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Chicago Scientists Who Promoted Bacteriology in the Early 1880's

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ABSTRACT

As more is learned about bacteriology's early days, America's importance becomes more apparent. The first American bacteriology course was taught earlier than many have thought (1883, not 1885) and its locale was Chicago, not the eastern seaboard. Henry Gradle, M.D., not only taught the first bacteriology course in America at Chicago Medical College but his course preceded the one Robert Koch created in Berlin. The earliest original general bacteriology book in English was written by a Chicagoan, William T. Belfield, M.D., and published there in 1883. Subsequently Greene V. Black, M.D., D.D.S., produced the first book in English on ptomaines or bacterial toxins (1884). The three men earned degrees from Chicago medical colleges, practiced their professions and taught in Chicago while promoting acceptance of bacteriology. The Chicago milieu, supplemented by postgraduate study in Europe for Belfield and Gradle, prepared the scientists to respond quickly and positively to bacteriology, a lifesaving discovery of the nineteenth century.

THREE INNOVATIVE PHYSICIANS

Chicago's contributions to late nineteenth century bacteriology have been underestimated. The idea that the new science first reached America's east coast and then progressed westward is mistaken. Instead, physicians and publishers in Chicago led opinion in the English-speaking world to value bacteriology in the early 1880's.

Three physicians having medical degrees from Chicago colleges promoted bacteriology in their lectures and writings. William T. Belfield, Henry Gradle and Greene V. Black tried to reverse national, regional and local resistance, the first rooted in "a vicious national training" grounded in a double standard: "It seems almost impossible for an original investigator in America to get a hearing, while any statement from the other side [of the Atlantic] at once finds readers, and generally an appreciative audience" (*Dental Cosmos* 1884). The three men also helped overcome a tendency by Easterners to neglect or disdain ideas emanating from west of the Appalachians. A reviewer of Gradle's Bacteria and the Germ Theory of Disease said its value "must be local", mistakenly dismissed it as neither new nor original and asserted it was merely one of many such books (*Boston*

Medical and Surgical Journal Apr. 3, 1884). Gradle, Belfield and Black consolidated the work of American pioneers in bacteriology such as Thomas J. Burrill of Illinois Industrial University, the first American to discover a bacterial pathogen (1877), and George M. Sternberg, M.D., whose 1880 translation of Les bactéries is the first general bacteriology book in English (Magnin 1880). Belfield published the first original general bacteriology book in English, On the Relations of Micro-organisms to Disease, in 1883. He also urged that bacteriology be recognized as a specialty and tried to raise money for research to support the discipline's autonomy (Flaumenhaft and Flaumenhaft 1991). Gradle helped institutionalize the subject by teaching the first bacteriology course in an American medical school. Black encouraged acceptance of the germ theory of disease in America by appealing to the general public. Gradle, Belfield and Black worked energetically as teachers, specialists and publicists.

Henry Gradle (1855-1911) was born in Germany and studied there until 1869 when he joined his father, a merchant, in Chicago. He graduated from Chicago Medical College in 1874, interned at Chicago's Mercy Hospital, and studied in Europe. At some time he visited Berlin, Heidelberg, Leipzig, Vienna and Paris, and may have studied with Koch. By 1883 Gradle was professor of physiology, Chicago Medical College; taught at the Chicago College of Pharmacy; practiced ophthalmology and otology in Chicago; and served as oculist, Michael Reese Hospital. He regularly surveyed medical literature to gather information. Gradle also edited summaries of foreign literature and probably contributed translations to the *Chicago Medical Journal and Examiner* as early as 1878. He published his first book, Bacteria and the Germ Theory of Disease, in 1883. About sixty percent of his book covers specific pathogens; the rest is about germ theory, classification, culture and examination of bacteria, and germs in healthy tissues. He concludes confidently: "No matter, whether further research will show, that many more, or--be it few other contagious diseases, are due to the agency of bacteria, the proof *is* absolute, that the invasion by these micro-organisms is the cause of anthrax, chicken cholera, the various forms of septicaemia in animals, tuberculosis, glanders, some forms of suppurative inflammation, malignant oedema, erysipelas, gonorrhoea and trachoma" (Gradle 1883). Besides lecturing to students and encouraging other physicians in their research, Gradle discussed bacteriology at popular and professional societies in Chicago, contributed to *Popular Science Monthly* and to a Chicago medical periodical, and worked on state projects. Two Illinois state reports, one by Nathan S. Davis (1883) and the other by Gradle (1884), publicized the germ theory and its Chicago proponents.

