PART II - CONTROVERSIES SURROUNDING AND FOLLOWING RÖNTGEN'S DISCOVERY

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Towards the end of the 19th century, scientists in many countries were investigating the effects of passing electricity through gases at low pressures. The study of phenomena produced by the application of high voltage, using an induction coil, through a partially-evacuated glass tube represented one of the frontiers in physics research at that time. Wilhelm Conrad Röntgen, Professor of Physics at the University of Würzburg, entered this field of experimentation in earnest only after his 1894-1895 term of University Rectorship had ended. He started his investigations by repeating the experiments of earlier workers and was conducting his own modifications of these experiments when he made his momentous discovery of X rays on 8th November, 1895. This article aims to review some of the controversies surrounding and following Röntgen's discovery.

It may be worthwhile recapitulating how X rays are produced. The basic requirement is an evacuated tube containing two electrodes connected to an external high voltage supply. One of the electrodes, the cathode, on being heated by an electric current, produces free electrons. The high voltage (usually in the range of 50 to 150 kilovolts), when applied across the two electrodes, causes the electrons to be attracted towards the anode at high speed. X rays are produced when the stream of electrons are rapidly decelerated: in modern X ray tubes, by striking the metal anode target; and in early X ray tubes, by colliding with the glass wall of the tube. Although this explanation is a simplified one, it may help the reader understand the contribution of various pioneers to the evolution of the X ray-generating apparatus.

RAYS BEFORE RÖNTGEN

The basic physical processes required for the generation of X rays can be traced to many progenitors – the early pioneers of electricity, magnetism and vacuum production are too many to mention. Francis Hauksbee, Curator of Experiments to the Royal Society in London, was the first to marry an electrical machine to a vacuum tube. This represented the initial step on the trail that lead to the discovery of X rays. Hauksbee, who was thought to have died in 1713 (estimated from the posthumous publication date of his last paper), described seeing "the shape and figure of all parts of his hand" during an experiment involving electricity and vacuum, but was unable to give an explanation for it. Although Hauksbee was a leading figure in the early exploration of electricity, the experiments he conducted in his short scientific career of seven years were, unfortunately, largely forgotten. Jean Antoine Nollet (1700-1770) made an "electric egg", consisting of a vacuum tube and an outside source of high tension electricity which was connected to the inside of the tube by a sealed-in wire. The production of X rays was hence theoretically possible with a higher vacuum and another sealed-in wire at the opposite end of the tube[1].

It was not until the middle of the 19th century that interest in the study of electrical discharges in evacuated tubes was renewed, mainly as a result of Michael Faraday's experiments on "radiant matter". In the 1850s, Johann Heinrich Geissler made vacuum tubes with sealed-in electrodes at both ends. Superior vacuum tubes were manufactured after Hermann Sprengal's invention of the mercury air pump in 1865. Julius Plücker (1801-1868) was the first to observe green fluorescence in the glass wall of the tube, opposite one of the electrodes. Plücker's pupil, Johann Wilhelm Hittorf (Fig 1), identified the cathode as the cause of the fluorescent light and the source of Faraday's "radiant matter"[2]. Sir William Crookes (Fig 2), inspired by Faraday, also designed a wide range of vacuum tubes. Crookes was,however, given much of the credit for observations that had been made earlier by Hittorf. As a consequence, even to this day, the high-vacuum tubes used in Röntgen's discovery have become known as "Crookes tubes", instead of "Hittorf tubes" (Fig 3). Whereas Hittorf's papers were generally technical and dry, and published with great modesty in largely inaccessible journals; Crookes was a brilliant writer and lecturer, and was highly effective in communicating his information about cathode rays to fellow scientists[3].

Fig 1 – Johann Wilhelm Hittorf (1824-1914).

