EARLY YEARS
1890–1902

Charles Lester Leonard, 1896–1902

Arthur Willis Goodspeed, 1884–1931

Arthur Willis Goodspeed: Physics and Photography

Arthur Willis Goodspeed showed an aptitude for the physical sciences early in his life and while a student at Harvard University was encouraged to pursue this interest. He graduated *summa cum laude* from Harvard in 1884, with highest honors in physics, and after graduation accepted the position as Assistant in Physics at Pennsylvania. Working with George Frederick Barker, an experienced physicist and brillant lecturer whose reputation was international, Goodspeed was also able to pursue graduate work in the University's newly established Graduate School.[1]

Goodspeed came to Philadelphia the summer that Eadweard Muybridge was conducting his well-known investigations in animal locomotion on the Pennsylvania campus. The studies were sponsored by the University, and Dr. Barker served as a member of the Muybridge Commission, appointed by the Provost, to oversee the project; the young physicist, Goodspeed, was therefore involved in these experiments as soon as he arrived. It is probable that he was involved in Muybridge's later work as well, and may have helped to design an electrical device used during the work on human locomotion which released the shutters on a series of cameras in automatic sequence.[2] These experiences were undoubtedly responsible for stimulating this interest in the scientific aspects of photography, if, in fact, his interest did not originate from these experiments.[3]

Goodspeed was named an Instructor in 1885 and an Assistant Professor in 1889 when he received his doctoral degree, the first degree conferred by the new Graduate School.[4] In the fall of 1889 he began a series of experiments with W. N. Jennings, a Philadelphian who wished to make use of the facilities in the University's Physics Department. The two men spent several years photographing electric sparks produced by various pieces of apparatus and comparing them to Jennings's previous photographs of lightning. In the process they produced some startling exposures which remained unexplained until the publication of Röntgen's communications.[5]

The Accidental, Unrecognized Production of X-Rays at Pennsylvania—1890

Goodspeed and Jennings spent the evening of February 22, 1890, in the University's physics lecture room photographing the brush from a large induction machine, as well as coins and brass weights which were sparked using an induction coil. After completing these experiments Dr. Goodspeed opened a cabinet to show Jennings the laboratory's collection of Crookes tubes and exhausted one to show him the attractive colors produced by the vacuum. Following this diversion Jennings packed the photographic plates exposed during the evening and departed.

Later, while analyzing the plates from the evening's work, Jennings noticed that several plates that had not been exposed directly, but which were developed with the exposed ones, appeared fogged. The image of a mysterious disc appeared on one of the fogged plates, and the character of its impression was entirely different from that of those exposed in the normal manner. These unusual results were soon forgotten, however, and stored with the records of the other early experiments.

Early in February, 1896, following the announcement of Röntgen's discovery, Goodspeed and Jennings consulted their old records to determine whether they had ever exposed a plate completely covered by a plate holder and came across the notes from the evening in February, 1890. Hypothesizing that the shadow picture of the disc actually showed one of the coins exposed during the viewing of the Crookes tube, the experiments were repeated—with identical results. Speaking before the American Philosophical Society on February 21, 1896, Dr. Goodspeed related:

> Now, gentlemen, we wish it clearly understood that we claim no credit whatever for what seems to have been a most interesting accident, yet the evidence seems quite convincing that the *first* Röntgen shadow picture was really produced almost exactly six years ago to-night, in the physical lecture room of the University of Pennsylvania.[6]

X-Ray Production in the Department of Physics—February, 1896

Soon after the announcement of Röntgen's discovery Goodspeed and his associates began to experiment with the available apparatus in the University's Physical Laboratory. They lacked a second induction coil as described by Röntgen, and were initially skeptical about the probability for success, but found that a simpler arrangement of apparatus, joining the tube to the secondary current of the first coil, would work as well. On February 5th a twenty minute exposure of a small slip of glass, a piece of sheet lead and a wedge of wood produced the first successful result. This experiment was immediately followed by an exposure of the skeleton of a human hand.[7]

In early February Goodspeed began working with John Carbutt, and their collaboration produced the first plate especially designed for X-rays. This new plate was considerably more sensitive than regular photographic plates, and when it was first tested at the Maternity Hospital in Philadelphia on February 11th, the length of exposure was decreased from over one hour to only twenty minutes.[8] Dr. H. W. Cattell, a Philadelphia physician, discussed the new discovery when he spoke before the Pathological Society in Philadelphia on February 13th[9]; most likely Goodspeed also made the exposures illustrating malformation of the hands and fingers which Cattell used in his presentation.[10] Throughout the first weeks of experimentation, in fact, physicists rather than physicians were most actively involved in the development of the field because they had ready access to the necessary apparatus.

