., "The Government's Plague Commission," *San Francisco Bulletin* (February 20, 1901). Kuhlman believed the commissioners (Novy in particular) were bacteriologists only, and unable to "comprehend the meaning embodied within the teachings of clinical medicine." He stated that the "youngster" commissioners adopted "hoodlum methods" of bacteriologists and were "fond of slang" in their "arbitrary self-sufficiency" and "sophism."
112. Ibid.
113. See: Kuhlman, "Government's Plague Commission" (n. 111). The "so-called experts", he believed, did not possess real skills because they had "never sat by the bedside of sick and dying man" and "never had their wits sharpened by keen competition or consultation never walked the floor night and day worrying over serious cases involving fee and reputation."
114. "Minutes from Meeting of Commission," February 26, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Wyman, "Report of the Commission Appointed by the Secretary of the Treasury for the Investigation of Plague in San Francisco" is in "Minutes from Meeting of Commission", Box 4. Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
115. Ibid.
116. Frederick Novy to Grace Novy, 6 March, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
117. Barker, Lewellys F., "On the Clinical Aspects of Plague," *Am J Med Sci* 122 (1901) p. 89.
118. Novy, F.G., "On the Bacteriology of Plague," *Am J Med Sci* 122 (1901) p. 4.
119. See: ibid., p. 7. Also stated in *Report of the Government Commission on the Existence of Plague in San Francisco* (April 1901) p.108.
120. See: ibid., p. 8. Also stated in *Report of the Government Commission on the Existence of Plague in San Francisco* (April 1901) p.108.
121. Novy, Frederick G., "The Bubonic Plague" *The Physician and Surgeon* 22; 5 (1900) p. 14.
122. Medical textbooks and articles in the late 19th century had described and defined plague in terms of its material ravages and societal devastation. One article refers to it as "the most formidable of all epidemic disease". See: Payne, J. F., "Plague Ancient and Modern," *St Thomas Hospital Reports* XVII (1887): 103-108; see: Cantle, James, "The Spread of Plague," *The Lancet* (1897) p. 4; see also: Flint, Joseph, "Notes on the Plague in China and India," *Bulletin of the Johns Hopkins Hospital* XI (June 1900): 119-127; see

also: Vaughan, V. C., “The Bubonic Plague,” *Popular Science Monthly* II (1897): 62-72; For texts, see: Welch, William “The Plague” in Alfred Lee Loomis and William Gilman Thompson, *A System of Practical Medicine* (New York: Lea Brothers, 1897) p. 391. Each of these sources describes the material and social devastation the epidemic has caused throughout history, detailing massive depopulation and fear in which epidemics were appreciated. The medical tests refer to literary sources, such as Boccaccio’s *Decameron*, and also Biblical sources (Deuteronomy, Chapter 28, paragraph 27 and Samuel I, Chapter 5, paragraphs 6 and 9 describing the plague that attacked the Philistines after they took the ark). These sources describe the horror to civilization, the disruption to society and ravages to civilization that have occurred over the “waves” of attacks over history, including the Justinian Plague of 542, the Black Plague of 1347, and the 1894 pandemic.

123. “Bubonic Plague. Professor Novy Traces History of the Disease,” *Toledo Blade* (June 7, 1902).

124. Novy, F. G., “On the Bacteriology of Plague,” *Am J Med Sci* 122 (1901) p. 4; Novy, F. G., "The plague in California, and what to do if that disease should be brought into Michigan," *Teachers' Sanitary Bulletin* 6 (1903) p. 59.

125. “Bubonic Plague. Professor Novy Traces History of the Disease,” (n. 123); Novy, F. G., “The Plague in California,” *Teacher’s Sanitary Bulletin* 6 (1903) p. 63.

126. Bulloch, William, *The History of Bacteriology* (London: Oxford University Press, 1938) pp. 1-406; Kramer, H. D., “The Germ Theory and the early public health program in the United States,” *Bulletin of the History of Medicine* 22 (1948): 233-237; Ford, William, *Bacteriology* (New Jersey: Paul B Hueber, Medical Department of Harper and Brothers, 1939) pp. 1-195; Gradman, Cristoph, *Laboratory Disease, Robert Koch's Medical Bacteriology* (Johns Hopkins University Press: 2009) pp. 1-318.

127. See: King, Lester, *Medical Thinking, A Historical Perspective* (Princeton University Press: 1982) p. 1336. King argues that tuberculosis was a disease that had once been defined by clinical phenomena (e.g., wasting, phthisis, consumption), became one that was defined by microbiologic and pathologic criteria (e.g., the presence of mycobacteria in a pathological structure--the tubercle).

128. “Where Bubonic Plague Cases were Discovered,” *Sacramento Bee* (February 15, 1901).

129. “Infamous Compact Signed By Wyman. Makes Agreement with Gage Not to Let Facts Become Known,” *Sacramento Bee* (March 16, 1901).

130. See: Hart, James D., *A Companion to California* (New York: Oxford University Press, 1978). This book contains the identity and occupations of the delegates, who agreed with Gage that only suppressing plague could avoid a financial threat of a trade embargo. Herrin and Young were editors of the Chronicle, and T. T. Williams joined the San Francisco examiner, first as a reporter, then as a business manager. He remained on the staff when Hearst took charge of the paper in 1886. Scott was first employed as a time-keeper in the Union Iron Works, then worked his way up to First Vice President by 1883. He also became President of the Pacific Telephone & Telegraph Company. Older eventually became editor of the *San Francisco Bulletin* (1895-1918) and *Call* (1918-1930). See also: Davenport, Robert W., “Older, Fremont,” *Biographical Dictionary of American Journalism* (1989): 525-526.

131. See: “Infamous Compact Signed by Wyman,” (n. 129). The newspaper published the arrangement signed by Wyman. The arrangement was also published “The Plague

Situation," *Occidental Medical Times* XV; 4 (April 1901) p. 135; Wyman disclosed the arrangement in a letter he wrote to Dr. Joseph White, a MHS quarantine officer who replaced Kinyoun; See also: Walter Wyman to Andrew White, 6 March, 1901, Box 4, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
132. Walter Wyman to Andrew White, 9 January, 1901, 6 March, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
133. Ibid.
134. *History of the Department of the Treasury* (Washington, D.C.: Office of the Curator, Department of Treasury, 2006).
135. See: "Infamous Compact Signed By Wyman," (n. 129). The article pointed out that Wyman violated Federal Law, Section 4 Chapter 114 of the Acts of the Fifty-second Congress", entitled, "An Act granting additional quarantine powers and imposing additional duties upon the Marine Hospital Service" approved February 15, 1893, wherein the Surgeon General of MHS, under direction of the Secretary of the Treasury, should perform quarantine duties and publish all cases of communicable disease."
136. Ibid.
137. "The Plague Situation," (n. 131) p. 135.
138. After obtaining Wyman's approval, the commissioner's report was published. See: "Report of the Commission Appointed by the Secretary of the Treasury for the Investigation of Plague in San Francisco," *Public Health Reports* 16; 16 (April 19, 1901): 801-817; The Public Health Report stated it was printed "under Instructions from the Surgeon-General, Marine Hospital Service." The Treasury Department-U.S Marine-Hospital report was reprinted with the revised title, "The Report of the Government Commission on the Existence of Plague in San Francisco" *Occidental Medical Times* XV; 4 (April 1901): 101-117.
139. See: "What Did Gage Do With Plague Funds?" *Los Angeles Times* (January 21, 1903) p. 2; see also: "A Shameful Record of Falsification," *Sacramento Bee* (September 10, 1903). The article stated that Gage squandered the $100,000 that was earmarked for the plague control campaign, for the maintenance of a troop of political hangers-on and parasites of the State Board of Health.
140. See: ibid. According to the *Los Angeles Times*, Gage used the remainder of the funds to "pay back political debts."
141. "Suppressing the Plague," *New York Times* (April 3, 1901).
142. "No Plague in Chinatown," *Washington Post* (March 26, 1901).
143. "Plague in California," *Lancet* (August 24, 1901) p. 572.
144. "The Bubonic Plague Fake," *San Francisco Chronicle* (October 20, 1901).
145. "The Bubonic Fake," *San Francisco Call* (February 24, 1903).
146. Ibid.
147. "Gage's Anti Plague Contention Sustained," *Los Angeles Herald* (June 16, 1901).
148. Ibid.
149. Alonzo Taylor to Frederick Novy, 30 May, 1901, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
150. Frederick Novy to Grace Novy, 6 Marc, 1901, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
151. Ibid.

