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Survey of Current Literature on Effects of Ionizing Radiations on Chemical and Cellular Systems as These Pertain to an Understanding of the Basic Biological and Biochemical Effects of Ionizing Radiations

FINAL REPORT

for the Period June 1, 1954 through May 15, 1956

on

Contract AF-19 (604)-1109
with the
USAF School of Aviation Medicine
Randolph Field, Texas

by

Bernard E. Proctor, Samuel A. Goldblith, and Philip M. Richardson

Department of Food Technology
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

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*This report, not necessarily in final scientific form, is intended only for the internal management uses of the contractor and Air Force.

Note:

This survey of the literature pertaining to the effects of ionizing radiations on biological and biochemical systems covers the period June 1945 - June 1955. Doubtless important papers have been omitted through oversight, but many of these are included in review articles mentioned in the bibliography.

Although a specific reference to all papers included in the bibliography has not been made in any section, it has been considered worthwhile to include them as they have been used in a general way in constructing the theme of each section.

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I. INTRODUCTION

Many of the fundamental phenomena of radiation biology were recognized in the early part of the century, following the discovery of X-rays and radioactivity. Recent developments in biochemistry, biophysics, pathology and related fields, together with easily available sources of particular radiations, have stimulated intesive research on the effects of ionizing radiations, and possible prophylactic measures.

The literature of this field is voluminous. During the period 1945-1955 (the period covered by this survey), thousands of papers were published pertaining to radiation effects on biological systems. Thomson (42) considers that much of the more recent experimental work seems to "deal with reiteration, extension, or refinement of previously established concepts" and that "new approaches to the solutions of problems in vertebrate radiobiology have been disappointingly small". Edelmann (11) is more optimistic. He believes that "significant advances and changes in ideas have taken place" in the latter part of the period, and that "the descriptive phase of radiobiology has passed, and investigations are more concerned with the mechanisms of the phenomenon". Many more laboratories are now engaged in radiation research, and are contributing extensively to our knowledge of radiobiology. That any contribution increasing our knowledge of the underlying mechanisms producing radiation effects is most essential, in this atomic era, cannot be denied. Much of these investigations have produced negative results. But as is so usual in biological research, negative results can be quite as important as the more encouraging positive results.

II. GENERAL

In examining the literature of this field, it appears that there have been published many review papers, bibliographies, and various compilations of research work pertaining to the subject. It is of interest, therefore, to consider some of the more valuable contributions from the chronographic point of view.

The investigations of Hevesy and his colleagues (7,8,16) following World War I, stand out as establishing a firm basis for further work in radiobiology. In 1933, Evans (14) described certain of the biologically destructive effects of radioactive substances which have become fixed in a living system, mentioning particularly that among the most common symptoms of radium poisoning are necrosis of the jaw, osteogenic sarcoma, and regenerative anemia. In 1940-41, Muller (25-27) was able to show the genetic effects of radiation on Drosophila, and somewhat later, Stadler (35) demonstrated the effects on maize. The effects of and reactions to ultra-violet and X-radiation were described in 1941 by Ellinger (13) and Lehmann (22). Much of the earlier findings were discussed in a comprehensive review by Duggar (10), and by Lea (20) on radiobiological effects at the cellular level. Lea's book is considered by many to be a classic in radiobiology. Recently (21), a revision of the book became available which is essentially unchanged from the earlier work. Of value, also, is Siri's (34) compilation of some of the material considered to be most essential to applications of isotopic tracers and nuclear radiations, and which brings together much of the data of biology and physics which, prior to 1949, was unavailable in a single volume.

At the outset, it may be noted that, except for total-body shielding, there appear to be no effective methods or materials especially promising for the successful treatment, after exposure, of radiation damage in higher animals. Obviously, complete protection from the effects of radiation is of primary concern. This fact, then, should continue to be impressed on all personnel engaged in experimental radiation studies, and extreme precautions should be taken for their protection, even at the very lowest dose levels.