Goodspeed's detailed presentation on the roentgen rays on February 21st before the American Philosophical Society, Philadelphia's learned scientific community, included a demonstration of his apparatus, and the fact that he transported this equipment to the meeting indicated the immediate, widespread interest created by the discovery. He outlined the historical developments preceding the production of roentgen rays, detailed his work at the University, and showed a number of slides illustrating a variety of techniques and possible uses for the X-ray. The slides included plates whose exposure time varied from a few to as many as forty-five minutes, and plates especially treated with a fluorescent material to increase their sensitivity. The exposures

included human and mouse skeletal views, a series using diamonds to determine the potential for reflection or refraction of the rays, and a series to detect structural flaws in small pieces of metal.[11]

The University's Physical Laboratory was only one of several locations in the city where experiments were being conducted with roentgen rays, and following Dr. Goodspeed's presentation several other gentlemen spoke of their experiences and suggested possible applications for the technique. Of particular interest were the comments of Edwin J. Houston, Professor of Physics at the Franklin Institute (who had had results similar to those of Dr. Goodspeed's early experiments when he produced, but did not recognize, roentgen rays while working at Central High School), and those of John Carbutt (who postulated the development of thin celluloid plates that would obtain better views of areas like the elbow and shoulder).[12]

The discussion presented a clear view of the virtually limitless possibilities for the development of X-ray techniques. From this early date, their application to surgery and medicine was of paramount importance.

The Introduction of X-Rays into Medical Use at Pennsylvania

Dr. Goodspeed's techniques were well developed by the time he presented his paper to the American Philosophical Society, and in late February or early March the roentgen ray procedure was first used on patients at the University. In the early months patients were sent to Dr. Goodspeed's laboratory, a short distance from the hospital buildings, and it was there that he made the exposures using his apparatus.

J. William White, Professor of Clinical Surgery and Chief of the Department of Surgery, was primarily responsible for the introduction of this new procedure. The earliest medical X-rays were taken of fractures or related injuries involving the extremities—areas which were easily accessible, shallow enough to require relatively brief exposures, and normally treated by members of the surgical staff. In the first written communication outlining the application of the new procedure at University Hos-

pital, however, White discussed the most unusual case to date, the utilization of an X-ray exposure to locate a foreign object within a human body.[13]

Writing in the *University Medical Magazine* in June, 1896, Dr. White described a young child who came to the hospital in May unable to keep down any solid food and complaining of a pain in her throat. She had been unable to eat for some time, and, as she became more seriously ill, was actually beginning to starve. The skiagraph exposure showed a toy jack lodged in her esophagus, and permitted a rapid and precise decision concerning the best possible surgical procedure. Dr. White's enthusiastic support for this new procedure was clearly outlined in his conclusion to the case's discussion:

> I have been much impressed by the practical importance of the Röntgen ray process in surgery, but in no instance more than in this, where, in a case in which every hour had become valuable and every effort at exploration dangerous, it substituted accuracy and promptness for otherwise unavoidable uncertainty and delay.[14]

At Pennsylvania, as elsewhere, the application of the roentgen ray process was initially almost exclusively limited to surgical procedures, but gradually it became utilized for general diagnoses as well. A particularly important paper, relating the process and detailing case histories, was written by Drs. White, Goodspeed, and Charles Lester Leonard, a young associate of White's, during the summer of 1896. Its publication in August served as a clear indication of the support for, and acceptance of, the new procedure.[15]