152. Novy, Frederick G., “The Bacteriology of Bubonic Plague,” *American Journal of the Medical Sciences* (October, 1901) p. 6.
153. “Black Death. Professor Novy thinks he has a case of it at Ann Arbor,” *Ann Arbor News* (April 8, 1901).
154. “Believe it is the Plague,” *Ann Arbor News* (April 9, 1901).
155. Novy, “The Bacteriology of Bubonic Plague” (n. 152) p. 7.
156. “Germ Hunters,” *Ann Arbor News* (May 15, 1901).
157. “Plague not Ominous,” *Ann Arbor News* (October 9, 1901).
158. “The Bubonic Plague Fake,” (n.144).
159. Ibid.
160. “Gage's Anti Plague Contention Sustained. Vindication for the Governor” (n. 147).
161. Ibid.
162. See: *Occidental Medical Times* XV; 7 (July 1901). The paper reported that White said Gage’s men would appear at the morgue and “argue over the meaning of symptoms, and press competing diagnoses” that did not seem logical to him.
163. “The Bubonic Plague Fake,” (n. 144).
164. “The Plague Fake. How San Francisco Has Been Outraged by a Set of Charlatans. No cases of Bubonic Plague could be found when the Fakers were watched,” *San Francisco Chronicle* (October 20, 1901) p. 21.
165. Ibid.
166. See: “Editorial: The Bubonic Plague Fake,” *San Francisco Chronicle* (October 20, 1901). It claimed misrepresentations had been made by irresponsible papers, which “created the impression in Washington that there was a disposition on the governors’ part to obstruct the operations of the MHS.”
167. Ibid.
168. Editorial Committee, “The plague in San Francisco,” *Science* XIII (May 13 1901) p. 763.
169. The journals objecting to the suppression of plague by the California government included the *Cleveland Journal of Medicine* (March 1901); *Public Health Reports* (July 1901) and the Board of Health San Francisco, “Annual Report” *Occidental Medical Report* (August 9 1902).
170. “The Plague,” *Pop Sci Monthly* 59 (1901): 105-106.
171. Kinyoun, J. J., “Bubonic Plague,” *Occidental Medical Times* XV; 8 (August 1901) p. 10.
172. Both the “Plague in San Francisco” *Philadelphia Inquirer* (April 12, 1901) and the “New plague cases appear,” *Fort Worth Morning Register* (April 18, 1901). Stated that the disease would continue to spread because of nominal sanitary measures.
173. See: Williamson, John, “Annual Report ending June 30,” *Occidental Medical Times* XVI (September 9, 1902). The paper reported how Williamson called for more aggressive sanitary measures and for rat control measures. He felt the “State Board cannot state with authority that plague does not exist, as its members do not have the “scientific qualifications” to make a reasoned judgment about plague.”
174. *Public Health Reports* V; 11(September 1901): 166-168.
175. Kinyoun, “Bubonic Plague” (n. 171).
176. See: “The Plague in California,” *Medical News* 81; 4 (July 26, 1902) p. 175. The journal argued that rat control measures were needed to handle the spread of plague.

177. “Alleged Existence of Bubonic Plague,” *San Francisco Argonaut* (December 16, 1901).
178. Ibid.
179. Ogata, M., “Of the cause of the peste,” *Kokka Igaku Kwai Sasshi* 201 (1897) p. 207.
180. Simond, P. L., “La Propagation de la Peste,” *Annales de L-Institut Pasteur* xii (1898): 625-687; P. L. Simond was from the L’Institut Pasteur.
181. “Professor Koch on the Plague,” *Science* VIII (1898): 101-102.
182. Wyman, Walter, *The Bubonic Plague* (Washington: Government Printing Office, 1900) pp. 16, 25, 38.
183. Loir, M.A., “Histoire des epidemies de peste a Tunis,” *Revue Scientifique* 4 (1900): 398, 399; Anders, James M., “The Plague,” *A Text-Book of the Practice of Medicine* (Philadelphia: WB Saunders, 1900) pp. 169-171.
184. Calmette, A, “Harben Lectures on the Plague delivered at the Examination Hall of the Royal Colleges of Physicians and Surgeons, London,” *Science* (December 21, 1900) p. 969.
185. Thompson, J. Ashburton, “A Contribution to the Etiology of Plague,” *J hygiene* 1; 2 (April 1901) p. 162.
186. Kinyoun, “Bubonic Plague” (n. 171), p. 7.
187. The medical texts are: Eichhorst, Hermann, “Bubonic Plague” *A Text-Book of the Practice of Medicine Volume II* (Philadelphia: WB Saunders, 1901), p. 372. “Rats play an important role in the dissemination…fleas may convey the infection, as it has been possible to demonstrate the presence of plague-bacilli in their blood" and William Osler, “The Plague” *The Principles and Practice of Medicine* (New York: D. Appleton and Co, 1902) pp. 189-193. Osler’s “Principles and Practice of Medicine” in 1902 reiterated this epidemiology, “rats are readily infected…and fleas die from the disease and may convey the infection to man.” The journal articles are: Thompson, “A Contribution to the Etiology of Plague,” (n. 185) p. 163. Thompson also captured rats, and noted that ‘the area over which the epizootic extended coincided with the area over which the epidemic was seen to have extended in 303 cases in man.’ Tidswell, Frank, “The Epidemiology of Plague: Note on the Fleas of Rats,” *Brit Med J* (June 27, 1903) p. 1491; Tidswell agreed with Simond that fleas that bite rats can also bite man and transmit the disease to man; and J.W.W.S., “Plague and fleas,” *Nature* 77 (1907): 59-60.
188. See: “Bubonic Plague,” *Current Literature* (1900): 176-179. This document places the date that the medical profession accepted rat and flea borne transmission at the time of the San Francisco plague.
189. Wyman, *Bubonic Plague* (n. 182), p. 43.
190. Ibid.
191. Williamson, John, *Biennial Report of the Board of Health of the City and County of San Francisco for the fiscal years 1899-1900* (San Francisco: The Hinton Printing Company, 1901) p. 14.
192. “The Plague Epidemic,” *The Independent* 52 (1900) p. 1750.
193. “Riddance of Rodents, Chinatown must be kept clean,” *Los Angeles Times* (June 17, 1900).
194. Osler, William, *The Principles and Practice of Medicine* (New York: D Appleton and Company, 1902) p. 192.

195. Wyman, *Bubonic Plague* (n. 182) p. 17. Wyman notes that these sanitary measures should be adopted while acknowledging that "a common belief in oriental countries is that the rat contracts the disease from miasmatic emanations from the soil, but this has never been scientifically demonstrated and is probably incorrect."
196. Eichhorst, *Bubonic Plague* (n. 187) p. 374.
197. Osler "The Plague" (n. 187) p. 191.
198. "Digest of Recent Observations on the Epidemiology of Plague," *J Hygiene* 7 (1907): 694-723.
199. Nancy Tomes, Judith Leavitt, and Thomas Worboys have pointed out the linkages between ideologies and practices in the pre-germ era and following the germ theory rather than positing a revolutionary break. Each author provides a different context whereby pre-germ theories have persisted in the germ era. Tomes linked public health movement at the turn of the 20th century in America with private, domestic hygiene practices. The cultural ideal of purity was transformed from a concern for visible tidiness during the prebacterial era to a preoccupation with unseen but potentially deadly microbes. Consequently, she argues, many aspects of the prebacterial health reform continued into the germ era. See: Tomes, Nancy, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Cambridge: Harvard University Press, 1998) pp. 1-351; Leavitt uses Mary Mallon's experience to show how even after the germ era, public health policies surrounding the management of disease carriers did not solely rely on scientific evidence to arrive at decisions. Instead, social views and biases shared by the public, health professionals and members of the legal community influenced policy just as they had done in the pre-germ era. See also: Leavitt, Judith Walzer, *Typhoid Mary: Captive to the Public's Health* (Boston: Beacon Press, 1996) pp. 1-331; Worboys emphasized the heterogeneity of germ theories and the continuities between the pre-bacterial era and post germ theory era--including surgical practices and "seed and soil" metaphors with regard to consumption. See also: Worboys, Michael, *Spreading Germs: Disease, Theories and Medical Practice in Britain, 1865–1900* (New York: Cambridge University Press, 2000) pp. 1-327.
200. Novy, "Plague" (n.121) and Wyman, "The Bubonic Plague" (n.182).
201. Osler, "The Plague" (n. 197) p. 192.
202. Flint, Joseph, "Notes on the Plague in China and India," *Bulletin of the Johns Hopkins Hospital* XI (1900): 119-135.
203. Risse, "Politics of Fear" (n. 16).
204. See: Chase, *Barbary Plague* (n. 1) p. 162. Chase notes that rat eradication programs were expensive as they included salaries of medical officers, wages for laborers, traps, cheese bait, poison, and laboratory equipment to sample rats for the presence of plague.
205. Duffy, John, "Health and Sanitation at the Close of the Nineteenth Century," *The Sanitarians*, (New York: Pantheon Press, 1990) pp. 17-192.
206. Kinyoun, "Bubonic Plague," (n. 171) p. 15.
207. Kellogg, W.H., "Present Status of Plague with Historical Review," *American Journal of Public Health* 10 (1920): 835-844.
208. "Annual Report ending June 30," *Occidental Medical Times* XVI; 9 (September 1902).
209. Wyman, "Andrew White" (n. 132).

