WILHELM CONRAD RÖNTGEN

1895 – 2020

AN EXHIBITION OF THE UNIVERSITY OF WÜRZBURG

Julius-Maximilians UNIVERSITÄT WÜRZBURG

RÖNTGEN X-RAY
125 JAHRE NEUE EINSICHTEN!

DPG
Deutsche Physikalische Gesellschaft

In 2020, the Julius-Maximilians-Universität Würzburg (JMU) celebrates the discovery of X-rays by Wilhelm Conrad Röntgen 125 years ago – an event that since 1895 has had the greatest global impact in many fields of science and application, and will continue to have far into the future. To accompany the great anniversary year, this catalogue provides insights into Röntgen's scientific career up to his epochal discovery at the University of Würzburg, into its international recognition, and also into the private life of the idealistic scientist. The pictures and exhibits collected here are also a representative selection of two exhibitions that are on display in the anniversary year at the University of Tokyo and Julius-Maximilians-Universität Würzburg. They include material collected for the JMU's publications on the 100th anniversary of the discovery. We are grateful for the provision of photographs to

the Bavarian State Archives Würzburg
the German Museum, Munich
the German Röntgen Museum, Remscheid
the Imperial War Museum, London
the Röntgen Memorial Site, Würzburg
the City Archive, Remscheid
the University Archive, Gießen
the University Archive, Zurich
the Central Library, Zurich.

We would like to thank Siemens Healthcare GmbH for the faithful reproduction of a tube from Röntgen's time and the evaluation of the corresponding correspondence.

 Some of the objects shown were partially damaged by the bombing of Würzburg in March 1945.

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CONTENT

125 YEARS OF NEW INSIGHTS – DISCOVERY OF THE RAYS BY WILHELM CONRAD RÖNTGEN, WÜRZBURG 1895

Dear readers,

An absolutely outstanding event in the history of science is being celebrated for the 125th time: on the evening of 8 November 1895 at Julius-Maximilians-Universität Würzburg (JMU), Wilhelm Conrad Röntgen discovered the rays which were named after him a little later. While Röntgen already enjoyed a high reputation in international circles as an experimental physicist, his revolutionary discovery catapulted him overnight into the spotlight of the global public and made him the winner of the first Nobel Prize in Physics.

Less than two weeks after Röntgen's submission of the first scientific publication, the discovery made its way to the world's press via the new telegraph and was well received, particularly in Japan. The reception and research of X-rays gave a new boost to the long-standing friendly German-Japanese exchange in science at the turn of the 20th century: within a very short time scientists from the University of Tokyo carried out their own X-ray experiments, and as early as 1898 the first X-ray equipment was delivered to Japan by Siemens. To this day, the exchange between JMU and Japan is fruitful and lively and continues to extend to many other fields, including semiconductor quantum structures, space research using picosatellites, chemistry and the life sciences.

In an early preparation phase of the programme in honour of the 125th anniversary of Röntgen's discovery, the idea of holding an exhibition at both the University Museum of Tokyo University and JMU was born. This catalogue presents a cross-section of both exhibitions. The Julius-Maximilians-Universität Würzburg provides original exhibits and historical photographs of the great physicist. Some of the objects have passed into the hands of the university through Röntgen's last will and testament. The exhibition provides insights into Röntgen's school, university education and scientific career before he became head of the Institute of Physics at JMU. It illustrates his discovery, the first experiments with X-rays and documents their immediate global resonance. But it also pays tribute to the private side of an idealistic and modest scientist.

I wish all guests an interesting and stimulating visit to our exhibition and hope you enjoy reading this catalogue.

A. Forchel

Prof. Dr. Dr. h.c. Alfred Forchel
President of Julius-Maximilians-Universität Würzburg

Dear Ladies and Gentlemen,

The year 2020 marks not only 175 years since Röntgen's birth but also the 175th anniversary of the founding of the Physikalische Gesellschaft zu Berlin, out of which the German Physical Society (DPG) emerged. Starting in 1899, Röntgen was a member of the DPG and, in 1919, became an honorary member. As such, I would like to warmly welcome you to this exhibition in the name of the DPG!

Now 175 years after his birth and almost a hundred years after his death, Wilhelm Conrad Röntgen still fascinates. On November 8, 1895, he observed that a fluorescent screen started to glow brightly when near a Lenard's cathode ray tube, even though the tube was covered. This discovery of X-rays was a milestone in science. Very rarely has a scientific discovery not only opened up completely new perspectives and possibilities in research but also spurred medical progress in such a fast and thorough way, providing mankind with manifold new opportunities and benefits.

On December 28, 1895, not even two months after he came across "this new kind of rays", Röntgen published the results of the extensive investigations that he had conducted until then. This "preliminary disclosure" is a paramount example of scientific prose and an impressive attestation of Röntgen's circumspection and profoundness as an experimenter. It electrified science: in 1896, more than 1,000 articles on the new type of radiation were published. In the course of that year, the Physikalische Gesellschaft dedicated seven lectures to X-radiation in which its members presented their own X-ray images and discussed how the apparatuses could be improved. Likewise, the general public took immediate notice: in Vienna, on January 5, 1896, the front page of "Die Presse" carried the headline "A sensational discovery." Instantly, daily newspapers all over the world began to report on the "wonderful triumph in science" (Daily Chronicle, London). This tremendous echo is certainly owed to the X-ray image that Röntgen took of his wife's hand on December 22, 1896. The bones and ring are clearly visible: such a photo—made of the inside of a living person!—had never been seen before. It was immediately evident that a powerful instrument had been made available to medicine.

It is remarkable that Röntgen declined the offer to protect his discovery via patents or to exploit it commercially. In general, he had the opinion that "his findings and discoveries belong to the general public, and should not be reserved to single enterprises due to patents, licensing contracts, and so forth." This circumstance contributed to the practical use of X-rays across a broad front immediately after their discovery. To this date, medicine cannot be imagined without X-rays and, moreover, they are applicable to various other areas.

As for Röntgen himself, X-rays certainly formed only one of various research topics he focused upon in the course of his lifetime. In 1876, he succeeded in proving the spin of the polarization plane of light in gases, an achievement that Michael Faraday and others had struggled in vain to accomplish. Later on, he occupied himself with electro- and thermodynamics but, most of all, he was fascinated by the physics of crystals. Röntgen was a very acute observer, an extremely meticulous experimenter, and a most scrupulous scientist. His character is described as rather introvert, sober, and modest. He refused to accept the title of nobility he was distinguished with and he donated the money that came with the first Nobel Prize in Physics, awarded to him in 1901, to his university. However, it is quite unlikely that he was as unworldly a scientist as he was occasionally classified, otherwise he would hardly have been elected rector of the University of Würzburg in 1893.

The example of Röntgen and the discovery of X-rays show that pioneering innovations in science cannot be planned, but that it would also be wrong to simply ascribe them to chance. Röntgen was a gifted physicist, but he had the freedom to pursue his interests and the opportunity to work with modern equipment as well as deal with current questions. Above all, he had the time and leisure to pursue his ideas without prior intention and driven instead by pure curiosity. In addition, he—and his discovery was also a result of this—had the right instinct and the necessary luck, for which there is the beautiful word "serendipity" in English.

At this point, I would like to build a bridge to the present, because even today it is still true that good science requires liberty and freedom. Young scientists, in particular, unfortunately now face ever-increasing expectations and find themselves under growing pressure to be successful and produce results. Knowledge, however, is not a product that can be manufactured according to predefined plans. More likely, it is won by unintentional interest in the matter itself, by a kind of childlike curiosity—by, I would almost like to say, a forgotten sense of play. Man "is only fully a human being when he plays," Schiller says, and perhaps this applies to scientists. The high scientific ethos to which Röntgen was committed in such an exemplary manner remains topical. Perhaps these two dimensions—the freedom to pursue one's own interests and to demand high standards of one's own work—are much more closely related than it initially appears.

The DPG has dedicated its science festival Highlights of Physics 2020 to the topic of "About Röntgen." Together with Julius-Maximilians-Universität Würzburg and the Federal Ministry of Education and Research, we expect tens of thousands to visit Würzburg in September. I hope that we will be able to familiarize them with who Wilhelm Röntgen was and the impact of his work. Moreover, I hope that we can impart to them the excitement of science and the adventure of physical research.

This wish also applies to you!

Dieter Meschede

Prof. Dr. Dieter Meschede,
Vice President of the German Physical Society

Sources:

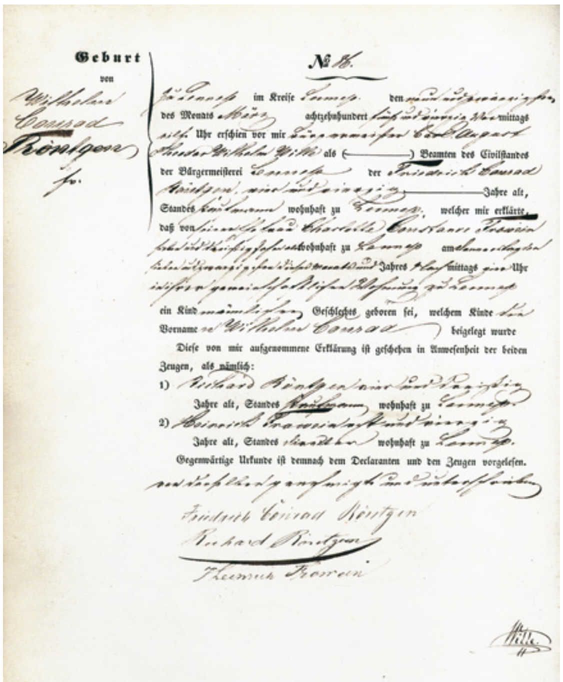
- Albrecht Fölsing, Wilhelm Conrad Röntgen, Aufbruch ins Innere der Materie, Hanser, München/Wien, 1995.
- Jubilee publication 150 Jahre DPG
- Directory of members of the DPG

SECTION I
– BIOGRAPHY OF WILHELM CONRAD RÖNTGEN

Wilhelm Conrad Röntgen was born on March 27, 1845 in Lennep, a small town in North Rhine-Westphalia, Germany. His father, Friedrich Conrad Röntgen, was a cloth merchant from a local family. Röntgen's mother, Charlotte Constance, also came from a Lennep family, but had family ties to the Netherlands. In 1849, the family moved to Apeldoorn in the Netherlands, where Röntgen spent most of his childhood. His parents renounced their German citizenship, and, together with their son, were naturalized as Dutch citizens.

THE HOME OF THE RÖNTGEN FAMILY IN LENNEP

Date unknown / Photograph / German Röntgen Museum, Remscheid



BIRTH CERTIFICATE OF WILHELM CONRAD RÖNTGEN

City Archive Remscheid

The birth certificate states:

No. 86

In Lennep, in the district of Lennep, on the twenty-ninth of the month March, eighteen hundred and forty-five, in the morning at eleven o'clock, appeared before me, Mayor Carl August Theodor Wilhelm Wille, as civil servant of the city hall Lennep, Friedrich Conrad Röntgen, forty-four years old, a merchant residing in Lennep, explaining to me that his wife, Charlotte Constanze Frowein, thirty-seven years old and residing in Lennep, bore him on Thursday the twenty-seventh of this month and year in the afternoon at four o'clock in their jointly shared lodgings, a child of the male gender, to whom the first names of Wilhelm Conrad were given. This declaration, recorded by me, was issued in the presence of both witnesses, namely:

1) Richard Röntgen, thirty-four years old, merchant residing in Lennep
2) Heinrich Frowein, forty-eight years old, director residing in Lennep

The present certificate was accordingly read to the declarant and witnesses, approved, and signed by the same.
Friedrich Conrad Röntgen, Richard Röntgen, Heinrich Frowein
[signed] Wille

(p. 9, LEFT) RÖNTGEN WITH HIS PARENTS, CHARLOTTE CONSTANZE AND FRIEDRICH CONRAD

1862 / Photograph in metal frame, damaged in World War II / University Archive, Julius-Maximilians-Universität Würzburg

(p. 9, RIGHT) RÖNTGEN AT THE AGE OF 17

ca. 1862 / Photograph / German Röntgen Museum, Remscheid

In Apeldoorn, Röntgen spoke Dutch. He spoke Dutch with his parents until his mother died in 1880, which is why Röntgen's German retained a slight accent throughout his life.

Röntgen attended various schools in Apeldoorn. At the age of seventeen, he was sent to live with the Gunning family in Utrecht, where he attended the local technical school. Under the guidance of Jan Willem Gunning, professor of chemistry at the University of Utrecht, Röntgen was introduced to natural science. Unfortunately, the initial prospects of a scientific career for Röntgen seemed dismal. No Latin and Greek courses were offered at the school—both subjects required for enrolling in studies at Utrecht University as well as at German universities. In addition, Röntgen left the school prematurely, before the final examinations. It is said that he was expelled from the school because he did not give information on the origin of a chalk caricature of one of the teachers, which was found with him, but supposedly was drawn by one of his classmates. In any case, the affair ended with Röntgen leaving school in 1863.

Through a school friend, Röntgen learned that the Swiss Eidgenössisches Polytechnikum in Zurich (today, ETH Zurich) accepted students who had not completed their school education, though usually an entrance examination was required in order to enroll. Röntgen had such good grades at the technical school in Utrecht that this condition was waived for him. Thus, Röntgen started his university education in Switzerland in the field of mechanical engineering, corresponding to what is now termed applied mathematics.

EIDGENÖSSISCHES POLYTECHNIKUM IN ZURICH

Ca. 1860 / Wood engraving / Central Library Zurich

Röntgen began his studies in the autumn of 1865, taking courses under Rudolf Clausius (1822-1888), who is regarded as the discoverer of the second law of thermodynamics. Probably he was able to inspire Röntgen for the subject of physics. In 1867 Clausius moved to Würzburg to the chair of physics, which was later held by Röntgen's mentor August Kundt.

There are a number of photographs showing Röntgen together with his classmates at university.

RÖNTGEN AS A STUDENT IN ZURICH

July 17, 1868 / Photograph / German Röntgen Museum, Remscheid

RÖNTGEN WITH FELLOW STUDENTS

1860s / Photograph, damaged in World War II / University Archives Würzburg

RÖNTGEN (ON THE LEFT) WITH HIS FELLOW STUDENTS

Date unknown / Photograph / German Röntgen Museum, Remscheid

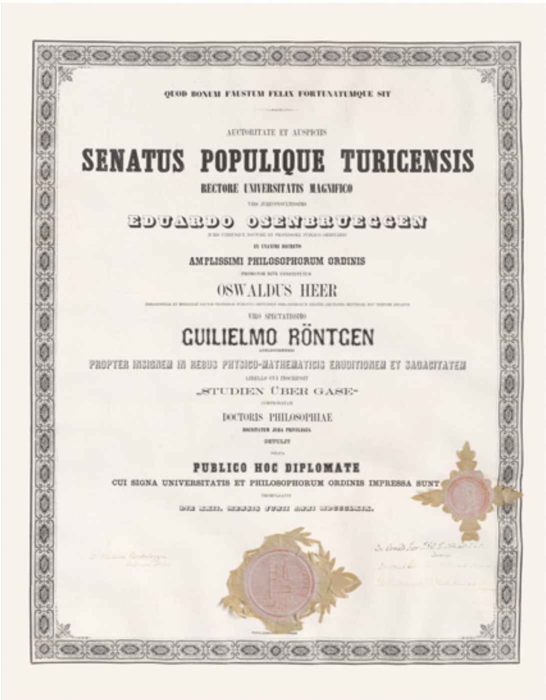
RÖNTGEN'S DIPLOMA CERTIFICATE

Eidgenössisches Polytechnikum Zurich / August 6, 1868 / Print on paper / Röntgen Memorial Site, Würzburg

Röntgen enjoyed his student life and graduated as one of the best in his class. His last report card was excellent, resulting in a mark of 5.8 (6 is the highest and 1 the lowest mark).

With the decision of the Swiss Education Authority of August 6, 1868, Röntgen obtained his diploma as a mechanical engineer from the Polytechnical School of Zurich at the age of twenty-three. His diploma subjects were: higher mathematics, descriptive geometry, chemical technology, metallurgy, civil building, technical mathematics, analytical mathematics, theoretical mechanical engineering, mechanical engineering, and mechanical technology of physics.

In the same year, August Kundt (1839-1894) was appointed as successor to Rudolph Clausius (1822-1888), who had moved to Würzburg in 1867. Kundt was regarded by Röntgen as his mentor in physics.



