Twenty five Years

A BRIEF HISTORY

of the

University of Rochester

ATOMIC ENERGY PROJECT

from

1943-1968

Department of Radiation
Biology and Biophysics

A BRIEF HISTORY

of the

UNIVERSITY OF ROCHESTER ATOMIC ENERGY PROJECT

from

1943 - 1968

by

Henry A. Blair

department of radiation
biology and biophysics

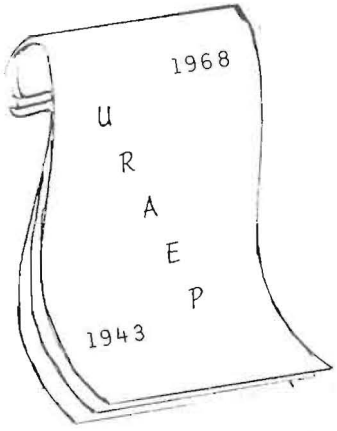
Dr. Henry A. Blair

Chairman of Department and Director of Project

1948 - 1965

TABLE OF CONTENTS

BACKGROUND



Because the UNIVERSITY OF ROCHESTER ATOMIC ENERGY PROJECT arose from the *Manhattan District of the United States Army Corps of Engineers* which was responsible for development of the atomic bomb, it will be convenient for orientation to outline the establishment of the *Manhattan District* as a background for the ROCHESTER PROGRAM.

During the year *1939* the existence of the process of nuclear fission was well established and by *1940* it was realized, both here and abroad, that it was probable that a practical fission bomb could be made for military purposes. After much discussion of feasibility both in the *United Kingdom* and in the *United States*, a decision was made to proceed in this country. Therefore, in *JUNE 1942* a new district, the *Manhattan District of the United States Army Corps of Engineers*, was authorized under the direction of *Colonel* (later *Brigadier General*) *J. C. Marshall* to organize a program of atomic bomb development. In *SEPTEMBER 1942 Brigadier General* (later *Lieutenant General*) *Leslie Groves* was placed in charge of all army activities devoted to the bomb.

In *DECEMBER 1942* the first self-sustaining chain reacting pile using natural uranium was demonstrated at the *University of Chicago*. This not only showed that a chain reaction such as that required to produce a bomb explosion would occur under proper conditions but it also showed the feasibility of manufacturing plutonium-239 which could be used as an alternative to uranium-235 as an explosive material.

Meanwhile, in *SEPTEMBER 1942* the *Manhattan District* purchased a 58,000 acre site at *Oak Ridge, Tennessee* which soon became a vast industrial complex employing up to 45,000 personnel engaged, for the most part, in the separation of fissionable uranium-235 from natural uranium. Shortly afterward another large site of 420,000 acres was purchased at *Hanford, Washington* where construction of facilities for production of plutonium was started in *APRIL 1943*.

It became evident during these developments that hitherto inconceivable amounts of radioactive materials would soon be produced. It was well known that their radiations would be very hazardous to health but it was not known how well they could be controlled. Furthermore, atomic bomb production, from the processing of uranium ore onward, would involve the use of large quantities of chemical materials with potentially toxic properties which had not been well studied.

Clearly a large medical program was required involving not only hospitals for the new atomic cities but also facilities for the surveillance of plants and the protection of personnel. In addition, research programs to determine potential dangers of the new materials were urgently needed.

ROCHESTER first became involved in this medical program in the middle of *FEBRUARY 1943* when *Dr. Albert K. Chapman*, then vice president and general manager of Eastman Kodak Co., invited *Dr. Stafford L. Warren*, then Professor of Radiology at the Medical School, to luncheon at the Rochester Club. At the luncheon he was introduced to *General Groves* and *Colonel Marshall* who queried him on his experience with radiation and radioactive materials.

Following the luncheon *Dr. Chapman* left after advising *Dr. Warren* to do whatever the officers requested. Then, according to *Dr. Warren's* account, the officers took him to a private room where, after locking the door, closing the transom and examining a closet, they asked him if he would consider working

on a medical program of great importance to the government but which involved the utmost secrecy.

Following consultation with President Valentine and Dean Whipple, on MARCH 2, 1943 Dr. Warren accepted an appointment as civilian consultant to the Manhattan District.

MANHATTAN PROJECT ERA

In APRIL 1943 Dr. Warren and Major H. L. Friedell of the Manhattan District (now Professor of Radiology at Western Reserve University) planned an initial research program at ROCHESTER. Shortly thereafter Captain (later Lieutenant Colonel) Van Horn was assigned as area engineer in ROCHESTER. On JUNE 2, 1943 the present B Wing of what is now called the Annex was started on the north side of Elmwood Ave. and was rushed to completion by SEPTEMBER 1943. This building, along with the adjoining, pre-existing A Wing of the Annex which had been built the previous year by the Radiology Department and equipped with a million volt X-ray machine to examine castings for the Armed Forces, provided a center for the new program. Additional space was provided by other departments, notably Biology, Physics, Biochemistry, and Radiology.

Although some medical research for the bomb program had been begun the previous fall at the University of Chicago Mettallurgical Project under the direction of Dr. Robert Stone, then normally Professor of Radiology at the University of California Medical School, San Francisco, it will be seen from the dates above that the ROCHESTER PROGRAM was developed quite early along with the two large production sites at Oak Ridge and Hanford.