210. See: Risse, "The Politics of Fear" (n. 16). Risse said that the accepted epidemiology of plague still emphasized the primacy of human transmission through inhalation or ingestion of particles (p. 11), and that the role of the rat in the transmission of plague was uncertain (p. 16). See also: Risse, "A Long Pull, A Strong Pull, and All Together: San Francisco and Bubonic Plague, 1907-8" *Bulletin of the History of Medicine* 66 (1992) p. 169. Risse states that the role of the rat and flea in the transmission of plague was not understood until the second plague epidemic in 1907. See also: Kraut, *Silent Travelers* (n. 2). Kraut said that in 1900 the epidemiology of the disease was not thoroughly understood, and that medical experts were not aware of the role of rodent fleas in spreading bubonic plague (p. 85), and that in 1901 health officials did not yet have evidence that fleas on rats were plague's vectors (p. 96). See also: Markel, *When Germs Travel* (n. 2). Markel said that the science and epidemiology of plague was far from perfect in 1900 (p. 60), and that in 1907 epidemiologists had worked out the role of rats and fleas in spreading the disease. See also: Chase, *Barbary Plague* (n. 1). Chase said the public health efforts of the day (1900) were handicapped by limited scientific knowledge (p. 4), that the city had no knowledge that the disease was spread by a rat flea (57), how the bacterium entered the human body remained a mystery (44), how in 1900 medical science had not recognized the connection between rats and the infection of people (58), and that it was not until 1906 when the medical establishment accepted the flea borne transmission as the 'spark of deadly epidemics' (106) and that in 1901 public health officers were not aware of how the disease spread (110). See also: Shah, *Contagious Divides* (n. 2). Shah mentioned that in 1900 the Public Health Service disregarded scientific evidence that rats were the primary conveyors of disease (p. 128), and that during the second epidemic in 1907, scientific medicine had readily identified the rat flea as the source of transmission of the disease from rats to humans (154). See also: Craddock, *City of Plagues* (n. 2). Craddock states that the role of the rat in harboring plague infested flees that in turn bit humans was not known by 1900 (127, 128). Craddock then goes on to say that by March 1903, sanitizing was thought not to be sufficient in handling plague, and that attention was paid to the rat, although the exact role of the rat in transmitting plague to humans was not understood (138). She states that the role of the flea in transmitting plague to rats, and subsequently to humans was finally understood in 1909 (150).
211. "Governor will act for state," *San Francisco Bulletin* (February 21, 1901); Craddock, *City of Plagues* (n. 2) pp. 138-141; Power, J. Gerald, "Media Dependency, Bubonic Plague, and the Social Construction of the Chinese Other," *Journal of Communication Inquiry* 19; 1 (Spring 1995) p. 89.
212. See: "Plague in San Francisco. None of the Inflicted are white," *Los Angeles Times* (March 12, 1901). The paper states that all cases have occurred among Chinese in Chinatown and that no cases occurred in white people, and that the existence of plague in San Francisco should excite no alarm and that it is safe to live in San Francisco.
213. See: "Plague or No Plague. Apparently Little Danger," *Los Angeles Times* (March 15, 1901). Officials such as Joseph White saw no cause for alarm or need to employ fully effective measures in combating plague, as he was certain that the disease would not spread outside of Chinatown to other parts of the city.
214. "Plague Situation," *Occidental Medical Times* XV; 7 (July 1901) p. 137.

215. See: “Plague in San Francisco,” *Scientific American* (1900). This article states, “The Chinese are of the lowest class, just those among who the disease, on account of their filthy habits and squalid surroundings, was certain to appear. Every precaution is being taken to prevent the contagion from extending into the interior.”
216. Austin, H. W., “Bubonic Plague in U.S.” *Public Health, A Monthly Journal of Sanitation* 5; 11 (September 1901): 170-172.
217. Kinyoun, “Bubonic Plague” (n. 171) pp. 8-9.
218. *Public Health Reports* 18; 5 (January 30, 1903).
219. “The Right Policy is to Tell the Truth,” *Sacramento Bee* (January 10, 1903).
220. Williamson, John, “Occidental Medical Report, Annual Report ending June 30,” *Occidental Medical Times* 15; 7 (July 1901).
221. “Bubonic Plague: Charge that Health Authorities of San Francisco Do Not Take Proper Precautions against it,” *Los Angeles Times* (October 29, 1902).
222. Novy, F.G., “The Plague in California,” *Teacher’s Sanitary Bulletin* 6 (1903): 59-60.
223. See: “How Dr. Novy Destroys the Microbes of Infectious Diseases with a New Germicide Based on the Chemical Principles of Gold and Sunlight,” (January 19, 1902). The article focused on Novy’s development of an antiseptic. But within the article, Novy commented on what he perceived was the inappropriate handling of plague by Gage.
224. “Bubonic Plague. Professor Novy Traces History of the Disease,” *Toledo Blade* (June 7, 1902).
225. Novy, F.G., “The Plague in California” *Teacher’s Sanitary Bulletin* 6 (1903): 63-64.
226. Ibid.
227. “Plague in San Francisco,” *Los Angeles Times* (November 1, 1902).
228. “Bubonic Plague in California” *New York Times* (November 2, 1902).
229. See: “Plague Situation in San Francisco Becomes Alarming,” *Washington Post* (November 3, 1902). The byline reads, “Situation in San Francisco becomes alarming. Ravages of Disease Steadily Increasing.”
230. See: “Plague in San Francisco,” *New York Times* (January 10, 1903). The Byline from the paper reads “British Columbian Health Official Suggests Quarantine.” Another paper that argues an embargo is also “The plague in California. Wanted: The Plain Truth.” *Los Angeles Times* (December 3, 1902).
231. “Plague on the Pacific Coast,” *The Independent* 55 (1903) p. 2826.
232. See: “The Bubonic Fake,” *San Francisco Call* (February 25, 1903). The article states that “the continuous good health of the city stands as evidence that there never was such a thing as bubonic plague.”
233. See: “Cleaning out Chinatown,” *San Francisco Chronicle* (December 14, 1902). The paper said, “We San Franciscans are called upon to pay a heavy penalty for the Chinese derelictions because of the suspicions which their presence has created.”
234. “Splenetic Farewell to Public Life,” *Los Angeles Times* (January 3, 1903).
235. “Gage Severely Arraigned. Bubonic Plague Exists in San Francisco,” *Los Angeles Times* (June 18, 1902) p. 1.
236. See: “To Discuss Plague in San Francisco,” *Los Angeles Times* (January 19, 1903). Another *Los Angeles Times* article stated, “despite all efforts that have been made to minimize the reports of plague in California, there is a widespread feeling that the situation is growing worse instead of better.”

