Reader's Guide to the

HISTORY OF SCIENCE

edited by

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FITZROY DEARBORN PUBLISHERS
LONDON • CHICAGO

FITZROY DEARBORN PUBLISHERS
919 North Michigan Avenue, Suite 760
Chicago, Illinois 60611
USA

or

310 Regent Street
London W1B 3AX
England

British Library and Library of Congress Cataloguing in Publication Data are available

ISBN 1-884964-29-X

First published in the USA and UK 2000

Typeset by Florence Production Ltd, Stoodleigh, Devon
Printed and bound by The Bath Press

Cover design by Philip Lewis

In the 18th century, chemists such as Antoine Lavoisier had noted the conservation of weight in chemical reactions and the constancy of various combining ratios of weights for particular elements. Discoveries such as these led to John Dalton's *New System of Chemical Philosophy* (1808), in which he proposed that atoms had the properties of chemical elements and that atoms of different elements had different, but regular, weights. Chemists dealt with molecules rather than individual atoms, a molecule being the smallest amount of matter that could take part in a chemical reaction, but which often consisted of two or more atoms. For the first half of the 19th century, the chemists' atom held sway, as ROCKE explains in great detail.

With an increasing amount of experimental data available, and with conflicting positions being taken up by both advocates of the chemical atom and advocates of the more simple physicists's atom, as well as by the anti-atomists who refused to regard the atom as something real, the debate was keen and constantly changing. Furthermore, thermodynamic theory suggested that the underlying reality of the universe was not matter but energy: nevertheless, atomism offered the possibility of a unified science and the holy grail of a causal, rather than statistical, explanation of everything. This crucial fourth phase of atomic theory has been documented by NYE, who offers a comprehensive collection of all the key papers in the development of modern atomic theory from 1860 to 1911, as well as providing an authoritative introduction to the issues at stake. Stanislao Cannizzaro proves to be a central figure in these discussions.

KELLER describes the origins of modern atomic physics. The discoveries of the electron by J.J. Thomson and of radioactivity by Pierre and Marie Curie focused further attention on the physicists' atom. Atomic spectra implied regular electron energy levels, but how could all this be explained? In 1901, Jean Perrin proposed a solar model of the atom. Thomson then suggested a plum-pudding model, with negative electrons being embedded in a positive mass. Thomson's model, however, was in conflict with many observations. New discoveries and theories followed in rapid succession: in 1904 Lorentz proposed that mass may vary with motion, an idea taken up the following year in the relativity theory of Einstein; in 1905 Einstein also introduced Planck's constant to solve the problem of the photoelectric effect; by 1909 Poincaré was able to reduce chemistry to physics by the identification of the physical with the chemical atom; finally, in 1911, Ernest Rutherford proved experimentally that the atom consisted of a large, positively-charged nucleus surrounded by relatively small, negatively-charged orbiting electrons.

But the modern atom made no sense: the negatively-charged electrons should give off radiation and spiral into the positively-charged nucleus, so what kept Rutherford's atom stable? Niels BOHR suggested in 1913 that there was a lower limit to continuity in nature, and hence that the electrons were not allowed to collapse below energy levels determined by a ratio of Planck's constant, the quantum of action: in this way, stability was established for Rutherford's atom and quantum theory conceived. Bohr's popular essays on this topic enjoy classic status and introduce key ideas of quantum theory, including Heisenberg's contribution in 1925, while GAMOW offers an intimate, entertaining, and more accessible history of these developments.

After two and a half millennia, the philosophers' atom, moving in a void, has been replaced by the physicists' atom, in which space and matter are relativistically connected. Nuclear experiments would identify hundreds of sub-atomic particles, all possibly formed from various combinations of quarks, so that the elusive quark now became the new atom.

JOHN HONNER

See also Atomism

Atomic Weapons

Hershberg, James G., *James B. Conant: Harvard to Hiroshima and the Making of the Nuclear Age*, New York: Knopf, 1993

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More than any other scientific development in the 20th century, or perhaps in any century, the creation and use of atomic weapons in World War II have transformed the relationship of science to society. Not only has science been harnessed by the state in a manner infinitely more destructive than the extensive militarization of science before the advent of atomic weapons, but the debates and controversies within societies about the extent and prevalence of atomic weapons have generated new societal controls over scientific work. The history of the development of atomic weapons provides unique insights into the often fraught relations between 20th-century science and postwar society.