QUOD BONUM FAUSTUM FELIX FORTUNATUMQUE SIT

AUCTORITATE ET AUSPICIIS

SENATUS POPULIQUE TURICENSIS

RECTORE UNIVERSITATIS MAGNIFICO

EDUARDO OSENBRUEGGEN

EX UNANIMI DECRETO

AMPLISSIMI PHILOSOPHORUM ORDINIS

PROMOTOR RITE CONSTITUTUS

OSWALDUS HEER

VIRO SPECTATISSIMO

GUILIELMO RÖNTGEN

PROPTER INSIGNEM IN REBUS PHYSICO-MATHEMATICIS ERUDITIONEM ET SAGACITATEM

LIBELLO CUI INSCRIPSIT

„STUDIEN ÜBER GASE"

DOCTORIS PHILOSOPHIAE

DIGNITATEM JURA PRIVILEGIA

DETULIT

PUBLICO HOC DIPLOMATE

CUI SIGNA UNIVERSITATIS ET PHILOSOPHORUM ORDINIS IMPRESSA SUNT

RÖNTGEN'S CERTIFICATE FOR HIS DOCTORATE, AWARDED FOR A "STUDY ON GASES" SUBMITTED TO THE FACULTY OF PHILOSOPHY AT THE UNIVERSITY OF ZURICH

The University of Zurich / June 22, 1869 / Print on paper / University Archives Zurich

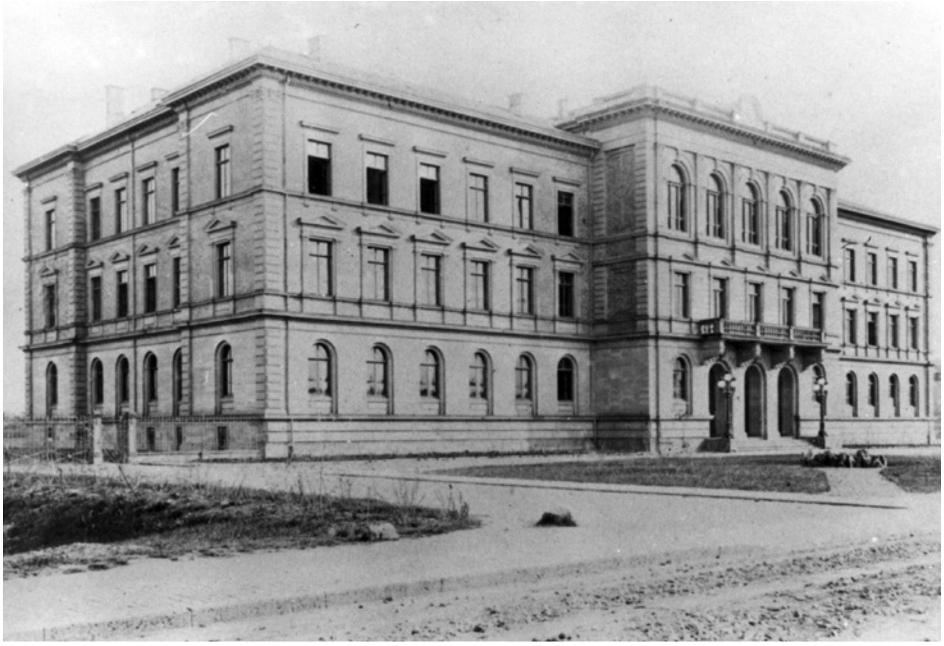
The Polytechnical School could not award doctoral degrees, but the University of Zurich, situated in the same building, was qualified to do so. Candidates were not required to study at the university; they only had to submit an independent scientific paper. Röntgen chose a theoretical topic on the physical relations between the volume and temperature of a gas.

Two reviews were obtained regarding the suitability of Röntgen's paper submitted at the beginning of the summer of 1869 for a doctoral degree. One review was from Albert Mousson (1805-1890), a professor of physics at the University of Zurich. At the end of his assessment, he wrote: "Following this presentation of the contents of the little paper, the same can be described as a mainly independent, scientifically executed paper with theoretically important final results, even though the main point, a new formulation of the Mariotte-Gay-Lussac Law, cannot be considered as adequately proven. In all events, the submitted paper contains more than enough proof of thorough knowledge of the subject and ability to conduct independent research. Thus, my petition is that Mr. W. Röntgen's paper be acknowledged as a fully sufficient basis for obtaining a degree."

SECTION II
– RÖNTGEN'S CAREER IN SCIENCE

THE EARLY YEARS

Physics has quite a long tradition at Julius-Maximilians-Universität Würzburg. In 1628, the famed Jesuit polymath Athanasius Kircher had started addressing questions and ideas in Würzburg that would nowadays be understood as relating to physics. Kircher was such a remarkable generalist that he has been called "the last man who knew everything." It was his research that provided a foundation for the establishment of the academic chair for experimental physics in Würzburg in 1749, despite the primarily hypothetical nature of physics at the time. The chair was located in the old university building, where Röntgen started his work as assistant of Professor Kundt in the spring of 1870.



THE NEW MAIN BUILDING OF GIESSEN UNIVERSITY, BUILT IN THE YEAR RÖNTGEN TOOK UP AN APPOINTMENT THERE

ca. 1879 / Photograph / University and Library Archives Giessen University

Unfortunately, rules for obtaining the right to teach as a lecturer at the University of Würzburg required successfully passing the high school termination exam (Abitur), which Röntgen had not obtained.

It was therefore fortunate for Röntgen that Kundt moved together with him to Strasbourg in 1872, as such rules did not exist there. In Strasbourg Röntgen obtained his lecturer qualification in 1874. In 1875, Röntgen made his first attempt regarding an independent career in science. He accepted the position as a professor of physics at the Academy of Agriculture and Forestry in Hohenheim (near Stuttgart). This was a very small university, consisting of twelve professors and about a hundred students at that time. However, as physics was required there only as a supporting subject for agricultural science, Röntgen decided some months later to return to Strasbourg where he became a physics professor in 1876.

Between 1876 and 1879, Röntgen worked with Kundt on the Faraday effect and the Kerr effect, where the plane of polarization of light is rotated by, respectively, a magnetic or electric field. He also constructed sophisticated measurement systems such as a barometer. The collaboration between Kundt and Röntgen came to an end in 1879 when Röntgen left Strasbourg to take up a chair in physics at the university in Giessen.

(p. 14) THE OLD UNIVERSITY BUILDING OF JULIUS-MAXIMILIANS-UNIVERSITÄT WÜRZBURG, BUILT BETWEEN 1581 AND 1591. IN THIS BUILDING KUNDT'S (AND RÖNTGEN'S) LABORATORIES WERE LOCATED AFTER THEIR MOVE TO WÜRZBURG IN 1870.

Julius von Leypold / 1603 / Copperplate engraving in glass and wooden frame / University Archives Würzburg

In Giessen, Röntgen received a salary of 5,000 marks per year in addition to the student fees he collected. Primarily due to the large number of medical students participating in physics courses, the total income from attendance fees approximately equalled his salary. Each student had a course register, which the professors signed at the beginning and end of every lecture cycle as a proof of participation. Röntgen's working conditions in Giessen improved with the completion of the new university building in Ludwig Street in 1880. There he could use the lecture hall and laboratories. The five laboratory rooms together had the size of approximately 110 square metres (about 1,184 square feet).

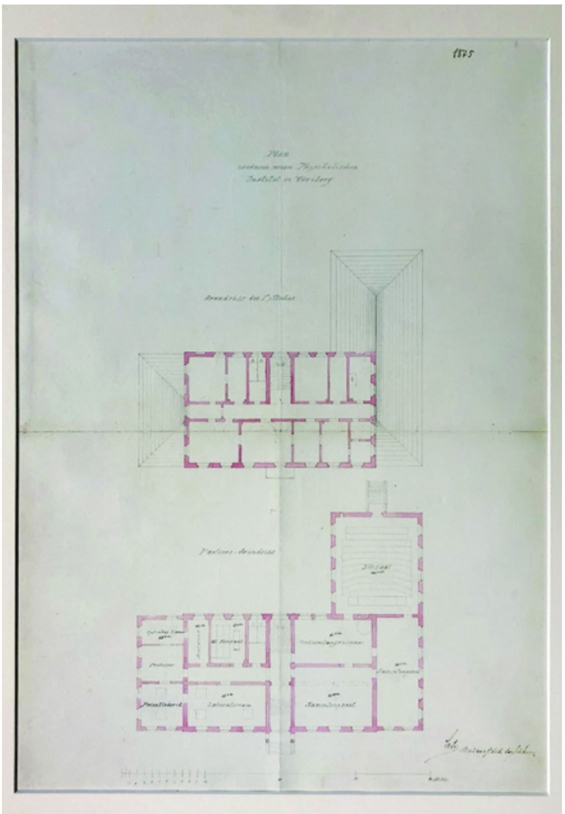
During his time in Giessen, Röntgen investigated the optoacoustic effect in gases. By shining modulated light on gas, he was able to generate acoustic waves. Part of these experiments followed experiments of Alexander Bell (1847-1922), who investigated optoacoustic phenomena in solids. These experiments formed the basis for photoacoustic spectroscopy, which can be used to analyse the molecular composition of gases. Over the following years, Röntgen refused offers of positions at the universities of Jena (1886) and Utrecht (1888).

In 1888, Röntgen proved the existence of the displacement current predicted by James C. Maxwell (1831-1879) as part of his electrodynamical theory (Maxwell's equations). This experiment immediately made him famous.

RÖNTGEN IN WÜRZBURG 1888-1900

In 1888, Röntgen left Giessen to accept an offer from Julius-Maximilians-Universität Würzburg. Here Röntgen succeeded Friedrich Kohlrausch (1840-1910) as physics chair and head of the Institute of Physics. Kohlrausch was a brilliant experimenter and, most importantly for Röntgen, had planned a state-of-the-art building for the Institute of Physics at Pleicherwall in Würzburg, including a special construction to minimize vibrations, the effects of electric fields, and so on in order to permit high-precision measurements.

It also incorporated space for teaching, experiments, workshops, and living quarters for the professor and his family. The entire building, including the living quarters, was connected to the municipal water and sewage system. By creating a gas connection, Kohlrausch was able to install a gas engine with a generator to secure an independent supply of electricity.



FLOOR PLAN OF THE INSTITUTE OF PHYSICS

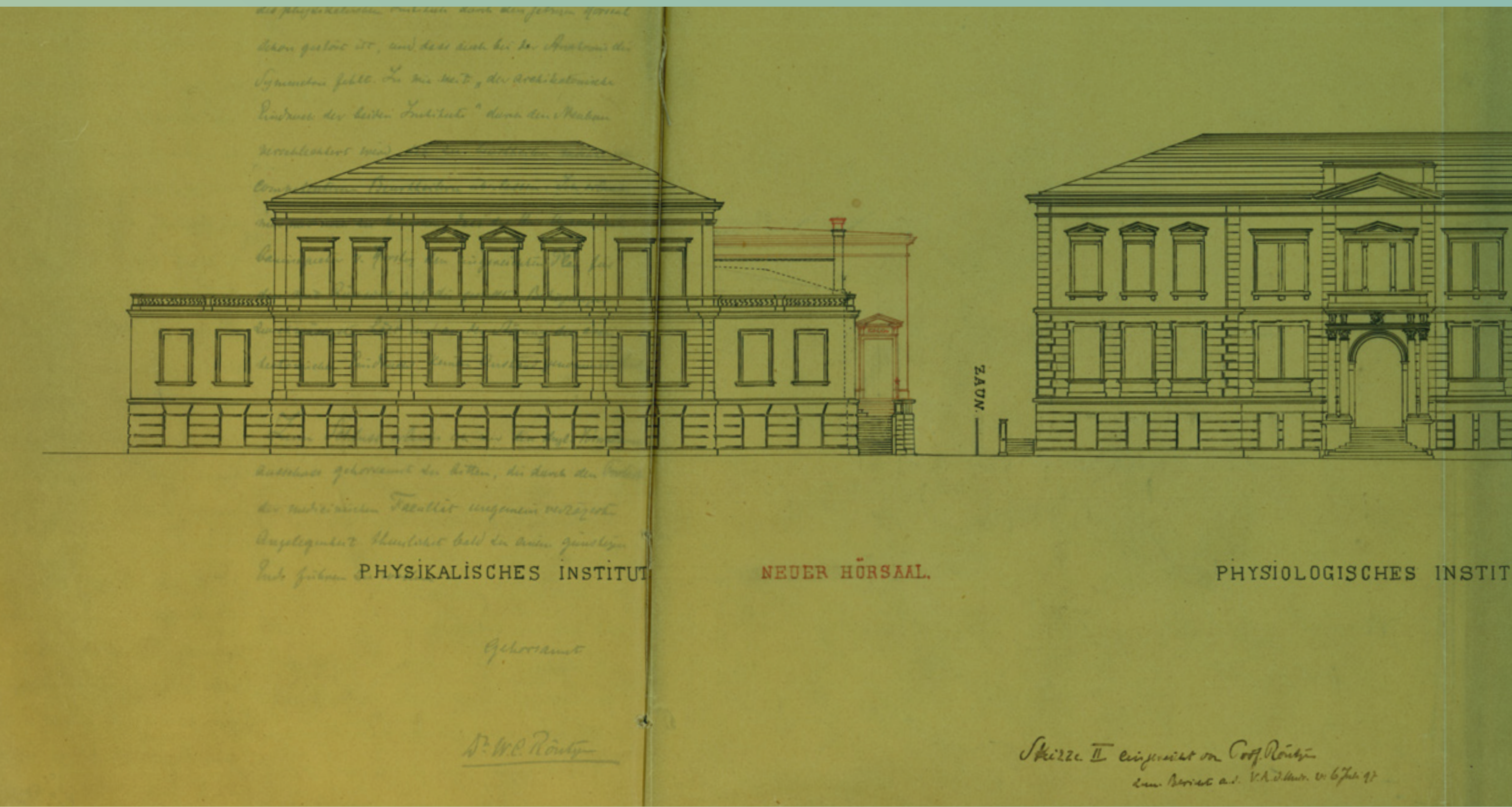
1875 / Paper, cardboard and frame / University Archives Würzburg

Top: top floor professor's apartment
Centre: ground floor with X-ray discovery laboratory (8),
professor's office (7),
lecture halls (1–4)
Bottom: basement with workshops,
laundry facilities, and coal cellar

Röntgen started to teach and do research in the building in 1888 and it is there that the discovery took place. The street in front, at that time called Pleicherwall, was later renamed Röntgenring in his honour.

PHOTOGRAPH OF THE INSTITUTE OF PHYSICS, 1885. THE BUILDING WAS OPENED ON NOVEMBER 8, 1879, BY KOHLRAUSCH, EXACTLY SIXTEEN YEARS BEFORE THE DISCOVERY OF X-RAYS TOOK PLACE IN THE RAISED GROUND FLOOR LABORATORY OF THE LEFT WING.

Ca. 1885 / Photograph / Institute of Physics, University of Würzburg



FACADE OF THE INSTITUTE OF PHYSICS WITH A PERSONAL ADDITION BY RÖNTGEN FOR THE PLANNING OF A NEW LECTURE HALL

Wilhelm Conrad Röntgen / July 6, 1897 / Print and handwriting on paper, University Archives Würzburg

(p. 19) RÖNTGEN IN THE LECTURE HALL IN THE INSTITUTE OF PHYSICS, WÜRZBURG (COLORIZED PHOTOGRAPH)

1890s / Röntgen Memorial Site Würzburg

RESEARCH AND TEACHING IN WÜRZBURG

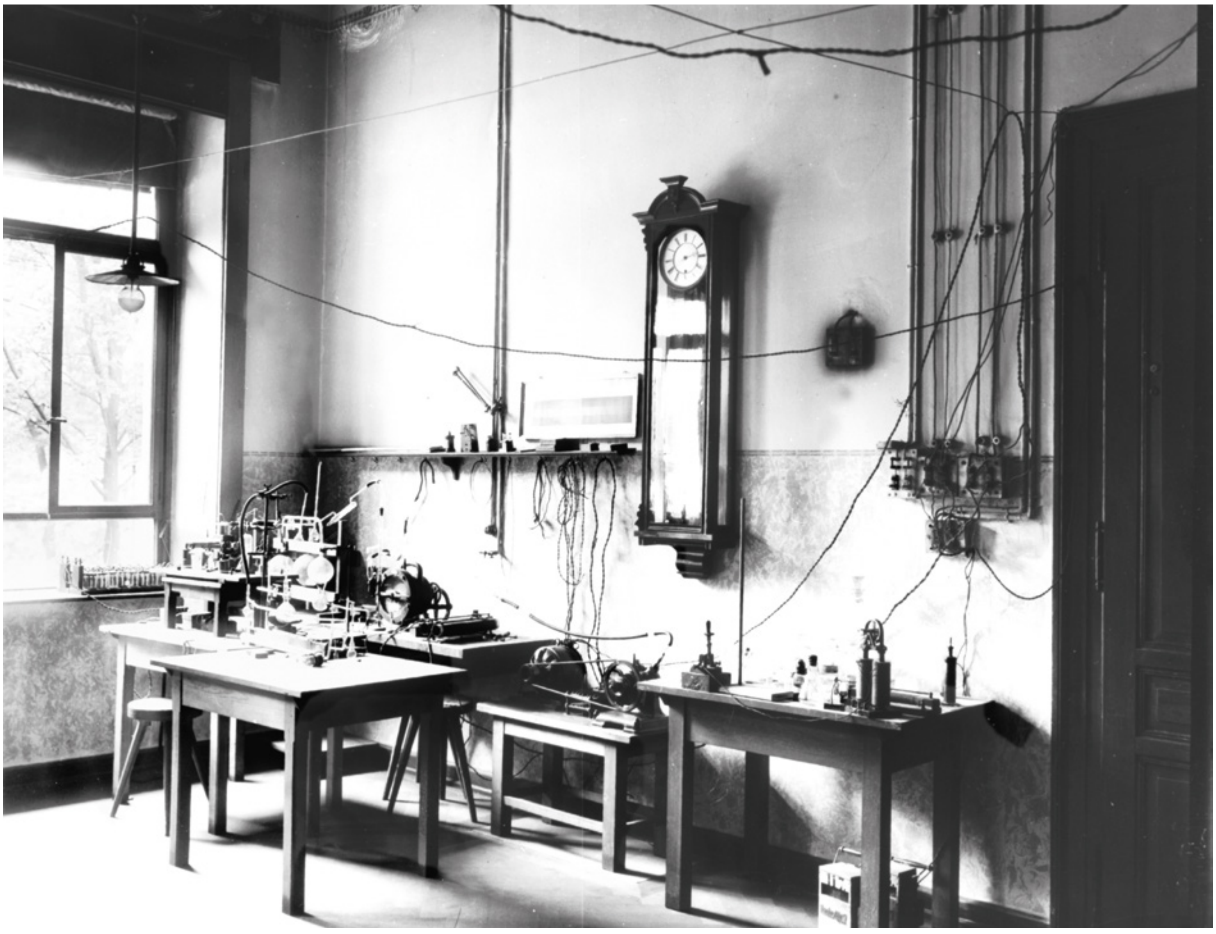
Röntgen enjoyed his time in Würzburg very much. He was a dedicated teacher. Due to the increasing numbers of students, the lecture hall was extended. In the late nineteenth century, Würzburg had approximately 60,000 inhabitants and more than 1,500 students, of whom some 200 attended lectures on physics.