Gradle's 1883 bacteriology course at Chicago Medical College preceded the one Robert Koch introduced in 1885 in Berlin. Gradle's course was the first such course in the United States associated with a medical school and spawned other courses. Earlier historians erroneously awarded priority to instructors in New York City, Boston or Philadelphia teaching later in the 1880's (Bergey 1917; Hastings and Morrey 1918; Gorham 1921; Beecher and Altschule 1977; Warner 1986; McFarland 1937; Davis 1927; Clark 1961). By 1888 Chicago Medical College was one of twelve American medical schools offering bacteriology and it supported "a well-equipped bacteriology laboratory" (Conn 1888). T. Yabe, a Japanese naval surgeon, translated Bacteria and the Germ Theory of Disease in 1887, perhaps because of Gradle's familiarity with research in Germany, Japan's scientific model (Gradle 1887).

The Chicago Medical College, where Gradle lectured on bacteria, was noted for its high standards, in part because it pioneered the graded medical curriculum and entrance

examinations (Ingals, 1883; Bonner 1957; Kaufman 1976). However, Gradle's tenure may have been difficult because a founder of the college, Nathan S. Davis, M.D., was skeptical of the germ theory. Davis, editor of the *Journal of the American Medical Association* (JAMA), taught the principles and practice of medicine at the college. His published lectures show that even when "nearly all our recent writers" were assuming "an organic germ of a specific character" caused typhoid, Davis was not persuaded. He cautioned his students that the much talked of typhoid germ existed only in the human imagination. Davis described "bacteria, micrococci, etc." as "accompaniments" of diseases such as diphtheria and tuberculosis. Some investigators confirmed Koch's belief in *Bacillus tuberculosis* as an etiologic agent, whereas others denied and modified it. Such contradictory statements disturbed Davis, as did lack of confirmation of results and lack of "direct or positive" microscopic or chemical evidence (Davis 1886 [c1884]). In his journal in 1884 Davis counseled "conservatism" defined as accepting bacteria as etiologic agents of a disease only after careful, repeated inoculation trials by different persons produced trustworthy results. Although Davis was not as ready to ground etiology and therapeutics in experimental science as was the younger generation, editorial responsibilities modulated his personal preferences. Before a state and a national audience Davis publicized Koch's work on the etiology of tuberculosis and cited Gradle and Belfield as refuting critics of Koch (Davis Oct. 13, 1883). Davis opened JAMA to bacteriological subjects such as letters from Europe and Black's papers. The letters describe, for example, the new "aga aga" culture medium and Koch's new laboratory complete with picture and the news of his new bacteriology course (JAMA Feb. 14, 1885; JAMA Aug. 15, 1885).

William T. Belfield (1856-1929) was born in St. Louis, Missouri. He attended public school in Chicago, studied science at the University of Michigan, 1872-73, and taught at Chicago's Central High School. He earned his M.D. at Rush Medical College, Chicago, 1877, and did postdoctoral work in London and on the Continent. Young Belfield's reputation was probably made when he reported from Vienna Koch's discovery of the tubercle bacillus (Belfield 1882). Belfield had contributed articles to the *Chicago Medical Journal and Examiner* before he went to Europe for postdoctoral study and acted as the journal's medical correspondant while abroad. He was teaching at Rush Medical College when the alumni association of the College of Physicians and Surgeons, New York City, invited Belfield to deliver the Cartwright Lectures in February 1883. The topic requested by the association, the relations of microorganisms to disease, echoes the title of a Joseph Lister paper. Remarkable publicity surrounded Belfield's Cartwright Lectures and their printed versions. The *Chicago Medical Journal and Examiner* announced his Cartwright Lectures in advance and arranged for Gradle to review Belfield's book, On the Relations of Micro-organisms to Disease, when it was published in Chicago and New York.

In his first Cartwright Lecture Belfield said that bacteriology verged on being an independent discipline. His four talks treated principles of identifying bacteria; sepsis and antiseptic surgery; specific organisms, accompanied by lantern slides; and immunology. Belfield also attended medical and pathological society meetings in New York City before returning to a rousing reception at the Chicago Medical Society on April 16, 1883, a meeting which attracted the highest attendance in several years. Before an audience of around one hundred members and guests from Illinois, Iowa, and Kansas, Belfield commented on thirty-one lantern slides of photomicrographs, twenty-four of which had illustrated his Cartwright Lectures (*Chicago Medical Journal and Examiner* June 1883).

Next he joined the American Medical Association circuit in Chicago and attended several of its national meetings as a Chicago delegate. In one instance Belfield's talk on the germ theory was praised by Dr. Austin Flint Sr., and Dr. Austin Flint Jr. assisted in the discussion. Another audience awaited Belfield when he spoke at a commencement of the Chicago College of Dental Surgery, where he taught microscopy and surgery as a colleague of Black.