237. “Some Reasons Why Gage Should Be Defeated,” *Los Angeles Times* (August 12, 1902).
238. Ibid.
239. “The Doctors Taboo Rats: Advise Persistent Warfare of Extermination,” *Los Angeles Times* (February 7, 1903). The byline reads, “The Danger of Bubonic Plague is not Imaginary. San Francisco Disgrace.”
240. “A Good Appointment,” *Los Angeles Times* (January 14, 1903).
241. “Proceedings in Detail: Surgeon-General Report,” *Los Angeles Times* (January 20, 1903).
242. *Los Angeles Times* (February 7, 1903).
243. “The Things to Do,” *Los Angeles Times* (January 20, 1903).
244. See: “First Steps in War on Plague,” *Chicago Daily* (January 20, 1903). The byline from the article states, “Bubonic Plague Hidden for Three Years by California Officials. Nation is now Aroused. Delegates from Nineteen States Demand Prompt Measures for Public Safety.”
245. Novy “The Plague in California,” (n. 225) p. 60.
246. See: “Bubonic Plague Matter. Merchants take action,” *Los Angeles Times* (January 27, 1903). The paper describes how the national condemnation of California handling of plague had escalated. In response to the Washington meeting, the merchants avowed to “take action on the statements made that bubonic plague exists in the city.”
247. See: Citizens' Health Committee, *Eradicating Plague* (n. 30). The committee included representatives from the Board of Commerce, Board of Trade, Merchants Exchange, and Manufacturers and Producers Association, and State Board of Trade. Specifically, the committee included L. M. King, L. M. Davis (Board of Commerce), George Newall, E. Scott, W. J. Dutton (San Francisco Board of Trade), A. A. Watkins, H. L. Smith, (Lippman Sachs, Merchants Exchange), G. W. McNaear, T. C. Friedlander, R. P. Schwerin, (Manufacturers and Producers Association), A. Sbarbaro, C. E. Bancroft, J. P. Currier, (State Board of Trade), N. P. Chipman, J. A. Filcher, A. R. Briggs, and M. H. de Young. The committee resolved to take such steps as might be necessary to satisfy the people from abroad regarding the condition of affairs in San Francisco. Of note, four of these men, Newall, Watkins, McNear, and Schwerin representing the San Francisco Board of Trade, the Merchants Exchange, and Manufacturers and Producers Association, had met with Novy and the Commissioners at the Occidental Hotel on February 4, 1901 to assist them in their investigations.
248. See: *Public Health Reports* 18; 7 (February 13, 1903). F.J. Symmes, president of the Merchants’ Association, chaired a meeting to “take some action in defense of their city’s good name, put a stop to misleading statements, and determine an effective course of action against the spread of plague.”
249. See: ibid. The Citizens Health Committee stated that unless San Francisco got together to stamp out plague, it would be necessary to enforce a general quarantine against the city. This motivated the formation of the Mercantile Joint Committee.
250. See: ibid. The committee met with Governor Pardee on February 4 to argue that a delay in measures would harm trade of the city as well as tourism.
251. “Plague in San Francisco,” *Los Angeles Times* (January 30, 1903).
252. “Let the Truth be brought out,” *Los Angeles Times* (February 5, 1903).

253. See: Wyman, *The Bubonic Plague* (n. 182) pp. 43, 44. In this paper, Wyman reviews the principles of rat proofing by employing rat-catching dogs and bounty hunters of rats; rat eradication by sulfurizing sewers and streets and poisoning rats, and of general sanitation measures that would accomplish destroying the nests of rats.
254. Citizens' Health Committee, *Eradicating Plague* (n. 30) p. 31.
255. "Pledge of Action," *Los Angeles Times* (February 16, 1903).
256. *Public Health Reports* 18; 5 (January 30, 1903) pp. 121-124; 18; 39 (September 25, 1903) p. 153. Each week, the Reports listed the number of rats bacteriologically examined, and the number showing pest infection. For the week of September 19, 17 rats were examined, and none showed evidence of plague.
257. See: "Monthly Statement of Inspection of the Chinese District of San Francisco, CA," *Public Health Reports* 18; 17 (April 24, 1903): 593-595. The article mentions "radical measures" introduced, including a "vigorous assault against the maintenance of unsanitary structures in Chinatown. It defines "excrescences" as "small wooden structures built on the sides of houses from top floor to basement.
258. *Public Health Reports* 18; 13 (March 27, 1903) p. 427.
259. "San Francisco Plague," *Los Angeles Times* (February 16, 1903).
260. "Health Officials Satisfied," *Los Angeles Times* (March 2, 1903). The article said, "For the first time in three years, the government is perfectly satisfied with the situation in San Francisco and feels free to take the statements of what the California officials will do toward preventing a recurrence of the disease in San Francisco at their face value."
261. "Pledge of Action" (n. 255).
262. See: "Boards of Health Conference at Washington" *Los Angeles Times* (June 4, 1903). The article describes Wyman's view that the state and national health boards had begun to work in cooperation. Wyman attributed the success of the work in Chinatown to the cooperation between the city, state and national health officers in eradicating infection.
263. Ibid.
264. Ibid.
265. See: *Public Health Reports* 15; 30 (July 24, 1903) p. 1165. For the week of July 24, 1903, for example, officials inspected approximately 280 buildings, examined 34 sick persons (none with plague), autopsied 82 (0 with plague), disinfected 845 buildings with carbolic acid and chloride of lime, and flushed 17 sewers.
266. "Plague in San Francisco: Four new cases in July despite health authorities' vigorous efforts to wipe out disease," *New York Times* (August 4, 1903).
267. Chase, *The Barbary Plague* (n. 1) p. 141.
268. Citizens' Health Committee, *Eradicating Plague* (n. 30) p. 9.
269. See: ibid, p. 33. The committee said, after two years of unremitting toil, of trapping and poisoning rats and destroying their harboring places, of tearing the sodden planking out of light wells, of letting the sun into old cellars, of inducing, persuading and compelling landlords and their agents to pave back areas and basements and fill the spaces in the underpinning of tumble down shacks with concrete and tear down and rebuild where the problem was hopeless of solution any other way, the last vestige of the disease disappeared. The fear of quarantine was a thing of the past, and the national papers had long since stopped reporting on it. The plague had been built out.

270. Keane, Augustin C., “San Francisco's Plague War,” *The American Review of Reviews* 38 (1908)*:* 561-571.
271. See: Rucker, William Colby, “Shutting out Bubonic Plague,” *Harper's Weekly* 53 (June 1909) p. 32. Rucker summarizes the lessons learned from the first San Francisco outbreak, including the importance of rat control, that were then put into place immediately at the time of the second outbreak in 1907.
272. “Protection from Plague,” *Los Angeles Times* (January 8, 1903). The byline reads “New Health Board Embraces the avoided issue. City will be faithfully kept clean. Bounty on Rats recommended as the starter of a general cleaning campaign.”
273. Lewis, Sinclair, *Arrowsmith* (New York: Signet, 1925) p. 343.
274. Ibid., p. 347.
275. Ibid., p. 370
276. Ibid., p. 371.
277. Ibid., p. 390.
278. Ibid., p. 175.
279. Ibid., p. 178.
280. Latour, Bruno, “Give Me a Laboratory and I will Raise the World,” in: Karin Jnorr-Cetina and Michael Mulkay, eds., *Science Observed: Perspectives on the Social Studies of Science* (London and Beverly Hills: Sage, 1983) pp. 141-170; see also: Latour, Bruno, *The Pasteurization of France* translated by Alan Sheridan and John Law (Harvard: Harvard University Press., 1984) pp.1-273.
281. Hammonds, Evelynn, *Childhood’s Deadly Scourge* (Baltimore: Johns Hopkins University Press, 1999).
282. Solomon, Harry Caesar, *Syphilis of the Innocent* (Washington: United States Interdepartmental Social Hygiene Board, 1922).
283. Cunningham, Andrew and Perry Williams, *The Laboratory Revolution in Medicine* (Cambridge: Cambridge University Press, 1992).

Chapter 4

1. Ludmerer, Kenneth M., *Learning to Heal: the development of American medical education* (Baltimore: Johns Hopkins University Press, 1996) pp. 1-46; Bonner, Thomas, *Becoming a Physician, Medical Education in Britain, France, Germany, and the United States* (Baltimore: Johns Hopkins University 1995) pp. 175-182, 195-200; see also: Rothstein, William, *American Medical Schools and the Practice of Medicine* (Oxford: Oxford University Press 1986) pp. 1-216.
2. Ibid., pp. 31-64.
3. Davenport, Horace W., *Victor Vaughan: Statesman and Scientist* (Ann Arbor: University of Michigan, 1996); Hinsdale, Burke A, *History of the University of Michigan. From 1837 to 1906* (Ann Arbor: University of Michigan, 1906) pp. 91–97.
4. Novy, F.G., "Fifty Years' Progress in Medical Education," *A Half century of Nu Sigma Nu, 1882-1932*, eds. Will Walter and Stuart Graves (Louisville, Ky.: The Nu Sigma Nu Fraternity, 1935) pp. 1669–1685.
5. “Zina Pitcher lecture,” February 22, 1908, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