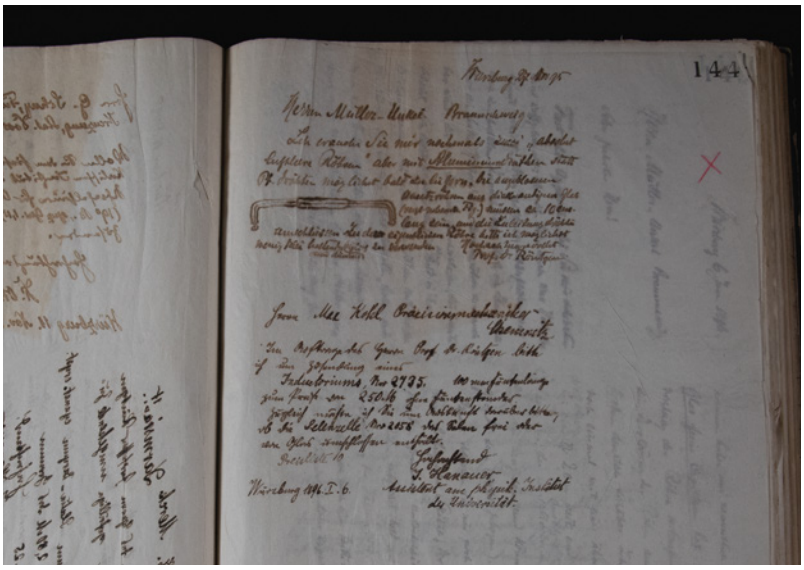
Röntgen continued his research on the influence of pressure upon various physical constants. The special place that water has as a solvent of many substances and its peculiar characteristic of increasing in volume when frozen had caught the interest of many physicists. Röntgen also tried to explain its structure with his analyses.

Other fields of physics interested him, too, as revealed by the physical apparatus inventory lists showing the years of purchase. In 1889, Röntgen purchased for 733 marks a double electrostatic generator, or influence machine, for the production of high tensions and in 1892, he bought two instruments for visualizing Hertzian waves, both probably intended for lecture demonstrations. In the same year, a mercury air pump developed by August Raps (1865-1920) was obtained for 327 marks, which had the ability to produce a powerful vacuum. This acquisition indicates his move toward a new field of research investigating the effects on objects under vacuum conditions.

RÖNTGEN'S LABORATORY IN WÜRZBURG

1890s / Photograph / Röntgen Memorial Site Würzburg





RÖNTGEN'S OUTGOING MAIL BOOK AT THE LABORATORY

Wilhelm Conrad Röntgen / 1888-1900 /
Notebook with handwriting /
University Archives Würzburg

At the beginning of his term of office in Würzburg, Röntgen created a meticulously kept outgoing mail book. It was mainly used for correspondence with companies and partners; orders for instruments and equipment for the Institute of Physics can be tracked using the entries. In the days of the discovery, there was also lively contact with companies: Röntgen complained about a delivery of accumulators, and he placed several urgent orders for barium platinocyanide. In addition, he requested with extreme urgency several custom-made tubes designed by him personally, insisting that the tubes should contain as little lead as possible and have aluminum electrodes. In order to illustrate his wishes, he added hand-drawn illustrations to the orders.

As in Giessen, Röntgen served on various academic committees at the University of Würzburg. In 1893, he was elected to the university council and signed, among other things, Theodor Boveri's (1862-1915) appointment to a chair in biology. On July 12, 1893, he was elected rector of the university for the period of one year, starting in October. lt was a tradition for the rector to open the academic year with a major inaugural speech on the founding day of January 2. Röntgen's speech was about "The History of Physics at the University of Würzburg."

PORTRAIT OF RÖNTGEN AS RECTOR MAGNIFICUS OF JULIUS-MAXIMILIANS-UNIVERSITÄT WÜRZBURG

1893-1894 / Photograph, damaged in World War II /
University Archives Würzburg

AUDITORIUM MAXIMUM (RÖNTGEN STANDING AT THE FRONT RIGHT HAND SIDE)

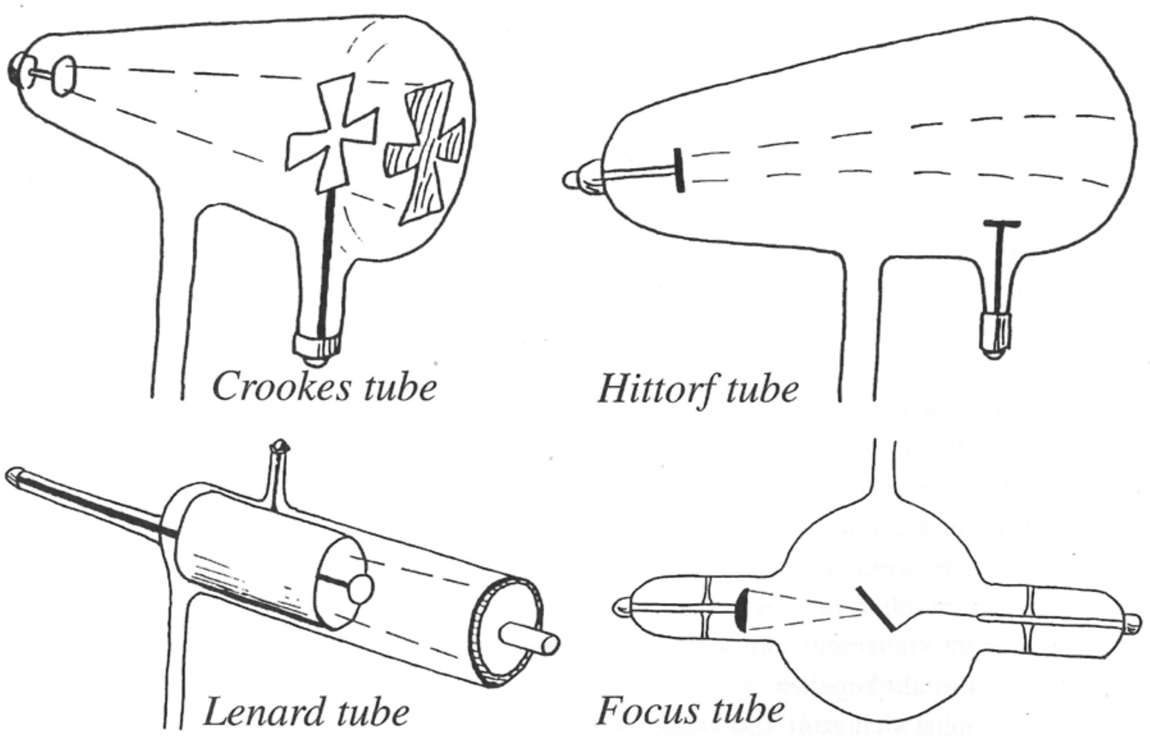
1897 / Photomontage, cardboard / University Archives Würzburg

The rector for 1896, Herman Schell (1850-1906), stands in the centre; to the left, there is the anatomist Albert von Koelliker (1817-1905); Röntgen is to the right. Behind the rector, there are the two beadles carrying the ceremonial maces symbolizing papal and imperial privileges.

SECTION III
– THE DISCOVERY OF THE X-RAYS

Röntgen investigated the emission of gas discharge vacuum tubes with which cathode rays could be generated. Cathode rays themselves had been discovered about twenty-five years earlier. The experiments required a suitable vacuum tube, a pump to evacuate the tube and create a strong vacuum, and a high-voltage generator to observe the effects from the cathode rays.

Gas discharge tubes, with which cathode rays are generated, contain electrodes connected to positive and negative voltage and can be evacuated. When a sufficiently high voltage (50kV or more) is applied to an evacuated tube, the tubes start to fluoresce near the electrode connected to the positive voltage (that is, the anode).



SCHEMATA OF DIFFERENT TUBES

University of Würzburg, Blick. 100 Jahre Röntgenstrahlen, Würzburg 1995, p. 14.

HITTORF-TUBE

2020 / Photograph / Röntgen Memorial Site Würzburg

The fluorescence pattern exhibits shadow effects due to the anode, as would be expected for rays that are emitted by the negative voltage electrode (the cathode). Cathode rays had been discovered in 1869 by Julius Plücker (1801-1868). They were the subject of intense investigations by various scientists including Heinrich Hertz (1857-1894), Hermann von Helmholtz (1821-1894), and Wilhelm Crookes. Johann Wilhelm Hittorf (1824-1914) discovered that cathode rays could be deflected by magnetic fields. Philipp Lenard (1862-1947) designed, among other tubes, one in which a special thin window allowed the detection of cathode rays outside the tube. Without similar precautions, cathode rays would stop after a very short distance.

In 1897, Joseph John Thomson (1856-1940) showed that cathode rays were due to negatively charged particles—until then, unknown electrons.

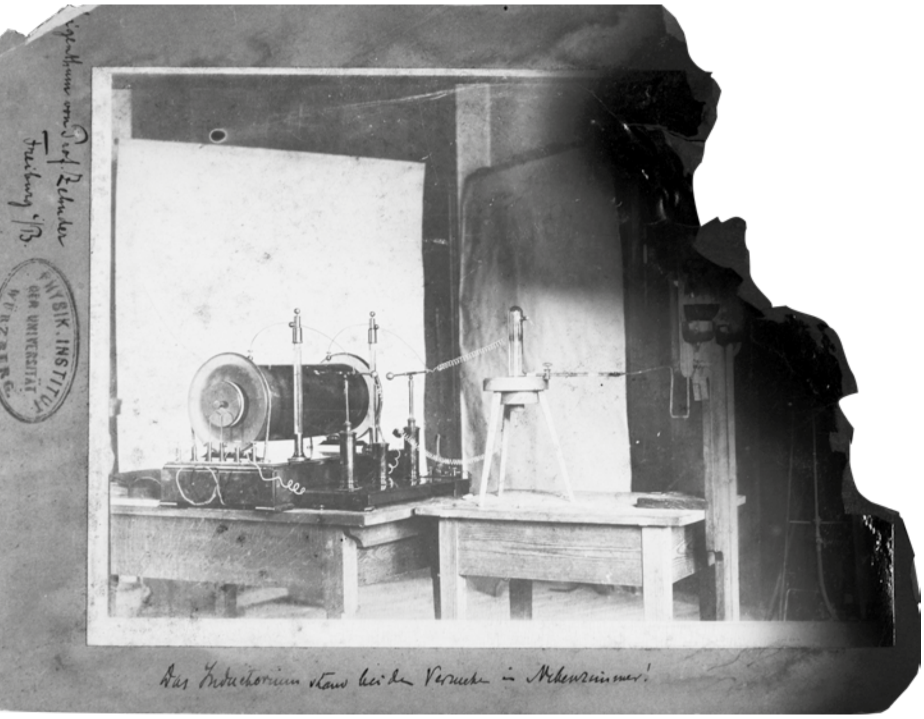
The reference illustration shows a photograph of a tube as used by Röntgen.

An induction coil, also known as a Ruhmkorff coil, was used to generate high voltage. It consists of two concentric coils, the primary coil of thick wire of hundreds of windings and a secondary coil of thousands of turns of thin wire. Both coils are installed on a common soft-iron core and carefully isolated from each other. When the first coil is fed with a self-interrupting electric current, the second coil produces, like a transformer, a much higher voltage of over 10,000 volts. Wires are connected to the two rods from where they lead to the anode or cathode of the tube. The current produced is fluctuating and only flows during discharges, thus causing experiments to be interrupted between discharges.

In order to observe gas discharge effects like cathode rays, the high voltage between anode and cathode has to be supplied to an evacuated tube. The evacuation removes a large part of the air molecules from the volume enclosed by the tube. In the case of the mercury pump (a Raps vacuum pump) purchased by Röntgen for his experiment, only about one out of a million molecules of the ambient air remains in the tube after several days of evacuation. This reduction of the number of molecules allows particles accelerated between the cathode and anode to gain their maximum energy.

A RUHMKORFF COIL, OR INDUCTION COIL, AS USED BY RÖNTGEN

1890s / Wood, metal / Institute of Physics, University of Würzburg



The photograph shows the experiment set-up used by Röntgen for his experiments in 1895. The induction coil is located on the left of the photograph, the tube with cathode and anode connections to induction coil in the centre, and the vacuum pump to evacuate the tube on the right.

EXPERIMENT SET-UP USED BY RÖNTGEN

ca. 1895 / Photograph, damaged in World War II / University Archives Würzburg

With this set-up, Röntgen studied the properties of gas discharges in evacuated Hittorf, Lenard, and Crookes tubes in autumn 1895. For his experiment, Röntgen covered the entire tube with light-tight black cardboard in order to suppress the fluorescence from the cathode rays inside the tube, or, more generally, all conventional light emitted from inside the tube including its walls. The laboratory was kept in darkness so as also to observe faint emission effects from the tube.

On November 8, 1895, while working in his laboratory, Röntgen discovered a new kind of emission, which he called “X-rays.” Although the cathode ray tube was completely enclosed by a light-tight wrapping, he observed fluorescence on a paper covered by barium platinocyanide on one side. The fluorescence occurred regardless of which side was facing the cathode ray tube. It was observable at distances of up to one metre between tube and paper. This excluded cathode rays as the origin. As there was also no possibility for light to leave the light-tight enclosure of the tube, Röntgen concluded that he was observing a new kind of radiation.

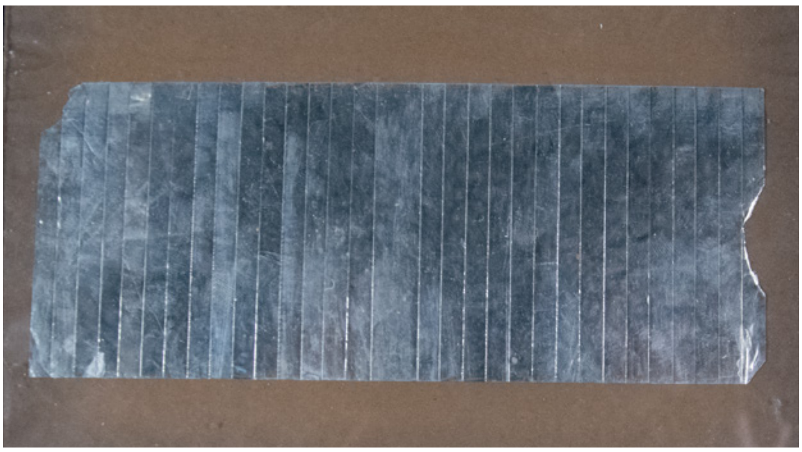
During the following weeks, Röntgen dedicated himself to conducting further experiments with the new kind of rays. It is reported that for several days after the discovery, he spent all day and night in the laboratory, eating his meals and even sleeping there.

DAYS AND NIGHTS OF RESEARCH IN THE WEEKS FOLLOWING THE DISCOVERY

The properties of the rays resulting in the fluorescence of the barium platinocyanide screen discovered by Röntgen on November 8, 1895 were incompatible with known properties of light and cathode rays.

Röntgen carried out a large number of experiments on the new radiation's ability to penetrate all kinds of substances. After having already established qualitatively that the rays could travel through a 1,000-page book, glass, wood, and various metals, he then set out to make quantitative statements about transmission. Since he did not yet have the means to measure the intensity of the invisible rays and the operation of the X-ray tubes was not always stable, he examined two different substances simultaneously with each exposure to work around these limitations.

The attenuation processes due to interactions of the new kind of rays with matter were of particular interest to Röntgen. He had found out the rays were only weakly attenuated after passing through distances of several metres in air. They could also be observed after passing through books and optically opaque media of considerable thickness. The following three figures correspond to findings reported in Röntgen's first publication on X-rays.



TIN SHEET CONSISTING OF VARYING NUMBER OF LAYERS IN A STRIPE PATTERN

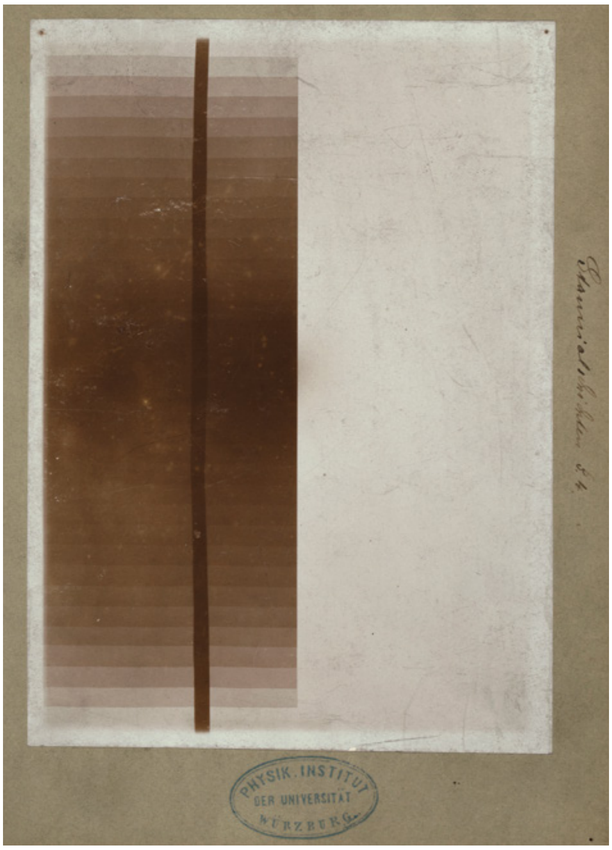
Wilhelm Conrad Röntgen / 1895 /
Layers of foil behind glass / Institute of Physics, University of Würzburg

As part of this investigation, Röntgen established the exponential attenuation of X-rays by matter. In order to investigate this, he used a sequence of tin layers based on a varying number of tin foils. The stripes are formed by one layer of tin foil on the right and left sides of the metal sheet. As they move toward the centre, the number of foil layers forming the stripe's thickness increases by one additional layer per stripe.