Belfield championed bacteriology as a discipline. He argued that identifying bacteria was a "more serious undertaking" than the literature in English implied. He asserted that experienced physicians, even pathologists, failed "to appreciate the first principles of mycological investigation." Therefore bacteriology could not remain the province of ordinary dermatologists, surgeons and pathologists. The "special methods and manipulations necessary for the recognition and cultivation of bacteria" constitute what he called "a special department of investigation" requiring "special study and experience." Only concentration, "the renunciation of other pursuits," produced good results. To drive his point home Belfield exposed various errors made, among others, by "an eminent practitioner of New England" who had toured the United States instructing audiences incorrectly about the etiologies of tuberculosis and syphilis (Belfield 1883).

One reviewer commended Belfield's On the Relations of Micro-organisms to Disease to more advanced students because of his "critical and even judicial flavor" (*Science* Feb. 1, 1884). Belfield said that only a dozen men "have given abundant evidence of competence in bacterial investigations" and seemed to rank George M. Sternberg among this elite. Belfield attacked Henry F. Formad, University of Pennsylvania medical school, for the internal contradictions of his work on diphtheria and tuberculosis, and for Formad's belief that narrow lymph spaces determined susceptibility to tuberculosis. It incensed Belfield that Formad ignored the research done in Great Britain and Europe over the last fifteen years. He criticized Pasteur and Klebs for publishing "hasty and, as subsequently appeared, erroneous conclusions, [which] forfeited much of the prestige acquired by their earlier classical works on fermentation and gunshot wounds respectively." Belfield said they "have ignored successive improvements in technique; have apparently assumed that all infectious diseases are of bacterial origin; that therefore the discovery of a bacterium in a diseased animal is ample proof of its pathogenic influence." Thus Klebs had claimed to discover the etiologic agents of tuberculosis, syphilis, typhoid fever, "etc." Belfield knew that some people were seeing debris under the microscope and calling it bacteria. To verify bacteria he directed attention to their size, shape, presence or absence of motion, distinctive chemical traits detected by certain chemical reagents, and, as the "only positive proof," their "independent exhibition of reproductive power." He asserted that much of the literature available in English was frivolous because the authors exercised insufficient care. Koch was Belfield's model because Koch used "all his influence, by precept and example, to raise ... bacterial investigation from the mire of uncertainty, doubt, skepticism, and contempt to the firm basis of exact science" (Belfield 1883).

Bacteriology required money to become an independent specialty so Belfield appealed for "State or corporate assistance." If supported by laboratories and other expensive facilities, bacteriology might yield trustworthy results. In urging national support for the study of infectious diseases of cattle he wrote as a Midwesterner living in a city so dependent on stockyards, rendering and meatpacking as Chicago. Belfield said American "live-stock interests" are already greater than in France and Germany, and he estimated

that in the United States a single disease of cattle and of hogs combined could cause a loss of $50 million in a year. He marveled that the American government that had spent money on local river and harbor improvements and expensive commissions sent, for example, to observe the transit of the moon, had not yet made "one judicious, systematic, liberally supported inquiry into the possibility of acquiring protection against pleuro-pneumonia, hog-cholera, and other devourers of the national wealth." The achievements of Pasteur and other Europeans in developing immunotherapy were publicized by Belfield and Gradle. Belfield not only included actinomycosis in his book but he shocked cattlemen and meatpackers by discovering the fungal disease at the Chicago stockyards (Actinomycosis 1883-1884). Belfield's appeal for funds failed to mention the United States Department of Agriculture and its role in research. For example, he seemed unaware of studies by Henry J. Detmers, D.V.M., then in Illinois, especially his reports to the Department of Agriculture between 1879 and 1883 about diseases of swine, sheep and other domesticated animals.

Sternberg also complained about the level of American government support of science compared to the liberal aid awarded to leading investigators of "disease germs" by the German and French governments (Sternberg 1884 [c1883]). Belfield's and Sternberg's pleas were healthy signs. Reingold (1972) suggests that when scientists stop complaining their nation is probably entering a period of relative decline. Support for science laboratories seemingly always trails needs. Still, when Belfield and Sternberg criticized the level of funding in America, the percentage of the gross national product devoted to scientific research and development "was probably roughly equal to Germany's--perhaps even slightly larger" (Reingold 1972). To illustrate his injunction for careful research, Belfield presented several models from which Americans might choose. Americans were indebted to France for the "very salvation of enormous interests" with eradication of silkworm disease and preventive vaccination against anthrax and chicken cholera; to England for individual innovators like Lister and Tyndall; to Germany for its model of state-sponsored research, the Imperial Department of Health; to an Austrian entrepreneurial surgeon like Theodor Billroth; and to corporate support for research (no names mentioned). Belfield's interest in these models reflects the pluralism of institutional support that characterized American science's considerable vitality around 1880 (Kevles et al. 1980).

