Wilhelm Conrad Roentgen and Early Roentgenology

"In the history of Science nothing is more true than that the discoverer, even the greatest discoverer, is but a descendant of his scientific forefathers; he is always essentially the product of the age in which he is born."

Sylvanus P. Thompson, The Roentgen Society, London
November 5, 1897.

On November the eighth, 1895, a light which, so far as human observation goes, never was on land or sea, was first observed. The observer was Professor Wilhelm Conrad Roentgen, who at that time was director of the Physical Institute of the Wurzburg University in Bavaria. That day will ever be memorable in the history of Science.

"What he saw with his own eyes, a faint flickering greenish illumination upon a bit of cardboard, painted over with a fluorescent chemical preparation. Upon the faintly luminous surface a line of dark shadow. All this in a carefully darkened room, from which every known kind of ray had been scrupulously excluded. In that room was a Crookes tube, stimulated internally by sparks from an induction coil, but carefully covered by a shield of black cardboard, impervious to every known kind of light, even the most intense. Yet in the darkness, expressly arranged so as to allow the eye to watch for luminous phenomena, nothing visible until the hitherto unrecognized rays, emanating from the Crookes tube and pentrating the cardboard shield, fell upon

1. Glasser, Otto, Ph.D., The Genealogy of the Roentgen Rays; _American Journal of Roentgenology and Radium Therapy_; 1933; 30:p. 180.

Röntgen.

the luminescent screen, thus revealing their existence and making darkness visible.

From seeing the illumination by the invisible rays of a fluorescent screen, and the line of shadow across it, the work of tracing back that shadow to the object which caused it, and of verifying the source of the rays to be the Crookes tube, was to the practised investigator but the work of a few minutes. The invisible rays- for they were invisible except when they fell upon the chemically painted screen-were found to have a penetrative power hitherto unimagined. They penetrated cardboard, wood, and cloth with ease. They would even go through a thick plank, or a book of 2000 pages, lighting up the screen placed on the other side. But metals such as copper, iron, lead, silver, and gold were less penetrable, the densest of them being practically opaque. And so the discoverer, interposing his hand between the source of the rays and his bit of luminescent cardboard, saw the bones of his living hand projected in silhouette upon the screen. The great discovery was made." 2

This report, given in the words of Sylvanus P. Thompson, a well-known English physicist, was published in November 1897, in the second volume of the world's first journal of roentgenology, the English Archives of Skiagraphy, or as it was later called, the Archives of the Roentgen Ray.

Many stories and fables have been woven about the discovery of roentgen-rays just as they have about other discoveries and inventions of great significance. Perhaps the most popular story and most widely circulated is the myth of the "book and key". This story, originally told by T.S.Middleton, of Chicago, is practically unknown outside the United States.

2. Glasser, Otto,Ph.D., The Science of Radiology;Charles C.Thomas, Springfield, Illinois; 1933.

The author states that Roentgen happened to lay a glowing Hittorf tube upon a book which contained a large flat key which was being used as a book mark. There happened to be a loaded photographic plate holder lying under the book. Turning off the current from the tube after being called away for a short time, he took the plate holder with several others and spent the afternoon out of doors exposing the plates in the practice of his favorite hobby photography. Later developing the plates he found the shadow of the key book mark made by the unknown rays.

The account contains so many accidental happenings leading to so great a discovery that was the result of a great amount of thought, and painstaking, laborious investigation. Laying a glowing tube on a book would necessitate disconnecting the high voltage from the tube, therefore no x-rays could be produced. Also Roentgen did not refer to the "book and key"experiment in any of his records or publications, and he was always most accurate in recording experimental data. It is popular opinion that would have us believe that Roentgen's discovery of roentgen rays was accidental in spite of well-founded historical facts to the contrary. A year before Roentgen made his discovery he gave an address as President of Wurzburg University and quoted one of his predecessors in the chair of Physics and Philosophy, who as early as 1602 stated:

"Nature often reveals the most astonishing phenomena by the simplest means, but these phenomena can only be recognized by persons who have sharp judgment and the investigative spirit, and who hav e learned to obtain information from experience, the teacher of all things."[3] This assertion was destined to become applicable in the case of Roentgen's own discovery.