6. Romano, Terrie M., *Making medicine scientific: John Burdon Sanderson and the culture of Victorian science* (Baltimore: Johns Hopkins University Press, 2002).
7. Novy, "Fifty Years' Progress in Medical Education," (n. 4) pp. 1669–1685.
8. Davenport, *Victor Vaughan: Statesman and Scientist* (n. 3) pp. 94-98.
9. Novy, "Fifty Years' Progress in Medical Education," (n. 4) pp. 1669–1685.
10. Gorham, Frederic, "The History of Bacteriology and its Contribution to Public Health Work," *A Half Century of Public Health*, ed. Mazyck Ravenel (New York: American Public Health Association, 1921) pp. 66–93.
11. Gorham, Frederic, "The History of Bacteriology and its contribution to public health work," *Science* 31 (1910).
12. Novy, Frederick G., "Doctor Vaughan's Influence in Medical Education," *Journal of Laboratory and Clinical Medicine* 15 (1930)*:* 7-9.
13. Novy, Frederick G., "Fifty Years Progress in Medical Education (1882-1932)," *Nu Sigma Nu; Historic and Biographic* 1 (1935)*:* 1669-1680.
14. Ibid., p. 1670.
15. Ibid., p. 1671.
16. Ibid., p. 1673.
17. "Faculty meeting, Thurs. November 16," University of Michigan Medical School, Records, 1850–2002, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan, 1889).
18. Davenport, Horace, *"Not Just Any Medical School: The Science, Practice, and Teaching of Medicine at the University of Michigan, 1850-1941,"* (Ann Arbor: The University of Michigan Press, 1999) pp. 1-306.
19. "Meeting of the faculty, March 18," University of Michigan Medical School, Records, 1850–2002, Box 127 and 128 (Ann Arbor: Bentley Historical Library, University of Michigan 1892).
20. Davenport, *Not Just Any Medical School: The Science, Practice, and Teaching of Medicine at the University of Michigan, 1850-1941* (n. 18) pp. 1-306.
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23. See: Novy, Frederick G., "Position of Bacteriology in a Medical Course," *Pan American Medical Congress* 2 (1893): 2209-2210. Among the faculty who attended was the professor of physiology, Henry Sewell, a sufferer of tuberculosis, who wished to study his own case by the new bacteriological techniques.
24. "Meeting of the faculty, April 26," University of Michigan Medical School, Records, 1850-2002, Box 127 and 128 (Ann Arbor: Bentley Historical Library, University of Michigan 1890).
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26. Novy, F.G., "Position of bacteriology in a medical course," *Transactions of the first Pan-American Medical Congress* 2 (1893): 2209-2210.
27. Ibid., pp. 2209-2210.
28. See: Davenport, *Victor Vaughan: Statesman and Scientist* (n. 3). Bacteriology at Harvard, Pennsylvania, and Columbia occupied 160 hours of the curriculum at other medical schools. See also: Bergey, David H., "Early instruction in bacteriology in the United States," *Annals of med. history* 1 (1917): 426-427.
29. Novy, F. G., "Preface," *Direction for Laboratory Work in Bacteriology* (Ann Arbor: George Wahr, 1894).
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31. Novy, Frederick, “Position of Bacteriology in a Medical Course,” *Pan American Medical Congress* 2 (1893): 2209-2210.
32. Novy, *Laboratory work in Bacteriology* (n. 30) pp. 295-385.
33. Novy, Frederick, "Teaching notes from bacteriology course," Box 4, 1891-1899, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
34. Novy, F. G. *Directions for Laboratory Work in Bacteriology* (Ann Arbor: George Wahr, 1894) p. 209, frontispiece.
35. Novy, *Laboratory work in Bacteriology* (n. 30) pp. 253-257.
36. See: ibid., pp. 255-261.Students were asked to identify pathogens such as *Streptococcus pyogenes* and *Vibrio cholera*.
37. Ibid., pp. 344-346.
38. Novy, Frederick G., “The Spirit of Research in Medicine,” *Physician and Surgeon* 24 (1902): 13-15.
39. See: Ludmerer, Kenneth, *Learning to Heal* (Baltimore: Johns Hopkins Press, 1985) pp.63-67, 78-103. Ludmerer reviews the importance teaching critical thinking and the logic of experimental design to medical students during a period when medical knowledge was enlarging and evolving. See also: Flexner, Abraham, *Medical Education in the United States and Canada* (New York: Carnegie Foundation for the Advancement of Teaching, 1910) pp. 36-37, 62, 92. Flexner recognized the importance of teaching the scientific method as it applied to practice as well as research.
40. See: Curti, Merle *The Social Ideas of American Educators* (Patterson, N.J.:Pageant Books, 1959) pp. 491-542. Dewey’s full views of his position on education is contained in his book, John Dewey, *Democracy and Education* (New York, Macmillan, 1916).
41. Ibid., pp. 3-6.
42. Novy, "Teaching notes from bacteriology course," (n. 35); Novy, Frederick G., *Laboratory work in Bacteriology* (Ann Arbor: George Wahr, 1899) pp. 15-531.
43. Novy, “The Spirit of Research in Medicine,” (n. 38) pp. 1-20.
44. "Meeting of the faculty, October 19," University of Michigan Medical School, Records, 1850-2002, Box 127 and 128 (Ann Arbor: Bentley Historical Library, University of Michigan, 1895).
45. Ibid.
46. "Meeting of the faculty, July 15," University of Michigan Medical School, Records, 1850–2002, Box 127 and 128 (Ann Arbor: Bentley Historical Library, University of Michigan, 1897).

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48. Ludmerer, *Learning to Heal*. (n. 39) pp. 1-64.
49. Novy, “The Spirit of Research in Medicine,” (n. 38) pp.1-20.
50. Novy, Frederick G., “Preface,” *Laboratory work in Bacteriology* (Ann Arbor: George Wahr, 1899) pp. 2-5.
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52. Ibid., p.7.
53. Novy, “The Spirit of Research in Medicine,” *Physician and Surgeon* (n. 38) p.14.
54. Ibid., p. 9.
55. Ibid., p. 9.
56. Ibid., p. 9-11.
57. Dewey, John, *Democracy and Education* (New York, Macmillan, 1916).
58. Novy, Frederick G., “Doctor Vaughan’s Influence in Medical Education,” *Journal of Laboratory and Clinical Medicine* 15 (1930): 7-9.
59. Novy, “The Spirit of Research in Medicine,” (n. 38).
60. Ibid., p. 19.
61. Ibid., p. 20.
62. Ibid., p. 14.
63. Ibid., p. 9.
64. Hannaway, Owen, “The German Model of Chemical Education in America: Ira Resen at Johns Hopkins (1876-1913),” *Ambix* 23 (1976): 145-164.
65. Owens, Larry, “Pure Sound Government: Laboratories, Playing Fields, and Gymnasia in Ninteenth-Century Search for Order,” *Isis* 76 (1985): 182-94.
66. Rowland, H.A., “A Plea for Pure Science,” *Science* 2 (August 24 1883): 242-250.
67. Owens, “Pure Sound Government: Laboratories, Playing Fields, and Gymnasia in Ninteenth-Century Search for Order,” (n. 65) p. 12.
68. Ibid., p. 2.
69. Ibid., p. 6.
70. Ibid., p. 10.
71. Ibid., p. 11.
72. See: ibid., p. 12. Novy provided Paracelsus as an example of someone who doubted, but replaced Galenism with his own dogma, because he lacked the scientific method. Paracelsus, according to Novy, was an alchemist who objected to Galen’s theory of humors and in their place substituted three chemicals, salt, sulphur, and mercury as volatile constituents of the body.
73. Novy, F.G., "Fifty Years' Progress in Medical Education " *A Half century of Nu Sigma Nu, 1882-1932*, eds. Will Walter and Stuart Graves (Louisville, Ky.: The Nu Sigma Nu Fraternity, 1935) pp. 1676-1677.
74. Holmes, Oliver Wendell, “Currents and Counter-Currents in Medical Science,” *Medical Essays: 1842-1882* (Boston and New York: Houghton Mifflin Co, 1895) pp.180, 203.