The primary reasons for choosing ROCHESTER as a research center were that Drs. George Whipple and Stafford Warren had done pioneer work on the injurious effects of X-rays in dogs some 15 years previously and that early applications of cyclotron-produced radioactive isotopes to biological problems had been made in the Medical School, especially through the efforts of Dr. William Bale who had developed the necessary instrumentation.

The new program in ROCHESTER was called the MANHATTAN PROJECT, a name designed to conceal its mission, which was very highly classified in those days, and a name already adopted by

the *Manhattan District* for the same reason.

The original staff of the *PROJECT* consisted of *Dr. Warren, Dr. Andrew Dowdy, Dr. William Bale, Dr. Luville Steadman, Mr. Francis Bishop* and *Miss Susan Glover,* all from the Radiology Department, and *Dr. Harold Hodge* from the Department of Biochemistry and Pharmacology. Recruitment of staff proceeded rapidly during the summer and fall of *1943* and later until the total number of personnel during the war reached about 350, some of whom were on military assignment.

Dr. Warren directed the local program in addition to advising the *Manhattan District* on its overall medical development until *NOVEMBER 3, 1943* when he was commissioned Colonel and appointed Chief of the Medical Section of the *Manhattan District* with headquarters in *Oak Ridge, Tennessee.* In this capacity he was responsible for all the health and medical activities of the *Manhattan District* and its contractors. *Dr. Dowdy* succeeded *Dr. Warren* as Chairman of the Radiology Department and Director of the local *PROJECT.*

During the period of the war the *ROCHESTER PROJECT* had two broad undertakings, one consisting of practical technical services and the other research.

In its service function the *ROCHESTER* group analyzed the periodic reports on medical examinations of personnel in the *Manhattan District* plants all over the country. It also advised these plants on how to protect their employees by: (*a*) determining "tolerance standards" for exposure to radiation and toxic chemicals; (*b*) developing instruments to measure exposure; (*c*) measuring intensities of radiation and concentrations of toxic dusts in plants; and (*d*) suggesting measures to make operations safer.

Work at *ROCHESTER* was coordinated through *Dr. Warren's* office with that of laboratories at the *Universities of Chicago, California,* and *Columbia,* which had also undertaken *Manhattan District* assignments, and with medical and industrial hygiene

Dr. Joe Howland began his atomic career during the war as a member of Colonel Warren's staff at Oak Ridge. Later he headed the Medical Division of the local Project.

workers at the production plants. The combined efforts of these groups, with the effective cooperation of the operating staffs, made possible the excellent health record of the *Manhattan District.*

The war-time work, being new to almost everyone involved, led on occasion to unexpected or amusing situations.

> One time, for example, *Drs. Bale* and *Enns* were assigned the task of determining radiation levels at an *Ohio* plant which was devoted to production of an alpha emitter. Because this radiation is difficult to measure, they developed an apparatus of high sensitivity and proceeded to *Ohio.* On reaching the plant and starting their measurement they discovered that the radiation levels in the administrative offices of the plant were so high that their instrument went off scale. Clearly, the housekeeping in this plant had fallen far short of ideal.

Another episode illustrative of the times involved shipment of radioactive material.

> Because there was some possibility that the Germans might be producing, in atomic piles, radioactive isotopes which could be spread on the ground to deny safe access to troops, an experiment was planned to obtain some data on how the exposure to personnel would be related to the amounts of dispersed radioactive material.
>
> A curie of radioactive sodium of short half-life was shipped by air by *Dr. Robley Evans* of *M.I.T.* for the experiment. *Drs. Warren, Bale* and *Hodge* met the shipment at the airport with a flat-bed truck piled high with concrete blocks for shielding the container which they thought might be emitting radiation because a curie was a colossal amount of radioactivity in those days. Also, they took with them a long pole with which the container could be carried at safe distance from the bearers. The truck was parked near the plane with the pilot in the cabin waiting to resume flight. When the pilot saw the container being borne on the pole and being carefully shielded after deposition on the truck, he opened the window and shouted, *"My God! What's that? I have been sitting over it all the way from Syracuse."*
>
> Actually, *Robley Evans*, being an old hand even in those days, no doubt shipped the material with adequate shielding but the pilot was so alarmed that after failing to receive answers, for security reasons,

from the ROCHESTER group on what he had been sitting over, traced the shipment. His report to the authorities resulted in suspension of air shipment of radioactive materials for some months until a federal code was established.

The experiment itself was conducted outdoors at night to avoid curious onlookers with no great hazard to anyone except Dr. Hodge. A young lady technician, who had just started to work that day, was asked to stay overtime to assist. When Dr. Hodge delivered her to her home at 4:00 o'clock in the morning, they were met by an irate parent who, fortunately, was ultimately reassured.

War-time security regulations were strict but conformity soon became routine. Unless especially authorized, personnel working on one topic in the laboratory were forbidden to discuss their work with those working on another topic. Guards on duty around the clock admitted no one without an official pass. Anyone who left his pass at home was escorted to the front office for identification and issued a special pass for the day, no matter how well he was known.