3. Glasser, Otto, Ph.D., The Science of Radiology; Charles C. Thomas, Springfield, Illinois; 1933.

After the news of the Roentgen's discovery reached the world, the general public demanded to know more about the man. Wilhelm Conrad Roentgen was born on March 27, 1845, in Lennep, a little town on the lower Rhine in the heart of the industrial section of that part of Germany. Roentgen was descended on his father's side from an ancient Rhenish merchant family. His mother came of good Dutch stock whose forebears had emigrated from Italy in the seventeenth century.

Wilhelm Conrad was an only child, and it has been pointed out by some educators that, properly brought up, the only child possesses attributes which tend to leadership. Roentgen's childhood was a very happy one and was spent in Utrecht, Holland, the birth place of his mother. His father, Frederick Conrad, was a farmer, a man of the soil, simple, reserved, taciturn and religious.

After a few years of primary school it was planned that he should follow the agricultural occupation of his father, and to this end he entered the Agricultural school at Apeldoorn, Holland. While there an incident occurred which not only gives proof of a high standard of honorable conduct, but was instrumental in eventually deviating his career into those paths of endeavor where he achieved greatness. Accused of a harmless schoolboy prank, while in the fifth year at school, he frankly admitted his part in it, but his sense of honor would not permit him to reveal the names of his companions in mischief, and for this refusal he was expelled from school. This was a severe blow to his ambitions. Later he attempted to pass the promotion examinations which would have permitted him to matriculate with the University without any further examinations, but he failed. These apparently trivial incidents seemed to Wilhelm Conrad, calamities. Nevertheless he was saved from the old educational system which ~~seeks~~ sought to repress all tendencies to diversity of mental development and to conform all heads to one mould. Duclaux, the successor of Pasteur and his biographers pointed out that those who show originality and achieve distindtion are recruited chiefly from the ranks of those who have escaped the sterilizing influence of the early years of standardized education. His boyhood passed --given more to contemplation than to action.

In the spring of 1865 Roentgen entered the Polytechnical Institute in Zurich, which accepted students without the usual matriculation examinations . The well-known Clausius, Professor of Theoretical Physics, and Kundt, the experimental physicist, awakened such a love for the physical sciences in the heart of the young student that he soon devoted himself entirely to this subject. His interest, industry and ability won him, immediately after graduation, an assistantship to Kundt, with whom he was associated for many years. It was for the work done with Kundt that he received from the University of Zurich his degree of Doctor of Philosophy. To Kundt, Roentgen owed much of his experimental skill and the thoroughness and exactness which characterized all his investigations. Two years later he followed Kundt to Wurzburg where he had accepted the offer of the chair of physics.

In Wurzburg, on July 7, 1872, Roentgen married Bertha Ludwig, of Zurich, with whom he lived very happily for nearly fifty years. They had no children but later adopted a niece of Mrs. Roentgen's.

In 1888 he accepted the call to the University of Wurzburg, the institution which a few years previously had refused to give him his academic standing. His rapid advance in academic standing plainly testifies to his great ability as an investigator and his excellence as a teacher and organizer. It was as Director of the Physical Institute in the Wurzburg University, at the age of fifty, that Roentgen discovered the X-rays.

After twelve years of service at Wurzburg and at the special insistence of the government, he accepted the position of Director of Technical Physics at the Universtiy in Munich, a position he held until the spring of 1921. The Presidency of the Royal Physical Institute of Berlin was offered to him, but he declined. Immediately upon announcing the discovery the Emperor invited him to demonstrate the X-rays at the Palace of Potsdam, where he was awarded the Crown Order. The title of Excellence was given him by the German government and his statue was erected on the Potsdam bridge in Berlin. Columbia University awarded him the Barnard medal and in 1901 he received the Nobel prize for physics, the first of the awards made.

At the height of the World War he returned the honors which he had received from various foreign governments, including the Rumford Medal of the English Royal Society. Such was his patriotism that, in the extremities of the war, he turned over his worldly possessions to his country.

Roentgen's last years were sad and lonely. His beloved wife died on October 31, 1919, after a long illness, through which he nursed her with tenderness and devotion. When he resigned his University position as Director of the Institute of Physics, and retired, a great silence fell about him. For the most part all of his old friends were dead, and having no children of his own he was peculiarly alone. Though his mind was clear and his mental vision undimmed, the infirmities of age were upon him. Roentgen died of carcinoma of the rectum. He was not aware of the disease, which did not produce many symptoms. His last illness was very short. He passed away quietly in Munich on February 10, 1923 in great poverty, under the roof of a friend, at the age of seventy-eight years. His ashes rest in Giessen cemetery beside those of his wife and of his parents. But from the distance of centuries Wilhelm Conrad Roentgen will be seen as one of the towering figures of our time.