The influence of this change of thickness upon the transmission of X-rays is shown on page 31. As seen on both sides, a single sheet of tin foil is almost transparent when radiographed. As the number of layers increases, the transmission of X-rays is strongly attenuated. The number of layers of foil that the radiation is able to penetrate given a constant time of exposure and identical development provides a scale for penetration strength and intensity. This is the basic principle behind the commonly used modern-day film badge or photographic dosimeter that people working with X-ray equipment wear.

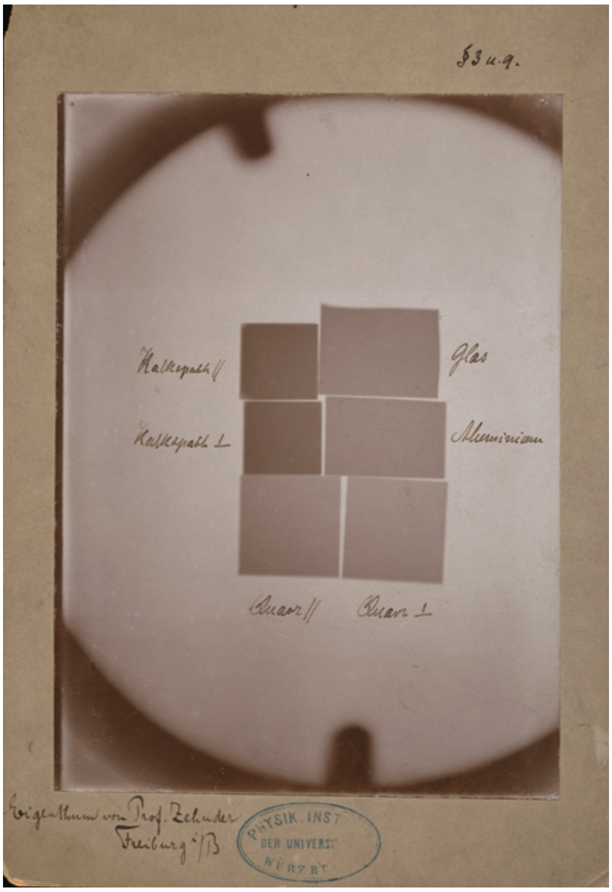
Röntgen also tried to compare the transmissivity of different materials with respect to the newly discovered rays. In the experiment depicted on page 31, he recorded X-ray transmission through glass, aluminium, calcite, and quartz platelets of nominally the same thickness. Röntgen discovered that calcite platelets were far less transparent than fragments made of other materials, but also that the transmissivity of an object correlated inversely with the density of the object. The denser the material, the more difficult it would be for rays to pass through it. By taking photographs, Röntgen documented every important observation.

On December 22, 1895, Röntgen continued his experiments on the transmission of X-rays through matter by exposing the hand of his wife, Anna Bertha, to the rays. Page 32 shows a photograph of the fluorescence intensity of a barium-platinocyanide-covered paper on which the shadow of Anna Bertha's hand is seen, which was placed between the X-ray tube and the paper. The bones of her hand as well as the wedding ring are clearly visible. A single image of this type required between five and ten minutes of exposure as well as several readjustments during that exposure period.



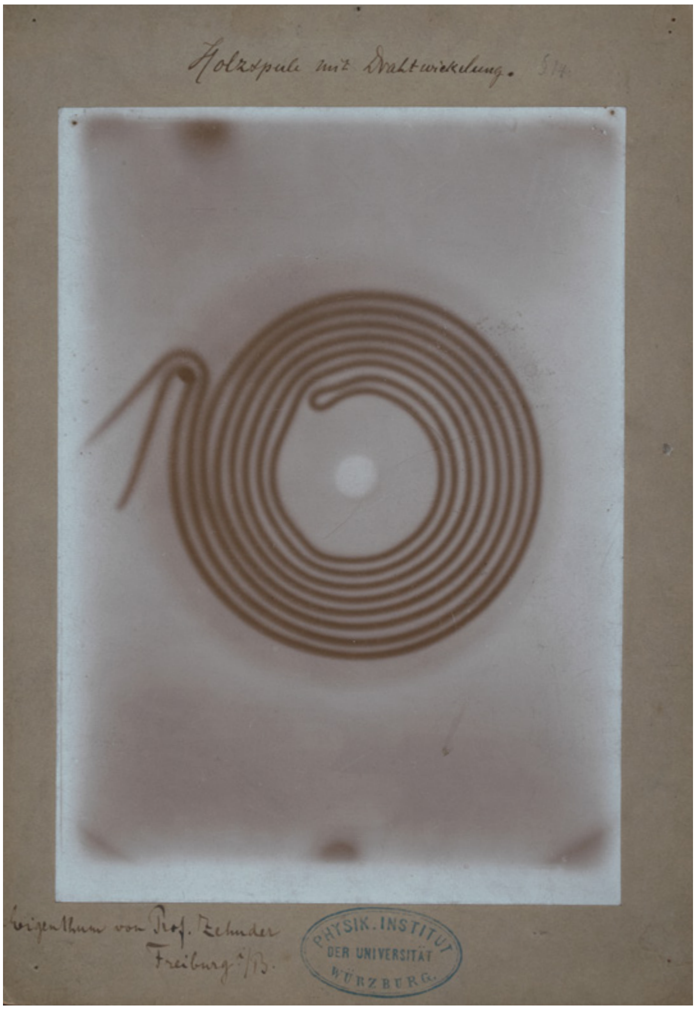
X-RAYS VARIOUS LAYERS OF STANNIOL PAPER

Wilhelm Conrad Röntgen / 1895 / Radiograph, cardboard / University Archives Würzburg



RADIOGRAPH OF DIFFERENT MATERIALS SUCH AS GLASS, ALUMINIUM, CALCITE, AND QUARTZ

Wilhelm Conrad Röntgen / 1895 / Radiograph, cardboard / University Archives Würzburg



(TOP) RADIOGRAPH OF THE HAND OF
ANNA BERTHA RÖNTGEN

Wilhelm Conrad Röntgen / 1895 / Radiograph, cardboard / University Archives Würzburg

(LEFT) RADIOGRAPH OF ONE OF THE FIRST X-RAY EXPERIMENTS: METAL COIL IN A CLOSED BOX

Wilhelm Conrad Röntgen / 1895 / Radiograph, cardboard / University Archives Würzburg

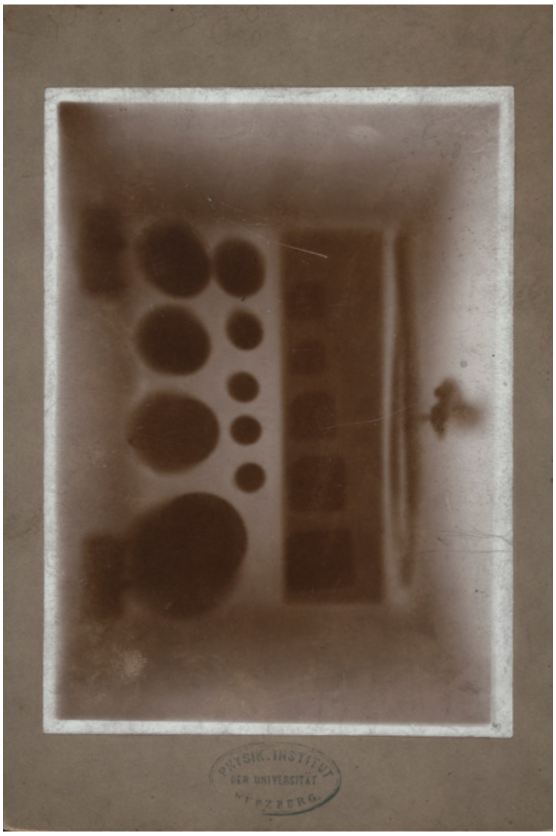
Made of calcium phosphate and calcium carbonate, bones are significantly more absorbent than fibres containing higher proportions of water and compounds of hydrogen, carbon, oxygen and nitrogen, and lower amounts of phosphorous and sulphur. For this reason, silhouettes of the bones can be seen on a radiograph.

This image was distributed together with “On a New Kind of Rays,” the initial report submitted by Röntgen for publication on December 28, 1895. It clearly indicates the huge potential of X-rays for medical applications.

In order to explore the properties of the X-rays further, during the following weeks Röntgen continued research on the attenuation of X-rays in different materials and in zoological objects. His production of the radiographic image of a door opened a new era for X-ray examination of paintings. Röntgen noticed that X-rays distinguished between substances of various absorptiveness. He learned that one section of the door had been painted with a paint containing white lead, resulting in a particularly high absorption.

The radiograph on page 32 capturing an X-ray of a coil in a closed wooden box is the result of one of Röntgen’s very first experiments with X-rays. The coil’s shape and position within the box are clearly visible. This early radiographic image indicates the potential of X-rays for device inspection, by allowing the identification of various components and their placement within a system without the need to dismantle anything.

In this early radiograph (on page 33), Röntgen shows the interior of a closed wooden box in which several mass weights seem to be arranged according to their size. The ability to see through solid objects “sometimes offers a very special attraction,” wrote Röntgen. X-rays continue to be used for this purpose, for example at airport baggage security checks.



(TOP) METAL WEIGHTS IN A WOODEN BOX

Date unknown / Radiograph of metal weights in a wooden box with velvet case / Institute of Physics, University of Würzburg

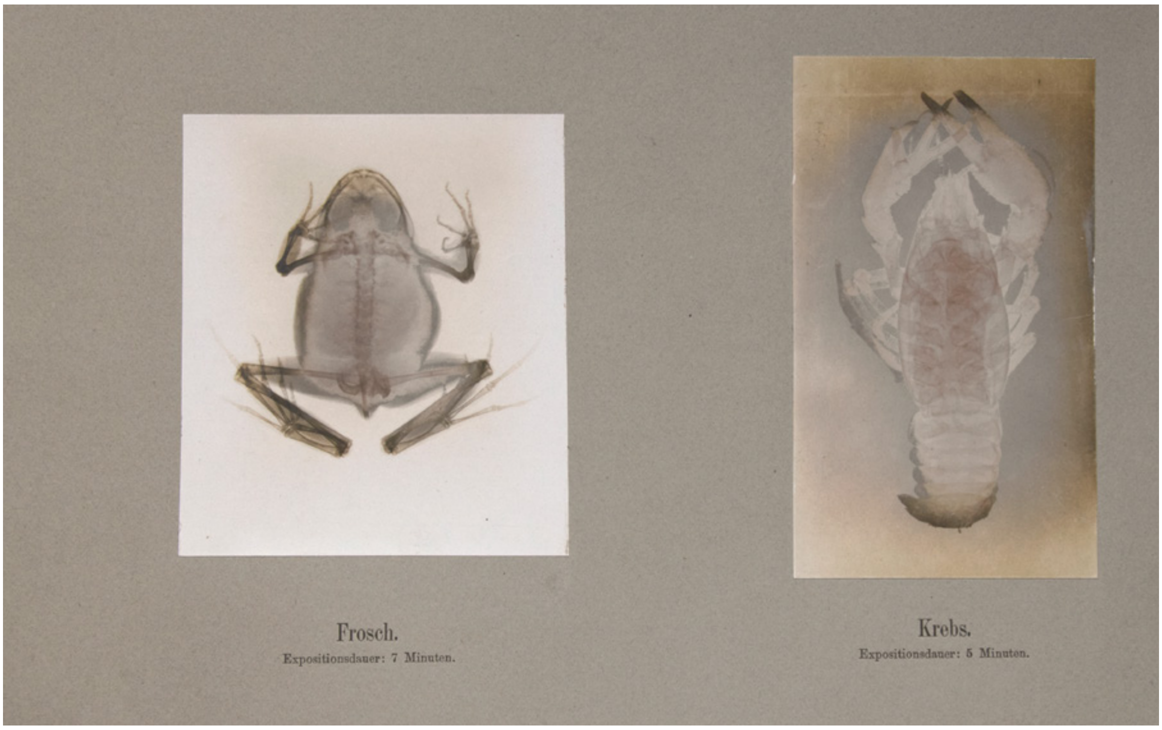
(RIGHT) PHOTOGRAPH OF X-RAYED OBJECTS:
WEIGHT MEASURE SET IN A CLOSED WOODEN CASE

Wilhelm Conrad Röntgen / 1895 / Radiograph, cardboard / University Archives Würzburg

As Röntgen explored the possibilities of his discovery, he also conducted X-ray experiments on animals. The images on this page show a frog and a lobster, both with their skeletal structures clearly visible. The duration of radiation exposure when capturing an image was very important, as Röntgen probably had already found out. Both overexposure and underexposure would impact the quality of the image in a negative way. With this in mind, Röntgen had noted the duration of radiation exposure under both images: seven minutes for the frog and five minutes for the lobster.

RADIOGRAPH OF A FIELDFARE (TURDUS PILARIS)

Date unknown / Radiograph, cardboard / University Archives Würzburg



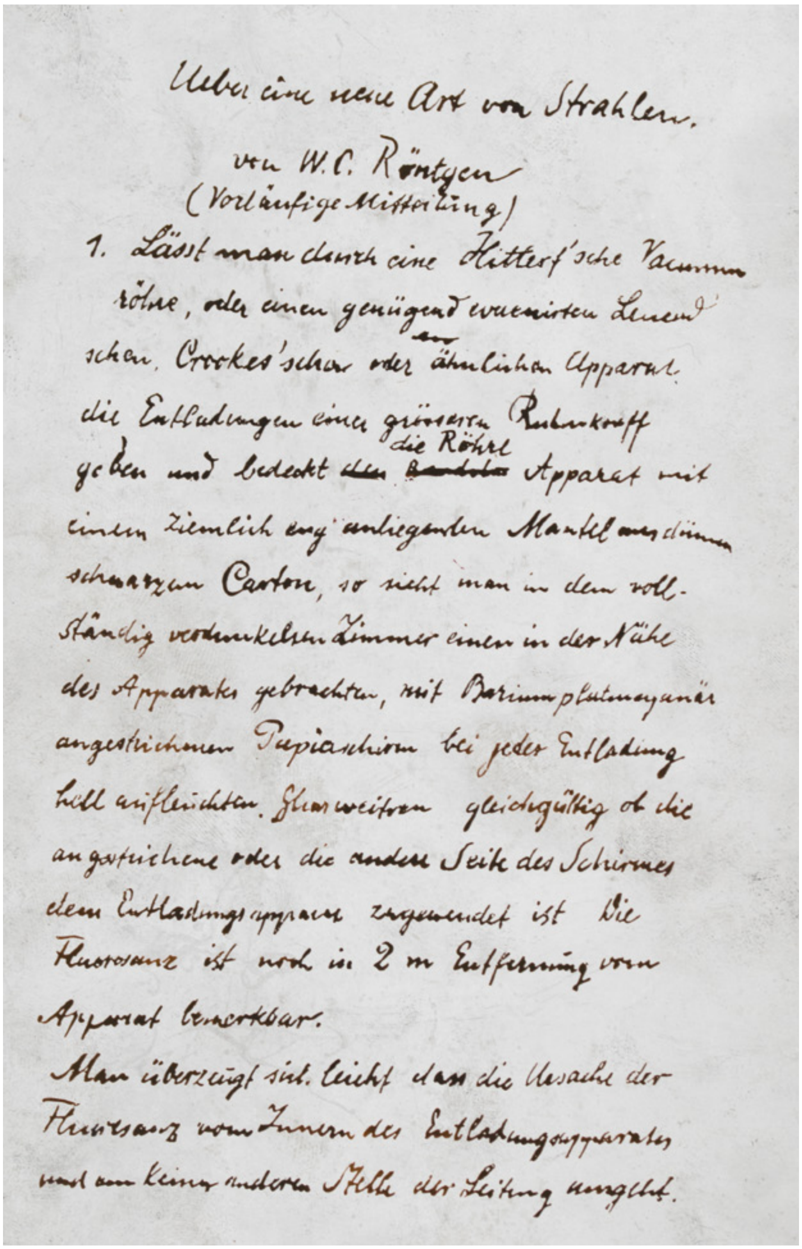
RADIOGRAPHS OF A FROG AND A LOBSTER

Date unknown / Radiograph, cardboard / University Archives Würzburg

On December 28, 1895, after several weeks of intense research, Röntgen submitted a manuscript on his findings to the journal of the Würzburg Physical-Medical Society: “On a New Kind of Rays (Preliminary Notes).”

RÖNTGEN’S PRELIMINARY REPORT TO THE WÜRZBURG PHYSICAL-MEDICAL SOCIETY

Wilhelm Conrad Röntgen / December 1895 / Ink on paper / University Archives Würzburg



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 ähnlichen Apparat
die Entladungen eines grösseren Ruhmkorff
gehen und bedeckt die Röhre ~~den [illegible]~~ Apparat mit
einem ziemlich eng anliegenden Mantel aus dünnem
schwarzem Carton, so sieht man in dem voll-
ständig verdunkelten Zimmer einen in der 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 an keiner anderen Stelle der Leitung ausgeht.

Aus den Sitzungsberichten der Würzburger Physik.-medic. Gesellschaft 1895.

W. C. Röntgen: Ueber eine neue Art von Strahlen.

(Vorläufige Mittheilung.)

1. Lässt man durch eine *Hittorf*'sche Vacuumröhre, oder einen genügend evacuirten *Lenard*'schen, *Crookes*'schen oder 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 vollständig 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 Entladungsapparat und von keiner anderen Stelle der Leitung ausgeht.