It may be apocryphal but it is said that Dean Whipple decided to visit the Annex on one occasion but forgot his pass and was refused admission by the guard. The Dean, of course, had been cleared along with other officers of the University who might be involved in administering the contract so, from the point of view of security regulations, he was a legal visitor in his own domain - *but not without his pass.*

In August 1945 Colonel Groves presented to President Valentine an award from Manhattan District for services of Project to war effort

Looking on - L to R: Dr. Hodge, Dr. Dowdy, Col. Warren and Dr. Bale

POST-WAR ERA

On JANUARY 1, 1947 the newly formed United States Atomic Energy Commission took over all contracts and facilities of the Manhattan District including the local program which was renamed THE UNIVERSITY OF ROCHESTER ATOMIC ENERGY PROJECT. Since that time the PROJECT has been responsible to the Manager of the New York Operations Office of the Commission for fiscal matters and to the Director of the Division of Biology and Medicine at the Commission's Washington Headquarters for the conduct of the scientific program. Association with the Commission's national laboratories and other contractors is maintained by periodic meetings at the various sites. In recent years the PROJECT has been responsible to the Director of the Commission's new Division of Nuclear Education and Training with respect to Commission-supported educational activities.

When Dr. Dowdy resigned in DECEMBER 1947 to become Chairman of the new Department of Radiology at the Medical School of the University of California at Los Angeles, where Dr. Warren had been appointed Dean after the war, it was decided to form, at ROCHESTER, a new pre-clinical department of the Medical School, the Department of Radiation Biology, to administer the contract with the Commission. Dr. Henry Blair was appointed Chairman of the new department and Director of the ATOMIC ENERGY PROJECT in JANUARY 1948 and he occupied these positions until he retired in JUNE 1965 to be succeeded by Drs. William F. Neuman and Aser Rothstein as Co-Chairmen and Co-Directors.

The reasons for forming a new pre-clinical department were that very few of the PROJECT staff were clinicians and that it was expected, when war-time security restrictions became lifted, integration of the activities of the PROJECT with those of the rest of the Medical School would be largely at the indicated

pre-clinical level. The present name of the Department, Radiation Biology and Biophysics, was adopted in *1965*; the addition of Biophysics being for the purpose of describing one of the major teaching and research interests in addition to Radiation Biology.

The program of the Department underwent considerably more evolution than is usual following the war. During the war, as was mentioned above, in addition to the research programs, other services were performed for the whole *Manhattan District*. The research programs were restricted largely to problems assigned by the *Manhattan District* and all reports and publications were highly classified and were distributed only to those other components of the *Manhattan District* that had need to know their content.

When the Commission assumed jurisdiction in *1947*, it established a new organization, the *Health and Safety Laboratory* in *New York City*, which took over all the service functions of the *PROJECT* leaving only research and consultation. To these were soon added an educational program and the administration of a fellowship program in Industrial Medicine. The overall mission of the *PROJECT* remained, as before, to develop information and to provide instruction on the biomedical problems of nuclear energy development.

Meanwhile, the security classification of research topics in biology and medicine was lifted rapidly until by *1950* virtually all of the local programs were unclassified. This permitted, for the first time, free exchange of information with the rest of the Medical School and free access to the laboratories by those other than employees with clearances. Other important effects of declassification were that the accumulated war-time research results could be published in the open literature and an educational program open to both foreign and domestic students could be undertaken.

Additions of space were required for the teaching program

O Wing - constructed in 1950

OO Wing - constructed in 1966, adjoining O Wing

Aerial view of Medical Center ca 1952
A - Medical School Annex; B - O Wing

Annex (ca 1962) after addition of third floor to B Wing

and for extension of the research programs. As mentioned above, the building occupied by the Department on the north side of Elmwood Avenue is called the Medical School Annex, or just the Annex. It now consists of three wings, A, B, and C. Wing A, 9700 sq. ft., was constructed in *1942* by the University to house high voltage X-ray equipment for testing castings for the Armed Forces as previously mentioned. Wing B, originally 15,000 sq. ft., and Wing C, originally 19,000 sq. ft., were built by the *Manhattan District* in *1943* and *1944*. Education space, O Wing, 53,000 sq. ft., was built by the Commission as an addition to the Medical School in *1950*. A tunnel under Elmwood Avenue connects this building to the Annex. Additions to B Wing of the Annex have been: the Alpha Laboratory, 6,000 sq. ft., in *1952*; a third floor, 5,200 sq. ft., in *1961*; and a low level counting facility, 600 sq. ft., in *1964*. In *1951* 900 sq. ft. were added to C Wing for flash burn studies. A radioactive storage vault, 200 sq. ft., was constructed off the tunnel joining the Annex and the Medical School in *1961*. All of these additions were built by the Atomic Energy Commission. During *1965* and *1966* additions to O Wing of the Medical School totaling 50,000 sq. ft. were constructed. These consisted of an underground radiation facility off the tunnel and an eight-story builing, OO Wing, adjoining O Wing and containing laboratories and lecture rooms. The total space occupied by the Department by *JANUARY 1967* was approximately 160,000 sq. ft., exclusive of storage.