Roentgen was one of the most outstanding physicists of the nineteenth century, even without his discovery of the unknown rays. He began his first experiments with cathode rays in October 1895, following the contributions made by other investigators..His discovery was the final step in a brilliant and logical correlation of a multitude of facts which had been disclosed by many scientists.

In tracing the "scientific forefathers" it is necessary to go back in ancient history to Thales of Milet, and to Theophrast. The former in 600 B.C. and the latter in 321 B.C. independently observed that friction caused amber to attract light bodies and therefore discovered the first electric phenomenon. These observations were entirely forgotten but they were re-discovered in the Middle ages and this re-discovery was the real birth of present-day knowledge of electricity and of magnetism.

William Gilbert (1540-1603), born in Colchester, Essex county, England was one of the first scientists to become dissatisfied with the lack of logic and system in the experiments of the alchemists, and emphasized the importance of accurate and detailed observations and information. He discovered magnetic induction and magnetic conductivity and many other similar phenomena. He discovered the frictional electricity and the electrical properties of amber which were known from the ancient times, and in addition he found a series of other materials such as sulphur, glass, resin, sealing wax and many crystals which, when rubbed, also possess electrical properties. Curiously enough, he did not observe electrical repulsion. Nicolaus Cabaeus, a Ferrara Jesuit (1585-1650), was the first to record the phenomenon of electrical repulsion in 1629. Gilbert died from the plague. Lord Kelvin said that Gilbert's work was one of the finest examples of inductive philosophy that had ever been presented to the world. His famous collection of instruments, globes, minerals and books, bequeathed to the College of Physicians, was destroyed in the great London fire of 1666.

Roentgen's "scientific forefathers" limits this discussion to those successors of Gilbert who worked on problems of magnetism and electricity and whose work eventually led to the development of the high tension apparatus which the Wurzburg savant used in the nineteenth century in his experiments. Of equal improtance are the numerous attempts to create an "empty space" which eventually led to the construction of the vacuum tubes which formed such an important part of the armamentarium of the Wurzburg physicist. The development of these apparatuses often went hand in hand, and many a scientist worked at the same time on the improvement of some electrical apparatus and on the creation and perfection of high vacuum tubes.

It was Gilbert who first used the word "electrical" from the Greek for amber, to apply to properties of attraction arising from friction. These phenomena happened to be the effects of high tension electricity, altho in minute quantities, and this happened to be the form of electricity capable of exciting a vacuum- one circumstance which determined the direction of the X-ray trail. This static electricity was the only form known until the discoveries of Galvani and the construction of the battery by Volta, in the closing days of the 18th century. Still static continued to be the only form of high tension electricity until some forty years later, when the co-discovery by Faraday and Henry of electromagnetic induction led to the invention of the coil, the dynamo, and the transformer.

In the development of the vacuum tube, Galileo, also a physician, made the first air pump in the world, for the distinct purpose of forming a vacuum. Von Guericke recognized that air had weight and invented an air-balance. Robert Boyle improved the air-pump by adding the pinion movement to it. Robert Hooke, by method, apparatus, and discovery , endowed the experimentalists who came after him, and his passing brings us to the most improtant figures in the early history of electrical exploration.

Francis Hauksbee was the first to bring electricity and the vacuum together by intent and design. This achievement was the indispensable step, and the longest step, on the trail that led to the X-ray and its manifold results; to radio and world wide communication; to incandescent and neon illumination, and to all the other multitudinous electrical inventions depending on vacuum tubes. Frances Hauksbee was a part of the renaissance of English science and philosophy which reaches its height in the mighty works of Sir Isaac Newton.

Abbé-Nollet made his vacuum tubes with sealed-in wires and produced the Hauksbee effects by conductors attached to static machines. He had actually assembled the essentials for the production of X-rays- the vacuum tube and an outside source of high tension electricity.