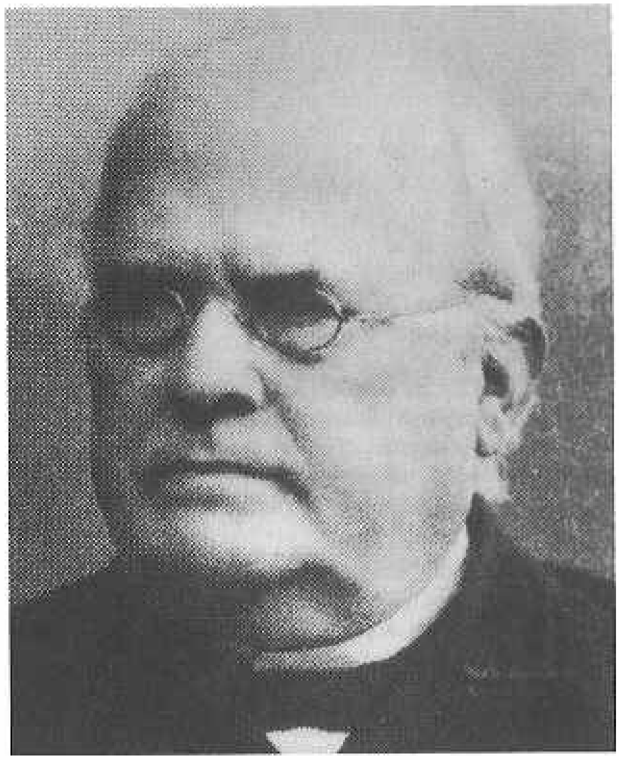

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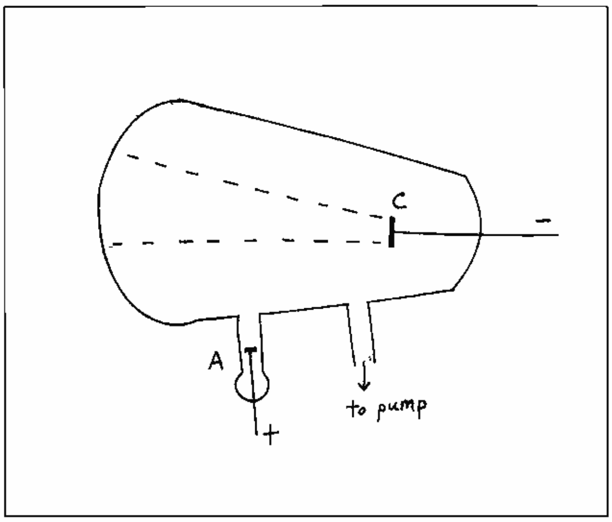
Fig 2 – Sir William Crookes (1832–1919).

Fig 3 – Sketch of a Hittorf-Crookes tube. A high voltage applied across the cathode (C) and anode (A) causes electrons (cathode rays) to be emitted from the cathode surface. X rays are produced when the stream of electrons are stopped at the glass wall of the evacuated tube.



Hermann von Helmholtz (1821-1894) is acknowledged as the "theoretical" discoverer of X rays, having predicted the places of X rays and radiowaves in the electromagnetic spectrum long before their respective physical discoveries. His pupil, Heinrich Rudolf Hertz, discovered radiowaves in 1888. Hertz then made the important observation that cathode rays could pass through a thin metal foil placed within a vacuum tube. Hertz's pupil, Philipp Lenard, constructed a tube (the Lenard tube) with an aluminium window at one end, from which cathode rays could escape and henceforth, be studied. Lenard, like Crookes, Hittorf and numerous other workers in this field towards the end of the 19th century, had unwittingly produced X rays during their experiments with cathode rays, without ever realising it[1].

After Röntgen's discovery was announced, a large number of priority claims were made. However, William Morgan, in experimenting as to whether electricity could pass through a perfect vacuum, was probably the first person to produce X rays back in 1785. During one of his experiments, air was slowly admitted into the tube due to cracking of the glass tube, allowing Morgan to record the development of yellow-green colouration, followed by a succession of other colours. After Röntgen's discovery, it was clear that Morgan had produced X rays over a century earlier[1].

Arthur W Goodspeed, of the University of Pennslyvania, was the first person to produce a radiograph. On 22nd February, 1890, he was demonstrating the properties of cathode rays generated by a vacuum tube to William Jennings, a photographer. Jennings had left two coins on top of a stack of unexposed photographic plates, placed next to the tube. Later, when Jennings developed the plate, he saw the two rounded shadows, which could not be accounted for at that time. The photographs were stored away and its significance only emerged after Röntgen's discovery[4].

In 1890, Ludwig Zehnder, assistant to Röntgen in Würzburg, was probably the first person to observe the fluoroscopic effect of X rays. Zehnder had covered a vacuum tube with a black cloth in order to eliminate the emitted light. Just after turning on the electric current supplying the vacuum tube, he noticed a momentary flash of light from a nearby flurorescent screen immediately before the tube punctured. Zehnder, recalling the incident after Röntgen's discovery, remembered Röntgen consoling him at that time with the prophetic words: "Many more tubes will have to be punctured before all their mysteries are solved"[5]. Zehnder remained a loyal lifelong friend to Röntgen, in contrast to Philipp Lenard (Fig 4), the most bitter contender for the credit given to Röntgen for the discovery of X rays.