This report deals with a critical examination and evaluation of the literature that has been published concerning the acute and chronic effects of

ionizing radiations on biochemical and cellular systems, purely physical factors being included only as they concern biological effects. The report is not intended to be a complete survey of the literature on ionizing radiations but rather to be a survey of the important information on radiobiology available in the literature, properly evaluated, with conclusions and recommendations that may serve as bases for planning research programs in specific areas within the field.

Following the operation of the first chain-reactor at the University of Chicago in December 1942, and the Alamogordo test explosion in July 1945, impetus was given to experimental studies of ionizing radiations, and with this expansion, the publication of results became plethoric. It became evident that some sort of organization was needed. Many informal discussions and a number of symposia were held at which an exchange of ideas could take place. Because of the vast literature accumulation, scattered through so many journals, organizational coordination in this field resulted in the formation of the Radiation Research Society, March, 1952. The Society now publishes its own journal (32), and an attempt is made to integrate the natural sciences and an understanding of radiation effects.

The publications of the Manhattan Project Technical Section of the National Nuclear Energy Series comprehensively review the scientific and technical achievements of the United States program for the development of atomic energy. Health volumes of this series contain reports of work done during the period September 1942 to June 1945. These reports represent much of the extensive medical and biological research undertaken as a part of the Plutonium Project. Bloom (6) gives detailed information on techniques and materials, and describes the effects of various rays (beta, gamma, fast and slow neutrons, X-rays) on cell structure and cell pathology. The medical services of the Plutonium Project, and studies relating to the protection of plant personnel and to the safe-guarding of the health of the public in surrounding territories is described by Stone (36). In 1951, Zirkle (46) published studies of pure beta irradiation of considerable tissue areas and whole body, of laboratory animals, and in 1954 (47) results of experiments using gamma radiation on several animal species (mice, guinea pigs, rabbits, dogs) together with in vitro biochemical studies.

Somewhat earlier, Fink (15) compared the biological effects of the three alpha-particle emitters, polonium, plutonium, and radium, and included a

survey of the critical literature of these elements. Predating these publications is a report of the results of chronic radiation on mice, guinea pigs, and rabbits (31).

An important forward step was made in 1950 when the Committee on Nuclear Science of the National Research Council decided to "sponsor the preparation of a series of annual review volumes covering the important developments in the fields of nuclear science each year" (33). This series, published as the "Annual Review of Nuclear Science", together with the Annual Review of Physiology, Physiological Reviews, and Progress in Biophysics, constitute essential references for the investigator of radiobiological phenomena. The National Academy-Research Council has been responsible for the organization of several conferences (23,28,29) concerned with radiobiology, energy transfers and degradations, and effects of radiation on biochemical substances and systems. The American Physiological Society sponsored a symposium on radiation protection at New York City in April 1952 (I), as did the Section of Biology of the New York Academy of Sciences in April 1954 (24). Several symposia have been sponsored by the Biology Division of the Oak Ridge National Laboratory and have been published in special supplements of the Journal of Cellular and Comparative Physiology (9,12,30,38,39,41,42). Recent developments on the Medical and Physiological Applications of Isotopes were discussed at Oxford in July 1954 (18). Also, in 1954 (August 29 - September 1), twelve countries were represented at a radiobiology meeting held at Liege, at which many valuable contributions to the field were presented (3).

General discussions of nuclear theory and its biological and medical applications, the nature of hazards, dosimetry, toxicity, and other subjects relating to the physical aspects of radiobiology have been published (5,19,37).

The effects of high energy, ultraviolet, and visible light radiations on biological and biochemical systems are well discussed in a recent text edited by Hollaender (17). Supplementing this, with differences of view-point, is a stimulating account of the present state of research in the field of radiobiology as it appears to a physiologist and a radiation chemist (4).

Of extreme importance are the research and development reports of the United States Atomic Energy Commission and its contractors, and the military agencies of the United States. Extensive bibliographies pertaining to the many aspects of atomic energy have also been published by the USAEC (2,43,44,45). These and other references will be cited in the appropriate place in this report. Certain papers of a general review nature, while not specifically referred to, have been of value in assembling material for this report, and are included in the bibliography for completeness.

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