Michael Faraday invented the dynamo and, in principle with Joseph Henry, the first induction coil or transformer which was the general type of apparatus used by Crookes and Roentgen in their experiments, and still is used for the production of X-rays in all the laboratories and hospitals of the world. It was Faraday's exquisite precision in the measurement of the quantity of electricity required to deposit a certain quantity of silver in the process of electroplating which first demonstrated that electricity existed in quanta or multiples of a unit of either energy or matter. Sir J.J.Thomson in the Cavendish laboratory, in 1897, showed that the cathode ray in an X-ray tube is a stream of these units not of energy but of matter which could be deflected by a magnet. These were the electrons before mentioned the "particles infinitely subtile" of Franklin, named by Johnston Stoney, weighed and measured by Millikan, and constituting in the aggregate the electric current. Thus did the X-ray lead directly to the discovery of the electron, which is the basis of our understanding of electricity and of the atom.

William Crookes used vacuum tubes in many different forms, original designs, containing various terminals and interior devices for demonstrating the properties of "radiant matter". In the long hiatus between Abbé Nollet and Crookes, vacuum tubes had undergone modification at the hand of Geissler, Plucker, Hittorf, and others. Hauksbee's tubes were without leading in wires, Nollet's tube had a single wire, and now the German tubes had two wires sealed in so that the electric current had to pass through the vacuum to complete the circuit. High vacuum tubes became known as "Crookes Tubes", because Crookes raised his vacuum to the millionth of an atmosphere, which is within the limits of X-ray production. He noted the greenish yellow color of the glass so familiar to workers with early X-ray tubes, and studied its spectrum. Unconscioulsy, unknowingly, he was generating X-rays in more than sufficient quantity and penetration for practical diagnostic work. It is indeed a poignant tragedy of research that a great experimenter, a worthy successor of his countrymen -Gilbert, Hauksbee, Boyle, and Gray, should have been unaware of the Golden Fleece when finally it lay captured, but invisible in his hands.

Although Crookes unknowingly produced X-rays, he was not the first. In 1785 Morgan in London, experimented to find if electricity would pass through a perfect vacuum and reported his observations to the Royal Society. He said that the degree of vacuum could be determined by the resulting color of the electrical discharge. After Roentgen's discovery, the identification of the yellow-green color with x-rays and a repetition of the experiment made it clear that Morgan was the first to produce them. It is also probable that before the date of Crookes publication, Plucker and his pupil Hittorf, in Germany, working with high vacuum tubes had unsuspectingly brought forth x-rays. Roentgen in his first announcement mentioned his use of the Hittorf tube. Leonard was still investigating cathode rays when Wilhelm Conrad Roentgen made his historic announcement.

Roentgen wrote two papers on his new discovery. The first, December

December 28, 1895 to the president of the Wurzburg Physico-Medical Society, "On a New Kind of Ray". The second and final on the subject March 10, 1897, "Further Observations on the Properties of the X-rays".

Roentgenology is one of the younger divisions of Science. While many years were required for the preparation of the groundwork for this science, practical information and basic knowledge of it began with Roentgen's discovery. The importance of this science is out of all proportion to the short period of its existence. Roentgenology has contributed something to almost every division of modern science, but one of its greatest contributions have probably been to the science of medicine.

January 24, 1896, Professor Mosetig-Moorhof of Vienna reported two cases in which he had used x-rays to help in diagnosis. One of these was used to show the position of a bullet in the hand. The second case was that of the use of x-ray before operation on a congenital duplication of the terminal phalanx of the left great toe. In North America, the earliest recorded clinical application of Roentgen's discovery seems to have been in Montreal. The picture was undoubtedly imperfect, but it was enough to guide Dr. Kirkpatrick in the successful extraction of the bullet, and was also admitted as evidence in the legal proceedings which followed the shooting. No earlier instance of the x-ray picture being accepted in a court of law is recorded.

Unfortunately the first physiologic effects of the roentgen rays were unexpected and undesireable and marked the beginning of the long and distressing chapter on the suffering of many of the roentgen pioneers. They recognized no reason for protecting themselves.

It is interesting that Roentgen himself made all his experiments with the x-rays in a big zinc box with the tube outside; later he even interposed a lead plate between the tube and himself outside the zinc. These experimental precautions completely protected him at the same time.

Some pioneers however were equally as careful. F.W.Williams of Boston said that rays having such power of penetrating matter as the x-rays had must have some effect upon the system. That was his reason for protecting himself. His colleague Walter James Dodd did not take precautions, the result being that his hands were vey badly burned by the roentgen rays. Edison was one of the first to notice some peculiar physiologic effects from roentgen rays. He complained that after several hours of work with the fluorescent tube he had severe pain in his eyes.