RHODES offers a broad survey in an accessible form, with his history of the American development of nuclear fission weapons at Los Alamos, New Mexico, and their use against Japanese civilians at Hiroshima and Nagasaki. He draws heavily on secondary literature to paint a picture of the project as a conflict between the internationalist ideals of scientists and the nationalist "death machine" that militarizes scientists' discoveries in a conscious attempt to subvert their ideals. As an introduction to the physics and politics of developing the bomb, this book is an excellent resource.

There is a series of more detailed studies on different aspects of the project. HODDESON *et al.* provide a highly technical history of the scientific work at Los Alamos. Based on archival documents, they trace the various scientific problems posed by the construction of a gun-type uranium bomb, and the more challenging implosion plutonium bomb. The emphasis throughout this book is on the bomb as "science", and not just the application of prewar physics. In this emphasis on the active and creative excitement of Los Alamos physicists, however, some of the destructive and moral implications of the weapons are lost.

HOUNSHELL & SMITH provide a different viewpoint of the work at Los Alamos. Instead of focusing on the scientists and their work on the Manhattan Project, they place the development of the bomb and the extensive uranium purification and plutonium production plants in the context of industrial history. Specifically, while tracing the history of DuPont as a giant of the American chemical industry, they devote considerable attention to the *engineering* of the bomb by industrial chemical engineers. As a complement to Hoddeson *et al.* this work is useful for showing how the Los Alamos project was directed from the start to be mass-produced as a tool of hostile statecraft.

As yet another aspect of the history of atomic weapons, SHERWIN discusses the complicated diplomatic political history surrounding the decision to use the bomb and the explicit denial of arms control arrangements with the Soviet Union. Sherwin concentrates on the decisions by president Truman and secretary of state Stimson about the choice of a target site, and the fear of the Soviet Union that motivated so many American decisions. The political picture presented is one of little doubt that the bomb would be used against Japan, and that the rejection of scientists' plans for arms control was a foregone conclusion. This political dimension nicely supplements the technical and engineering approaches of Hoddeson *et al* and Hounshell & Smith.

A biographical approach to similar material is offered by HERSHBERG in his biography of James B. Conant, a former president of Harvard and an atomic scientist and policymaker. Conant's career is traced through his early work mobilizing scientists for the bomb effort, through the early postwar attempts to control the bomb, and then to his outspoken opposition to an acceleration of the arms race. Hershberg's account reminds historians that the course of the history of atomic weapons was determined by individuals, and by using Conant as a tool to trace the contours of both science and diplomacy, Hershberg allows the personal side of atomic weapons to emerge.

For all the extensive study of the American development of atomic weapons, military nuclear projects in other nations have been relatively understudied, with some excellent exceptions. WALKER's concise and detailed history of the German uranium project traces the Nazi decision to begin a nuclear project, and then the fairly rapid rejection of nuclear bombs as unfeasible (a decision made by the German military), and a refocusing of war work on nuclear reactors to power military vehicles. Given that the prospect of a German bomb was a major incentive for the American Manhattan Project, Walker's study provides an illuminating insight into science-state relations under the Third Reich, and forcefully argues for the remoteness of a Nazi nuclear threat.

HOLLOWAY's magisterial study of the Soviet bomb is, on the other hand, a success story. He not only outlines the early attempts to initiate a nuclear project, begun in earnest only after Stalin saw the end of World War II approaching, but also documents the massive atomic "empire" built by prisoners and marshaled by Lavrenti Beria, head of the secret police. The book also extensively explores the importance of atomic espionage and the suitability of the Stalinist command economy in facilitating the Soviet atomic and hydrogen bombs. Diplomacy and the origins of civilian nuclear energy are also carefully presented.

A word should be said about the impact of atomic weapons on other sciences. It is widely acknowledged that the spectacular success of the Manhattan Project provided new political support and massive funds for the physical sciences. LINDEE's work on the American attempts to study the Japanese survivors of the bombings of Hiroshima and Nagasaki highlights how much of the new sciences of human genetics and population biology also rode in on atomic coattails. Her archival work on the American side of the project is regrettably not complemented by adequate study of Japanese perceptions of this work, but her integration of "big biology" into the atomic age of big physics was much overdue.

Even within the localized history of atomic weapons during and immediately after World War II, one can detect the complicated intertwining of science and society. As the history of atomic weapons is expanded in time and depth, the evidence of the relationship is broadened for all cultures and states. This feature makes this history an exceptionally good guide to social aspects of the history of science.

MICHAEL D. GORDIN

Atomism

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