This clinical paper suggested general areas for application of the new process, specifically: to locate foreign bodies imbedded in tissue or located in certain organs or viscera, to analyze fractures and dislocations without further disturbing the sensitive area, and to discern deformities, primarily those of a skeletal nature. The paper highlighted fifteen cases in which the procedure had been used and included detailed photographic documentation of the various conditions. From the outset, the authors stressed their strong commitment to the rapid incorporation of this discovery into medicine: "The Röntgen method is, of course, in its infancy. It has, however, already reached a degree of usefulness that makes it obvious that the necessary apparatus will be an essential part of the surgical outfit of all hospitals and will be employed constantly in a variety of cases."[16]

This August publication was particularly important for two reasons: it was the first formal introduction of Charles Lester Leonard, and it spoke in optimistic terms of the many possible applications of the process for diagnostic work in medicine, as well as surgery. Within a short period of time Leonard was to assume primary responsibility for X-ray work at University Hospital, and his personal interest in gallstones and other forms of calculi was clearly expressed even at this time:

> No practical results have yet been obtained in the discovery of these forms of calculi, but it seems within bounds to expect that after we become more familiar with the shadows cast by the normal viscera and the normal skeleton, we may be able to distinguish gallstones from malignant disease involving the ducts; may locate or exclude renal calculi in doubtful cases . . . [17]

The acceptance and utilization of the roentgen ray procedure in the work of many departments in the hospital was firmly established by early 1897. Opthalmologists and laryngologists used skiagraphy to locate foreign bodies, internists used it for diagnosis of disease growths and general diagnosis, as well as to view the internal organs, and surgeons used it as a precision tool to augment their procedures, both before surgery as an investigative aid and following surgery to determine success or failure.[18] Even more importantly, Dr. Leonard's work in a room in the William Pepper Clinical Laboratory established the operation's independence from the surgical staff.

Charles Lester Leonard, M.D.—Early Years

Charles Lester Leonard was born in Massachusetts in 1861, but grew up in Philadelphia. He graduated from the University of Pennsylvania in 1885 with a Bachelor of Arts Degree, and graduated from Harvard University in 1886 with a second undergraduate degree. He returned to Philadelphia to enter the University's School of Medicine, graduating in the class of 1889, and by the early 1890s was involved in his career work at the University: teaching and practicing medicine and investigating a variety of research projects.

Leonard was interested in photography while a student in the 1880s and was the subject in at least one series of photographs

in Eadweard Muybridge's experiments on human locomotion, in the group entitled "Man Running."[19] He became interested in microscopy and microphotography as his studies progressed, and after graduating from medical school spent time in Europe observing various techniques. Leonard returned to the University in the fall of 1891 to continue his studies in microscopy, and designed an electrically-operated lens shutter which enabled him to photograph various stages in the life cycle of microorganisms. He received a Master of Arts Degree in 1892 while serving as an Assistant Instructor in Clinical Surgery on the faculty of the School of Medicine.

Leonard continued his teaching and research work and was given space in the new William Pepper Clinical Laboratory, adjoining the hospital, when it was opened in 1895. His combined interest in photography and work in surgery under J. William White led to a natural inquisitiveness about the new roentgen ray process, and when a separate skiagraphy service was established in the Pepper Laboratory, he was chosen to run it.[20]

X-Ray Laboratories in the William Pepper Clinical Laboratory and the Department of Clinical Surgery

The roentgen ray process was accepted so quickly at University Hospital that in a few months it became inconvenient to transport patients outside the hospital complex to Dr. Goodspeed's laboratory. By September, 1896, Dr. Leonard had been given a small room on an upper floor of the William Pepper Clinical Laboratory, near his own research area, and was operating a skiagraphy service for the entire hospital community. Shortly thereafter a second roentgen plant was installed, this one in the Department of Clinical Surgery at the hospital.[21] Unlike Leonard's operation, however, this second plant was apparently used almost exclusively as a teaching resource by Dr. White: "It has been a source of great satisfaction to Dr. White in teaching and of otherwise unattainable instruction to the students."[22]

An extant photograph provides detailed information about Dr. Leonard's installation in the Pepper Laboratory, clearly showing the simplicity of its arrangement. The roentgen ray plant was