75. Novy, "Fifty Years' Progress in Medical Education " (n. 73) p. 1677.
76. Ibid., p. 1673.
77. See: “How Dr. Novy Destroys the Microbes of Infectious Diseases with a New Germicide Based on the Chemical Principles of Gold and Sunlight,” *Ann Arbor News* (January 19, 1902). The article, says Novy has been experimenting with a new germicide wherin benzoyl acetate peroxide can produce marvelous germicidal properties…it could be used as a mouth or colon cleanser to rid the intestine of harmful or ‘ravenous’ bacteria. But Novy, interviewed by the writer, “who had no comment about any potential application of his work.” In his published article (Frederick G, Novy, “On the Formation, Decomposition and Germacidal Action of Benzoyl Acetyl and Diacetyl Peroxides,” *Am Chemical Journal* 27 (1902): 161-192.), he is silent about any possible practical application of his work. He simply demonstrated the germicidal activity of benzoic acid, and benzoyl acetyl peroxide on organisms (184) including Bacillus, cholera, and Streptococcus.
78. Ibid., p. 10.
79. Ibid., p. 14.
80. Novy, Frederick G., “Doctor Vaughan’s Influence in Medical Education,” *Journal of Laboratory and Clinical Medicine* 15 (1930) p. 1685.
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83. Novy, F.G., "Notes on medical education and medical institutions in Michigan," *Annals of Internal Medicine* (January 9, 1936): 1025-1042.
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85. Ibid., pp.10-12.
86. Ibid., p.11.
87. Ibid., p.12.
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90. Ibid.
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94. Ibid., pp.79-144.
95. Novy, "Fifty Years' Progress in Medical Education " (n. 4) pp. 1669–1685.
96. Novy, F.G., "Laboratory methods in bacteriology (Six papers.) I. Examination of bacteria.," *Journal of Applied Microscopy* 1 (1898): 157-160.
97. Ibid., pp. 157-160.
98. Bonner, T. N., *Becoming a Physician: Medical Education in Britain, France, Germany, and the United States, 1750-1945* (New York: Oxford University Press, 1995).
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244.
100. Novy, F.G., "Notes on medical education and medical institutions in Michigan," (n. 83) pp. 1025-1042.
101. Ibid, pp. 1025–1042.
102. Novy, "Fifty Years' Progress in Medical Education " (n. 4) pp. 1669–1685; Novy, "Notes on medical education and medical institutions in Michigan," (n. 100) pp. 1025-1042.
103. Shaw, Wilfred B., *The University of Michigan, an Encyclopedic Survey, Part V, The Medical School, the University Hospital, the Law School, 1850–1940* (Ann Arbor: University of Michigan Press, 1951) pp. 773–808, 821–827.
104. Ibid., p. 1007.
105. Ibid., p. 1004.
106. Ibid., p. 1009.
107. Kobayashi, Victor N., "From 'Germ Theory' to Bacteriology: A case in academic freedom at the University of Michigan," 1962 (Ann Arbor: Bentley Historical Library, University of Michigan).
108. See: "June meeting, 1895," Board of Regents of the University of Michigan, Proceedings, p. 402 (Ann Arbor: Bentley Historical Library, University of Michigan). Reducing expenses was desirable for the medical school because funding for the homeopathic school was always strained.
109. Vaughan, Victor, *A Doctor's Memories* (Indianapolis The Bobbs-Merrill Company, 1926).
110. "June meeting, 1895," (n. 108).
111. Ibid.
112. Kobayashi, "From 'Germ Theory' to Bacteriology: A case in academic freedom at the University of Michigan," (n. 107).
113. Lewis, Sinclair, *Arrowsmith* (New York: Signet, 1925) p.18.
114. Ibid., p. 24.
115. Ibid., p. 29.
116. Ibid., p. 32.
117. Ibid., p. 40.
118. Ibid., p. 51.
119. Ibid., p. 111.
120. Ibid., p. 113.

Chapter 5

1. See: David Sugar to Frederick Novy, 22 November, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). David Sugar wrote this passage to Novy in a letter addressed to Novy in 1929. Sugar expressed similar sentiments in an article he later published entitled, "Novy: Our Teacher," *Detroit Medical News* xxvi (1937) p. 8.
2. Lewis C. Knapp to Frederick Novy, 28 September, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
3. Thomas Cooley to Frederick Novy, 15 October, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
4. Pernick, Martin S., *The Black Stork* (Oxford: Oxford University Press, 1996).

5. Charles George to Frederick Novy, 14 November, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
6. Dodson, John, "Doctor Novy in Medical Education," 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
7. Fred Taylor to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
8. Earl McKinley to Frederick Novy, 26 June, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
9. George Herrmann to Frederick Novy, 31 October, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
10. See: Rosenberg, Charles, *No Other Gods* (Baltimore: Johns Hopkins University Press, 1976) pp. 1-209. On page 209, Rosenberg discusses how a scientist's conception of his task, and the enthusiasm in which he carried it out, was shaped by their education by individual leaders within a particular discipline.
11. Justin Hill to Frederick Novy, 26 June, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
12. See: Charles Behrens to Frederick Novy, 29 November, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Charles Behrens became professor of microbiology at Purdue University.
13. Benjamin. T. Terry to Frederick Novy, 15 February, 1913, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Ward J. MacNeal to Frederick Novy, 12 July, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
14. In his letters to Novy, de Kruif acknowledged that Novy encouraged de Kruif to explore ideas of his own regarding immunity to trypanosomes, and then provided the lattitude for him to do so in a laboratory setting. See: Paul de Kruif to Frederick Novy, 17 April, 1917, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: Paul de Kruif to Frederick Novy, 21 October, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
15. MacNeal "Frederick Novy" (n. 13); George Hermann, "Frederick Novy" (n. 9); de Kruif, "Frederick Novy" (n. 14).
16. de Kruif, Paul, *The Sweeping Wind* (New York, Harcort Brace, 1962) p.83.
17. Ibid., p. 85.
18. Lewis, Sinclair, *Arrowsmith* (New York: Signet, 1925) p.111.
19. Ibid., p. 314.
20. Cotkin, George, Chapter 1 "The Tangled Bank of Evolution and Religion" *Reluctant modernism: American thought and culture, 1880-1900* (New York & Toronto: Twayne Publishers, Maxwell Macmillan Canada & Maxwell Macmillan International, 1992).
21. A. C. Furstenberg to Frederick Novy, December 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
22. de Kruif, "Frederick Novy" (n. 14).
23. Benjamin T. Terry to Frederick Novy, 28 February, 1918, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
24. Campbell Bonner to Frederick Novy, 24 August, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

25. See: W. C. Hoad to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Hoad also said,"You have exemplified the highest ideals and quest towards the ideal of truth of the scientific life, spirit and methods and your influence and contributions have added conspicuously to the glory of American science and medicine."
26. T. J. Mackie to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
27. George Herrmann to Frederick Novy, 31 October, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
28. de Kruif, "Frederick Novy" (n. 14).
29. L. R. Jones to Frederick Novy, 27 June, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
30. Lewis, *Arrowsmith* (n. 18).
31. Ibid., p. 278.
32. Ibid., p. 280.
33. Ibid., p. 120.
34. Ibid., p. 119.
35. Ibid., p. 123.
36. Ibid., p. 114.
37. Ibid., p. 24.
38. Ibid., p. 126.
39. Pernick, *The Black Stork* (n. 4) pp. 98-99.
40. Hollinger, David, "Inquiry and Uplift: Late Nineteenth Century American Academics and the Moral Efficacy of Scientific Practice," *The Authority of Experts* ed. Thomas Haskell (Bloomington: Indiana Press, 1984) pp.142-156.
41. Warthin, Adrid S., *Proceedings of the National Conference on Race Betterment* (1928).
42. Pernick, *The Black Stork*, (n. 4) p. 98.
43. See: Ivan Hall to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Hall claimed that he was one of Novy's hero worshipers.
44. Henry Bates to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
45. See: Winslow, C.E.A., "Some leaders and landmarks in the history of microbiology," *Journal of Bacteriology* 2 (1950): 99-114. Winslow noted that to Novy, the students ascribed attributes of perfection.
46. Several students noted Novy's impatients at intolerance of careless mistakes. See: Henry Sewell to Frederick Novy, 9 July, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: W. D. Frost to Frederick Novy, 11 November, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: D. M. Cowie to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: Harlow Brooke to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
47. Students commented on Novy's insistence on repeating experiments prior to publishing in order to duplicate results, and to credit earlier authors with ideas from

which experimental premises were derived. See: James Reeves to Frederick Novy, undated 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: Ivan Hall to Frederick Novy, 13 October, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

48. Students mentioned his strict demeanor, and how he impressed his assistants with the high standards that he set for the validity of scientific data. See: M. Gomberg to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

49. de Kruif, *The Sweeping Wind* (n. 16) p.39.

50. Lewis, *Arrowsmith* (n. 18) p.123.

51. Ibid., p.8.

52. Several of the students remarked on how Novy used humor to ease the harshness of his criticisms. See: John F. Norton to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); See also: Max S. Marshall to Frederick Novy, 24 October, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

53. Nungester, W.J., "Frederick George Novy 1864–1957," *Journal of Bacteriology* 74 (1957): 545-547.

54. Some described how Novy's wit would be preceded by a bright twinkle in his eye and a good natured smile. See: R. G. Leland to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Good, Ruth, "Dr. Frederick G. Novy: biographic sketch," *University of Michigan Medical Bulletin* XVI (1950): 257-268.

