TIME PERIODS

1890s-1939: Atomic Discoveries

1939-1942: Early Government Support

1942: Difficult Choices

1942-1944: The Uranium Path to the Bomb

1942-1944: The Plutonium Path to the Bomb

1942-1945: Bringing It All Together

1945: Dawn of the Atomic Era

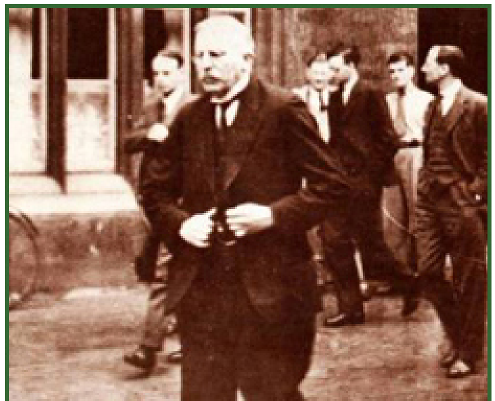
1945-present: Postscript -- The Nuclear Age

EXPLORING THE ATOM

(1919-1932)

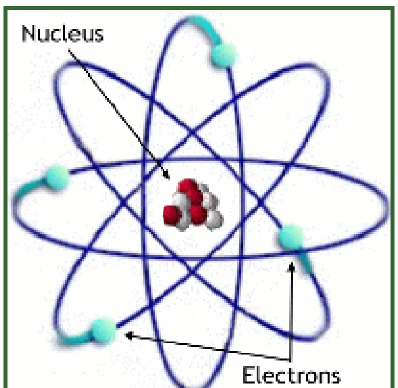
Events > Atomic Discoveries, 1890s-1939

- **A Miniature Solar System, 1890s-1919**
- **Exploring the Atom, 1919-1932**
- **Atomic Bombardment, 1932-1938**
- **The Discovery of Fission, 1938-1939**
- **Fission Comes to America, 1939**



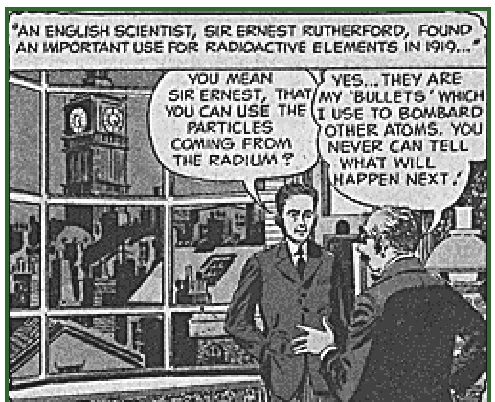
Ernest Rutherford (and James Chadwick, on the far right)

The road to the atomic bomb began in earnest in 1919, when New Zealander Ernest Rutherford reported on a series of experiments he had been conducting, which involved the bombardment of light element nuclei with energetic α (alpha) particles. Rutherford reported that nitrogen nuclei ejected what he suspected was "a hydrogen atom" (a proton). He concluded the nitrogen atom was "disintegrated" in the process, and he subsequently asked Patrick Blackett (a research fellow working under Rutherford) to study what precisely was happening. For the next four years Blackett used a cloud chamber to observe some 400,000 alpha particle tracks, which ultimately revealed that the nitrogen atom being bombarded had been transformed into an oxygen isotope in the process. Blackett published his discovery of the atomic transmutation of nitrogen into oxygen in 1925. The final addition to the atomic "**miniature solar system**" first proposed by Niels Bohr came in 1932 when **James Chadwick**, Rutherford's colleague at Cambridge, identified the third and final basic particle of the atom: the **neutron**.