Speculation about mechanisms of bacterial action took Belfield, Black, and predecessors like Sternberg beyond germ theory toward substances that, said Belfield, have acquired "noxious properties through previous vital activity" of bacteria. In trying to understand how pathological conditions arise Belfield discussed septicemia at length and mentioned anthrax. He said septicemia "may be induced on the one hand by the vital action of isolated bacteria, and on the other by unorganized substances" such as the boiled septic materials proposed by P. L. Panum and J. A. Rosenberger, or the sepsin proposed by Ernst von Bergmann. Panum's work went back to the 1850's and Bergmann's to the 1860's. A reviewer of Belfield's book predicted that "The future of cellular biology seems to lie in these obscure ferments and ptomaines, affording a golden opportunity for the physiological chemist" (*Science* Feb. 1, 1884). Over time, research defined some of the substances called unorganized ferments or ptomaines as bacterial toxins and/or enzymes. For example, the problem of exactly how *Bacillus anthracis* operates remained a mystery until 1954 when its exotoxin, a poison liberated by Gram positive bacteria, was first demonstrated.

Although his title omits the word ptomaines, Black's Formation of Poisons by Micro-organisms addressed this subject which was popular in America. As early as 1882 Appleton's *Annual Cyclopaedia* began publishing news about ptomaines, describing discoveries by Italian, French and German scientists. As more European, English and American scientists investigated ptomaines, the putrefactive alkaloids, and leucomaines, the physiological alkaloids, references to them in American technical books and medical yearbooks proliferated. Black's book may be the first book in English about ptomaines. Black attributed "each infectious disease" to the poisonous metabolic products of a microorganism "capable of developing in the tissues, or blood ...." He reasoned that microorganisms produce something analagous to higher plant alkaloids and cited Koch, Klebs, Sternberg and Gradle to confirm this. Black said Koch clearly demonstrated that fluids deprived of bacteria will poison or kill, and his research on anthrax and gangrene in mice suggested a search for anthracine and for "some product" such as a poisonous alkaloid. As a host defense mechanism Black adopted the idea of phagocytosis Sternberg proposed in 1881 and covered in his 1884 book. Black envisaged a contest of cell against cell and quoted Sternberg's idea that the capture of a pathogenic organism by the white corpuscles would occur "if the captor is not *paralyzed by some potent poison evolved from it* (italics are mine)," that is, Black's.

Black listed a range of pathogens as "positively demonstrated": five bacilli (the etiologic agents of anthrax, septicemia, erysipelas, leprosy and tuberculosis), the micrococcus of pyemia, the "cocco-bacterium" of gangrene, and the spirillum of relapsing fever. He said "the mere presence of the organisms is not a sufficient cause of the diseases that experiment teaches us are induced by them ...." Although some microorganisms possibly cause disease mechanically by irritation, their "general mode of action is through their soluble ferment and the toxic properties of their waste products" of respiration and excretion. Black noted bacteria's "especial" characteristic is remoleculization whose effects range from "entirely harmless" through "production of the most deadly poisons." As a vitalist he defined remoleculization as "that disturbance or change of the molecular form of matter which occurs under the influence of the life force." Yet one example he uses, starch in the presence of saliva, suggests Black had enzymatic action in mind. In another example he said lactic acid, thought to promote tooth decay, results from remoleculization "brought about by the life force, as manifested in the form of microorganisms." Black based his germ theory of caries on research by others, including the American dentist then working in Berlin, Willoughby D. Miller. Black's sources showed that lactic acid produces decay through "fermentation or decomposition" resulting from "the activity of living organisms." Consequently, "the old acid theory [of dental caries] glides easily into the new germ theory...." (Black 1884a).

Thus Black's quest for the why and how of microbial action led him toward bacterial toxins and he forecast that poisonous alkaloids "will be isolated at no distant day." Although Black sensed the importance of toxins he was not enough of a chemist to prove his point. In 1884 Friedrich Loeffler suspected that a toxin made the diphtheria bacillus pathogenic, and in 1888 Émile Roux and Alexandre Yersin characterized that toxin. Black correlated microorganisms and ptomaines. Some "antimicrobists" exploited ptomaines in an effort to exclude microorganisms as etiologic agents and reduce them to "accompaniments" of disease. Another tactic was to blame a single substance, for example ammonia, an "organic alkali," as the sole cause of all diseases (Ziegler 1884).

Like Gradle and Belfield, Black wanted the germ theory to be widely accepted yet he worried that ordinary people could not comprehend the existing "mass of unexplained facts" based on experiment. Black knew that even though the "thought of the present time demands absolute demonstration", experimental facts supporting the germ theory "will satisfy the minds of but very few." However, he believed such facts were sufficient to support generalizations that would persuade more people to accept the germ theory of disease. Black offered nine points he had adduced as "presumptive evidence that all contagious and infectious diseases are produced by disease germs." Then he generalized by answering why (poisons) and how (remoleculization) bacteria work. Black described how "these low organisms produce disease" so that the principles of bacteriology could "find a firm basis in the minds of the masses of men" (Black 1884a).