Upon completion of the new building, a conference room in OO Wing was named the CHARLES L. DUNHAM ROOM in honor of *Charles L. Dunham*, Chairman of the Division of Medical Science, National Academy of Science National Research Council, who was associated with the Division of Biology and Medicine of the Atomic Energy Commission from *1949* to *1967* and was Director of the Division from *1955* to *1967*.

The Department Library in O Wing, which had to be remodeled because of the new construction, was named the HENRY A. BLAIR LIBRARY in honor of the first Chairman of the Department.

Dr. A. Rothstein, Dr. H. A. Blair
and Dr. W. F. Neuman
at dedication of "Blair Library"

The total personnel of the Department usually numbers about 340, including approximately 260 full-time employees, 30 student assistants, and 50 other students and fellows. The academic staff, including 14 to 17 technical associates, usually numbers about 70.

Owing to the breadth of the teaching and research programs, the faculty represents a wide diversity of training and interests. These include biochemistry, biology, biophysics, chemistry, engineering, health physics, physiology and toxicology. Many of the research problems in the Department require the application of various groups of these disciplines for their solution and the teaching program requires elements of them all.

The faculty has tended to remain relatively stable, particularly at the senior levels. About 20 of the current faculty (listed in the Appendix) have been on the staff since before the present Department was formed in *1948*.

Six supervisory members of the Department have died while in office. *Dr. S. Lee Crump*, head of the Statistics Section for about 14 years, died in *APRIL 1963*. *Dr. Elliot Maynard*, who served on the staff for about 20 years and who was head of the Chemical Toxicity Section, died in *MARCH 1964*. *Mr. William L. Downs*, who joined the staff in *1944* and made large contributions to studies of toxicity, died in *APRIL 1967*. *Mr. Carson M. Jarvis*, who served ably as Business Manager for about 15 years, died in *JULY 1961*. *Mr. Norman Oakes*, who supervised maintenance for nearly 20 years, died in *AUGUST 1962* and his successor, *Mr. Clarence Fuller*, died in *AUGUST 1966*.

It is not possible, in a reasonable amount of space, to list the particular contributions to the program of various

individuals. This is particularly true of the supporting staff, business, mechanical, and technical, who were unusually numerous because the Department has always maintained its own services separate from those of the Medical School. In the Appendix, however, are listed the names of all the staff members who were authors of Departmental publications along with the names of those in other departments or at other organizations who collaborated in the publications from the beginning of the *PROJECT* up to *JANUARY 1967*.

Dr. E. A. Maynard, Dr. A. Rothstein, Dr. J. N. Stannard,
Dr. H. C. Hodge, Dr. J. K. Scott and Dr. W. F. Neuman
in 1958

Dr. Hodge remained in charge of the Division of Pharmacology of the Medical School when it was transferred from the Department of Biochemistry in 1946. The reason for the transfer was that most of the personnel in Pharmacology were then employed on the PROJECT and carried out all their research activities there. The Division of Pharmacology became a division of the Department of Radiation Biology when it was formed in 1948 and remained so until it became a separate department in 1958.

Until the Department of Radiation Biology was formed, the principal medical teaching responsibility of the PROJECT was in Pharmacology although various individuals took part in some other courses. Graduate work in Pharmacology and Biophysics was carried on but at a low level because of the classification of thesis research and the paucity of candidates during the war. However, only a small part of the PROJECT staff was involved in teaching and when the Department of Radiation Biology was formed, there was considerable enthusiasm for starting greatly expanded graduate teaching programs in the biomedical fields of interest to the Commission.

In 1948 the Commission inaugurated a fellowship program in Health Physics. Vanderbilt and ROCHESTER were selected as the initial training schools and Oak Ridge National Laboratory and Brookhaven National Laboratory were chosen to supply practical experience to the fellows in the summer following the academic year.

The Department developed, in 1948-49, a curriculum for these fellows in Radiation Biology, Radiological Physics, Industrial Hygiene and Toxicology, and Statistics. A general course in Tracer Chemistry was begun at that time.

The following year a program in Industrial Medicine was developed in collaboration with Eastman Kodak Company physicians and representatives of some other industrial organizations. This was to accommodate holders of a new fellowship in Industrial Medicine first offered by the Atomic Energy Commission in *1950*.

During the academic year *1950-51* the expanded graduate program was well under way with 57 students in various specialties in Health Physics, Radiological Health, Industrial Medicine, Radiation Biology, Biophysics, and Pharmacology.

The program in Industrial Medicine was taken over by the Department of Preventive Medicine and Community Health when it was formed in *1958* and the newly formed Department of Pharmacology assumed responsibility for graduate work in Pharmacology the same year.

This left the Department of Radiation Biology with graduate degree programs in the two fields, Radiation Biology and Biophysics, which it retained alone until *1965* when a degree program in Toxicology was developed in collaboration with the Department of Pharmacology. This program was initiated in *1966*.

Since the expanded graduate program was begun in *1950* it has undergone considerable evolution both because of widening interests of the faculty and because of various requests for training in the nuclear energy field. One of these requests was for basic training of physicians in preparation for assignment to nuclear powered submarines. Another came from the Defense Atomic Support Agency for training of physicians and health physicists to deal with radiation health problems in the various Armed Services. Considerable demand came from foreign nationals whose countries were planning atomic energy development.

