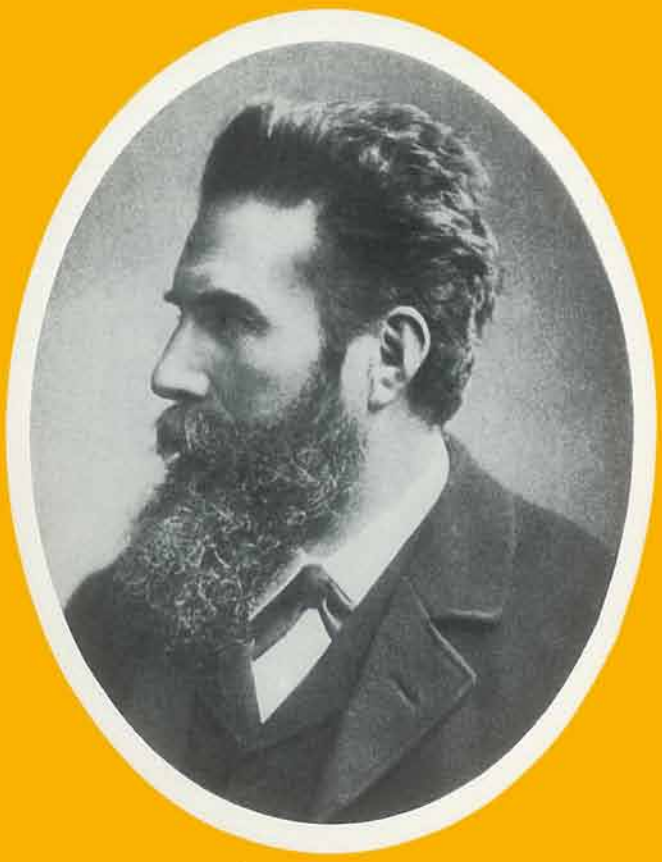
W. C. Röntgen – An European Scientist



Dr. W. C. Röntgen

P. E. Peters, M. D.
Professor and Chairman, Dept. of Clinical Radiology
University of Münster
D-48129 Münster / GERMANY

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Introduction

We tend to assume that moving freely across borders, working or studying in foreign countries is a rather new achievement of European unification. Yet, more than 100 years ago, W. C. Röntgen practised the freedom of travel quite impressively. As a matter of fact, his momentous discovery would not have been possible without the input and the help of friends from different European countries. On the occasion of the Centenary Meeting of the European Congress of Radiology, let us follow W. C. Röntgen's trails through Europe before 1895 and remember how incredibly fast the message from Würzburg spread all over the world.

Childhood and Adolescence

W. C. Röntgen was born on March 27, 1845 in Lennep (today a suburb of Remscheid, Germany) to Friedrich Conrad Röntgen, a distinguished cloth manufacturer, and his wife Charlotte Constanze, nee Frowein.

The house in which W. C. Röntgen was born still exists today at Gänsemarkt 1 (Goose Market 1) and is now part of the German Röntgen Museum, where it houses a large library *(Figure 1)*. Visitors are able to study there in the peace and quiet of a secluded district town.

Figure 1: Röntgen's birthplace at Remscheid-Lennep, Germany (Courtesy Deutsches Röntgen-Museum)

The Röntgen family was well known at Lennep. They had been weavers, cloth manufacturers and merchants there for many generations. His mother was of Dutch origin.

In 1848 many European countries, including Germany, were shattered by revolution. W. C. Röntgen's parents sold their house in Lennep and emigrated to Apeldoorn (The Netherlands).

Wilhelm Conrad attended primary school there, and later a private boarding school, until 1861 when he left home to continue his studies in Utrecht.

He spoke fluent Dutch, and when he submitted his thesis to the University of Zürich (Switzerland) in 1869 he wrote on the front page "Wilhelm Röntgen von Apeldoorn (Holland)". He must have felt very much at home in this Dutch town.

In Utrecht a somewhat curious event took place which was to have a considerable impact on his future life. What would be a harmless student prank by today's standards caused a "consilium abeundi" – in other words, he was expelled from school.

