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October 1897: The Discovery of the Electron

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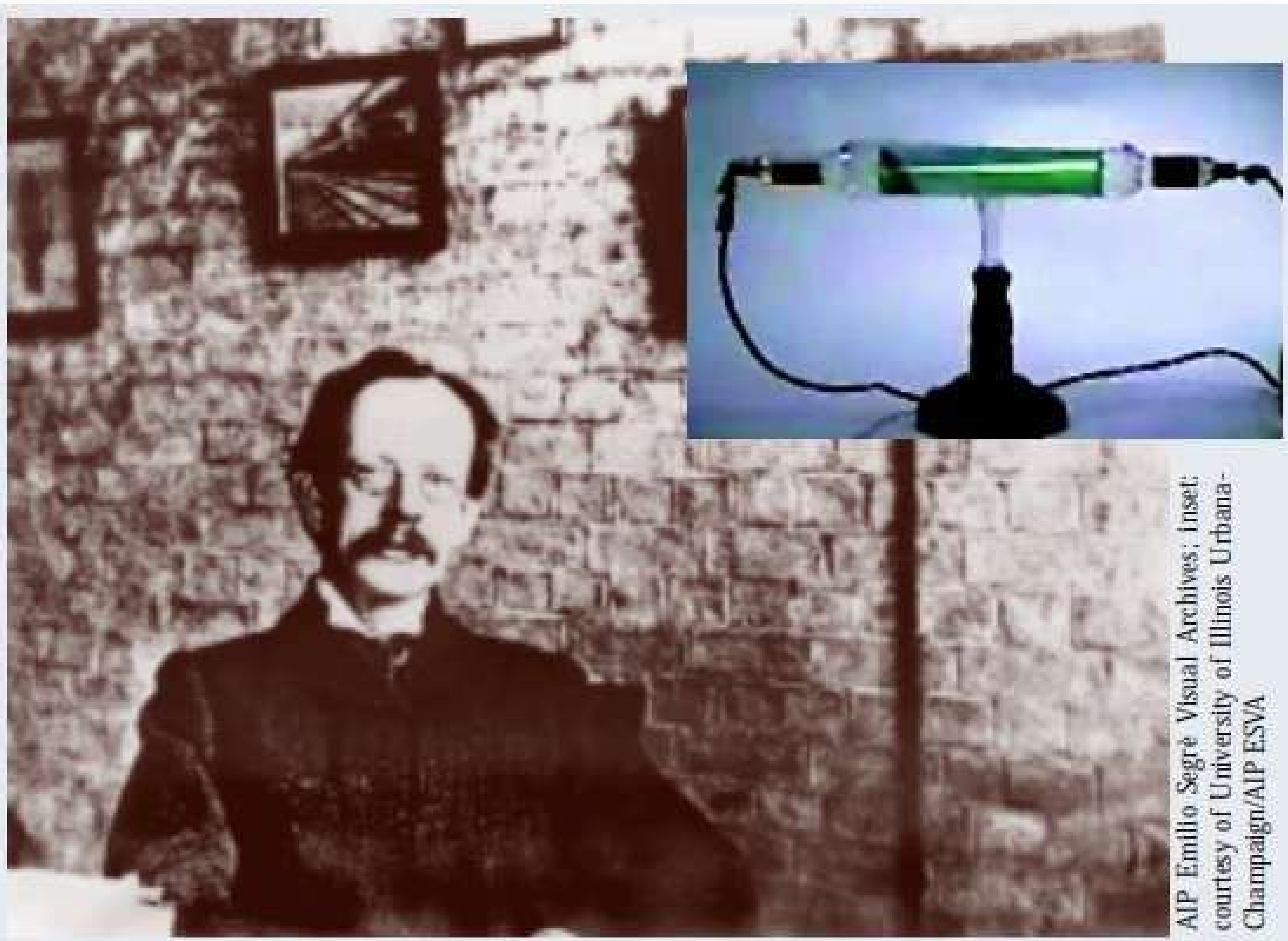