Fig 4 – Philipp Lenard (1862-1947)

RÖNTGEN AND LENARD

Philipp Lenard was born on 7th June, 1862, in Pressburg, Hungary. He had an interest in the luminescence of crystals since his high school days, and pursued this interest throughout his career. He obtained his Ph.D. from the University of Heidelberg and subsequently contributed significantly to the understanding of impurity-activated inorganic phosphors. In 1892, he was appointed as an assistant to the famous physicist, Hertz, at the University of Bonn. Hertz was then investigating the phenomenon of cathode rays, produced by an electrical discharge through an evacuated glass tube. Lenard's interest was sparked by the observations that cathode rays induced fluorescence in substances that were not fluorescent to ultraviolet light(6). It was Lenard's decision to study cathode rays that brought him in communication with Röntgen. To put their relative positions in perspective, Röntgen was then at the height of his career – being internationally-known in his field, holding an important Professorship and Directorship of the new Physical Institute and was on the verge of being appointed Rector of the University of Würzburg; while Lenard, 17 years Röntgen's junior, was still a budding young physicist working under someone else, albeit a famous Professor.

Following up on Hertz's observation that cathode rays could pass through a thin metal foil of gold, silver or aluminium, Lenard constructed a vacuum tube with a thin (0.00265cm) aluminium foil window at one end. On 12th October, 1892, Lenard demonstrated that cathode rays penetrated the aluminium window and travelled through a few inches of room air. For the first time, cathode rays could be studied outside the tube from which they were produced. Lenard made many observations regarding the properties of cathode rays and their effects on matter, for which he was later awarded the 1905 Nobel Prize for Physics.

In 1894, Lenard published a paper entitled "Cathode rays in gases of atmospheric pressure and in extreme vacua", in which he described that cathode rays induced fluorescence up to a distance of 8cm, had a photographic effect up to a distance of 8cm and discharged an electroscope 30cm away. To demonstrate fluorescence, Lenard used principally a screen coated with "keton" (pentadecylparatolylketone), which was an unfortunate choice, on retrospect, as this substance fluoresced brightly when exposed to cathode rays but not to X rays. Hertz actually had a large collection of platinocyanides, including barium platinocyanide which was X ray fluorescent, kept in a locked cabinet but Lenard did not have access to them as "Hertz kept the keys"(7). When he passed the cathode rays through a thin sheet of cardboard, Lenard did not observe fluorescence on the keton screen but yet noted that the photographic material was blackened. He did not offer an explanation for this apparent paradox. To block out the annoying presence of fluorescence in the glass walls of the tube, Lenard enclosed his entire tube in a metal jacket, leaving only the aluminium window unshielded. Looking back, the metal casing would have absorbed much of the "soft" X rays generated by the vacuum tube. His missed observations and experimental techniques contributed to Lenard's failure to identify the X rays that he was producing(8).

Röntgen, as was his practice when embarking on any new field of investigation, wanted to repeat Lenard's experiments and so wrote to Lenard asking him where to find good aluminium foil required for the tube window. On 7th May, 1894, Lenard, much honoured by Röntgen's request, replied by letter and at the same time, sent two of his own aluminium sheets. During the same month, Röntgen repeated Lenard's experiments but used a barium platinocyanide-coated screen to detect fluorescence instead of a keton one, as he was still awaiting the arrival of the keton he had ordered. He placed the barium platinocyanide-coated screen next to his own Hittorf tube and again noted fluorescence. When the keton stock was delivered in July 1894, he found that the keton-coated screen only fluoresced when placed next to the window of the Lenard tube. Unlike barium platinocyanide, keton did not fluoresce in any other position around the Lenard tube and in the vicinity of Hittorf and Crookes tubes(7). Röntgen's work in this area was disrupted by his appointment as the Rector of the University of Würzburg for the academic year 1894-1895. It was soon after resumption of his experiments in the later half of 1895 that he made his discovery of the new rays.