What actually happened has never been completely clarified. According to Glossar's biography, one of Röntgen's classmates had drawn a caricature of a teacher on the firescreen when the teacher unexpectedly arrived and discovered the picture. He became very angry and asked Röntgen to name the culprit, which Röntgen refused to do. The teacher threatened him with suspension and eventually succeeded in having him expelled.

On the advice of friends of his father's, Röntgen studied at home in preparation for the entrance examination at the university. Unfortunately, in the decisive examination one of the examiners was a teacher who had been involved in the suspension proceedings at his former school — with the result that Röntgen failed to secure a place. It seemed that the road to university had been permanently blocked.

Studies in Switzerland

In November 1865 W. C. Röntgen moved to Zürich (Switzerland) and enrolled at the Polytechnical School (today Eidgenössische Hochschule, ETH) which accepted students who — like Röntgen — did not have a normal school leaving certificate, but not until they had passed a strict admission test.

Figure 2:
Röntgen as a student.

He successfully studied mechanical engineering and in 1868 he received his diploma in this discipline *(Figure 2)*.

He continued his studies in close cooperation with August Kundt who had become professor of Physics at the Polytechnical School at the age of only 29. On June 12, 1869 Röntgen obtained his Ph. D. degree from the University of Zürich following submission of his thesis entitled "Studies on Gases".

At the age of 24 W. C. Röntgen became Prof. Kundt's assistant at the Department of Experimental Physics.

However, Zürich was not only the place where W. C. Röntgen took his first successful steps into science; it was also in Zürich he met his wife and made many friends. He lived at "Im Seilergraben 48" in a rented accommodation with widow Hägi and paid 35 Swiss Francs per month including breakfast.

Next to the Polytechnical School was the Café "Zum Grünen Glas" where students and professors met after their daily work. The proprietor, Johann Gottfried Ludwig, was not an ordinary inn-keeper. During the revolution while a student at the University of Jena, he escaped to freedom in Switzerland. In his spare time he acted as fencemaster for the students and also gave private lessons in classical languages. Ludwig had three attractive daughters working in the café. The middle one, Bertha, eventually became W. C. Röntgen's wife, a marriage that lasted almost 50 years.

W. C. Röntgen learned to love the mountains and later in life he used to return to Switzerland for vacation almost every year. Thus, W. C. Röntgen's years in Switzerland were extremely important both for his academic career and for his private life.

Würzburg I – Frustration

W. C. Röntgen's mentor, Prof. Kundt, accepted the Chair of Physics at the University of Würzburg in 1870 and Röntgen followed him there.

Würzburg University, however, considerably impeded the advancement of Röntgen's academic career. Bavarian law barred his academic promotion, both because of his lack of a school leaving certificate and his inability to supply proof of having fulfilled the requirements in classical languages — despite Kundt's efforts on his behalf.

People with less strong nerves than W. C. Röntgen would probably have given up at that point, for the only way to accede to the lofty heights of the academic world in Germany is the "venia docendi", which he was denied.

On November 8, 1995 the University of Würzburg and the State of Bavaria will praise W. C. Röntgen as one of its greatest sons in its almost 600 years-history, and if the State will follow the expected train of thought, the main speaker will say a few regretting words implying that the famous University of Würzburg had not initially recognized the talents of W. C. Röntgen.

Strasbourg – Hohenheim – Strasbourg 1872–1879

Strasbourg, the capital of Alsace-Lorraine, has a very varied history. Located at the border between France and Germany, it belonged alternatively to both countries. Today it is a French city best known for its cathedral, its famous cuisine and for the European Parliament.

In 1871 it happened to be part of Germany and a new German University had just been founded there. Prof. Kundt was invited to be Head of the Physics Department and once again took his assistant with him. This new University was less dogmatic and supported Röntgen in his scientific career. In 1874 he finally became assistant professor and was appointed lecturer at Strasbourg University.

Only one year later, in 1875, Röntgen then aged 30 was appointed Professor of Physics and Mathematics at the Agricultural Academy of Hohenheim (near Stuttgart, Germany). However, he was not happy there because the institute was poorly equipped and this prevented him from carrying out his scientific work.