2. Das an dieser Erscheinung zunächst Auffallende ist, dass durch die schwarze Cartonhülse, welche keine sichtbaren oder ultravioletten Strahlen des Sonnen- oder des elektrischen Bogenlichtes durchlässt, ein Agens hindurchgeht, das im Stande ist, lebhafte Fluorescenz zu erzeugen, und man wird deshalb wohl zuerst untersuchen, ob auch andere Körper diese Eigenschaft besitzen.

Man findet bald, dass alle Körper für dasselbe durchlässig sind, aber in sehr verschiedenem Grade. Einige Beispiele führe ich an. Papier ist sehr durchlässig:[1]) hinter einem eingebundenen Buch von ca. 1000 Seiten sah ich den Fluorescenzschirm noch deutlich leuchten; die Druckerschwärze bietet kein merkliches Hinderniss. Ebenso zeigte sich Fluorescenz hinter einem doppelten Whistspiel; eine einzelne Karte zwischen Apparat

[1]) Mit „Durchlässigkeit" eines Körpers bezeichne ich das Verhältniss der Helligkeit eines dicht hinter dem Körper gehaltenen Fluorescenzschirmes zu derjenigen Helligkeit des Schirmes, welcher dieser unter denselben Verhältnissen aber ohne Zwischenschaltung des Körpers zeigt.

RÖNTGEN'S FIRST PUBLICATION "ON A NEW KIND OF RAYS"

December 28, 1895 / Journal of the Physical-Medical Society of Würzburg

Die Presse.

№ 5. Wien, Sonntag den 5. Jänner 1896. 49. Jahrgang.

Des Feiertages wegen erscheint das nächste Blatt der „Presse“ Dienstag Früh.

Die heutige Nummer der „Presse“ enthält auf Seite 9 den Verlosungs-Anzeiger Nr. 1.

Wien, 4. Jänner.

Eine sensationelle Entdeckung.

In den gelehrten Fachkreisen Wiens macht gegenwärtig die Mittheilung von einer Entdeckung, welche Professor Routgen in Würzburg gemacht haben soll, große Sensation. Wenn sich dieselbe bewährt, wenn die hierauf bezüglichen Mittheilungen sich als begründet erweisen, so hat man es mit einem in seiner Art epochemachenden Ergebnisse der exacten Forschung zu thun, das sowol auf physikalischem wie auf medicinischem Gebiete ganz merkwürdige Consequenzen bringen dürfte. Wir hören hierüber:

„Professor Routgen nimmt eine Crookes'sche Röhre — eine sehr stark ausgepumpte Glasröhre, durch die ein Inductionsstrom geht — und photographirt mit Hilfe der Strahlen, welche diese Röhre nach außen hin aussendet, auf gewöhnlichen photographischen Platten. Diese Strahlen nun, von deren Existenz man bisher keine Ahnung hatte, sind für das Auge vollständig unsichtbar; sie durchdringen, im Gegensatz zu gewöhnlichen Lichtstrahlen, Holzstoffe, organische Stoffe und dergleichen undurchsichtige Körper. Metalle und Knochen hingegen halten die Strahlen auf. Man kann bei hellem Tageslicht mit „geschlossener Cassette“

FIRST PUBLICATION ABOUT X-RAYS IN THE “WIENER PRESSE”, JANUARY 5, 1896

Röntgen sent around a hundred preprint copies of his report to friends on New Year’s Day, 1896. He had enclosed some of the very first X-ray photos, including that of his wife’s hand. From then on, the sensation spread quickly in the press: after the first newspaper coverage in Vienna’s Die Presse on January 5, 1896, the report was sent to London by telegraph, where it was published the following evening in the London Standard as a “marvellous triumph of science.” Via submarine cable, the news had already made it to American newspapers by January 8.

By the end of the month, Röntgen’s report also made it into prestigious scientific journals. A translation of the Würzburg Physical-Medical Society article was published in Nature on January 23, 1896, followed by L’Eclairage Electrique (February 8, 1896) and Science (February 14, 1896).

VOTE OF CONVOCATION ON THE COWPER COMMISSION SCHEME.

ANOTHER step has been taken in the long controversy with respect to the equipment of the University of London with teaching functions. While the other bodies represented on the recent deputation to the Duke of Devonshire had passed resolutions asking the Government to introduce a Bill similar to Lord Playfair's "London University Commission Bill, 1895," but with an added clause giving a right of appeal to the Privy Council (NATURE, December 5, 1895), Convocation had not expressed any opinion either on the Bill or on the proposed appeal, owing to Lord Playfair's Bill being introduced into the House of Lords too late to allow of a resolution approving its terms to be moved at the last meeting in May. On Tuesday last, the Annual Committee recommended Convocation to adopt the following resolution: "That this House desires the early introduction into Parliament of a Bill for the reconstitution of the University similar to that introduced last year by Lord Playfair, but with an inserted clause securing to the Senate, to Convocation, and to other bodies affected, the right of appeal to the Privy Council on any of the provisions which may hereafter be settled by the Statutory Commission." This resolution was carried by 470 votes against 244, and thus for the third time Convocation, in the only legal way, has pronounced decisively in favour of the Cowper Commission scheme. The progressive rise in the majorities is not the least satisfactory feature of the struggle in Convocation—a majority of 24 in a house of 290 in January of last year rose to 122 in a house of 354 in May, and has now become 226 in a house of 714. The next step rests with the Government, but in view of the remarkable unanimity existing among the bodies affected by the scheme, and the universally favourable attitude of the metropolitan press towards it, we can be in no doubt as to what the final settlement must be.

ON A NEW KIND OF RAYS.[1]

(1) A DISCHARGE from a large induction coil is passed through a Hittorf's vacuum tube, or through a well-exhausted Crookes' or Lenard's tube. The tube is surrounded by a fairly close-fitting shield of black paper; it is then possible to see, in a completely darkened room, that paper covered on one side with barium platinocyanide lights up with brilliant fluorescence when brought into the neighbourhood of the tube, whether the painted side or the other be turned towards the tube. The fluorescence is still visible at two metres distance. It is easy to show that the origin of the fluorescence lies within the vacuum tube.

(2) It is seen, therefore, that some agent is capable of penetrating black cardboard which is quite opaque to ultra-violet light, sunlight, or arc-light. It is therefore of interest to investigate how far other bodies can be penetrated by the same agent. It is readily shown that all bodies possess this same transparency, but in very varying degrees. For example, paper is very transparent; the fluorescent screen will light up when placed behind a book of a thousand pages; printer's ink offers no marked resistance. Similarly the fluorescence shows behind two packs of cards; a single card does not visibly diminish the brilliancy of the light. So, again, a single thickness of tinfoil hardly casts a shadow on the screen; several have to be superposed to produce a marked effect. Thick blocks of wood are still transparent. Boards of pine two or three centimetres thick absorb only very little. A piece of sheet aluminium, 15 mm. thick, still allowed the X-rays (as I will call the rays, for the sake of brevity) to pass, but greatly reduced the fluorescence. Glass plates of similar thickness behave similarly; lead glass is, however, much more opaque than glass free from lead. Ebonite several centimetres thick is transparent. If the hand be held before the fluorescent screen, the shadow shows the bones darkly, with only faint outlines of the surrounding tissues.

Water and several other fluids are very transparent. Hydrogen is not markedly more permeable than air. Plates of copper, silver, lead, gold, and platinum also allow the rays to pass, but only when the metal is thin. Platinum ·2 mm. thick allows some rays to pass; silver and copper are more transparent. Lead 1·5 mm. thick is practically opaque. If a square rod of wood 20 mm. in the side be painted on one face with white lead, it casts little shadow when it is so turned that the painted face is parallel to the X-rays, but a strong shadow if the rays have to pass through the painted side. The salts of the metals, either solid or in solution, behave generally as the metals themselves.

(3) The preceding experiments lead to the conclusion that the density of the bodies is the property whose variation mainly affects their permeability. At least no other property seems so marked in this connection. But that the density alone does not determine the transparency is shown by an experiment wherein plates of similar thickness of Iceland spar, glass, aluminium, and quartz were employed as screens. Then the Iceland spar showed itself much less transparent than the other bodies, though of approximately the same density. I have not remarked any strong fluorescence of Iceland spar compared with glass (see below, No. 4).

(4) Increasing thickness increases the hindrance offered to the rays by all bodies. A picture has been impressed on a photographic plate of a number of superposed layers of tinfoil, like steps, presenting thus a regularly increasing thickness. This is to be submitted to photometric processes when a suitable instrument is available.

(5) Pieces of platinum, lead, zinc, and aluminium foil were so arranged as to produce the same weakening of the effect. The annexed table shows the relative thickness and density of the equivalent sheets of metal.

	Thickness.	Relative thickness.	Density
Platinum	·018 mm. ...	1 ...	21·5
Lead	·050 ,, ...	3 ...	11·3
Zinc	·100 ,, ...	6 ...	7·1
Aluminium......	3·500 ,, ...	200 ...	2·6

From these values it is clear that in no case can we obtain the transparency of a body from the product of its density and thickness. The transparency increases much more rapidly than the product decreases.

(6) The fluorescence of barium platinocyanide is not the only noticeable action of the X-rays. It is to be observed that other bodies exhibit fluorescence, *e.g.* calcium sulphide, uranium glass, Iceland spar, rock-salt, &c.

Of special interest in this connection is the fact that photographic dry plates are sensitive to the X-rays. It is thus possible to exhibit the phenomena so as to exclude the danger of error. I have thus confirmed many observations originally made by eye observation with the fluorescent screen. Here the power of the X-rays to pass through wood or cardboard becomes useful. The photographic plate can be exposed to the action without removal of the shutter of the dark slide or other protecting case, so that the experiment need not be conducted in darkness. Manifestly, unexposed plates must not be left in their box near the vacuum tube.

It seems now questionable whether the impression on the plate is a direct effect of the X-rays, or a secondary result induced by the fluorescence of the material of the plate. Films can receive the impression as well as ordinary dry plates.

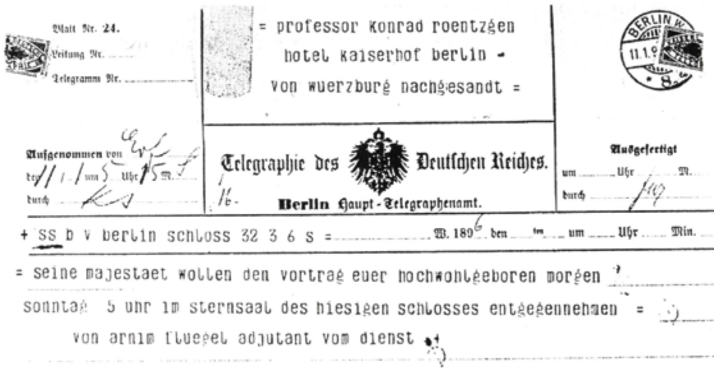
[1] By W. C. Röntgen. Translated by Arthur Stanton from the *Sitzungsberichte der Würzburger Physik-medic. Gesellschaft*, 1895.

TRANSLATION OF RÖNTGEN'S REPORT
"ON A NEW KIND OF RAYS" IN NATURE, JANUARY 23, 1896

On Saturday, January 11, 1896, the newspapers announced that Röntgen had received an invitation from the German emperor (the Kaiser) to present his new discovery on Sunday afternoon at the royal palace in Berlin. The emperor was very interested in science and in technological developments. As crown prince, he had personally presented a phonograph invented by Thomas Edison (1847-1931) to the court, after having been initiated into the instrument's secrets by a company representative.

THE GERMAN EMPEROR WILHELM II

ca. 1887 / Photograph / Imperial War Museum, London



Amt Nr. 24.
Leitung Nr.
Telegramm Nr.

= professor konrad roentzgen
hotel kaiserhof berlin -
von wuerzburg nachgesandt =

Aufgenommen von
Telegraphie des Deutschen Reiches.
Berlin Haupt-Telegraphenamt.
Ausgefertigt

+ ss b v berlin schloss 32 3 6 s = W. 1896 den

= seine majestaet wollen den vortrag euer hochwohlgeboren morgen
sonntag 5 uhr im sternsaal des hiesigen schlosses entgegennehmen =
von arnim fluegel adjutant vom dienst

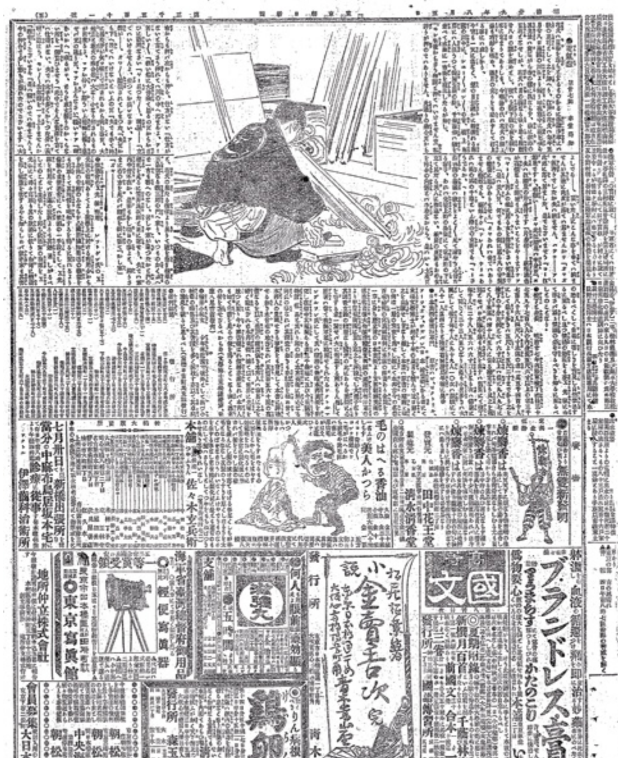
TELEGRAM FROM EMPEROR WILHELM II TO RÖNTGEN

"His Majesty would like to hear Your Excellency's lecture tomorrow, Sunday 5 o'clock at the Sternsaal of the local castle – von Arnim, Adjutant in Charge."

Arnim Fluegel / January 11, 1896 / Telegram / German Röntgen Museum, Remscheid

The imperial invitation also attracted the attention of the international press. On January 19, the New York Times reported that "Emperor Wilhelm had Prof. Röntgen to rush from Würzburg to Potsdam to give an illustrated lecture to the royal family on his alleged discovery of how to photograph the invisible." Only a week later, the same newspaper summarized: "Röntgen's photographic discovery increasingly monopolizes scientific attention. Already numerous successful applications of it to surgical difficulties are reported from various countries, but perhaps even more striking are the proofs that it will revolutionize methods in many departments of metallurgical industry."

The news of Röntgen's discovery also reached Japan. Several newspaper reports were already published in 1896, among others in the newspaper Asahi Shimbun, which is shown in the picture below.



NEWSPAPER REPORT FROM JAPAN

August 5, 1896 / Newspaper / Asahi Shimbun, Tōkyō edition

THE MEETING OF THE PHYSICAL-MEDICAL SOCIETY IN WÜRZBURG

January 23, 1896 / Colorized photograph / Röntgen Memorial Site Würzburg

(BOTTOM)
RADIOGRAPH OF THE HAND OF PROFESSOR ALBERT VON KOELLIKER AT THE MEETING OF THE PHYSICAL-MEDICAL SOCIETY IN WÜRZBURG

Wilhelm Conrad Röntgen / January 23, 1896 / Radiograph, copy in a magazine / University Archives Würzburg

Despite his global fame, Röntgen remained a scientific idealist throughout his life. American companies offered him a lot of money to exploit his discovery. The ever-modest Röntgen, however, never filed a patent. It was more important to him that the new rays could be used quickly everywhere for the benefit of all people instead of marketing them to his advantage.

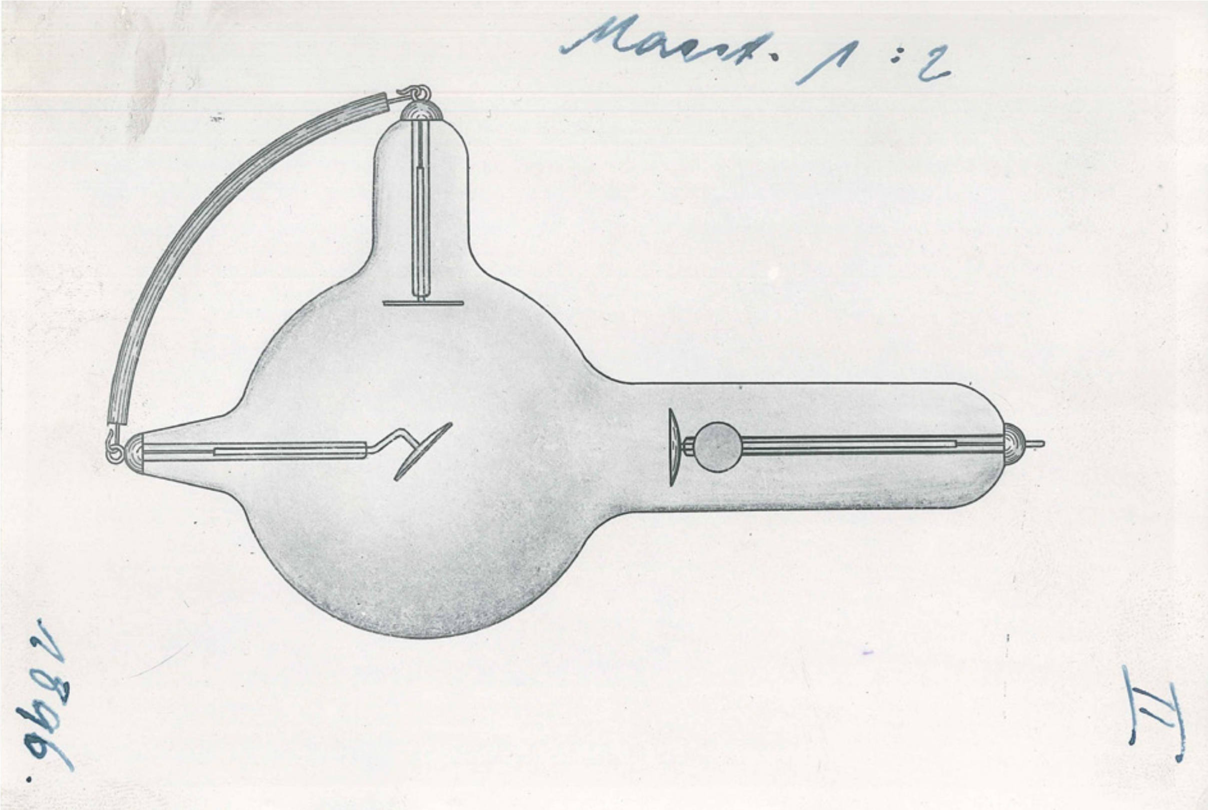
The only public lecture Röntgen ever held on his discovery was for the Würzburg Physical-Medical Society and took place on January 23, 1896, in the auditorium of the Institute of Physics. He demonstrated the effects of the new radiation with numerous experiments and handed around his radiographs of the wooden spool, the set of measures, and his wife's hand. In conclusion, Röntgen asked the Chairman of Medicine, His Excellency Albert von Koelliker, a privy councillor and anatomy professor, to be allowed to photograph his hand with the new radiation. The exposure was apparently developed immediately at the institute and the sharply focused radiograph was shown to attendees. In expressing his thanks, von Koelliker noted that in the forty-eight years of his membership of the Würzburg Physical-Medical Society, he had never witnessed such a splendid and important presentation as at that meeting.