Black's Formation of Poisons by Microorganisms was probably the "satisfactory thesis" required of M.D. candidates at Chicago Medical College. Like Belfield's and Gradle's books, Black's was based on a series of lectures. Black addressed Chicago College of Dental Surgery students and "a number of practitioners who were ticketed especially for this course" (Black 1884a). As did Belfield, Black took part in the American Medical Association circuit by addressing two different sections of the association at a single meeting. These presentations as published are brisker and more direct than their source, Formation of Poisons by Micro-organisms (Black 1884b; Black 1885). Some reviews of Black's book in professional and popular journals noted it was not based on original research. And the book was completely overlooked by Victor C. Vaughan and F. G. Novy who said their Ptomaines and Leucomaines (1888) was the "first attempt to ... embrace everything of importance on this subject." Black, himself largely self-taught, acknowledged the risk of generalizing upon the research of others. Still he attempted, none too successfully, to provide people with something more intelligible than a forest of facts. Other factors contributing to the eclipse of Black's book include his attempt to generalize about a rapidly developing field, his rather mechanical grasp of chemistry, the book's origin as a thesis, and the competition of Vaughan and Novy's study which coincided with Roux and Yersin's breakthrough.

Greene V. Black (1836-1915) rose to the top of his profession. Born near Winchester, Illinois, Black began practicing dentistry in 1857 and continued after being wounded during the Civil War. Next he invented a foot and cord driven dental drill and taught at Missouri Dental College, St. Louis (1870-1880), which conferred a D.D.S. degree upon him in 1878. Black served as first head of the Illinois State Board of Dental Examiners beginning in 1881, and in 1883 he began lecturing at the Chicago College of Dental Surgery. Black received an M.D. degree from Chicago Medical College in 1884, the same year he published Formation of Poisons by Micro-organisms, his first book. After studying, practicing and teaching dentistry in downstate Illinois, Missouri, Chicago, and Iowa, Black moved to Northwestern University's dental school in Chicago (1891) and served as its dean, 1897-1915. Black's partisans call him the "Father of Modern Dentistry," a title that appears on a statue erected in his honor in Chicago's Lincoln Park (Black 1931?; Black and Black 1940; Henderson 1961; Pappas 1983). His office equipment, including microscope, is displayed at the Smithsonian Institution. Although Belfield and Gradle studied abroad as postgraduates, it was unnecessary for Black to do the same. When Black was developing professionally, American dentists were much sought after by the European aristocracy as "superior practitioners" (*Chicago Medical Journal and Examiner* 1876). Unlike bacteriology, dentistry was a medical field in which Americans were ahead and thus highly respected abroad.

Together these three men created powerful synergy on behalf of bacteriology. Black, a student at Chicago Medical College when Gradle was teaching bacteriology there, cited Gradle's and Sternberg's books in his own. In the 1880's Black and Belfield taught at the Chicago College of Dental Surgery, and in the 1890's Black and Gradle became colleagues at Northwestern University's dental and medical schools. Early in their medical careers, Gradle and Belfield contributed to the *Chicago Medical Journal and Examiner*, and Gradle reviewed Belfield's book there. Both men helped Bayard Holmes, a homeopathic physician, learn bacteriological techniques. For example, as Holmes became an avid microscopist and experimentalist, Gradle suggested he use whiskey bottles turned on the side when Petri dishes are unavailable (Hektoen 1937). Belfield, as secretary of the Chicago Pathological Society, recorded Dr. Christian Fenger's demonstration of the bacterial nature of endocarditis for the first time in America in 1879 (Bonner 1957). Later Fenger wisely encouraged Dr. Charles W. Earle to consult Gradle for help in staining tubercle bacilli. Gradle, an Illinois State Microscopical Society trustee, had published a paper about identifying that bacillus (Gradle and Woltmann 1883). In time, Gradle and Belfield practiced medicine at the same address, 100 State Street, Chicago.

CHICAGO NURTURED PRACTICAL INNOVATION

The Chicago milieu encouraged new ideas with practical applications, such as bacteriology. If Chicago were to flourish, the enteric and other diseases so prevalent in the 1870's had to be controlled. Some residents believed Chicago's slaughterhouses and glue factories disseminated organic poisons and caused a large percentage of the mortality in the city (Ingals 1877). As Chicago's commercial and industrial base expanded, its railroad ramifications developed, and its population rose, Chicago advanced toward intellectual eminence. Trains, including the Pullman cars designed and built in Chicago since 1864-65, brought settlers, scientists, students and others from long distances swiftly and relatively comfortably. Gradle, Belfield and Black were attracted to the city, as was Walter H. Bulloch, internationally known maker of microscopes and microtomes.