As a result he readily accepted an offer to become Associate Professor at the University of Strasbourg in order to stay with his former teacher Kundt, and returned there in 1876.

Giessen 1879–1888

W. C. Röntgen's scientific work was well recognized in the scientific community. Thus, at the age of 34 he was offered the Chair of Physics at Giessen University which he accepted. His predecessor was Prof. Buff who had lectured for more than 40 years in his private home. When Röntgen came, a new physics laboratory and lecture hall were built.

The time in Giessen was scientifically very prolific. There he also found some of his most faithful friends and enjoyed game hunting in the surroundings. In his own words he considered the years at Giessen University the most pleasent period of his life *(Figure 3)*.

Figure 3: Röntgen and his wife in Giessen

In Giessen W. C. Röntgen published 18 scientific papers, among other things dealing with pyro- and piezo-electrical phenomena in crystals. In 1888 he discovered the "Röntgen current" which he himself considered as important as — later on — the Röntgen rays.

In 1888 he also received an offer from the University of Jena (Germany) and another one from the University of Utrecht (The Netherlands), both of which he declined.

Würzburg II – Triumph

Later the same year Würzburg University offered W. C. Röntgen the position of a full professorship and the appointment as director of its highly esteemed and well-equipped Physics Department *(Figure 4)*. This offer must have given him great satisfaction since it came from the very university which years before had prevented his academic career. He accepted the appointment and moved back to Würzburg where he received the ultimate academic accolade by being elected "Rector" (President of the University) in 1894.

Figure 4: Institute of Physics of the University of Würzburg (1896)

In his inaugural address, one year prior to the discovery of X-rays, he quoted P. A. Kircher who had occupied the chair of philosophy at Würzburg University in 1602:

> *"Nature often allows amazing miracles to be produced which originate from the most ordinary observations but which are, however, recognized only by those who are equipped with sagacity and research acumen, and who consult experience, the teacher of everything."*

Only after his term as "Rector" he found the time to take up his research on cathode rays again, which lead to the discovery of a new kind of rays on November 8, 1895.

A new kind of rays

The story of the discovery of "X-rays" as Röntgen called them, has been told in countless variations. This is mainly due to the fact that in his will Röntgen requested that on his death all his papers, including his laboratory books, be burned unread. There is thus much room for speculation and relatively little safe historical ground.

One of the most often quoted early sources is that of a journalist (H. J. W. Dam) who visited Röntgen in spring 1896 and published his interview in McClure's magazine in April 1896. In a recent review Patton stressed the fact that the fluorescent material barium platinocyanide constituted the main experimental difference between Röntgen and other scientists of his time (Patton 1993). Even during Röntgen's lifetime, rumors said that the discovery was made more or less accidentally. Yet Röntgen had not only observed fluorescent light on a barium platinocyanide screen, he also demonstrated its nature. He did this with such flawless experimental technique that following the publication of his three papers entitled "On a New Kind of Rays", no publication of equivalent importance was made by any other scientist until 1905 when Charles C. Barkla from Liverpool discovered the so called "characteristic" X-rays.

The prevailing tenor of contemporary discussion regarding the circumstances of Röntgen's discovery is best encapsulated in a comment made by the contemporary philosopher Münsterberg of Harvard University who wrote in a report to Science on January 15, 1896:

> *"Suppose chance helped. There were many galvanic effects in the world before Galvani, by chance, saw the contraction of a frog's leg on an iron gate. The world is full of such chances and the Galvanis and Röntgens are few."*

In his original communication Röntgen reported the experimental set-up and his observations (Röntgen, 1895) *(Figure 5)*.

He acknowledged the achievements of several renowned scientists of his time:

H. D. Rühmkorff (1803–1877) originally built musical instruments. In later life he moved to Paris and became famous for the invention of electromagnetic devices, such as the induction coil alluded to in Röntgen's communication.

J. W. Hittorf (1824–1914), Professor of Physics and Chemistry at the University of Münster, Germany, studied cathode rays and developed a tube with a vacuum more complete than had hitherto been available.