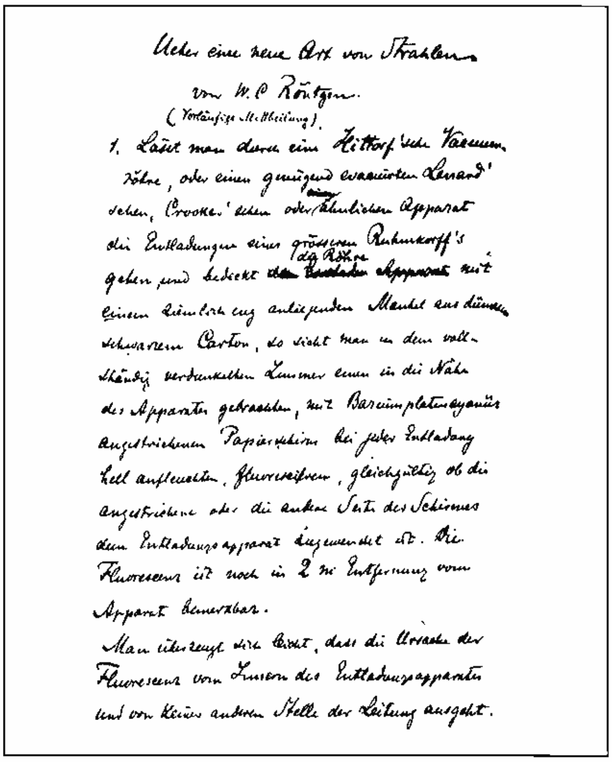
Lenard was acutely disappointed at not being the first to discover X rays, a sentiment reflected in his letter dated 16th January, 1896, less than three weeks after Röntgen's announcement, to his friend and astronomer, Max Wolf: "It is certainly a peculiar situation [I find myself in] with regard to his discovery, one that makes it a rather bitter one for me. Let me fill you in on this matter, according to the "Preliminary Communication" Professor Röntgen sent me, in his local rag". Lenard's name was mentioned five times in Röntgen's famous paper, published in the "local rag", the *Annals of the Würzburg Physical Medical Society.* Lenard's contribution to Röntgen's discovery was widely recognised, with the two scientists sharing many awards; three worth mentioning being the 1896 Baumgartew Prize of the Academy of Science of Vienna, the 1896 Rumford Medal of the Royal Society of London and the 1898 La Caze Prize of the Paris Academy. Somehow, Röntgen and Lenard were never at the same place at the same time, so were fated not to meet in their lifetimes(6).

For the five years following Röntgen's discovery, both scientists continued to correspond, generally expressing mutual respect and admiration for each other. In a letter to Röntgen dated 21st May, 1897, Lenard wrote: "Because your great discovery caused such swift attention in the farthest circles my modest work also came into the limelight, which was of particular luck for me, and I am doubly glad to have had your friendly participation ..... A short while ago, I had repeated my former experiments with cathode rays in the open air to find out whether my former experiments have been disturbed, especially through the presence of rays discovered by you. However, I have found to my satisfaction that this was not the case ...". The beginning of Lenard's great animosity towards Röntgen could be traced to Röntgen's award of the First Nobel Prize for Physics in 1901(7).

Lenard believed himself to be the true discoverer of X rays and started to wage a systematic campaign of disinformation against Röntgen. Even his own award of the Nobel Prize in 1905 did not ease Lenard's hatred for Röntgen. In his Nobel acceptance speech, he tried to play down Röntgen's role saying: "The discovery of X rays ...... by Röntgen, the first one to use the [Lenard] tube, is generally cited as a good example of discovery by accident. But given the tube, ..., it seemed to me that at this stage of development the discovery would follow inevitably". It was never proved which tube Röntgen used in his discovery of X rays, although his assistant Zehnder maintained that it was a Hittorf tube(6). Debates over whether a Lenard tube was utilised, whether or not it was contributory to Röntgen's discovery and even alterations to Röntgen's original manuscript (Fig 5), have surfaced from time-to-time, even in the late 1970s(8-11).

After Röntgen's award of the Nobel Prize, Lenard discontinued referring to Röntgen or X rays, instead took to calling them "high frequency radiation". He disallowed the mention of Röntgen's name in his household or laboratory(6). He was quoted as saying: "I am the mother of the X rays. Just as a midwife is not responsible for the mechanism of birth, so was Röntgen not responsible for the discovery of X rays, which merely fell into his lap. All Röntgen had to do was to push a button, since all the ground work had been prepared by me".

Fig 5 – Röntgen's original handwritten draft of his preliminary communication, "On a New Kind of Rays".