He closed his speech by giving three cheers to the discoverer with the entire audience enthusiastically joining in. He then proposed that in the future X-rays be called "Röntgen rays," which was greeted with a rousing ovation.

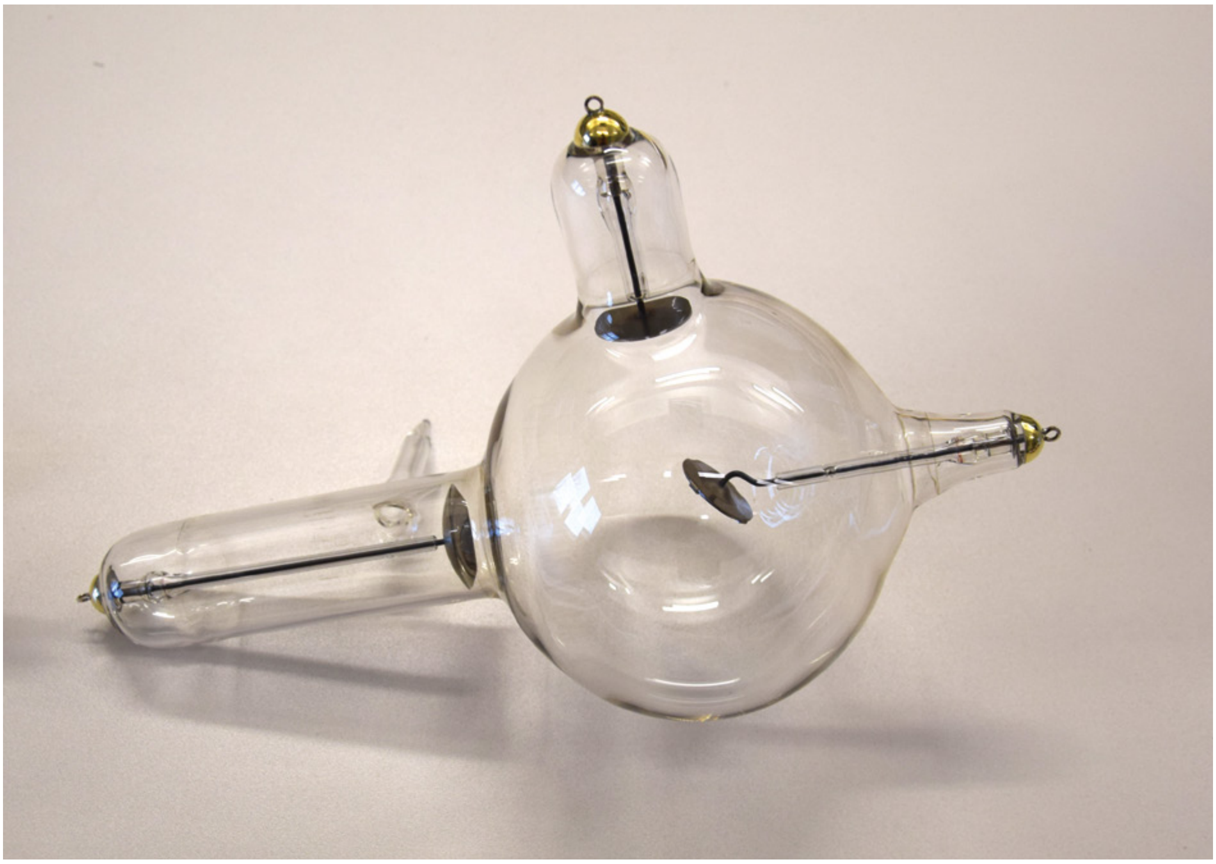
X-RAY WITH A SMALL TUBE MADE BY THE COMPANY REINIGER, GEBBERT & SCHALL (RGS), TEMPLATE FOR THE STATUE AT THE POTSDAM BRIDGE IN BERLIN

1896 / Photograph /
German Röntgen Museum, Remscheid

In mid-January 1896, the newly discovered rays had already found their way into medical application. However, many doctors had to recognise the limited technical possibilities, as only a few of the early radiologists had the necessary knowledge. As a consequence it was not unusual for the tubes used, which were often unsuitable for this purpose, to burst causing damage to patients and equipment. Therefore, Heinrich Albers-Schönberg (1865-1921), the first radiologist and founder of radiology in Germany, advised covering patients' faces with a cloth in order to protect their eyes in case of possible explosions. Soon, however, suitable tubes were to be made available to the new discipline. Max Gebbert, the owner of the Erlangen-based company Reiniger, Gebbert & Schall (RGS), which specialises in medical technology and is the second oldest root of Siemens Healthineers after Siemens & Halske, sent one of his colleagues to Würzburg in order to meet with Röntgen three days after the discovery became known. Röntgen, however, did not receive Robert Fischer, but had his assistant show him the experimental set-up. With the help of the high-voltage current engineer Josef Rosenthal, X-rays were successfully generated. Rosenthal recognised the special need for suitable tubes and, using an X-ray tube specially designed for medical use, took a picture of the head of a living sixteen-year-old girl and sent the picture to Röntgen. A few days later, on 2 November 1896, he received a postcard from Würzburg with Röntgen's thanks, and an order for two vacuum tubes of his design. The tubes, which were sent, were very well received in Würzburg and were immediately re-ordered. It was such a smaller RGS tube with which Röntgen modelled for a statue, which was erected on the Potsdam bridge.



TECHNICAL DRAWING OF AN X-RAY TUBE MADE BY THE ERLANGEN COMPANY REINIGER, GEBBERT & SCHALL (RGS), 1896



X-RAY TUBE FOR MEDICAL PURPOSES PRODUCED BY SIEMENS-HEALTHINEERS WITH THE HELP OF TECHNICAL DRAWINGS FROM 1896.

Jörg Linke, Stefan Werner and Andre Knäblein / 2020 / Rudolstadt

SECTION IV – HONOURS

SCIENTIFIC HONOURS

The discovery of X-rays immediately spurred researchers worldwide to use the new rays in different fields including physics, medicine, and material analysis. As the application potential especially in medicine became evident, several companies started to develop systems for X-ray inspection of humans in 1896 or shortly afterward.

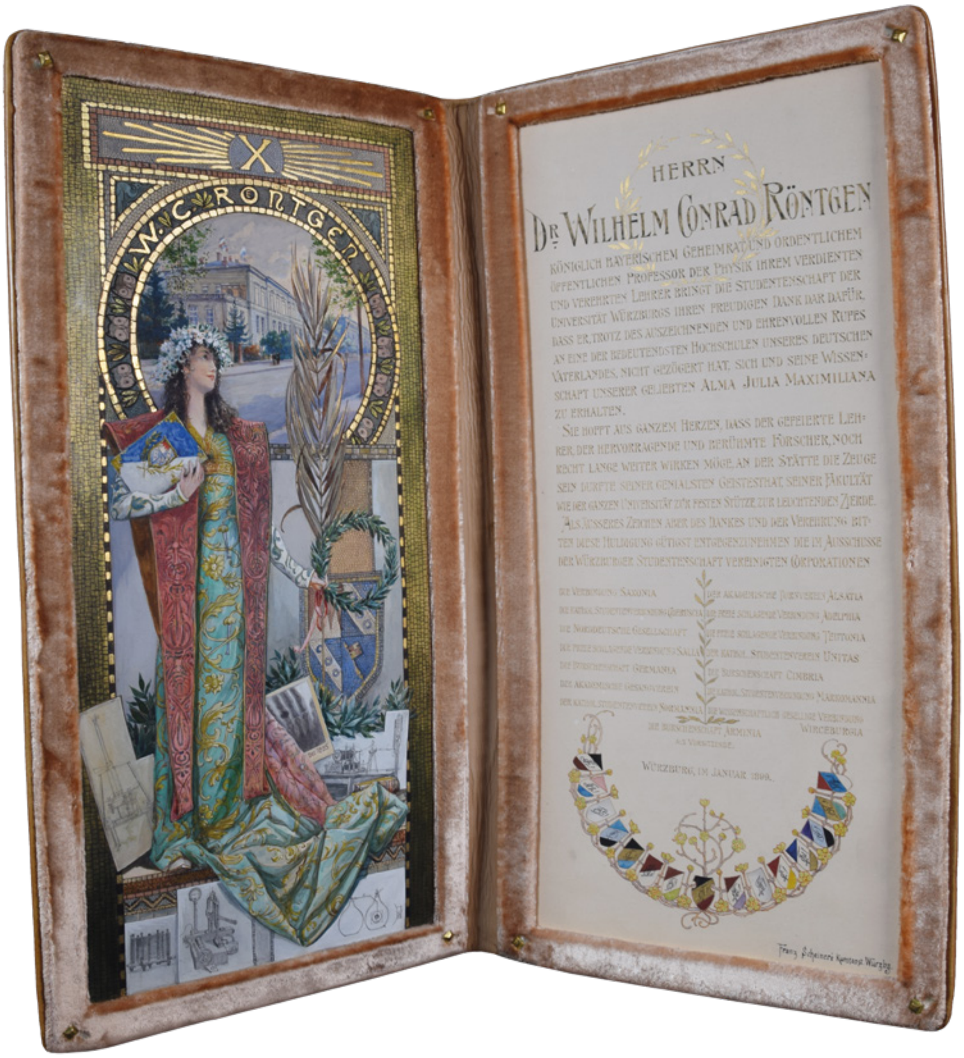
Both the importance for further scientific discoveries as well as for new applications made Röntgen internationally famous and he received various scientific and political or royal honours. What follows are just selected examples of these honours according to the year in which they were awarded. For a more complete list, see the Röntgen biography by Otto Glasser (1895-1964), who lists a total of eighty-nine awards that were given to Röntgen.[1] Due to its outstanding importance the first Nobel Prize in Physics, which was awarded to Röntgen in 1901, is treated separately in the next section.

The Faculty of Medicine of the University of Würzburg conferred upon Röntgen its highest honour, the title of doctor medicinae honoris causa, signed by the Dean, Prof. Dr. Karl Schoenborn (1840-1906). Very remarkable is the speed with which this happened: Röntgen received this title on February 15, 1896, about three weeks after the presentation of his discovery at the Physical-Medical Society in Würzburg.


AUSPICIIS SUMMIS
AUGUSTISSIMI AC POTENTISSIMI
BAVARIAE REGIS
OTTONIS I.
EX
UNANIMI DECRETO ORDINIS MEDICORUM
ACADEMIAE IULIO-MAXIMILIANAE
RECTORE MAGNIFICO
GUILELMO OLIVERIO DE LEUBE
IN
VIRUM PRAECLARISSIMUM ET DOCTISSIMUM
GUILELMUM CONRADUM ROENTGEN
SUMMOS IN MEDICINA HONORES
DOCTORISQUE NOMEN ET DIGNITATEM
RITE CONTULIT
CAROLUS SCHOENBORN

DOCTOR HONORIS CAUSA OF THE MEDICAL FACULTY, UNIVERSITY OF WÜRZBURG

1896 / Parchment / University Archives Würzburg



LETTER OF THANKS TO RÖNTGEN FROM STUDENT FRATERNITIES IN WÜRZBURG

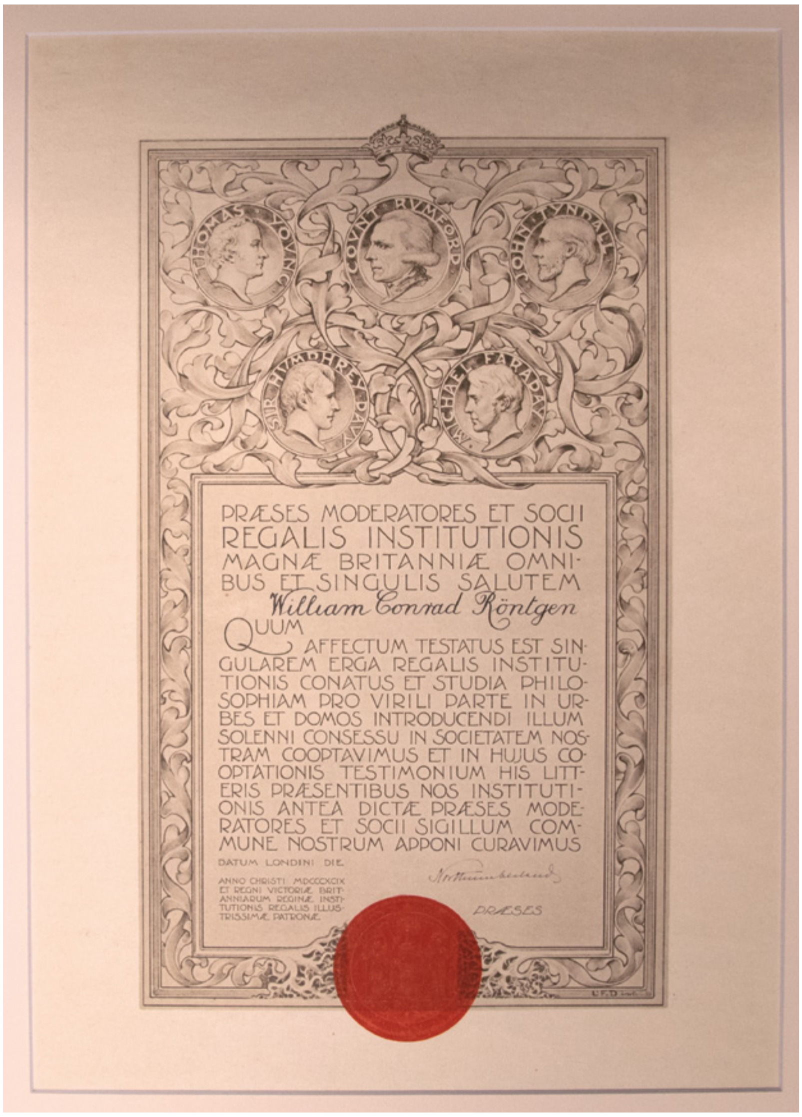
Franz Scheiners Kunstanstalt Würzburg / January 1899 /
Leather, parchment, and fabric, handmade and gilded /
University Archives Würzburg

Though not formally comparable to the honoris causa degree, a clear indication of the extraordinary esteem in which the students of the University of Würzburg held Röntgen is a document in which they thank him for not leaving Würzburg to accept a position in Berlin. The Würzburg student fraternities extended their gratitude to Röntgen with a torchlight procession and an exquisite letter.

The artwork shows a woman holding a palm leaf and a laurel wreath in her left hand. The palm leaf is a symbol of martyrdom in Christianity, but can also mean eternal life. In her right hand, she holds a book with the coat of arms of Julius-Maximilians-Universität Würzburg. The woman looks at a picture of the Institute of Physics, which is decorated with Röntgen's name in golden lettering. The flags of the Kingdom of Bavaria and the Empire are depicted on the building.

In the lower part, there are technical drawings of Röntgen's experiments. The experiment setup is shown on the right side by means of a small induction coil below the coat of arms. The X-ray of Anna Bertha Röntgen's hand is shown next to it. At the woman's feet, on the left, the experiment setup for Röntgen's research is depicted. On the bottom left, there is the primary coil of a Tesla generator, which was used by him to demonstrate that X-rays can also be generated with this device.

The bottom of the letter shows the student associations' coats of arms.


THOMAS YOUNG
COUNT RUMFORD
JOHN TYNDALL
SIR HUMPHREY DAVY
MICHAEL FARADAY

PRÆSES MODERATORES ET SOCII REGALIS INSTITUTIONIS MAGNÆ BRITANNIÆ OMNIBUS ET SINGULIS SALUTEM

William Conrad Röntgen

QUUM AFFECTUM TESTATUS EST SINGULAREM ERGA REGALIS INSTITUTIONIS CONATUS ET STUDIA PHILOSOPHIAM PRO VIRILI PARTE IN URBES ET DOMOS INTRODUCENDI ILLUM SOLENNI CONSESSU IN SOCIETATEM NOSTRAM COOPTAVIMUS ET IN HUJUS COOPTATIONIS TESTIMONIUM HIS LITTERIS PRÆSENTIBUS NOS INSTITUTIONIS ANTEA DICTÆ PRÆSES MODERATORES ET SOCII SIGILLUM COMMUNE NOSTRUM APPONI CURAVIMUS

DATUM LONDINI DIE

ANNO CHRISTI MDCCCXCIX ET REGNI VICTORIÆ BRITANNIARUM REGINÆ INSTITUTIONIS REGALIS ILLUSTRISSIMÆ PATRONÆ

PRÆSES

RUMFORD MEDAL CERTIFICATE OF THE BRITISH ROYAL SOCIETY

1899 / Parchment and sealing wax / University Archives Würzburg

The Rumford Medal is one of the oldest awards granted by the British Royal Society, given to scientists who have made important contributions to science. The medal was endowed in 1796 by Benjamin Thompson (1753-1814), also known as Count Rumford of the Holy Roman Empire. Since 1800, the medal has been awarded every second year to outstanding physicists. The award, comprised of a silver gilt medal and a grant of £2,000, has been conferred upon more than one hundred scientists.