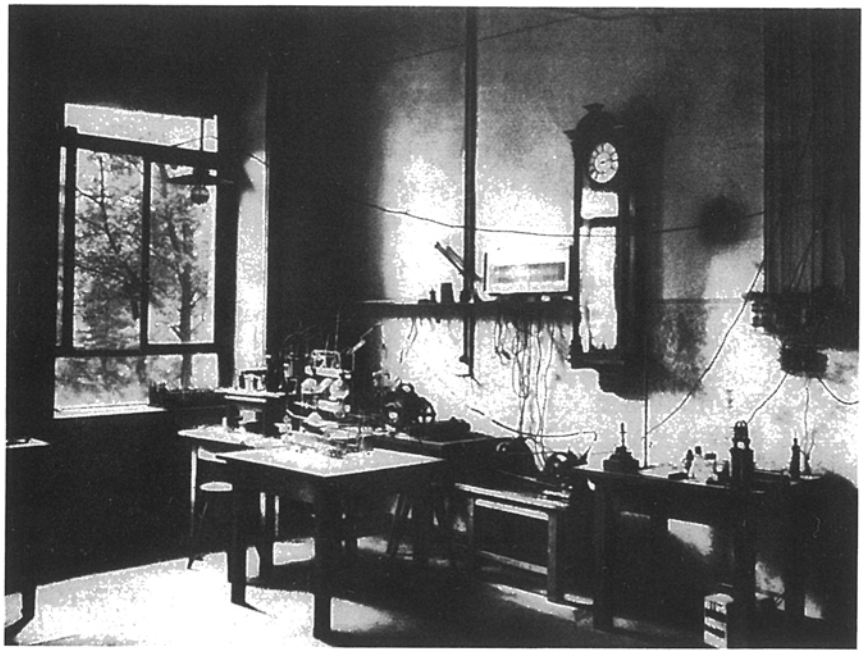


Figure 5:
Laboratory in the Würzburg Institute of Physics. Photograph taken 1923.

Sir William Crookes (1832–1919) built a wide variety of vacuum tubes designed for research into "radiant matter". He was of such renown that even in his lifetime the term "Crookes tube" was used to refer to any kind of vacuum tube.

Lastly, Röntgen referred to P. Lenard (1862–1947) who was awarded the Nobel Prize in Physics in 1905 for his ingenious work on cathode rays. In 1892 he built a tube with rays directed toward a thin aluminium window, for the first time enabling scientists to study cathode rays outside the tube in which they were produced.

It is not known which of these various tubes W. C. Röntgen actually used; in his original communication he merely mentioned the three different types in a general way. Lenard, however, considered himself to be "the mother of X-rays" while Röntgen was "the midwife who happened to deliver the child". Certainly, both scientists were nominated for the first Nobel Prize in Physics in 1901 and the committee recommended that the prize should be divided equally between Röntgen (Munich), and Lenard (Kiel). However, the Royal Academy of Science did not follow this recommendation but decided to award the prize to Röntgen alone. Yet in 1896 the two scientists were jointly awarded the Rumford Medal of the Royal Society of London. Neither of them actually travelled to London to receive his prize and therefore the two men did not meet on this occasion, nor, indeed, on any other.

Following his first observation on Friday, November 8, 1895 Röntgen worked very hard for seven weeks in his laboratory investigating the newly discovered rays. It is said that he even ate his meals in the laboratory and had his bed moved there so that he could work without interruption.

Figure 6: Röntgen picture of the hand of Bertha Röntgen, obtained on December 22, 1895 (Courtesy Deutsches Museum München).

Röntgen had already proved his capability as an experimental physicist and the experimental set-up for the study of the "new light" was carefully planned. To document his observations he used photographic plates. On the evening of December 22, 1895 he asked his wife Bertha to let him photograph her hand, using the new rays. After a fifteen minute exposure the first radiograph of a human being was obtained, showing clearly the bones of the hand and the two rings she was wearing. This date is the true birthday of radiology as a medical speciality *(Figure 6)*.

In retrospect it is apparent that many scientists unknowingly encountered X-rays in the course of their experiments. For example, Crookes complained to Ilford, his supplier of photographic plates, about fogged and blackened plates in unopened boxes. The company replaced the plates but observed that the damage must have occurred in the physicist's institute since no other complaints had been received.