Dr. Charles Leonard, nurse, and patient in the skiagraphy facilities, William Pepper Clinical Laboratory, 1896

located in a single, high-ceilinged room, with minimal equipment and furniture. Dr. Leonard appears attending a male patient on a litter, while Mrs. McNally, later head nurse in the Men's Surgical Ward, stands nearby, although during a routine procedure a nurse would have been present only when the doctor was examining a female patient. The apparatus included a specialized X-ray tube, probably designed by Edison, suspended over the patient from a regular lab stand, since there was no roentgen ray table in this facility. Other equipment included a 7-inch Queen coil, powered by twenty-volt storage cells, and a mechanical spring interrupter. There was also a fair-sized, hand-held fluoroscope, but since Dr. Leonard was never very fond of the procedure the instrument was probably used more often to test the apparatus, to determine whether or not rays were being produced, than for fluoroscopy.[23]

The Move to the Agnew Pavilion—October, 1897

The operation of the roentgen ray apparatus in the Pepper Laboratory, although somewhat more convenient than the earlier arrangement, still provided transportation difficulties for patients. Since the operation required only minimal space, a small area was found in October, 1897, and Dr. Leonard and the entire operation moved. The hospital installed the apparatus in the new Agnew Memorial Pavilion, a decision made, however, long after building designs had been completed.

The new area was partitioned off from the waiting room of the surgical dispensary, and became a room approximately ten by twenty feet in size, with a single door and small windows high in the wall.[24] The importance of physically installing the apparatus in a main hospital building was stressed during the dedication of the new wing: ". . . laboratories, photography and Röntgen ray appliances, etc., add to the precise and scientific requirements of the day."[25]

Dr. Leonard was given a tiny room two floors above the apparatus, underneath the surgical amphitheatre, to serve as his darkroom. The space was so small that the developer could barely turn around, and because so much room was occupied by the sink a visitor or student could not observe the developing of plates. A few years later Dr. Leonard was given a larger darkroom, but the single examining room was all the working space he had for skiagraphy while at the University. These cramped quarters caused difficulties in an otherwise routine examining schedule, and would have been grossly overtaxed as a teaching facility were it not for Dr. White's installation.

The Department Under Leonard: 1896–1902

Although Charles Lester Leonard had operated the roentgen ray apparatus as an official hospital activity ever since its location in the William Pepper Clinical Laboratory, he did not use a title publically until the spring of 1898. Writing in the *Annals of Ophthalmology* in April, he was listed as "Skiagrapher to the University Hospital," the title which he retained throughout his work there.[26] Recognition of this new field of study was first accorded

by the School of Medicine in the *University Catalog* for the 1898–99 academic year, under the Department of Surgery, where Leonard was listed as "Instructor in Skiagraphy," and "Assistant Instructor in Clinical Surgery"[27]; however, another faculty listing for skiagraphy did not appear until the 1903–04 *Catalog,* and Leonard was not listed as Skiagrapher in a hospital publication until the *Annual Report of the Board of Managers* for 1899.[28]

The rapid incorporation of roentgenographic procedures in many departments at University Hospital suggests a sizeable patient load, yet this was not actually the case. The first figures available, for the year 1900, indicate that Dr. Leonard saw a total of 100 patients, including sixty-nine ward patients, fourteen out-patients, ten private hospital patients, four private out-patients, and three students.[29] Considerably more than 100 exposures would have been made during the year, however, and many exposures would have lasted up to several minutes each, since the pelvis and abdomen were investigated most frequently. Because he was working alone, a fair portion of Dr. Leonard's nonteaching time was involved in preparing each patient and caring for apparatus. Patients for his final full year at the hospital, 1901, numbered 141, and the breakdown of patient categories, as well as the areas of the body examined, closely paralleled the figures from the previous year.[30]