Most of these special training programs were of one-year duration and were largely didactic. Consequently, although the faculty appreciated the need for rapid increase of specialists

in radiation health, they looked forward to a decrease in this type of short-term instruction in favor of an increase in Ph.D. programs with concomitant emphasis on research. This change gradually took place partly because numerous programs for radiation health specialists were developed in other schools and partly because more good candidates for advanced training became available.

In anticipation and in promotion of this change, more general graduate courses were introduced beginning in 1953-54 with Physical Chemical Principles in Medical Science and Physico-Chemical Principles in Pharmacology. Various changes and additions were made from time to time in the original curriculum, especially in the fields of aerosols, toxicology, radiation detection electronics, and biological effects of radiation.

With the award of a Biophysics Training Grant from the U. S. Public Health Service in JANUARY 1963, the scope of teaching was broadened to emphasize the cellular and molecular aspects of this subject previously largely confined to radiation biophysics.

In 1965 the whole curriculum was revised and extended with the main objective of providing three parallel, although not mutually exclusive, Ph.D. programs in Radiation Biology, Biophysics, and Toxicology. Most of the special courses in subjects related to radiation health were retained but with the expectation that those not incorporated in the Ph.D. programs would be reduced to a level of providing only necessary supplementation to the basic Ph.D. curriculum which would also be used for students in radiation health as far as was appropriate.

In recent recruitment of new staff members, attention has been paid to additions of disciplines which will strengthen the new curriculum.

With the acquisition of additional space it is expected that the graduate student population, which has been about 70 to 80 in recent years, will be increased to about 100 and

that the proportion of Ph.D. candidates, which exceeded one-half for the first time in *1964*, will increase further.

Including those registering in *1967*, there have been 799 graduate students in the Department since *1948*. A substantial number of these on one-year programs were not degree candidates and many others are still in residence. Degrees awarded up to *1958* in Pharmacology and for the whole Department up to *1967* are as follows:

Field	*Degree*	
	Ph.D.	*M.S.*
Biophysics	*26*	*11*
Radiation Biology	*55*	*256*
Pharmacology	*25*	*20*
Total	*106*	*287*

The preponderance of M.S. degrees in Radiation Biology arose from the practice of awarding this degree to those who satisfied degree requirements in radiation health programs. Recipients of the various degrees are listed in the Appendix.

Throughout this period the Department made very substantial contributions to training in the field of radiation health both here and abroad. It was also instrumental in the development of a body of scientists skilled in the application of the new methods provided by atomic energy and to the elucidation of problems in the biomedical field.

During several recent summers a new educational experiment sponsored by the AEC Division of Nuclear Education and Training has been carried out. This involves giving summer appointments in the laboratory to about two dozen undergraduate college sophomores and juniors to provide them with the opportunity of determining their possible interest in pursuing careers in scientific research. Students of very high quality have been available from wide areas of the country. The experiment appears to be a success in terms of the enthusiasm and diligence of the students but whether it will lead more good students

into scientific careers cannot, as yet, be determined.

At the other end of the scale, the Department has made considerable contribution to research training at the post-doctoral level with candidates from both the *United States* and abroad.

Most of the research during the war and for some time afterward was devoted to answering urgent questions raised in atomic energy production facilities on the toxicity of materials and the biological effects of radiation. Associated development of instrumentation was undertaken as it was required. When publication was permitted, a large portion of this work was reported in six volumes of the National Nuclear Energy Series printed by McGraw-Hill in the early 1950's. Four of these volumes were entitled, "Pharmacology and Toxicology of Uranium Compounds". Another was on "Biological Studies with Polonium, Radium and Plutonium" and still another on the "Biological Effects of External Radiation". The material in these volumes has been used very extensively to provide guidelines for the protection of workers at the many installations involved in atomic energy development.

Subsequent studies in these fields were reported as individual papers except that later work on polonium was published in 1964 as a supplement of some 400 pages to the journal Radiation Research under the title "Metabolism and Biological Effects of an Alpha Particle Emmitter, Polonium-210". This serves as a prototype of the study required to evaluate the effects of an alpha-emmitting radioactive material.

More recent studies of uranium toxicity involved exposures of dogs and other species for periods as long as five years to insoluble compounds to determine whether they were injurious to the lungs and associated organs after long retention.

Major efforts have also been devoted to determinations of the toxicities of beryllium, fluorine, radon, thorium, zirconium, mercury, strontium-90, and phosphorus-32. The toxicities of a number of other substances including heavy metal

carbonyls, indium, thallium-204, and iridium-192, have been investigated to a lesser extent.

During the war and for some time afterward two programs on the genetic effects of ionizing radiation were carried out in collaboration with the Biology Department. One of these, directed by Dr. Curt Stern, was on the rate of mutation of fruit flies as a function of dose and the other, directed by Dr. Donald Charles, employed about one-half million mice to determine the rate of dominant mutations as a function of dose in this species.

Much post-war work on the biological effects of external ionizing radiation has been carried on. One of the larger programs is a study of the effect on the fertility of male dogs of radiation levels at, and slightly above, those judged to be permissible for human exposure. This is a lifetime study which will probably last about 18 years - into the late 1960's.

Considerable other work on dogs has been devoted to attempted therapy against radiation injury, rates of recovery, evaluation of late effects of exposure, and the differences between whole- and partial-body exposures.