55. Furstenburg, A.C. and W. J. Nungester, "Doctor Federick George Novy," *The Pharos* (1958): 31-35.

56. Many students remarked on the fact that Novy was so consumed with work that he lacked time for outside interests. See: Mackie, "Frederick Novy" (n. 26). Others noted he took an interest in military matters and geography, and he was a member of the local militia at one time. See also: G. McCoy to Frederick Novy, 16 June, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Others noted his interest in a graduate member of Nu Sigma Nu medical fraternity and how he was instrumental in the building of its local house. See: Reuben Peterson to Frederick Novy, undated, 1929, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

57. George Dock, head of Medicine at Michigan in the 1890s, paid tribute to the personal sacrifice of Mrs. Novy as a factor in her husband's success, saying that she never complained or put any obstacle in the way of his work. See: George Dock to Frederick Novy, 7 November, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); see also: personal interview with Dorothy Wilson Novy, granddaughter of F.G.Novy, December 18, 2008.

58. Students commented on his distinctive posturing motions and recognizable hand gesticulations. See: Dodson, "Doctor Novy in Medical Education," (n. 6); See also: Behrens, "Frederick Novy" (n. 12).

59. Justin Hall, a former student, remarked on Novy's distinct body language while delivering his lectures. See: Justin Hall to Frederick Novy, 21 September, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).

60. J. Rosenau to Frederick Novy, 28 August, 1915, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
61. Frederick Novy to J. Rosenau, 8 September 1915, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
62. See: “University professors, their eccentricities and their everyday life," *Michigan Daily* (October 18, 1898). The article said, “His habits were mild; he was a moderate eater, occasionally drank a glass of beer, and frequently smoked cigarettes or a briar pipe, or, sometimes a cigar. He did much walking. His mannerisms were many and unique and served as a favorite theme for imitation by the students. One of his assistants said that when he was angry, he would close his eyes and clench his teeth, and the top of his scalp would become red. The assistant then knew enough to stay out of his way”
63. See: Baker, Ray, "The Diagonal Walk," *The Ann Arbor Daily* (July 19, 1928) p. 3.The paper said, “Novy doesn’t like to talk about himself. He has a way of peering up at you from under half lowered eyelids and weighing your questions, and declining to answer, with an easy grace but with emphatic finality. ”
64. Ibid.
65. "Germ hunters in U. of M. professors and students who handle death in dreaded form," *Michigan Daily* (June 15, 1901).
66. See: ibid. The writer also wrote in the article, “It is unfortunate that people of this state do not come here oftener and become acquainted with one of the most magnificent institutions of learning in the world.”

Chapter 6

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2. Millerson, Geoffrey, *The Qualifying Associations* (London: Routledge, 1964).
3. Freidson, Eliot, *Professional Dominance* (Chicago: Aldine, 1970).
4. Berlant, Jeffrey, *Profession and Monopoly* (Berkeley: University of California Press, 1975).
5. Larson, Magali, *The Rise of Professionalism* (Berkeley: University of California Press, 1977).
6. Bledstein, Buton, *The Culture of Professionalism* (New York, Norton, 1976).
7. Ibid.
8. Ibid.
9. Ibid.
10. Starr, Paul, *The Social Transformation of American Medicine* (U.S.A.: Perseus, 1982) pp. 220-226.
11. Abbott, Andrew, *The System of Professions* (Chicago, University of Chicago Press, 1988) pp. 1-142.
12. Kimball, Bruce, *The Professional Ideal in America: A History* (Blackwell Publishers, 1992).
13. Haber, Samuel, *The Quest for Authority and Honor in American Professions, 1750-1900* (Chicago: Chicago University Press, 1991).
14. Parsons, Talcott, *Essays in Sociological Theory* (New York: Free Press, 1954) pp. 34-49.

15. Cohen, Barnett, "Comments on the relation of Dr. Welch to the rise of microbiology in America," *Bulletin of the History Medicine* 24 (1950).
16. Cohen, Barnett, *Chronicles of the Society of American Bacteriologists 1899-1950* (Baltimore: Waverly Press, 1950) pp. 17-20.
17. Ibid.
18. Cohen, Barnett "Comments on the relation of Dr. Welch to the rise of microbiology in America," (n. 15).
19. Clark, Paul F., "A half century of presidential addresses of the society of American bacteriologists," *Bacteriol Rv.* 17 (1953) p. 215.
20. Sedgwick's speech to the members of the Society of American Bacteriologists that evening was published in the journal *Science* in 1901. See: Sedgwick, William T., "The origin, scope and significance of bacteriology," *Science* 13 (1901): 121-128.
21. Ibid., p. 124.
22. Ibid., pp. 121-128.
23. Ibid., p. 127.
24. Pasteur, Louis, "Mémoire sur les corpuscles organisés qui existent dans l'atmosphère. Examen de la doctrine des générations spotanées," *Annales des Sciences Naturalles 4th series* 16 (1861): 5-98.
25. See: ibid., p. 141.Sedgwick argued that bacteria led to an improved understanding of the following natural events in nature: "bread making, brewing, vinegar-making, the fermentations of milk and its products, butter making, cheese making, lactic acid manufacture, tanning, and nitrification."
26. Ibid., p. 144.
27. Ibid., p. 145.
28. Rettger, Leo F., "The science of bacteriology and its relation to other sciences," *Journal of Bacteriology* 3 (1918): 104, 114.
29. Clark, Paul F., "A half century of presidential addresses of the society of American bacteriologists," (n. 19) pp. 211-223.
30. Winslow, C.E.A., "The characterization and classification of bacterial types," *Science* 39 (1914): 77-91.
31. Sedgwick, "The origin, scope and significance of bacteriology," (n. 20) pp. 121-128.
32. Brown, J. Howard, "The biological approach to bacteriology," *Journal of Bacteriology* 23 (1932) p. 7.
33. Ibid., p. 11.
34. Pasteur and Spallanzani grew organisms in liquid broth and postulated that a bacterial organism could generate successive progeny. See: Pasteur, Louis, "Mémoire sur la fermentation appelée lactique. (Extrait par l'auteur). ," *Comptes rendus de l'Académie des sciences* 45 (1857): 913-916; see also: Spallanzani, Lazzaro, "Tracts on the nature of animals and vegetables; observations and experiments upon the animalcula of infusions," *Milestones in Microbiology, 1546 to 1940* ed. Thomas D. Brock (Madison: University of Wisconsin, Madison, 1799) pp. 13–16.
35. Pasteur, "Mémoire sur les corpuscles organisés qui existent dans l'atmosphère. Examen de la doctrine des générations spotanées," (n. 24).
36. Schwann, Theodore, "Vorläufige Mitteheilung, betreffend Versuche über die Weingährung und Fäulnis," *Annalen der Physik und Chemie* 41 (1837): 184-193.

37. See: Brown, “The biological approach to bacteriology,” (n. 32) p. 13. Brown claimed that the industrial revolution brought on by biology can be compared to that wrought by the use of electricity. Even Pasteur cared little about the relation of bacteria to each other but was intensely interested in their activities so far as they affected human welfare.
38. Ibid., p.11.
39. Rettger, Leo F., "The science of bacteriology and its relation to other sciences," *Journal of Bacteriology* 3 (1918): 103-113.
40. Winslow, C.E.A., "The characterization and classification of bacterial types," *Science* 39 (1914) p. 106.
41. Clark, W. Mansfield, “Evolution Toward a Mature Scientific Literature.” *Journal of Bacteriology* XXVII (1933): 1-18.
42. See: Clark, "A half century of presidential addresses of the society of American bacteriologists," (n. 29) pp. 213-247. Clark lists the titles of four of the first 10 presidents were chairs of newly created bacteriology departments at their respective institutions. Harry Russell, who gave the 1908 lecture, was professor of bacteriology at the Alumni Research Foundation at the University of Wisconsin; Joseph Kinyoun, who gave the 1909 lecture, was professor of bacteriology at Georgetown University, and Frederick Gorhan, who delivered the 1914 lecture, was professor of bacteriology at Brown University.
43. Brown, "The biological approach to bacteriology," (n. 32).
44. During the bi-weekly faculty meetings that were held in the laboratory of hygiene in the late afternoon, a group of 6-12 faculty members would meet and discuss issues of student promotion and faculty promotions. On a meeting held September 7, 1902 at the Hygienic Lab, Vaughan made a motion that Novy be promoted from Junior professor of hygiene and physiological chemistry to Professor of Bacteriology. The bacteriology department was started at the medical school in 1902. See: "Meeting of the faculty, September 7, 1902," University of Michigan Medical School, Records, 1850-2002 (Ann Arbor: Bentley Historical Library, University of Michigan 1890).
45. The theme of progressive narrative and countering the objections of anti-vivasectionists is evident in several of Novy’s works. See: Novy, F.G., "Germs, what they are and how they produce disease," *Teachers' Sanitary Bulletin* 1 (1898) : 1-7; Novy, F.G., "The spirit of research in medicine," *Physican and Surgeon* 24 (1902): 385-405.
46. Novy, F.G., "Bacterial toxins and anti-toxins," *The Medical and Surgical Reporter* LXXIV; 12 (1896): 351-359.
47. The theme of laboratory medicine as a means of advancing medicine is evident in many of Novy’s writings. For example, after the hygienic laboratory was constructed, he acknowledged its value in scientific research again in 1900. See: Novy, F.G., "The Hygienic Laboratory," *The Michigan Alumnus* 6 (1900): 242-244. In other lectures, he stresses the importance of leaving “old school” teaching behind, of demonstrating skepticism of received wisdom, and empiric testing of hypotheses “in laboratories” to search for truth to “correct mistakes of the past and to advance medicine. See: Novy, "The spirit of research in medicine," (n. 45) pp. 385-405.
48. Novy, F.G., "Practical Benefits of Bacteriology," *First Report of the Michigan Academy of Science* ed. Walter B. Barrows (Lansing: Robert Smith Printing Co., 1894) p. 79.