Occasional references to apparatus during this period indicate the introduction of some new equipment to the department's operation, but there was no concerted effort to expand the services offered by the department or the physical plant in which it operated. Dr. Leonard was using self-regulating X-ray tubes by 1898, an especially important technological advance since they had ". . . made it possible to obtain a relative measurement of the vacuum employed, and to repeat at will exposures with equal vacua."[31] Leonard was also concerned with the utility of the fluoroscope, and although relatively unimpressed with its reliability in detecting accurate detail, he did recommend it for procedures such as adjusting fractures, particularly when a permanent exposure could be made later to verify the final position.[32]

Dr. J. William White presented the department with a Leeds and Northrup coil in 1899, a model which proved to be relatively portable and helped alleviate some of the difficulties caused by the narrower-than-a-bed entryway into the depart-

ment's single room. The coil produced a spark somewhat heavier than earlier apparatus, and operated on a twenty volt primary circuit, supplied by a motor generator which, with proper conditions, transformed the 110 volt hospital potential into twenty volts.[33]

Cooperation among Philadelphia's physicians and scientists commenced as soon as experimentation was begun, and as one of the first skiagraphers in the city, Leonard was asked to assist in the introduction of roentgen ray apparatus at Philadelphia General Hospital in 1899. George E. Pfahler, a young physician on their staff, was asked to operate the equipment, and Leonard provided valuable insight into matters of installation and technique. He was able to persuade Pfahler to use the Queen and Company Sayen self-regulating tube, which was developed in Philadelphia and proved so successful in his own work.[34]

In addition to his clinical and teaching responsibilities, Charles Lester Leonard spent a considerable amount of time doing research and publishing the results of his clinical and research analyses. These works reveal that he considered the roentgen ray procedure an important diagnostic tool. He detailed its use in the location of foreign bodies in the eye and its practicality for the determination of fractures, and stressed the utility of the fluoroscope in a number of articles. His most extensive and sophisticated work was in the field of calculus diagnosis, and beginning in 1898 he devoted as much time as possible to this project.

Leonard was the first roentgenologist to identify kidney stones in a skiagraph, a possibility which he had foreseen as early as the summer of 1896. Several technical obstacles complicated the diagnosis of calculus nephritis, principally the fact that kidneys lie deep inside the body cavity and stones vary considerably in their individual opaqueness; however, the development of the self-regulating tube enabled the roentgenologist to duplicate conditions time and time again, and after making exposures of the organs and completing follow-up surgery, Leonard was able to delineate criteria to analyze future exposures. His initial communication on this subject, in *The Philadelphia Medical Journal* of August, 1898, continued to explain:

> The absolute conditions essential to the detection of calculi in the kidney have been determined and proved repeatedly by positive clinical

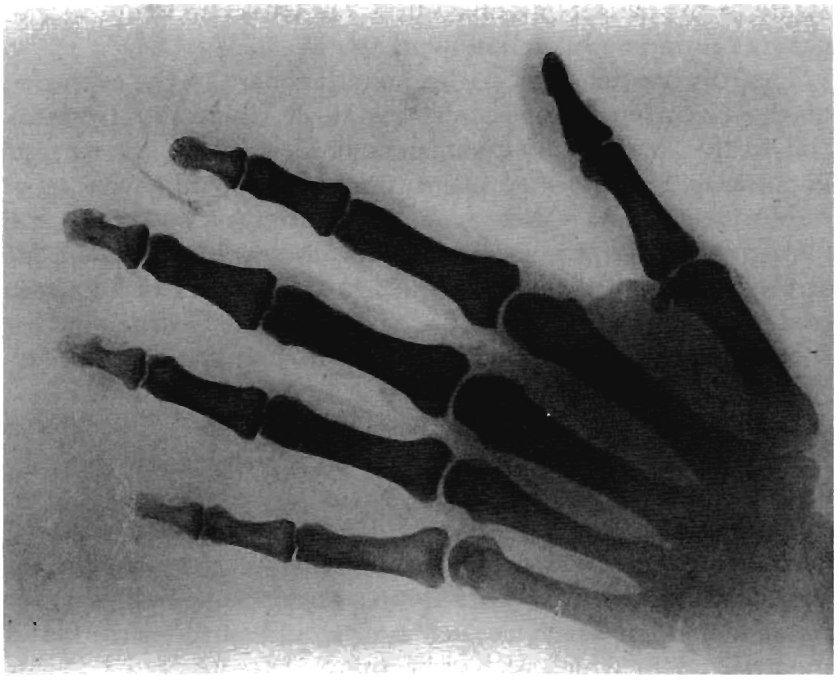
evidence, so that it is certain that under these known conditions a renal calculus must be detected, and that the absence of the shadow of a calculus, in a negative showing certain definite details, is conclusive evidence of the non-existence of all calculi in that region.[35]