Chicago was becoming a convention center even as the Chicago Medical Society first discussed the germ theory of disease. The American Medical Association, founded in Chicago, the American Public Health Association, and the Association of American Medical Authors held meetings in Chicago in 1877, and national political conventions followed. Chicago publishers started at least five new medical journals and one dental journal in the 1880's. The city supported several medical schools: the Chicago College of Dental Surgery; the Chicago College of Pharmacy; and the Illinois Training School for Nurses, founded in 1870 to service Cook County Hospital. Chicagoans boasted of its new and planned hospitals and laboratory facilities. Rising standards of medical, dental, pharmacy and nursing education in Chicago attracted so many students that enrollment in its medical schools soared to the largest in the United States in the 1880's. The city drew some of the best. For example, William Worrall Mayo, who had sent his elder son William J. to the University of Michigan, chose Chicago Medical College for his younger son Charles in 1885 because of its three year program.

The theme of Chicago as ranking among the most prominent medical centers in America gained momentum between 1884 and 1886. A large audience of graduates and guests at the March 1884 commencement of the College of Physicians and Surgeons of Chicago applauded Professor Charles W. Earle, M.D., when he spoke on the subject. Late in

1885 the *Chicago Medical Journal and Examiner* also took up the cause. Of two editorials in the American Medical Association's *Journal* on the theme, the first emphasized the initiative of Chicago physicians and the other provided statistics. Editor Nathan S. Davis wrote about a Chicago he had known since 1849. In 1885 he noted rising standards of admission and of curriculum without mentioning his struggle to establish them. Davis praised Chicago for the "number and extent" of the hospitals and dispensaries open for clinical instruction, the "number and ability" of Chicago's specialists and teachers, and the number of medical students these attracted to Chicago. He said Chicago medical schools enrolled 755 students and graduated 292 men and women annually. Then Chicago's medical register listed 557 regular physicians practicing in Chicago, up from 353 a decade earlier. Davis challenged the Easterners of New York, Boston and Philadelphia: "If Chicago does not at this day rank with the first three cities of America in respect to population and commerce, the foregoing facts show that she certainly does as a centre of medical education and scientific progress" (Davis Dec. 12, 1885; Davis Apr. 3, 1886).

Gradle specialized in ophthalmology, Belfield in genito-urinary surgery and Black in dental surgery. Beginning in 1882 polyclinics were being organized in America to offer practitioners short courses in surgery and new specialties like ophthalmology. In 1885 the American Medical Association's *Journal* reported that Chicago would soon have a polyclinic for postgraduate medical students similar to those in New York and Philadelphia and Paris and other foreign cities. The editor did not mention Belfield's involvement (Davis Dec. 12, 1885). As a founder of the Chicago Policlinic, Belfield was among the first Americans to initiate postgraduate clinical study in America. As its secretary Belfield advertised "entirely clinical" postgraduate teaching in which "didactic and formal lectures on practical branches ... [were] strictly excluded." The literature's habitual focus on East Coast scientific activities in America has left Belfield's teaching innovation in Chicago unappreciated (example: Peitzman 1980). More important, bacteriology, like clinical teaching, encourages students to participate in hands-on learning in addition to more passive forms of study. Ludmerer (1985) views the introduction of "laboratory and hospital work" as one of the major developments of American medical education in the latter part of the nineteenth century. Although Ludmerer does not dwell on bacteriology, the subject fits his thesis admirably and also illuminates the evolution of Belfield's career. Belfield belonged to the first generation of American surgeons to integrate the antiseptic principle into their work. His knowledge of bacteriology freed Belfield to become an imaginative surgeon and to create new procedures (Flaumenhaft and Flaumenhaft 1991).

Henry Gradle, William T. Belfield and Greene V. Black embodied lively scientific curiosity. These physicians encouraged positive yet critical consideration of the germ theory of disease etiology and addressed a wide audience in their effort to build popular, scientific and financial support for bacteriology as an independent discipline. This essay on innovators from Illinois extends the work of P. Allen Richmond and others who have studied different aspects of how American scientists received the germ theory of disease in the 1880's (Allen 1947; Richmond 1954; Warner 1985).

Why has the role of these Chicagoans in the genesis of bacteriology been obscured? Writers like King (1983, 1991) who minimize the Chicago context overlook the city's capacity to catalyze intellectual development. The fact that Chicago attracted and sustained dynamic scientists like Gradle, Belfield and Black demonstrates how successful

cities grow. Instead of repeating the gestation phases of older communities, Chicago advanced with its era's growth. It did what the most modern parts of older cities were doing, whereas many institutions in older communities remained captives of the fixed interests of an earlier era. In a rejuvenated Chicago, sometimes called Phoenix City after the 1871 fire, medical schools and their teachers could innovate. An English visitor described Chicago as "full of energy and enterprise" and receptive to "such science as serves its purpose" (Duffus Hardy 1881). Belfield, Gradle and Black capitalized on this situation to usher in America's golden age of public health in the early 1880's by explaining the utility of bacteriology.