49. Ibid., p. 87.
50. Novy, "The spirit of research in medicine," (n. 45) pp. 385-405.
51. Ibid., p. 388.

Chapter 7
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4. Rosenberg, Charles, "Science, Technology, and Economic Growth: The Case of the Agricultural Experiment Station Scientist," in Rosenberg ed. *No Other Gods: On Science and American Social Thought* (Baltimore: The John Hopkins Press, 1976) pp. 153-172.
5. Novy, F. G., "Practical Benefits of Bacteriology," in *First Report of the Michigan Academy of Science* ed. Walter B. Barrows (Lansing: Robert Smith Printing Co., 1894) p. 79.
6. Ibid.
7. Novy, F. G. "Bacterial toxins and anti-toxins," *The Medical and Surgical Reporter* LXXIV; 12 (March 21, 1896): 351-359;
8. Long, Esmond R., "Frederick G. Novy and some origins of American bacteriology," *Transactions and studies of the College of Physicians of Philadelphia* 26 (1958): 34-39; Long, Esmond R., *Frederick George Novy, 1864-1957* (Washington, D.C.: National Academy of Sciences, 1959).
9. Katz, Frank F., "The Rockefeller Institute for Medical Research and a change in the State of New Jersey's animal experimentation laws in 1915," (Newark: Medical History Society of New Jersey, 2008).
10. *Who's Who in America: A Biographical Dictionary of Notable Living Men and Women of the United States* (Chicago: A. N. Marquis and company, 1903-1905) pp. 120, 689, 719, 1201, 1578.
11. See: Katz, "The Rockefeller Institute for Medical Research and a change in the State of New Jersey's animal experimentation laws in 1915," (n. 9) pp. 7-9. Rockefeller letter dated April 29, 1901.
12. Ibid., pp.12-15.
13. Ibid., p.16.
14. Ibid., pp.17-21.
15. See: "Rockefeller Institute for Medical Research," *The British Medical Journal* 1 (1912): 560-561. In January of 1907, a farm of 100 acres with buildings was acquired in Clyde, New Jersey as a place for the breeding and care of laboratory animals.
16. Ibid., pp. 560-561.
17. Simon Flexner to Frederick Novy, undated, 1929, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
18. Ibid.
19. "August meeting, 1901," Board of Regents of the University of Michigan, Proceedings (Ann Arbor: Bentley Historical Library, University of Michigan, 1901).

20. Frederick Novy to Simon Flexner, 23 May, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
21. Ibid.
22. Ibid.
23. Frederick Novy to Emmett Holt, 30 March, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Frederick Novy to Emmett Holt, 28 June, 1909, Box, 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Frederick Novy to Emmett Holt, 14 January, 1912, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
24. See: William Welch to Victor Vaughan, 14 May, 1901, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). This was a confidential note, before a public announcement of the new Institute had been made.
25. Ibid.
26. See ibid. Welch invited Novy to apply, to see if he had "any investigation for which he needed an appropriation such as I describe." Welch wanted to have a statement about the "nature of the proposed study, what amount of money will be needed to conduct it satisfactorily, and how he would propose to expend the money."
27. Frederick Novy to Emmett Holt, 13 September, 1901, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
28. Emmett Holt to Frederick Novy, 16 June, 1902, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
29. Novy, "Emmett Holt" (n. 23).
30. Frederick Novy to Emmett Holt, 8 April, 1903, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan); Novy, "Emmett Holt" (n. 18); Novy, "Emmett Holt" (June 28, 1909). (n. 23).
31. Frederick Novy to William Welch, undated, 1903, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
32. Novy, "Emmett Holt," (n. 30).
33. Novy, "William Welch" (n. 31).
34. Simon Flexner to Frederick Novy, 27 May, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
35. Novy, "Simon Flexner"(n. 20).
36. Ibid.
37. Flexner, "Frederick Novy" (n. 34).
38. Ibid.
39. Ibid.
40. Simon Flexner to Frederick Novy, 7 June, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
41. Simon Flexner to Frederick Novy, 23 June, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
42. Frederick Novy to Simon Flexner, 3 July, 1907, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
43. Ibid.
44. Welch, "Victor Vaughan" (n. 24).

45. Emmett Holt to Frederick Novy, 3 August, 1912, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
46. Ibid.
47. Frederick Novy to Rockefeller board, 1 June, 1912, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
48. Simon Flexner to Frederick Novy, 13 January, 1913, Box 2, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
49. Robert Gait to Frederick Novy, 18 February, 1909, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
50. Frederick Novy to Robert Gait, 21 February, 1909, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
51. Ibid.
52. de Kruif, Paul, "Laboratory Notebook 32," January 14, 1918, Box 7, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
53. See: Paul de Kruif to Frederick Novy, undated, 1918, Box 2, pp. 1-3, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan). Two other workers also left Novy's lab to serve in the military, Levin and Eggerth.
54. de Kruif, Paul, "Dear Doctor Novy," in Frederick G. Novy Papers, Call No. 852257 Aa/2 UAm (Ann Arbor: Bentley Historical Library, University of Michigan, Box 2, April 17, 1917).
55. de Kruif, Paul, *The Sweeping Wind* (New York, Harcort Brace, 1962) p. 8.
56. Lewis, Sinclair *Arrowsmith* (New York: Signet, 1925) p. 325.
57. Ibid., p. 314.
58. Ibid., p. 321.
59. Ibid., p. 322.
60. Ibid., p. 323.
61. Ibid., p. 316.
62. Ibid., p. 443.
63. Novy, "Notes on the department of bacteriology," (n. 1).
64. William Welch to Frederick Novy, 12 August, 1899, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
65. See: Winslow, C.E.A., "Some leaders and landmarks in the history of microbiology," *Journal of Bacteriology* 2 (1950) p. 102. Winslow said Novy's work was original and basic in the field.
66. Novy, Frederick, *Curriculum vitae,* Frederick Novy Papers (Ann Arbor: Taubman Medical Library, 1887) pp. X-XII.
67. Novy, Frederick, "Miscellaneous speeches and speech notes," 1895-1901, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
68."Zina Pitcher lecture," February 22, 1908, Box 1, Frederick Novy Papers (Ann Arbor: Bentley Historical Library, University of Michigan).
69.See: Novy, Frederick G., "Some Results of Microscopical research which have been Significant for Human Welfare," *Science* 84 (1936): 124-125. Novy said, "The science of bacteriology has enabled man to unveil the mysteries of fermentation…and other connections between bacteria and the processes of nature…bacteriology has uplifted medicine and enabled man to gain mastery over his ancient enemies."
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74. Rothstein, William, *American Medical Schools and the Practice of Medicine* (Oxford: Oxford University Press 1986) pp. 1-216.
75. Rosenberg, “Science, Technology, and Economic Growth: The Case of the Agricultural Experiment Station Scientist,” (n. 4) pp. 153-172.
76. Daniels, G.H., “The Process of professionalization of American science,” *ISIS* 58 (1967): 150-166.
77. Daniels, G.H., “The pure-science ideal and democratic culture,” *Science* 156 (1967).

Conclusion

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4. Cotkin, George, *Reluctant modernism: American thought and culture, 1880-1900*, (New York & Toronto: Twayne Publishers, Maxwell Macmillan Canada & Maxwell Macmillan International, 1992) pp. xi-xvi, 148-154.
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