This early publication was only the beginning of a long series of important papers on calculus which he continued to write throughout most of the remainder of his life, and for this work Leonard is recognized as one of the most important American contributors to work on the gastrointestinal tract.[36]

Some of Leonard's patients with calculus nephritis were examined at University Hospital, but a great many were private patients whom he saw during his morning office hours in his office in center city Philadelphia. As his reputation spread he became more and more involved in the diagnosis of calculi, although at the same time he also expanded his general roentgenologic work, accepting the position of Demonstrator in Roentgen-Ray Diagnosis at the Philadelphia Polyclinic Laboratories.[37] Eventually he became Director of the program there as well as at Methodist Episcopal Hospital.[38] To further complicate this increase in his outside responsibilities, not to mention his teaching and clinical responsibilities at the University, Leonard's health was failing as a result of overexposure to X-rays.

Charles Lester Leonard, like nearly all of the pioneers of American roentgenology, suffered severely from X-ray burns. He first mentioned this problem in June, 1897, when he spoke to the Section on Practice of Medicine of the American Medical Association, indicating that the burns were caused by induced electric currents in the patient's tissues, rather than by the X-rays themselves. Leonard, along with a great many other roentgenologists, thought that the solution to the problem was to provide a means for grounding the electrical current. For some time the placement of a sheet of aluminum between the patient and the tube, with a wire leading to the floor to ground the metal, was thought to prevent the X-ray burn while still allowing the ray's beneficial penetrating force to be transmitted.[39]

Leonard's theories about the properties of the X-ray eventually changed, quite likely as the result of his continued problem with burns on his hands. At the Fourth Annual Meeting of the American Roentgen Ray Society in 1903, he described the simple form of protection he had devised: a pasteboard box covered with lead surrounding the X-ray tube to prevent secondary rays from



Print of an X-ray of the hand of William Pepper, Dean of the School of Medicine, c. 1900

spreading throughout the room. He also outlined the treatments he had used to provide relief of his condition, concluding: "We all have used some kind of treatment, and I think we ought to tell each other just what we have done, so that these various remedies that have been used may be tried by others, perhaps with some success."[40]

Charles Lester Leonard left University Hospital in September, 1902, and although his other responsibilities were undoubtedly a consideration, the severity of the burns on his hands must have played a role in his departure. Skepticism and fear still surrounded the roentgen ray process, and Dr. Leonard's disability could only have served to increase the uncertainty felt by the hospital's patients. He continued to work steadily until a few years before his death in 1913, but in that period cancer spread from his hand, where a single finger had been amputated, throughout his entire body. The subsequent amputation of his hand, forearm and finally the upper arm at the shoulder joint could do nothing to stop the spread of the disease. Continually

aware of the dangers involved in X-ray work, he wrote several papers cautioning his fellow workers.[41]

The contributions of Charles Lester Leonard to the evolution of the Department of Roentgenology at University Hospital, and to the specialty of roentgenology as a whole, are of vital importance. He published twenty-nine articles while working at the University and a great many more after his departure, and his reputation in the diagnosis of calculi was international. He served as the American representative to a number of European conferences,[42] and remained a vital force in the Philadelphia roentgenologic community. In 1905 he invited the city's roentgenologists to his office for a meeting, and under his guidance a dozen physicians and scientists founded the Philadelphia Roentgen Ray Society; he served as its permanent secretary until his death.[43]

The success Leonard achieved at University Hospital, working in cramped spaces with minimal equipment, set the precedent for the department's future. With limited resources he built a sturdy foundation upon which his successors would nurture and expand the department which he had begun.

NOTES

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