Thomson in his office. Inset: a simple cathode ray tube.
University of Illinois Urbana-Champaign/AIP ESVA

Science lecturers traveling from town to town in the mid-19th century delighted audiences with a device that could be considered the ancestor of the neon sign. They took a glass tube with wires embedded in opposite ends, administered a high voltage and pumped out most of the air. The result: the interior of the tube would glow in lovely fluorescent patterns. Scientists theorized that the glow was produced by some kind of ray emitted by the cathode, but it took the seminal research of a British professor in Cambridge University's Cavendish Laboratory to finally provide a solution to the puzzle.

J.J. Thomson refined previous experiments and designed new ones in his quest to uncover the true nature of these mysterious cathode rays. Three of his experiments proved especially conclusive. First, in a variation of a pivotal 1895 experiment by Jean Perrin, he built a pair of cathode ray tubes ending in a pair of metal cylinders with a slit in them, which were in turn connected to an electrometer. The purpose was to determine if, by bending the rays with a magnet, Thomson could separate the charge from the rays. Failing this, he concluded that the negative charge and the cathode rays were somehow stuck together.

All previous attempts to bend cathode rays with an electric field had failed, so Thomson devised a new approach in a second pivotal experiment. A charged particle will curve as it moves through an electric field, but not if it is surrounded by a conducting material. Thomson theorized that the traces of gas remaining in the tube were being turned into an electrical conductor by the cathode rays themselves, and managed to extract nearly all of the gas from the tube to test his hypothesis. Under these circumstances, the cathode rays did bend with the application of an electric field. From these two experiments, Thomson concluded, "I can see no escape from the conclusion that (cathode rays) are charges of negative electricity carried by particles of matter."

However, he still lacked experimental data on what these particles actually were, and hence undertook a third experiment to determine their basic properties. Although he couldn't measure directly the mass or electric charge of such a particle, he could measure how much the rays were bent by a magnetic field, and how much energy they carried, which would enable him to calculate the ratio of the mass of a particle to its electrical charge (m/e). He collected data using a variety of tubes filled with different gases. Just as Emil Wiechert had reported earlier in the year, the mass-to-charge ratio for cathode rays turned out to be over one thousand times smaller than that of a charged hydrogen atom. Subsequent experiments by Philipp Lenard and others over the next two years confirmed the conclusion that the cathode rays were particles with a mass far smaller than that of any atom.

Thomson boiled down the findings of his 1897 experiments into three primary hypotheses: (1) Cathode rays are charged particles, which he called "corpuscles. (The term "electron" was coined in 1891 by G. Johnstone Stoney to denote the unit of charge found in experiments that passed electrical current through chemicals; it was Irish physicist George Francis Fitzgerald who suggested in 1897 that the term be applied to Thomson's corpuscles.) (2) These corpuscles are constituents of the atom. (3) These corpuscles are the only constituents of the atom.

Thomson's speculations met with considerable skepticism from his colleagues. In fact, a distinguished physicist who attended his lecture at the Royal Institution admitted years later that he believed Thomson had been "pulling their legs." Gradually scientists accepted the first two hypotheses, while later experiments proved the third to be incorrect, thanks to the efforts of Ernest Rutherford and subsequent researchers. The electron itself turned out to be somewhat different from what Thomson imagined, acting like a particle under some conditions and like a wave under others, a phenomenon that would not be explained until the birth of quantum theory. Physicists also discovered that electrons were only the most common members of an entire family of fundamental particles, which are still the subject of intensive research to better understand their properties.

Thomson's work earned him recognition as the "father of the electron," and spawned critical experimental and theoretical research by many other scientists in the United Kingdom, Germany, France and elsewhere, opening a new perspective of the view from inside the atom. The knowledge gained about the electron and its properties has made many key modern technologies possible, including most of our society's computation, communications, and entertainment.

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