Later, there were reports of more definite and more serious damages from roentgen rays. J. Daniel, of Vanderbilt University, reported in April, 1896 that 21 days after taking a picture of the skull of a man with an exposure time of one hour, that he noticed an epilation two inches in diameter on that part of the head which was nearest the tube. An exposure time of one hour is quite different from the exposure time of two seconds or even less, if necessary, that we use today. An English physician reported that those who work with x-rays often suffer from changes of the skin which are similar to the effects from sunburn. Another case of epilation following roentgen examination of the skull was that of William Levy at the physical Laboratory of the State University of Minnesota. A high tension of 100,000 volts was used. The next day Mr. Levy began to notice a peculiar effect on t the skin wherever it had been most exposed to the rays, and the hair on the right side of his head began to fall out. In a few days the right side of his head was perfectly bald. His right ear had swollen to twice its normal size and presented the appearance of being badly frozen. Sores were visible on his head, his mouth and throat were blistered so that he could not eat solid food for three weeks, and his lips were swollen, cracked and bleeding. Mr Levy recovered from the effects of the rays, but he still had one-half a bald head.

Following the early reports of cases of epilation caused by exposure to roentgen rays, some optimists immediately hoped to make practical use of this effect. An enterprising Frenchman, M.Goudoin of Dijon, hurried to Paris after reading some of these reports, intending to make a fortune. He was aware that a considerable proportion of his countrywomen are endowed with soft, silky moustaches, which are by no means appreciated by marriageable young girls and even by married ladies. He therefore resolved to use the roentgen rays as a depilatoire, to remove the superfluous hair from their lips and their chins. Having discreetly made known his benevolent intention, he was not long in securing fair customers. They flocked into his laboratory, patiently waiting their turn, cheerfully paid their fees and received the invisible rays on their full-blown moustaches and incipient beards. But these appendages made no sign of vanishing, and some of the ladies who had been under the treatment asked to have their money refunded. M. Goudoin hurriedly retired from business with the fees he had accumulated.

The first experiments on the therapeutic use of roentgen rays were by the Vienna roentgenologist, L. Freund, in November 1896. A little girl was badly disfigured by a tremenduous fur-like hairy pigmented birth mark. Freund irradiated his little patient daily for two hours for a period of ten days. One day while working in his laboratory, the door opened suddenly and the excited father of the little girl burst into the room shouting,"Herr, Director, the hair has come out". The hair had come out. This was the first successful experimental proof of a biologic effect, and at the same time the first successful use of roentgen rays for therapeutic purposes.

But even though these first experiments of the roentgen rays used therapeutically were unsuccessful for the most part, the observations made in 1896 on the physiologic effects of the new rays furnished the essential fou furnished the essential foundation for the therapeutic use of roentgen rays which later developed. The earliest announcements of proved therapeutic value concerned diseased of the skin. Applications to malignant disease dates from 1899, 1900, 1901, and 1902, in the reports of Sjorgren, Stenbeck and Pusey.

The development of roentgen therapy to its present state of relative enlightenment has been immeasurably aided by the excellent work of physicists and engineers. They made advances technically possible. First came the physicists with accurate methods of measurement under standardizable and reproducible conditions. This important advance paved the way for the work of the research biologist, who brought forth scientific data regarding the effects of measured amounts and specified qualities of x-rays on standardized biologic material.

Today the radiologist and the surgeon stand face to face, each in need of the other's help, each ready to do his proper share of the work of combating malignant disease. Their brotherhood is made more complete by the common knowledge that neither has the final answer to the cancer problem. Real cooperation between physician, surgeon, pathologist and radiologist constitutes the best armamentarium in the present day battle.

Coming to the end of the research trail of roentgenology, we find a new starting point for advancement. Thus it must be with every discovery so long as the human mind thirsts for knowledge. And the name of Wilhelm Conrad Roentgen will be held in honor and benediction as long as disease and disability continue to levy their heavy toll of human suffering.

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"........... when congratulations and honors were showered upon me, unconsciously the new impressions erased the older ones, but one thought has always remained lively and fresh, and that is the memory of the satisfaction which I felt when my work was finally developed and completed. This is the joy derived from successful effort and from progress"........

From Wilhelm C. Roentgen's Writings and Lectures.

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