The rat has been used extensively in studies of tissue injury and recovery, metabolic changes, life-span shortening, and other late effects of exposure. Other species such as rabbits, guinea pigs, and fruit flies have been used to a lesser degree in studying various problems.

Two programs involved studies of the effects of radiations other than ionizing. One of these, done in collaboration with members of the Department of Surgery, determined the effects in swine of thermal energies in the range of those which cause flash burns when emmitted by atomic bombs. Part of this work was done with actual bombs during tests in Nevada and in the Pacific. The other program was to evaluate the possible injurious effects of exposure to the microwave radiation used in radar. This was carried out under the auspices of the Air

Force at *Rome, New York.*

During the war and for some time thereafter, as was indicated above, the principal research questions posed to the Department related to determination of toxic levels of radiation and of toxic materials. Research to provide direct answers to such questions involved exposures to these agents of various species of animals in numbers large enough to yield answers of statistical significance. Although in studying these problems the fundamental biological mechanisms involved were not neglected, they could not be given principal attention. Accumulation of knowledge of toxic effects through the years has greatly diminished the necessity for quick practical answers and has permitted the research program to evolve to the stage in which the search for fundamental biological information can be made paramount. This change in character of the research programs has made them much more productive and satisfying scientifically and more appropriate as an adjunct to the training of students in fundamental areas.

As a result of this development, very productive investigations of the physiology, biochemistry, and structure of bones and teeth evolved from earlier studies of the toxicity of the bone-seeking heavy metals. Efforts to elucidate the action of toxins on cells similarly gave rise to considerable advances in knowledge of basic cellular mechanisms. Problems associated with the entry of toxic materials into the body, particularly by inhalation, and their distribution and excretion have led to gaining much knowledge about the properties of aerosols and dusts, on how they are deposited in the lungs, on how they are absorbed or excreted from the lungs, on how those portions absorbed are transported in body fluids, and on how they are ultimately retained or excreted by the body. The vulnerability to radiation of the blood- and sperm-forming mechanisms led to extensive studies of these systems. Because it can be controlled in degree by appropriate dosage,

radiation injury, in general, has provided a means of gaining exceptional insight into living processes at all levels from the cellular to that of the whole organism.

In support of biological programs, significant advances have been made in such diverse fields as aerosol measurement, analytical and biophysical chemistry, radioautography, electron microscopy, radiation dosimetry, radiation measurement, and nuclear magnetic resonance.

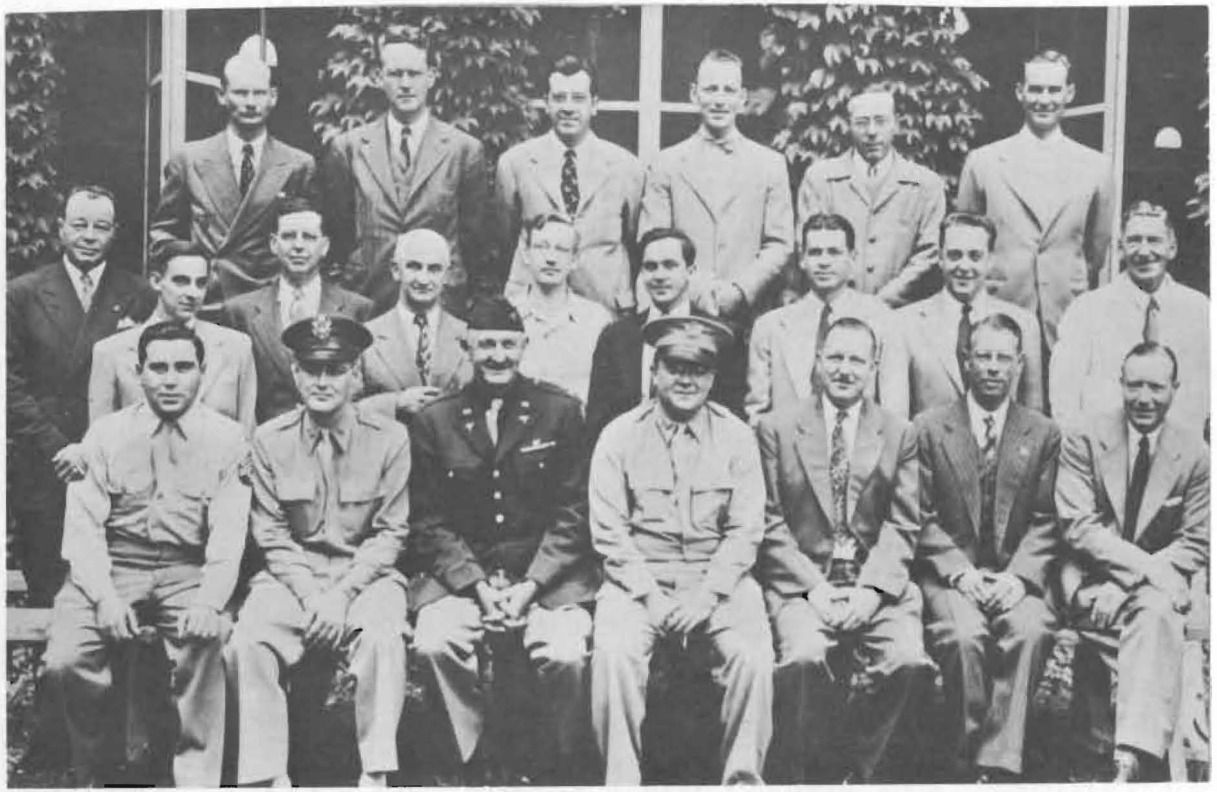
Radioactive isotopes, one of the most useful products of the atomic age, have become commonplace tools in biological research and in medical diagnosis and therapy. Two areas of their use in topics not previously mentioned are studies of the metabolism of proteins and diagnosis and possibly therapy of cancer. Important advances in knowledge of the formation of various species of proteins have come from radioactive labelling of their building blocks, the amino acids. In cancer work, antibodies to fibrin, one of the blood elements, will deposit selectively in certain cancers carrying with them sufficient radioactive iodine to permit easy localization and, it is hoped, possible therapy of the cancer.