Another well-known case of an unintentional experiment with X-rays is the one reported by Professor A. W. Goodspeed of the University of Pennsylvania which ocurred on February 22, 1890 when he was carrying out studies with Crookes tubes. It was only after the publication of Röntgen's paper that those involved were able to explain the cause of the strange shadowy pictures they had taken six years earlier *(Figure 7)*.

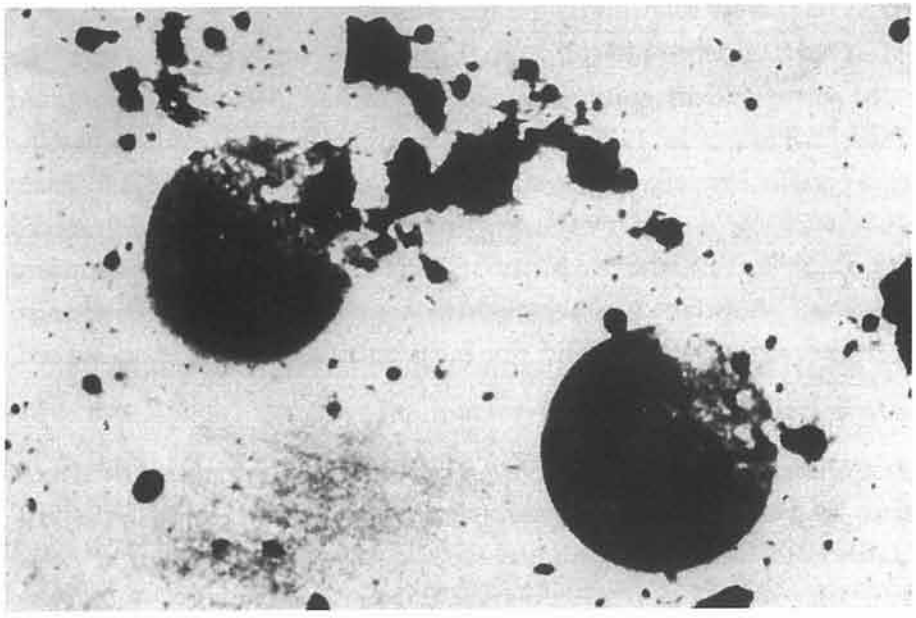
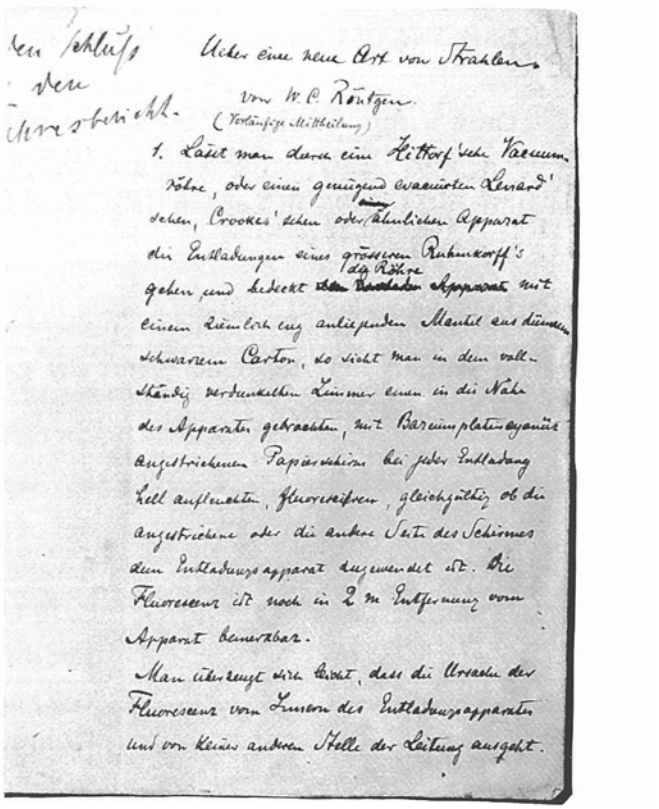


Figure 7: First X-ray shadow picture taken accidentally by A. W. Goodspeed at the University of Pennsylvania, February 22, 1890

Telecommunication in 1895/96

Today scientific publication in high-ranking peer-reviewed international journals requires at least two to three months following submission of the manuscript — in spite of fax machines, satellites and global computer networks. 100 years ago Röntgen's discovery spread all over the world with astonishing speed.