Crediting Röntgen's "investigations of the phenomena produced outside a highly exhausted tube through which an electrical discharge is taking place," the award was given to Röntgen in 1899. Other awardees of note include Ernest Rutherford (1871-1937), Heinrich Hertz (1857-1894), and James Clerk Maxwell (1831-1879).

Overseas, Röntgen was awarded, for example, the Barnard Medal for Meritorious Service to Science by New York City's Columbia University. The medal is named after Frederick August Porter Barnard (1805-1889), who became the tenth president of Columbia University in 1864. Awarded every five years until its cessation in 1985, the medal honoured physicists and astronomers who, during the same five-year period, had discovered something of significant benefit to humanity. The award was to honour discoveries of global importance and there were no restrictions on the nominee's nationality, permitting the Dutch-German Röntgen to receive the medal in 1900.

The front side of the medal is adorned by the figure of Columbia holding a laurel wreath in one hand and an oil lamp in the other, flanked by two river deities. As per Barnard's wishes, "Magna est veritas" (great is the truth) is inscribed above Columbia's shoulder. The reverse side of the medal reads "Deo optimo maximo, gloria in excelsis" (to the Lord, the best and the greatest, be glory in the highest).

COLUMBIA COLLEGE BARNARD MEDAL

Tiffany & Co., New York; Columbia University in the City of New York / 1900 / Solid gold / University Archives Würzburg

HERMANN VON HELMHOLTZ MEDAL

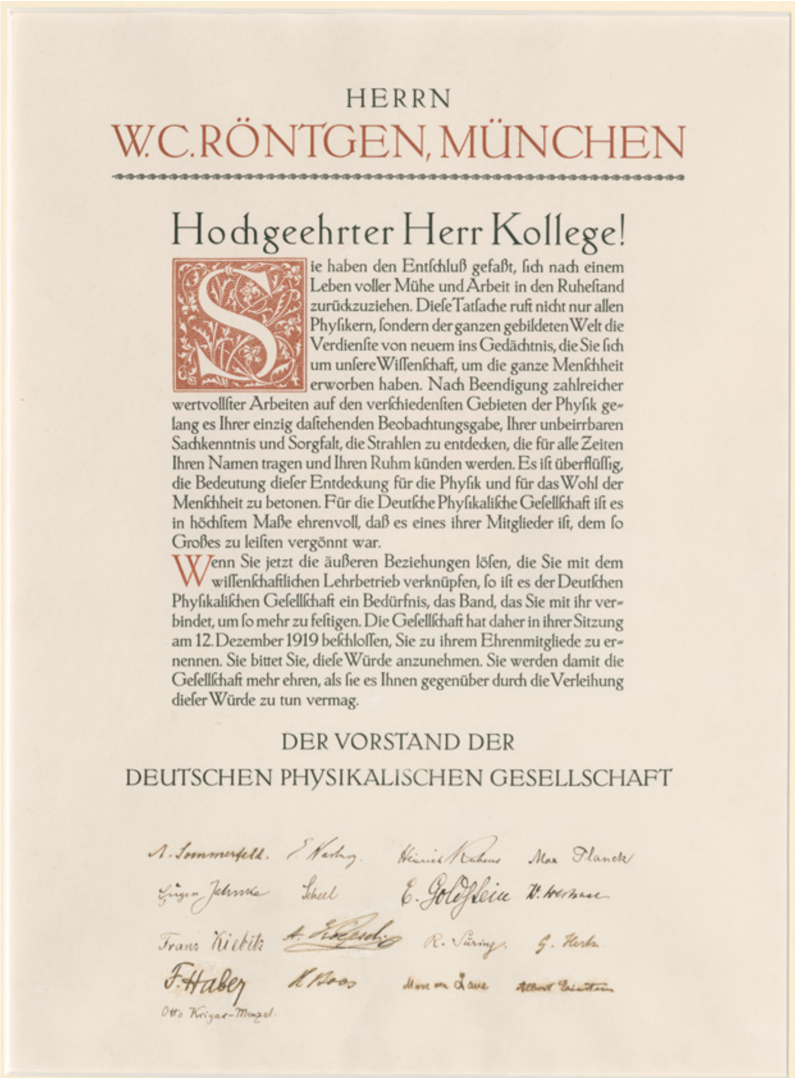
Royal Prussian Academy of Sciences / 1919 / Solid gold / University Archives Würzburg

The Prussian Academy of Sciences recognizes individuals who make outstanding contributions to sciences, especially natural science, with the Hermann von Helmholtz Medal. The award was endowed by von Helmholtz in 1891, on the famous scientist's seventieth birthday.

In 1892, von Helmholtz himself nominated the first four prize winners. Röntgen received the award in 1919, having distinguished himself as a preeminent scholar in the field of physics. Since 1994, the medal has been awarded once every two years. The medal depicts its namesake on the front, accompanied by the inscription of von Helmholtz's name. On the back, Röntgen's name and the year of his award is encircled by a laurel wreath.

Also in 1919, the German Physical Society awarded honorary membership to Röntgen. Established in 1845 and with a membership presently numbering around 60,000, the German Physical Society is recognized as the world's oldest and largest organization of physicists. It is not so much the content of the letter, but rather the scientific significance of its signatories, that accounts for the historical value of this document.

The letter is signed by the members of the board of the German Physical Society. Endorsed by persons such as Max Planck, Max von Laue, Fritz Haber, and Albert Einstein, the letter attests to the lasting recognition of Röntgen's discovery by his contemporaries.


HERRN

W.C. RÖNTGEN, MÜNCHEN

Hochgeehrter Herr Kollege!

Sie haben den Entschluß gefaßt, sich nach einem Leben voller Mühe und Arbeit in den Ruhestand zurückzuziehen. Diese Tatsache ruft nicht nur allen Physikern, sondern der ganzen gebildeten Welt die Verdienste von neuem ins Gedächtnis, die Sie sich um unsere Wissenschaft, um die ganze Menschheit erworben haben. Nach Beendigung zahlreicher wertvollster Arbeiten auf den verschiedensten Gebieten der Physik gelang es Ihrer einzig dastehenden Beobachtungsgabe, Ihrer unbeirrbaren Sachkenntnis und Sorgfalt, die Strahlen zu entdecken, die für alle Zeiten Ihren Namen tragen und Ihren Ruhm künden werden. Es ist überflüssig, die Bedeutung dieser Entdeckung für die Physik und für das Wohl der Menschheit zu betonen. Für die Deutsche Physikalische Gesellschaft ist es in höchstem Maße ehrenvoll, daß es eines ihrer Mitglieder ist, dem so Großes zu leisten vergönnt war.

Wenn Sie jetzt die äußeren Beziehungen lösen, die Sie mit dem wissenschaftlichen Lehrbetrieb verknüpfen, so ist es der Deutschen Physikalischen Gesellschaft ein Bedürfnis, das Band, das Sie mit ihr verbindet, um so mehr zu festigen. Die Gesellschaft hat daher in ihrer Sitzung am 12. Dezember 1919 beschlossen, Sie zu ihrem Ehrenmitgliede zu ernennen. Sie bittet Sie, diese Würde anzunehmen. Sie werden damit die Gesellschaft mehr ehren, als sie es Ihnen gegenüber durch die Verleihung dieser Würde zu tun vermag.

DER VORSTAND DER

DEUTSCHEN PHYSIKALISCHEN GESELLSCHAFT

HONORARY MEMBERSHIP OF RÖNTGEN IN THE GERMAN PHYSICAL SOCIETY; SIGNED BY THE MEMBERS OF THE MANAGEMENT BOARD

1919 / Paper / University Archives Würzburg

1st line, left to right:
Arnold Sommerfeld (1868-1951), Emil Warburg (1846-1931), Heinrich Rubens (1865-1922), Max Planck (1858-1947)

2nd line, left to right:
Eugen Jahnke (1861-1929), Karl Scheel (1866-1936), Eugen Goldstein (1850-1930), Wilhelm Westphal (1882-1978)

3rd line, left to right:
Franz Kiebitz (1878-1962), Adolf Köpsel (1856-1933), Reinhard Süring (1866-1950), Gustav Hertz (1887-1975)

4th line, left to right:
Fritz Haber (1868-1934), Hans Adolf Boas (1869-1930), Max von Laue (1879-1960), Albert Einstein (1879-1955)

5th line: Otto Krigar-Menzel (1861-1929)

ROYAL ORDERS

In the wake of Röntgen's discovery many accolades followed. Several honours were intended to coincide with Röntgen's fifty-fifth birthday at the end of the century. Not only was Röntgen knighted as part of the Order of Merit of the Bavarian Crown (which he never accepted), he also received the Grand Commander's Cross of the Order of Merit of Saint Michael, in addition to being awarded membership in the Order of Pour le Mérite for Science and Art.

In 1808, King Maximilian I Joseph (1756-1825) of Bavaria donated the Order of Merit of the Bavarian Crown as a prestigious award that also provided the recipient with the right to a title of nobility. The Bavarian Prince Regent Luitpold (1821-1912) alongside Emperor Wilhelm II (1859-1941) bestowed this honour upon Röntgen in a personal meeting. Röntgen was awarded the rank of commander and was given a medal in gold. However, the physicist refused to change his name.

The insignia is an eight-armed, sixteen-pointed, white enamelled cross surrounded by an oak wreath with a medallion in the centre. This shows the golden royal crown on a white-blue rhombus, surrounded by a golden and red hoop with the inscription "virtus et honos" (virtue and honour). On the reverse, there is a portrait of the founder, King Maximilian I Joseph, with the inscription "MAX.JOS.BOJOARIAE.REX." As commander, Röntgen also received a highly decorated breast star.

Recognition extended far beyond German borders. Italy honoured the physicist with high foreign honours. Röntgen received the Order of the Crown of Italy and became Commendatore dell'Ordine della Corona d'Italia. The order consists of a gilt cross with curved edges, enamelled in white, with the so-called Savoy knots between the arms of the cross. The obverse central disc features the Iron Crown of Lombardy on a blue enamel background. The reverse central disc shows a black-enamelled eagle bearing the Savoy cross on a golden background.

(TOP) ORDER OF MERIT OF THE BAVARIAN CROWN

Kingdom of Bavaria / 1900 / Metal and enamel / University Archive Würzburg

(BOTTOM) ORDER OF THE CROWN OF ITALY

Kingdom of Italy / 1900 / Metal and enamel / University Archive Würzburg

Naming of a new element: Roentgenium $\boxed{111Rg}$

On December 8, 1994, an international team led by Sigurd Hofmann at the GSI Helmholtz Centre for Heavy Ion Research (GSI) near Darmstadt, Germany, created an extremely radioactive element that cannot be found in nature and can only be synthesized in a laboratory. Before 1979 , roentgenium would have been known as eka-gold, using Dmitri Mendeleev's nomenclature for unnamed and undiscovered elements. In 1979, the International Union of Pure and Applied Chemistry (IUPAC) had published recommendations according to which the element was to be called unununium (with the corresponding symbol of Uuu), a systematic element name as a placeholder, until the element was discovered (and the discovery then confirmed) and a permanent name decided. As suggested by the GSI team, however, it was named after Röntgen. The suggestion was accepted by the International Union of Pure and Applied Chemistry on November 1, 2004. Roentgenium is a chemical element with the symbol Rg and the atomic number 111.

In June 2016, the European Physical Society (EPS) distinguished the institute where Röntgen discovered the X-rays in 1895 as one of only five "Historic Sites" in Germany.

THE FORMER INSTITUTE OF PHYSICS
OF THE UNIVERSITY OF WÜRZBURG

2016 / Photograph / Private collection

THE FORMER INSTITUTE OF PHYSICS OF THE UNIVERSITY OF WÜRZBURG
RECEIVED THE TITLE “HISTORIC SITE” FROM THE EUROPEAN PHYSICAL SOCIETY

2016 / Photograph / Private collection

SECTION V
– NOBEL PRIZE

Though Röntgen received many honours in his lifetime, the most significant was the Nobel Prize in Physics in 1901.

The origin of the award goes back to Alfred Nobel (1833-1896), who made a fortune with his invention of dynamite in the 1860s. He donated a large part of his fortune to prizes for physics, chemistry, medicine, and literature, all to be named after him. Due to inheritance disputes in his family, however, the first award ceremony did not take place until five years after his death.

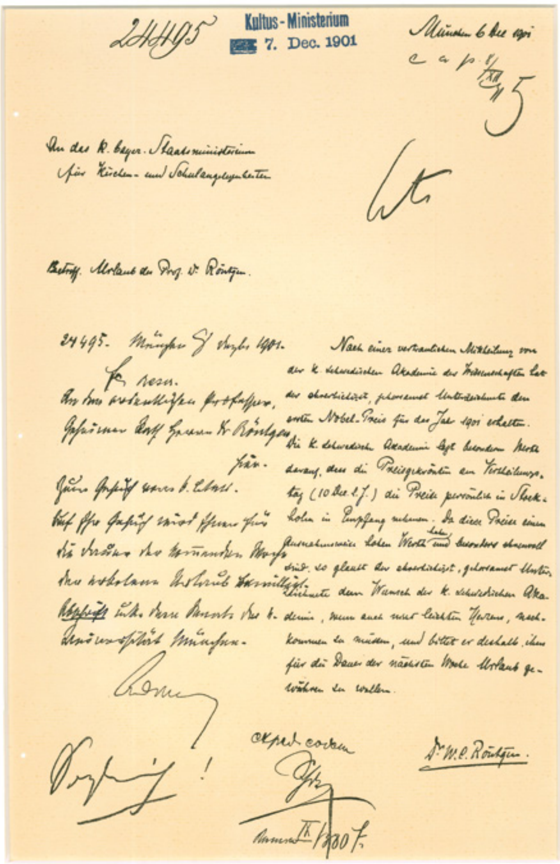
The field for the first Nobel Prize was particularly wide. As long as the discovering scientist was alive, all the great discoveries and inventions of the preceding decades were available for selection. The awardees were selected by the Royal Swedish Academy of Sciences, based on the recommendations of eminent external scientists.

At the beginning of December 1901, Röntgen was informed by the Royal Swedish Academy of Sciences that he had been selected to receive the first Nobel Prize in Physics.

He applied for a leave of absence at the Bavarian Ministry of Religious and Educational Affairs in a letter dated December 6, 1901:
"According to confidential information from the Royal Swedish Academy of Sciences, the undersigned humbly and dutifully reports that he has received the first Nobel Prize for the year 1901. The Royal Swedish Academy attaches particular importance to having the prizewinners accept the prizes personally in Stockholm on the day of the award (December 10 of the current year). As these prizes are of such extraordinarily high value and are so particularly honourable, the humble and deferential undersigned believes, albeit reluctantly, that he must satisfy the wishes of the Royal Swedish Academy, and thus requests the granting of leave for the duration of the following week. Dr. W. C. Röntgen."
The letter was received by the Ministry on December 7, 1901. The request was granted on December 8, just in time for Röntgen to travel to Stockholm to receive the Prize.

THE FIRST NOBEL PRIZE IN PHYSICS

Sophia Gisberg / 1901 / Leather, parchment, and gold / University Archives Würzburg



24495 Kultus-Ministerium 7. Dec. 1901

Dr. W. C. Röntgen

RÖNTGEN'S LETTER TO THE BAVARIAN MINISTRY
OF RELIGIOUS AND EDUCATIONAL AFFAIRS

Wilhelm Conrad Röntgen / 1901 / Handwriting on paper /
Archives of the Bavarian State

The award ceremony took place on December 10, 1901, in the richly decorated hall of the Royal Swedish Academy of Music in Stockholm. After music and speeches, the director of the Swedish National Archives paid tribute to the discovery of X-rays, whereupon Röntgen received the first Nobel Prize in Physics, awarded by the crown prince.

The medal shows a portrait of the founder Alfred Nobel and the years of his birth and death. Since the design of the medals had not yet been fully determined, substitutes had to be presented at the first ceremony in 1901. It was not until 1902 that the awardees of the previous year received their official medals. The medal diameter is 66 millimetres (2.6 inches), with a width varying between 5.2 millimetres and 2.4 millimetres (0.2 and 0.09 inches). The front shows the profile and name of its founder Alfred Nobel (1833-1896) as well as the Roman numeral dates of his birth and death; the reverse shows the laureate's name. In his will, Röntgen bequeathed the medal, the certificate, and the considerable prize money of 50,000 Swedish crowns to the Julius-Maximilians-Universität Würzburg.

In addition to the award ceremony and an official banquet, it was also expected that the awardees give a lecture on their discovery. Röntgen, however, did not give a speech, nor did he give an explanation for the lack thereof, as he had already left the following day.

In the following years, Röntgen was nominated five more times for the Nobel Prize in Physiology or Medicine.

The Nobel Prize certificate is bound in a blue leather folder, which is embossed with elaborate ornamentation and the initials of the prize winner. The two adjacent pages are made of parchment and were handcrafted for the prizes in physics and chemistry for 25 years by the Swedish artist Sofia Gisberg (1854-1926). No two certificates are the same, because in the design the artist always referred to the respective research achievements that were to be honoured. In Röntgen's certificate, the left-hand side contains the signature of the Royal Swedish Academy of Sciences, under which the date of the ceremony, the name of the name-giver and the date of discovery are written, followed by the reason for the award and the name of the prizewinner. On the right-hand side, the date of issue of the certificate and the signature of the President of the Royal Swedish Academy of Sciences, the seal of the Academy and the signature of the permanent secretary are shown.