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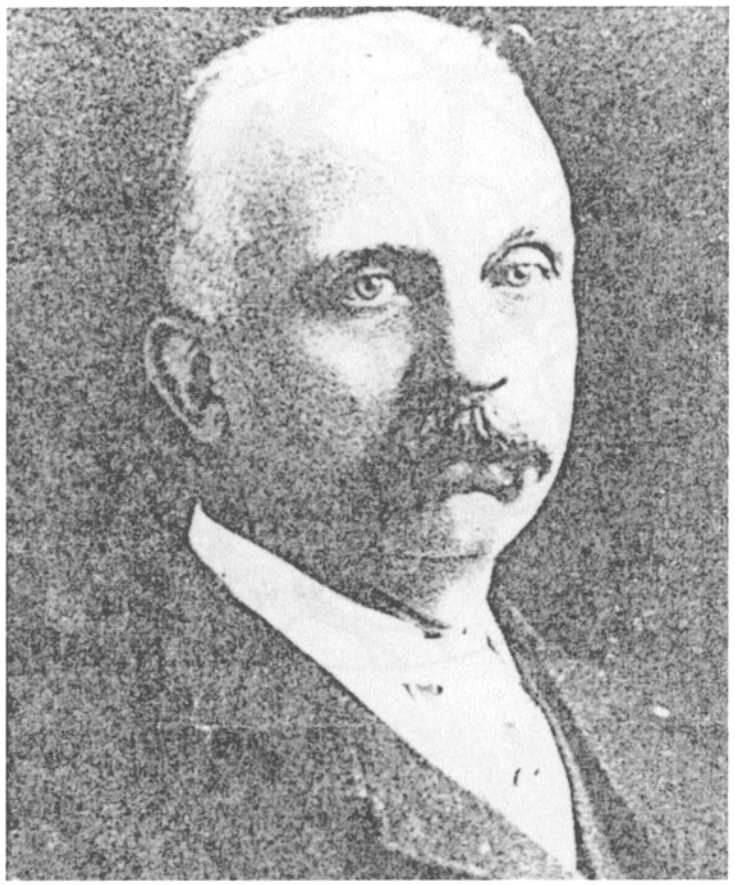
Figure 1 (Portrait of William T. Belfield, M.D., 1856-1929)

William T. Belfield, M.D., 1856-1929. Bacteriology captured Belfield's interest in the late 1870's and early 1880's. After publishing the first original general bacteriology book in English (1883), he became a leading surgeon and first president of the Chicago Urological Society (1903). For a portrait of Belfield as a young man see Unrivaled Chicago (1896), page 101. Henry Gradle, M.D., 1855-1911, called the Little Giant by some of his friends, looks directly and searchingly at the viewer in the portrait owned by the Chicago Historical Society. By 1870 Greene V. Black, M.D., D.D.S., 1836-1915, was balding and had adopted the full beard and mustache he wore until the end of his life (Pappas 1983, fig. 21).

Source of WTB portrait: *Ill. Med. J.*, 137 (Jan. 1970): 54-59.



Figures 2 and 3 (Illustrations from Belfield's "Micro-Organisms")

Belfield illustrated his Cartwright Lectures to the alumni of the College of Physicians and Surgeons, New York City, with lantern slides. Among the copies of eighteen original photomicrographs Belfield published and widely circulated were "Anthrax bacilli showing spore formation" (300X), and "Spirochaete of Obermeier and human blood-corpuscles," based on Koch (700X). Relapsing fever's spirochete discovered in 1873 has since been named for Borrel rather than Obermeier.

Source: *Med. Rec.*, New York, 23, no. 8 (Feb. 24, 1883):fig. 4, and no. 12 (Mar. 24, 1883):fig. 10.

Figure 2 (Anthrax with spores)

Figure 3 (Spirochaete of Obermeier)

Figures 4 and 5 (Microscope and Microtome)

Without master instrument makers students of bacteriology would have been stymied. Walter H. Bulloch, a Scotsman trained by an optician in New York City, moved to Chicago in 1866. These early 1880's products are his Congress stand (magnifying power, 2,000 diameters) and combination microtome for cutting serial sections ($65). Of twenty companies making microscopes in the United States by 1880 Bulloch's was one of two based in Chicago, and his work was known world-wide.

Source: *Amer. Monthly Micros. J.* 3, no. 1(Jan. 1882):9-13, and 6, no. 3 (Mar. 1885):45-46.