Röntgen submitted his short manuscript "On a New Kind of Rays. First Communication" on December 28, 1895 to the secretary of the Würzburg Physico-Medical Society where the oral presentation was schedulded for January 23, 1896 *(Figure 8)*.



Über eine neue Art von Strahlen.

Von W. C. Röntgen.

(Vorläufige Mittheilung)

Figure 8: First page of the handwritten manuscript "Über eine neue Art von Strahlen" (1895).

Three days later, on January 1, 1896, he had already obtained the preprints of the manuscript and had sent them, together with a few illustrating pictures, to his scientific colleagues and friends as a New Year's Greeting. One of these preprints was sent to his old friend Prof. Exner in Vienna whom he had known since college days in Zürich. Prof. Exner showed manuscript and pictures to a group of physicists who were attending an informal scientific get-together in his home. One member of the group was Prof. Lecher from Prague who asked Exner if he might borrow the material just for one day. Lecher's father was the editor of the Vienna newspaper "Die Presse", and it was he who wrote the first article on the discovery which appeared in the Sunday edition of that newspaper on January 5, 1896. Owing to haste in the preparation of the article, the name of the Würzburg Professor was misspelled as "Routgen". By the following evening, Monday January 6, 1896, the news had been announced to the whole world by cable from London. The press notice read:

> *"The noise of war's alarm should not distract attention from the marvellous triumph of science which is reported from Vienna. It is announced that Professor Routgen (sic) of Würzburg has discovered a light which for the purpose of photography will penetrate wood, flesh and most other organic substances. The Professor has succeeded in photographing metal weights which were in a closed wooden case, also a man's hand showing only the bones, the flesh being invisible."*

The London Standard printed the report on January 7, 1896, adding the following remarks:

> *"Die Presse" assures its readers that there is no joke or humbug in the matter. It is a serious discovery by a serious German Professor.*

While the first reports in New York were published on January 8, 1896 the first report by the local newspaper, "Würzburger Generalanzeiger", did not appear until January 9, 1896.

Thus, within ten days of the submission of the manuscript the news had spread to the entire world, even before Röntgen had presented his findings to the scientific society. On January 23, 1896 an English translation appeared in Nature (London) and two weeks later in Science (USA).

On January 13, 1896 Röntgen presented his work to Emperor Wilhelm II in Berlin and on January 23, 1896 he eventually gave his oral presentation to the Würzburg Physico-Medical Society.

Figure 9: Röntgen picture of v. Kölliker's hand, taken at the Würzburg Physico-Medical Society meeting, January 23, 1896.

On that occasion he demonstrated the properties of the "new rays" by taking a photograph of the hand of Professor von Kölliker, anatomist at Würzburg University *(Figure 9)*. The audience gave him standing ovations after the presentation of his work and von Kölliker recommended to call the new rays "Röntgen rays". This expression became popular in German speaking countries and subsequently specialists using these rays were called roentgenologists. However, the typical German "Umlaut" in Röntgen's name caused serious problems in other countries; therefore his own term "X-rays" became more popular all around the world (X-rays, rayons-X etc.).

The significance of the Röntgen rays in medicine was recognized very early in Germany. The Medical Faculty of the University of Würzburg honored W. C. Röntgen on March 3, 1896 by conferring on him the honorary degree of Doctor of Medicine.

Röntgen rays conquer the world

The tubes and other equipment that Röntgen used were available in most physics laboratories, thus the experiments could be reproduced rather easily. In addition, Röntgen refused to apply for patents and never derived personal profit from his discovery. He actually stated that "... in the good tradition of German University professors ... his inventions and discoveries should belong to humanity and should not in any way be hampered by patents, licences, contracts, or be controlled by one group" (M. Levy quoted by Glasser 1934).