Ueber eine neue Art von Strahlen
von W. C. Röntgen.
(Vorläufige Mittheilung).
1. Lässt man durch eine Hittorf'sche Vacuum-
röhre, oder einen genügend evacuirten Lenard'-
schen, Crookes'schen oder einen ähnlichen Apparat
die Entladungen eines grösseren Ruhmkorff's
gehen, und bedeckt die Röhre mit
einem ziemlich eng anliegenden Mantel aus dünnem
schwarzem Carton, so sieht man in dem voll-
ständig verdunkelten Zimmer einen in die Nähe
des Apparates gebrachten, mit Bariumplatincyanür
angestrichenen Papierschirm bei jeder Entladung
hell aufleuchten, fluoresciren, gleichgültig ob die
angestrichene oder die andere Seite des Schirmes
dem Entladungsapparat zugewendet ist. Die
Fluorescenz ist noch in 2 m Entfernung vom
Apparat bemerkbar.
Man überzeugt sich leicht, dass die Ursache der
Fluorescenz vom Innern des Entladungsapparates
und von keiner anderen Stelle der Leitung ausgeht.

Another example of Lenard's antagonism may be found in his statement referring to his 1897 letter to Röntgen: "In my letter to Röntgen where I praised him for his great discovery I thought he would reply that he owed it all to me and my tube, but I waited for this acknowledgement in vain"[7]. Röntgen's reaction to Lenard's hatred was philosophical, and he refused to reciprocate Lenard's animosity[6,12].

Lenard's intentions to minimise Röntgen's contributions continued unabated following Röntgen's death in 1923. Lenard's close association with the Nazi movement from 1933 to 1945, together with his powerful position as a prominent scientist, gave him further opportunity of erasing Röntgen from the history of physics, in Germany at least. Scientists such as Johannes Stark, Röntgen's successor at Würzburg, F. Schmidt, Assistant Professor of Physics at the Reichsinstitute in Berlin, and Lenard engaged in mutual self-promotion, mainly at Röntgen's expense. During the Nazi ascendency, articles appeared in the popular press suggesting that Röntgen had done nothing remarkable but had merely carried the work of the great Aryan scientist, Lenard, to its inevitable conclusion[7]. Both Lenard's biographical book on great scientists and his four-volume book on German Physics made no mention of Röntgen in the text. In Etter's 1945 interview with Lenard, in reply to the question "Was Röntgen a Jew?" Lenard answered: "No but he was a friend of Jews and acted like one"[7]. Lenard died in Messelhausen, Germany, on 20th May, 1947, without any inkling of how close he had come to sharing the 1901 Nobel Prize with Röntgen.

What Lenard and Röntgen would never know was that the Nobel Prize committee of the Royal Swedish Academy of Sciences had initially recommended that the first Nobel Prize for Physics be awarded jointly to both Röntgen and Lenard. According to the minutes of this Academy committee's deliberations, released about 70 years later, 29 proposals submitted by distinguished scientists were considered. Of these 29 proposals, 12 suggested Röntgen alone, 5 both Röntgen and Lenard, one Lenard alone, with the rest sparsely divided among other physicists. The Academy itself, however, overrode the recommendations of the committee and decided to award the Prize solely to Röntgen[13].

RÖNTGEN'S CONTRIBUTION

By the time Röntgen was appointed to the Chair of Physics at the University of Würzburg in 1888, he had an internationally-established reputation in the field of experimental physics. Still only 43 years of age, he had already published 29 papers, almost all of them in the prestigious *Annals of Physics*. In retrospect, by May 1894, Röntgen had all the equipment at hand that he would need for the discovery of X rays. If not for his one year term of service as Rector of the University of Würzburg, (Fig 6) Röntgen could possibly have made his discovery 18 months earlier. Moreover, Röntgen's experimental set-up differed from Lenard's in several respects, namely: he used a significantly different fluorescent indicator, he wrapped his tube in cardboard instead of metal, he probably used a cathode ray tube other than the Lenard tube, and may have utilised a higher voltage and a higher vacuum[14].

Fig 6 – Wilhelm Conrad Röntgen dressed in the ceremonial robes of the Rector of the University of Würzburg (1894-1895).

Detailed analysis of Röntgen's intellect, human potential and available resources produced the following conclusion: nature had but a small chance of concealing the phenomenon of X rays once a person like Röntgen had decided to study the electromagnetic phenomena associated with gas discharges. Röntgen was able to ask the crucial question as to whether cathode rays were more penetrating than previously indicated, and hence devise and perform the appropriate experiment in order to find the correct explanation to the question[15]. More importantly, Röntgen's genius lay in realising the significance of his observations where others had not. A quotation from Sylvanus P. Thompson's inaugural Presidential address to the Röntgen Society in 1897 perhaps sums it up best: "Röntgen's discovery cannot in any sense be called accidental; it was the result of deliberate and directed thought. He was looking for something – he knew not precisely what. And he found it.

Fortunate the discovery may well be deemed, but not fortuitous."

ACKNOWLEDGEMENT

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