Figure 4 (Bulloch Microscope)

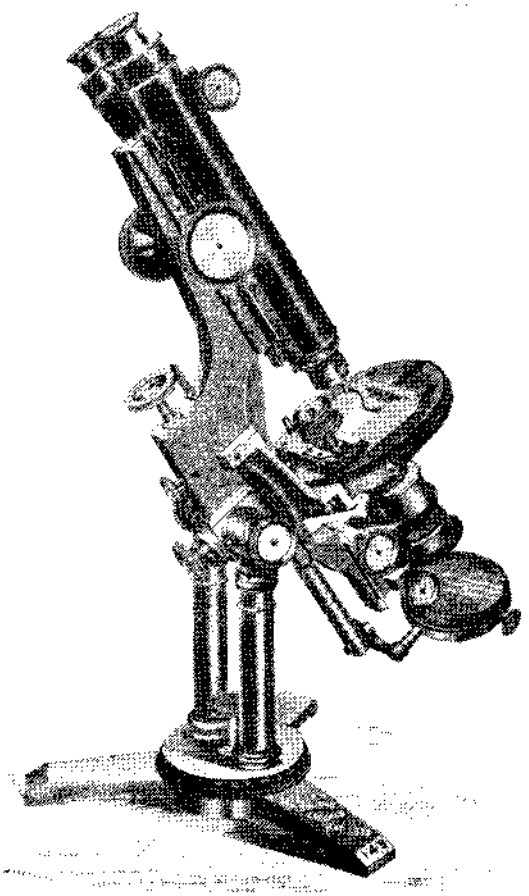


Figure 5 (Bulloch Microtome)

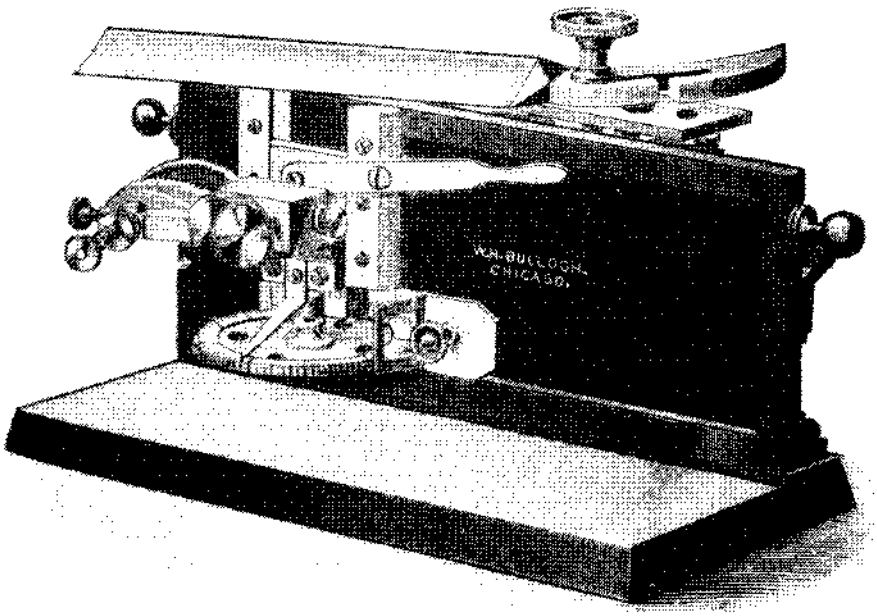


Figure 5 — Bulloch Freezing Microtome.

Figure 6 (Editorial)

Debut of *The Dental Review* (1886), one of at least six new medical journals started in Chicago in the 1880's. Allison W. Harlan, M.D., D.D.S., 1851-1909, editor of the periodical, later participated in the World's Columbian Dental Congress, Chicago, 1893. The germ theory article by George H. Cushing, M.D., D.D.S., occupied one-seventh of *Dental Review*'s first number. Harlan earned his M.D. at the College of Physicians and Surgeons of Chicago, 1883, and Rush, where Belfield taught, conferred an honorary M.D. upon Cushing, 1885.

Source: *Amer. Monthly Micros. J.* 8, no. 1 (Jan. 1887):14.

EDITORIAL.

VOLUME I and Number 1 of *The Dental Review*, devoted to the advancement of dental science, and published by W. T. Keener, Chicago, Ill., has recently been received. We are pleased with its appearance and its claims, and most heartily wish it a successful, and that means, we trust, useful career. It contains articles on the periosteum and peridental membranes, with a very creditable plate; the germ theory in its relation to daily practice; gold foil; oral surgery; doings of societies; correspondence; editorial review, and other matters. This first number is a well printed pamphlet of 56 pages, and in every respect a creditable magazine. We are especially glad to note the high-toned manner in which its editor introduces himself, proposing for his guidance the maxim, 'With malice toward none, with charity for all,' and trust that he may be able to so maintain the difficult position of stating the truth fearlessly, and yet so impersonally, as to be able to leave out the element of rancor which we regret to ever see in the columns of any journal.

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