While most of the research both during and after the war was carried out locally in the *PROJECT* or in collaboration with other departments of the University, there were some notable exceptions. The first of these was a collaborative program with the *Biochemical Research Foundation, Newark, Deleware,* directed by *Dr. Ellice McDonald.*

One of the problems of early concern was the biological effect of neutrons. A source of neutrons was available locally owing to the generosity of the Physics Department in allowing the *PROJECT* free use of its original small cyclotron. However, although the output of this machine was quite suitable for instrument calibration and various other purposes, it was not great enough for exposure of large animals. Therefore, a program was set up with the *Biochemical Foundation* which had a larger cyclotron designed especially for biological work. The *Foundation*

exposed various species of animals to fast neutrons daily for about a year and studied the resulting gross pathology. The microscopic pathology and hematology studies were done at ROCHESTER.

Beginning with the *Bikini* bomb test in *1946*, individual staff members have participated, as part of the health and safety groups, in many of the tests in *Nevada* and in the *Pacific*. In addition, PROJECT personnel have conducted nine biological experiments in the field. Five of these were the observations of the effects of flash burns on swine, mentioned previously. The other four were studies on various species of animals of the effects of inhalation of radioactive particles released by the non-nuclear detonation of plutonium weapons and by melting reactor fuel elements. *Robert Wilson*, who played an important role in these latter studies, enjoyed the opportunity afforded by the desert test sites to add to his collection of rattle snakes.



Personnel from the Project and other departments of the University who attended bomb tests at Bikini in 1946 as part of Health and Safety Group

L to R - Front Row: Sgt. G.H. Tishkoff, Capt. R.J. Buettner, Col. S.L. Warren, Capt. F.A. Bryan, F.W. Bishop, Dr. G.P. Berry, J.E. Hoffmeister; *Second Row:* Dr. P. Guptill, C.J. Spiegl, Dr. S.H. Bassett, Dr. J.J. Morton, J.F. Bonner, F.L. Esler, H.C. Hodge, G. Dessauer, Dr. H.E. Pearse; *Third Row:* H. Mermagen, R. Hayes, R.M. Fink, A. Zuehlke, J.B. Hursh, G.A. Boyd

APPENDIX

List of Authors and Co-Authors of Publications from Project up to 1967

Current Faculty Members as of January 1, 1968

Degree Recipients through 1967

Bonner, G.
Booth, C.
Borle, A. B.
Bosmann, H. B.
Bowdler, A. J.
Box, C. J.
Boyd, E. S.
Boyd, G. A.
Boyd, J.
Boyle, F. P.
Bradford, W. L.
Bramley, R.
Brand, J. S.
Brandt, A. E.
Brayer, F. T.
Brent, R. L.
Brodie, D. C.
Brothers, G. B.
Brown, B.
Brown, J. B.
Brown, T.
Bruce, A. K.
Bruce, M.
Bruce, R. A.
Brudevold, F.
Bruns, F. H.
Bruton, W.
Bucci, T. J.
Buchanan, J. M.
Burke, W. T.

Cabot, C.
Calkins, M. C.
Campbell, H. S.
Campbell, W.
Cantarow, A.
Caplin, S.
Carlson, A. B.
Carpenter, C. M.
Carr, M.
Carsten, A. L.
Caruso, F. S.
Casarett, A. P.
Casarett, G. W.
Casarett, L. J.
Casarett, M. G.
Caspari, E.
Cedars, N.
Chaffee, E.
Chapman, B.
Charles, D. R.
Chen, P. S., Jr.
Chiquoine, A. D.
Chowdhury, A.
Christian, R. M.
Chu, F. C.
Church, H. W.
Clark, R. K.
Clark, R. S.
Clark, R. T., Jr.
Clarkson, T. W.
Claus, C. J.
Clayton, J. W., Jr.
Cleall, J. F.
Cleveland, R. S.
Cloutier, P. F.
Cloutier, R.
Cobler, J. G.
Coco, S.
Coelho, M. A.
Coghlan, E. R.
Cohenour, L. B.
Coleman, A.
Coleman, R. D.
Colgan, J.
Collier, V.
Collin, R. L.
Collyns, B.
Colodzin, M.
Colwill, J. M.
Conley, J.
Contreras, M. A.
Cool, W. S.
Cooper, B. J.
Cooper, P. H.
Coopersmith, A.
Coonan, L.
Copeland, E. S.
Cotton, W. K.
Cottone, M. A.
Coulter, M. P.
Cox, G. J.
Coye, R. D., Jr.
Craddock, C. G., Jr.
Craig, D. K.
Crain, R. C.
Cramer, L. M.
Craver, B. N.
Crociata, M.
Crookston, J. H.
Cross, A. C.
Cross, R.