Regardless of Röntgen's personal altruism the first patent applications by commercial companies and individuals were filed as early as February 3, 1896 in England and the United States, and on March 13, 1896 in Germany.

Literally within days physicists, engineers, professional and amateur photographers all over the world produced pictures of living and dead objects and presented them publicly. Glasser in his biography "Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays" (Glasser 1931, 1934, 1959) has carefully compiled the scientific communications in different countries. While these reports are very fascinating, indeed, there are too many to cover them in the context of this short historical article.

Since we are celebrating Röntgen's discovery on the occasion of the European Congress of Radiology, I will — as an "Homage to Vienna", host city of our biannual meeting — briefly touch upon the first days in 1896 here in Vienna.

F. Exner, who involuntarily had been so instrumental in spreading the news almost immediately, started hiw own experiments together with E. Haschek. On January 15 the famous physicist L. Boltzmann demonstrated these pictures to the Vienna Electrotechnical Society. Just as a reminder, this demonstration occurred eight days before Röntgen's first and only public presentation at Würzburg.

A classic early roentgenogram quoted in every historical article, is that of an amputated hand with visualization of the arteries as the first "arteriogram". The study was published January 23, 1896 by E. Haschek and O. Th. Lindenthal. Exposure time was 57 minutes, Teichmann's mixture, consisting of lime, cinnabar, and petroleum, was used as contrast medium *(Figure 10)*.

Eder and Valenta presented a number of X-ray pictures from animals as early as January 22, 1896 and started research on the composition of surgically removed gallstones.

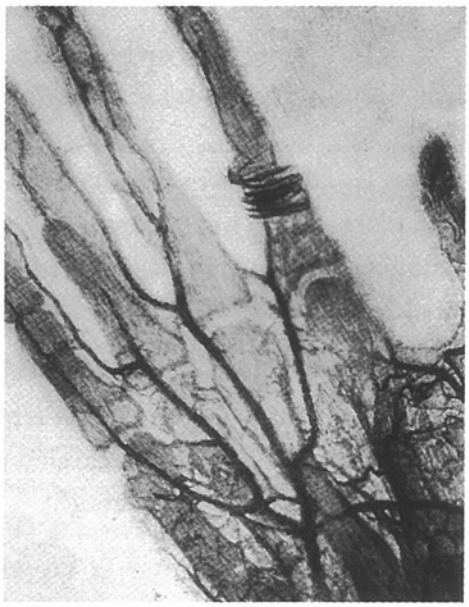


Figure 10: First "arteriogramm" of an amputated hand (Haschek and Lindenthal 1896).

Siegel at the Vienna Department of Internal Medicine stated at the end of January 1896 that "...kidney and bladder stones absorb Röntgen rays like bones, and gallstones are less transparent to the rays than liver tissue, therefore the Röntgen method may well be used in the diagnosis of such diseases" (Siegel 1896).

Vienna continued to be one of the major research centers in the field. G. Kaiser founded a small Röntgen laboratory at the Department of Internal Medicine (II. Medizinische Klinik des Allgemeinen Krankenhauses Wien). Because of severe illness due to ionising radiation he went into private practice and in 1902 G. Holzknecht became the new head of this laboratory. In 1914 an independent Department of Röntgenology was created (Röntgenzentrale des Allgemeinen Krankenhauses Wien), directed by G. Holzknecht. The "Vienna School of Roentgenology" was famous at that time and still is. Scientists such as Meyer, Hitzenberger, Haudek, Schüller, Fleischner, Freund, Zdansky, Kienböck, Holzknecht and many others give evidence of the innovative spirit that prevailed in Vienna.

We all know that this innovative spirit of the Vienna radiology is strong and alive even 100 years later. Therefore it has been a good decision for European radiologists to hold their meeting here.

Honours

During his lifetime W. C. Röntgen has been elected honorary or corresponding member of more than 50 scientific societies and academies from all over the world.

He also became Honorary member of the Röntgen Society London (1897), Röntgen Society Berlin (1903), German Röntgen Society (1905), Swiss Röntgen Society (1913), New York Röntgen Society (1914) and Nordisk Fœrening for med. Radiology (1921).