The Swedish national colours are used throughout the diploma. The gilded leaves and fruits are lined with resin or wax so that they appear very plastic. The fruits almost seem like droplets, an impression reinforced by rays of gold ink.

(p. 54) NOBEL PRIZE MEDAL AWARDED TO RÖNTGEN

Erik Lindberg / 1901 / Solid gold / University Archives Würzburg

KONGLIGA SVENSKA VETENSKAPS-AKADEMIEN

har vid sitt sammanträde den 12 Nov. 1901, i enlighet med föreskrifterna i det af

ALFRED NOBEL

den 27 November 1895 upprättade testamente, beslutat att tilldela det pris som detta år bortgifves "åt den som inom fysikens område har gjort den viktigaste upptäckt eller uppfinning" till

WILHELM CONRAD RÖNTGEN

såsom ett erkännande af den utomordentliga förtjenst han inlagt genom upptäckten

af de egendomliga strålar, som sederme-
ra uppkallats efter honom.

Stockholm den 10 December 1901

C. T. Odhner

Kgl. Vet. Ak:s Præses

Chr. Aurivillius

Kgl. Vet. Ak:s Sekreterare.

Sofia Gisberg.

On the second page, the experiment set-up for generating X-rays is illustrated in place of the Academy's seal. In front of a blue background, there is an image of a gold-embossed table, upon which rests a horizontally aligned vacuum tube (in the foreground), a second device (on the left), and the induction coil's round edge (at the back). Loose cable ends imply the connection of the three devices and the open laboratory book with red sheets supports the perspective view of the laboratory devices.

The seal of the Royal Swedish Academy of Science rests above the bottom portion of the frame. It shows a gold-embossed sphere within blue oval wings and three crowns. At the apex of the sphere, there is a larger sphere and, above it, the five-pointed star with an aureole of rays. The inscription, which runs from one wing to the other, names the distinguishing institution in capital letters: "KUNGL. WETENSK.ACAD.SIGILL." The name of the institution, "KUNGLIGA SVENSKA VETENSKAPS-AKADEMIEN," is written in blue minuscule serif script.
The letters appear as if set against a gold background, which upon closer inspection reveals to be a fine lining ornamenting the letters with a shadowing effect. The same golden shadowing effect can be seen adorning Alfred Nobel's (1833-1896) name and in the red-inked initials. The name of the awardee is written in the same majuscule script as above. The original text itself is written in minuscules using golden lines, with fracture script in sepia ink.

SECTION VI
– BEYOND PHYSICS: FAMILY, HIKING AND HUNTING

BREAKFAST WITH FRIENDS AT TSCHIERVA HUT, SWITZERLAND

September 1, 1907 / Photograph / University Archives Würzburg

Röntgen, a lover of nature, used to spend his semester break with his family and friends. Particularly popular with the Röntgens were destinations in Switzerland such as Pontresina or Cadenabbia on Lake Como in northern Italy. The family always stayed in the same Hotel Bellevue in Cadenabbia and, thanks to the friendliness of the Prince of Meiningen (1826-1914), they were able to visit the garden of the Villa Carlotta outside visiting hours.

Among the physicist's favourite activities during his holidays were self-organized automobile and steamboat excursions as well as mountain hikes with family and friends. Röntgen shared his passion for climbing above all with Margret Boveri, the daughter of Theodor Boveri (1862-1915), the famous biologist, friend, and colleague at Julius-Maximilians-Universität Würzburg.

The excursions were always planned by Röntgen so that his wife, who suffered from a renal disease, could take part and reach the destinations by car.

RÖNTGEN WITH HIS WIFE IN THE ENGADIN, SWITZERLAND

Spring 1903 / Photograph /
German Röntgen Museum, Remscheid

RÖNTGEN WITH WIFE, NIECE, AND CIRCLE OF FRIENDS IN PONTRESINA

Wilhelm Conrad Röntgen / ca. 1891 / Photograph / German Röntgen Museum, Remscheid

SMALL HUNTING LODGE

Date unknown / Photograph / German Röntgen Museum, Remscheid

During his time in Würzburg, Röntgen leased a small piece of woodlands in order to be able to retreat from the hustle and bustle of the city. Röntgen often took colleagues such as the anatomist Albert von Koelliker and Theodor Boveri with him to the hunting grounds of Rimpar to go hunting together.

After his move to the University of Munich in 1900, Röntgen leased another hunting ground and bought a stately hunting lodge in Weilheim, where he often invited his friends from Würzburg. Röntgen's love for hunting is also manifest in his letters in which he often writes about his "beloved shotgun".

Röntgen used this shotgun for one of his early X-ray experiments with unsatisfactory results. Only after ordering new, more powerful tubes was he able to generate radiation that penetrated the thick metal layers. For demonstration purposes, he irradiated his own shotgun in the presence of Emperor Wilhelm II, who himself was known for his passion for the military and science.

The radiograph shows the barrel of Röntgen's shotgun loaded with shotshell. Visible in the central part of the two barrels are the pellets side by side inside a paper-made shell case. At the end of each barrel, the base of the shell case and the primer are visible. In addition to the photograph, Röntgen wrote various remarks noting a material defect, a deepening in the material, and the structure of the shotgun.

RÖNTGEN'S BELGIAN LEFAUCHEUX DOUBLE-BARRELED SHOTGUN

1850s / Wood, metal / University Archive Würzburg

RADIOGRAPH OF RÖNTGEN'S GUN

Wilhelm Conrad Röntgen / ca. 1895 / University Archive Würzburg

PRIVATE IMPRESSIONS

Röntgen was an avid amateur photographer. His first photographs date back to 1885. It was at that time that the industrial production of photographic material had become possible.

VIEW OF WÜRZBURG, PHOTOGRAPH BY RÖNTGEN HIMSELF

1894 / Photograph / German Röntgen Museum, Remscheid

RÖNTGEN AND HIS WIFE TAKING A CARRIAGE RIDE DURING AN EXCURSION TO A LAKE IN MUNICH

1906 / Photograph / German Röntgen Museum, Remscheid

RÖNTGEN IN THE “KUR- UND SEEBADEANSTALT WALDHAUS FLIMS”

Date unknown / Photograph / German Röntgen Museum, Remscheid

ANNA BERTHA AND PROFESSOR ALBERT VON KOELLIKER

Wilhelm Conrad Röntgen / 1898 / Photograph, cardboard / University Archives Würzburg

ANNA BERTHA AND WILHELM CONRAD RÖNTGEN WITH FRIENDS IN PONTRESINA, SWITZERLAND

Lotte Baur / September 10, 1890 / Photograph, cardboard /
University Archives Würzburg

CHINESE TOWER IN THE ENGLISH GARDEN MUNICH

Wilhelm Conrad Röntgen / After 1900 /
Photograph / University Archives Würzburg

RÖNTGEN AT CADENABBIA, ITALY

March 24, 1896 / Photograph / University Archives Würzburg

PERSONALITY, LAST YEARS AND DEATH

Essential to Röntgen's character and strongly contributing to his success as a scientist was his devotion to research. He was ambitious in his work, accepting results as reliable only after repeated verification. His devotion reached its peak when he discovered the X-rays, at that time he even moved his bed into his laboratory. Röntgen only went public with his report "On a New Kind of Rays" after having ascertained that his discovery was, in fact, the breakthrough he suspected.

Although Röntgen became widely known for his discovery, he was not looking for fame or money. As an introvert, he was rather shy in public and did not enjoy the public appearances that came with his discovery. This became apparent at the Nobel Prize ceremony, where he accepted the award without giving a speech. It was only at the evening banquet that he said a few words of thanks. He consistently turned down invitations to conferences and other events in his attempt to withdraw from public attention.

Although he was repeatedly asked to exercise the patent rights to X-rays or to transfer the rights to lawyers, he never did so. He wanted his discovery to be immediately and freely accessible for the well-being of mankind. By selflessly abstaining from personal profit, Röntgen demonstrated his understanding of the importance of X-rays to humanity.

Despite his rather introverted nature, Röntgen was quite passionate. His fiery temper occasionally caused him trouble. Close friends were careful not to play cards with him, because he did not like losing and would become very angry if dealt a bad hand. If his partners played badly, Röntgen was also quite resentful.

From 1900, Röntgen served as the Chair of Physics at the University of Munich. Both the university policy there and the atmosphere of World War I caused great stress to Röntgen, who meanwhile wasn't a young man any longer. Due to this stress it was his health began to decline. Yet it was not until 1919, after the turmoil of war and revolution, that Röntgen retired, albeit asking for continued access to the institute.

His wife, Anna Bertha, had died before his retirement, plunging him into a deep crisis. Theodor Boveri's widow was the only personal contact the physicist kept.

On February 10, 1923, Röntgen died of intestinal cancer in Munich at the age of seventy-seven. He was buried in the Alter Friedhof (Old Cemetery) in Giessen, next to his parents. He had already begun to arrange his estate two years beforehand and, in his will, had donated much of his fortune to charities. Most of his personal papers were burned, as Röntgen had directed, which makes the few remaining documents all the more valuable.

Only a small handful of discoveries can be compared with X-rays in terms of their significance and impact upon humanity.

MARCELLA BOVERI, NÉE O`GRADY, WAS THE FIRST WOMAN TO BE ADMITTED AS A GUEST AUDITOR AT THE UNIVERSITY OF WÜRZBURG IN 1896, BUT ONLY "EXCEPTIONALLY" BECAUSE OF HER SEVEN YEARS AS PROFESSOR OF BIOLOGY IN THE USA.

1890s / Photograph / German Röntgen Museum, Remscheid

SECTION VII
– THE UNIVERSITY OF WÜRZBURG

In 1402 Pope Boniface IX (1350-1404) granted the privilege of establishing a full university in Würzburg, which should comprise a theological and a legal faculty. The University of Würzburg was thus the fourth university on German soil, and soon afterwards Prince Bishop Johann von Egloffstein (+ 1411) granted it extensive university privileges, including its own jurisdiction. The University was thus the sixth higher education institution in the entire German-speaking world at that time, after the universities of Prague, Vienna, Heidelberg, Cologne and Erfurt.

PAPAL PRIVILEGE WITH SEAL

1402 / Parchment, silk and lead seal / The Archives of the Bavarian State

Julius Echter von Mespelbrunn (1545-1617), elected Prince Bishop of Würzburg in 1573, continued to expand the university originally founded in 1402 and applied to Emperor Maximilian II (1527-1576) for the corresponding imperial privileges in 1575, with Pope Gregory XIII (1502-1585) confirming the original papal privileges one year later. Thus, the university was re-inaugurated as Academica Catholica Herbipolensis in 1582 under Julius Echter. At the time, the university consisted of four faculties: theology, philosophy, law, and medicine. Würzburg came under Bavarian rule in 1802 due to secularization, leading to the loss of the university's noble privileges. The disappearance of the Catholic element led once again to a fundamental restructuring of the university, this time into a state institution.

During the March Revolution at the end of March 1848, the University of Würzburg submitted an application for autonomy, unrestricted freedom of teaching, and the strengthening of the university departments. The statutes finally adopted on October 1, 1849, brought clear improvements for the students and the university. From then on, students could establish their own associations, the rector enjoyed more powers, and the courses of study became more liberal overall.

After the foundation of the German Empire in 1871, the University of Würzburg saw another wave of rapid developments. Medicine and the natural sciences, in particular, enjoyed a heyday of innovation and research.

During World War II, the university was badly hit by an air raid on March 16, 1945. After the war, the university experienced quite a comeback. Today, Julius-Maximilians-Universität Würzburg, along with the University Hospital, is the largest employer in the city. It is composed of ten faculties with almost 30,000 students.

AERIAL PHOTOGRAPH OF THE UNIVERSITY'S OLDEST COMPLEX OF BUILDINGS

Gerhard Launer / 2006 / Photograph / University of Würzburg

RENOWNED SCHOLARS
OF JULIUS-MAXIMILIANS-UNIVERSITÄT WÜRZBURG

In its more than 600-year history, the university has been home to numerous scientists, many of whom were awarded the Nobel Prize for their findings. Among them are Emil Fischer (chemistry, 1902), Eduard Buchner (chemistry 1907), Wilhelm Wien (physics 1911), Johannes Stark (physics 1919) and Hans Spemann (medicine 1935). Many other renowned scholars should be mentioned at this point; a selection will be presented below.

Johann Zantfurt (unknown-1413), rector of the University of Würzburg ca. 1410. From 1392 he studied law at the University of Erfurt and was appointed professor of canon law at the newly founded University of Würzburg in 1402. In March 1405 he was appointed vicar of the cathedral chapter. From 1410 he was active as cathedral canon and chancellor. Zantfurt had lived in the "Hof zum großen Löwen" since 1412, where he was murdered by a servant on 1 December 1413.

Athanasius Kircher (1602-1680) was a polymath who, through his research, came to findings that were far ahead of his time. He can also be seen as the forerunner of many inventions, such as a calculating machine, and a predecessor of the modern film projector. In 1629 Kircher accepted a call to the University of Würzburg as professor of mathematical sciences and of Hebrew and Syrian languages.

Kaspar Schott (1608-1666) spent more than half of his life as a Jesuit acquiring a large spectrum of knowledge before he passed it on as a lector. During his time as a student in Würzburg and later in Rome he was strongly influenced by Athanasius Kircher. In 1655 Schott was appointed professor of mathematical sciences in Würzburg, and in just eleven years he published twelve scientific works, all of which dealt with mathematics and its applications.

Carl Caspar Siebold (1736-1807) revolutionised surgical medicine by, among other things, setting up the world's first modern operating theatre. He studied medicine at the University of Würzburg, graduating with honours and a doctorate, and was subsequently appointed personal physician to the prince bishop. From 1769 he was professor of anatomy, surgery and obstetrics at the Alma Julia. Siebold developed new surgical methods, hygiene standards and improved midwifery training.

Albert von Koelliker (1817-1905) laid the foundations for the development of neuron theory and is considered the founder of microscopic anatomy. He demonstrated the existence of unicellular organisms and produced evidence of cell nuclei in human fat cells. One of the first X-rays made shows von Koelliker's hand.

Emil Fischer (1852-1919) was awarded the Nobel Prize in Chemistry in 1902 for his work on the chemical structures of sugar and purines. By discovering the lock-and-key principle between enzymes and substituents, Fischer laid the foundation for organic chemistry and biochemistry.

Ernst von Bergmann (1836-1907) is regarded as a pioneer of brain surgery and, due to the introduction of revolutionary methods of wound treatment such as the use of steam-sterilized dressing material, as the “father of asepsis”.

Johann Lukas Schönlein (1783-1864) made important contributions to the field of medicine, such as the fundamental improvement of medical diagnostics and the recognition of tuberculosis as an independent disease. He also discovered the disease Purpura Schönlein-Henoch, an inflammation of the small blood vessels that can attack the skin, joints and internal organs.

Philipp Franz von Siebold (1796-1866) was a doctor, naturalist, botanist and ethnologist. He is regarded as the founder of western research on Japan and is one of the most important witnesses of the isolated Japan of the Edo period.

Rudolf Virchow (1821-1902) is considered the founder of cellular pathology and is called the “father of pathology”. Besides his research on and identification of thrombosis and leukaemia, Virchow also established “social medicine”.

Theodor Boveri (1862-1915), founder of experimental cell research and the chromosome theory of inheritance, is considered the initiator of modern cancer research.

Wilhelm Conrad Röntgen (1845-1923). His discovery of X-rays is one of the most important innovations of modern times. He laid the foundation for new diagnostic possibilities, which are essential for modern medicine.

Eduard Buchner (1860-1917) was awarded the Nobel Prize in 1907 for his work on fermentation processes by showing that cell-free pressed juice from brewer’s yeast causes sugar to ferment. Buchner is considered the founder of enzymology.

Wilhelm Wien (1864-1928) was awarded the Nobel Prize in Physics in 1911 for his findings on thermal radiation and the discovery of the Vienna Radiation Law. Wien was Röntgen’s successor as director of the Institute of Physics at the University of Würzburg.

Hans Spemann (1869-1941) was nominated six times for the Nobel Prize in Physiology or Medicine before he finally received it in 1935. His greatest scientific achievement was the discovery of the organizer effect.

Johannes Stark (1874-1957) was awarded the Nobel Prize for Physics in 1919 for his discovery of the optical Doppler effect in channel beams and the discovery of the splitting of spectral lines in electric fields. The latter is called the Stark effect.

Erika Simon (1927-2019) was the first woman to hold a chair of Classical Archaeology in Germany. From 1964 to 1994 she had a decisive influence on classical archaeology in Würzburg and was director of the antiquities department of the Martin von Wagner Museum. Under her direction a museum of excellent reputation was established.

Harald zur Hausen (*1936) revolutionized modern cancer research by discovering that human papilloma viruses can cause cervical cancer. His research in tumour virology enabled new measures for the prevention and treatment of cervical cancer, such as the HPV vaccine. Zur Hausen was awarded the Nobel Prize for Medicine in 2008.

Klaus von Klitzing (*1943) worked at Julius-Maximilians-Universität Würzburg from 1969 to 1980. In 1985 he was awarded the Nobel Prize in Physics for his research on the quantum Hall effect. His fundamental discovery opened up a new field of research that is still of great significance today.

Hartmut Michel (*1947) became known primarily for the production of crystallized membrane proteins in bacteriorhodopsin, which had previously been considered impossible. The biochemist was awarded the Nobel Prize in 1988 for his research into the three-dimensional molecular structure of the action centre of photosynthesis in the purple bacterium.

WILHELM CONRAD RÖNTGEN

1895 - 2020

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