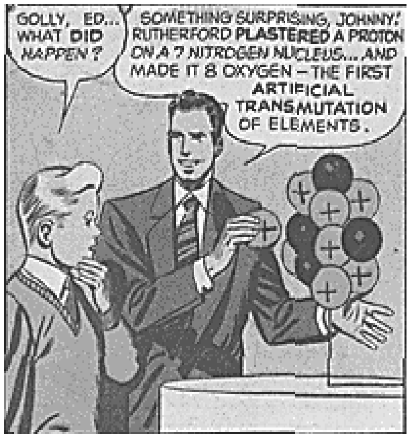


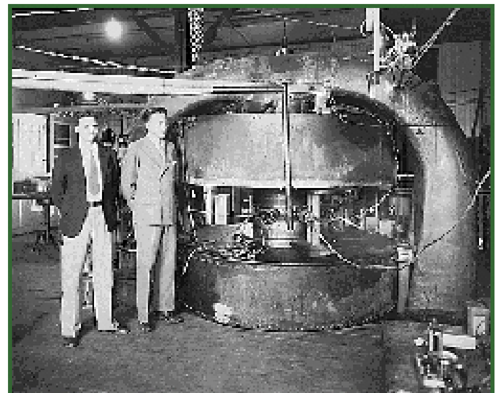
(Simplified) modern model of an atom (of beryllium).

By the early 1930s, the atom was thought to consist of a positively charged nucleus, containing both protons and neutrons, circled by negatively charged electrons equal in number to the protons in the nucleus. The number of protons determined the element's atomic number. Hydrogen, with one proton, came first and uranium, with ninety-two protons, last on the periodic table. This simple scheme became more complicated when chemists discovered that many elements existed at different weights even while displaying identical chemical properties. It was Chadwick's discovery of the neutron in 1932 that explained this mystery. Scientists found that the weight discrepancy between atoms of the same element resulted because they contained different numbers of neutrons. These different classes of atoms of the same element but with varying numbers of neutrons were designated isotopes. The three isotopes of uranium found in nature, for instance, all have ninety-two protons in their nuclei and ninety-two electrons in orbit. But uranium-238, which accounts for over ninety-nine percent of natural uranium, has 146 neutrons in its nucleus, compared with 143 neutrons in the rare uranium-235 (.7 percent of natural uranium) and 142 neutrons in uranium-234, which is found only in traces in the heavy metal. The slight difference in atomic weight between the uranium-235 and uranium-238 isotopes figured greatly in nuclear physics during the 1930s and 1940s.



Adventures Inside the Atom




M. Stanley Livingston and Ernest O. Lawrence in front of a 27-inch cyclotron, Rad Lab, University of California, Berkeley, 1934.

The year 1932 produced other notable events in atomic physics. The Englishman J. D. Cockroft and the Irishman E. T. S. Walton, working jointly at the Cavendish Laboratory, were the first to split the atom when they bombarded lithium with protons generated by a type of **particle accelerator** (dubbed a "**Cockroft-Walton machine**") and changed the resulting lithium nucleus into two helium nuclei. Also in that year, **Ernest O. Lawrence** and his colleagues M. Stanley Livingston and Milton White successfully operated the first **cyclotron** at the **University of California, Berkeley** (right).

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Sources and notes for this page.

The text for this page was adapted from, and portions were taken directly from, the Office of History and Heritage Resources publication: F. G. Gosling, *The Manhattan Project: Making the Atomic Bomb* (DOE/MA-0001; Washington: History Division, Department of Energy, January 1999), 1. For additional information on the work of Rutherford and Blackett, see: American Institute of Physics, Center for History of Physics, "Rutherford's New World," accessed October 12, 2017, https://history.aip.org/exhibits/rutherford/sections/atop-physics-wave.html; Peter Galison, *Image and Logic: A Material Culture of Microphysics*, Chicago, IL, and London, UK: University of Chicago Press, 1997; and Steven B. Krivit, *Lost History: Explorations in Nuclear Research*, vol. 3, San Rafael, CA: Pacific Oaks Press, 2016. The photograph of Ernest Rutherford (and **James Chadwick** in the background) is courtesy the Lawrence Berkeley National Laboratory. The atom graphic is a combination of graphics that were originally produced by the Washington State Department of Health (the nucleus) and the Environmental Protection Agency (everything else); the combination of the two graphics, the labels, and other customizations, are original to the Department of Energy's Office of History and Heritage Resources. The photograph of the cyclotron at the "Rad Lab," and its caption, are courtesy the National Archives. Click **here for more information on the comic book images**.