Röntgen received an honorary M. D. degree from the University of Würzburg (1896), an Honorary Doctorate from the Technical University of Munich (1918) and an Honorary Ph. D. degree from the University of Frankfurt. The cities of Lennep (1896), Weilheim (1909) and Würzburg (1921) awarded Honorary Citizenship to him. Innumerable streets and places have been named after him, starting in 1904 with the Röntgen Street in Cologne. Röntgen was awarded the first Nobel Prize in Physics (1901). He travelled to Stockholm but refused to give an official Nobel lecture. In his will Röntgen bequeathed the Nobel prize-money of 50.000 Swedish Kroners to the University of Würzburg.

The Prince Regent of Bavaria, Luitpold, bestowed upon him the Royal Bavarian Order of the Crown which carried peerage with it. Röntgen accepted the decoration but declined to accept the peerage.

According to Röntgen's biographer, Margret Boveri, who knew him personally as a friend of her family, Röntgen did not like all the excitement created by his discovery. He remained loyal to his friends and continued to live a normal life.

Munich 1900–1923

In 1899 Röntgen declined a call to the University of Leipzig but one year later accepted an appointment at the Philosophical Faculty of the University of Munich on the special request of the Bavarian Government. He took over the Institute of Physics and resumed his research on the physical properties of crystals and the influence of radiation upon crystals. The first world war and post-war depression made his life as well as that of everybody else in Europe very difficult. After the death of his beloved wife Bertha in 1919, Röntgen became very lonely *(Figure 11)*. He retired from the Chair of Physics in 1920 but continued to serve as Curator of the Physico-Metronomical Institute of the Munich Academy of Science. On February 10, 1923 W. C. Röntgen died in Munich from intestinal carcinoma. His mortal remains were put to rest beside those of his wife and his parents in a cemetery at Giessen.

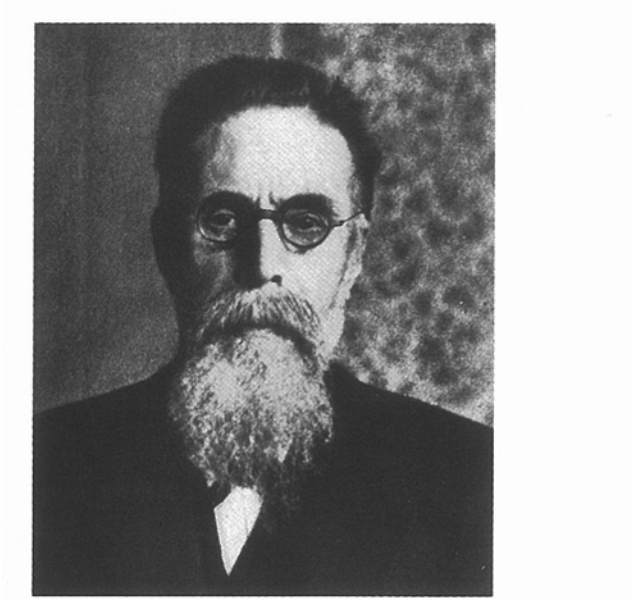


Figure 11: Röntgen a few weeks before his death (1923).

W. C. Röntgen was not a brilliant orator and did not think much of popular lectures on science but he liked to write extensive letters to his friends and preferred to express his thoughts in this way. I would like to conclude this essay by quoting from a spontaneous speech which he made at a torch-light parade given in his honor by the students of Würzburg University.

> *"During the time when congratulations and honors were showered upon me new impressions subconsciously erased older ones, but one thought has always remained lively and fresh in my mind, that is the memory of the satisfaction I felt when my work was finally developed and completed. This is the joy derived from successful efforts and progress. All of you can enjoy this happiness in life and each one of you can and must reach this goal which in principle depends upon your own endeavours. May this happiness, this inner satisfaction, come to you all and may the circumstances permit you to attain this end by treading on a path which is not too difficult."*

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LEGENDS

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Figure 2: Röntgen as a student

Figure 3: Röntgen and his wife in Giessen

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