Crossland, R. S.
Crump, S. L.
Cucci, M. R.
Cucci, M. W.
Cuddihy, R. G.
Cusson, K. Y.

Dagirmanjian, R.
Dahl, A. H.
Dailey, M. E.
Dale, P. P.
Dalton, C.
Dancewicz, A. M.
Danley, R. A.
Dautrebande, L.
Davies, H.
Davis, J.
Davis, K. E.
Davis, K. H.
Davis, R. W.
Davis, T. P.
Davis, W.
DeBottis, D. J.
deKnudt, G.
DeLalla, V.
DeLaVergne, L.
DellaRosa, R. J.
Demis, C.
Demis, D. J.
Demis, V.
DeMott, D. W.
DeNardi, J.
Dent, C. E.
Desiderio, M. A.
Dessauer, G.
DeVoldre, J. J.
Dewey, P. A.
Dewey, W. C.
DiChiro, G.
Dinse, A. G.
DiPasqua, A. C.
DiStefano, V. F.
Dittman, D.
Djurić, D.
Dodyk, F.
Doherty, D. G.
Dohl, J. M.
Dole, N.
Doran, E.
Dounce, A. L.
Dowdy, A. H.
Downs, W. L.
Dowse, C. M.
Dresel, P. E.
Duffy, B. J., Jr.
Dunham, C. L.
Dustan, C.
Dutton, A. M.
Dwight, E.
Dygert, H. P.
Dygert, P.
Dziuba, S. P.

Eber, J.
Eberl, J. J
Eddy, H. A.
Edwards, V. M.
Egawa, J.
Eisenbud, M.
Eldredge, D. M.
El-Tamami, M. Y.
Ely, J. O.
Emery, A. J., Jr.
Emmel, V. M.
Enns, T.
Epstein, B.
Erickson, J. O.
Eriksen, N.
Ernst, H.
Ervin, D. M.
Esler, F. L.
Estabrook, R. W.
Evans, T. C.

Failla, G.
Falconer, D. W.
Falkenheim, M.
Falkenheim, R.
Fancher, J. A.
Fanta, P. E.
Farhi, L. E.
Fassett, D. W.
Feldman, I.
Feltman, R.
Fenn, W. O.
Feola, J.
Field, J. B.
Fink, K.
Fink, R. M.
Firschein, H. E.
Fisch, S.
Fish, B. R.

Flagg, J. F.
Fleisch, H.
Fleming, R. W.
Flick, J. J.
Fosdick, L. S.
Frank, P. B.
Frankel, D. R.
Frazell, E. L.
Freer, R. M.
Frenkel, A. W.
Friedberg, K. D.
Friend, J. P.
Frisch, M.
Fuller, M. E.
Furman, N. H.
Furth, F. W.

Gabourel, J. D.
Gabrio, B. W.
Gallimore, J. C., Jr.
Ganis, F. M. G.
Gardner, D. E.
Garrido-Pinson, G. C.
Gates, A. A.
Gates, E.
Gatzy, J.
Gaunder, R.
Gazioglu, K.
Gehrmann, G.
Gerber, G.
Gerber, G. B.
Gerschman, R.
Gibb, F. R.
Gilda, J. E.
Gilt, S.
Gitelman, H. J.
Giunta, P. D.
Glasser, S. R.
Glegg, R. E.
Glicksman, A. S.
Glover, J. N.
Goldman, M.
Goldstein, D. A.
Goldstein, R.
Goodland, R. L.
Goodman, J. W.
Goodson, L. L.
Gordon, E. R.
Gordon, L. H.
Gorham, A. T.
Goksel, S. A.
Gosselin, R. E.
Grace, J. L.
Grachus, T.
Gray, E. LeB.
Green, M.
Greenberg, L. J.
Greenstein, E. T.
Grier, R. S.
Grimaldi, A. J.
Grobman, A. B.
Gruschow, J.

Haberland, G. L.
Haft, D. E.
Hahn, E. W.
Hald, P. M.
Hall, R. H.
Hammond, W. E.
Hanavan, H. R.
Hansen, C. L., Jr.
Hardy, H. L.
Hargrave, P. A.
Haroutunian, L. M.
Harper, P. V.
Harris, P. D.
Harris, M. D., Jr.
Harris, W. B.
Harrison, W.
Hart, L. S.
Harvey, R. A.
Harwood, J. H.
Hatch, T. F.
Hausmann, E.
Haven, F. L.
Havill, J. R.
Hawkins, D. R.
Haydock, I. C.
Haydon, H.
Hayes, A. D.
Hein, J. W.
Helmkamp, R. W.
Hempelmann, L. H.
Henderson, B. J.
Hendrickson, M. W.
Herling, F.
Hewitt, R. R.
Heyer, L.
Hilcken, J. A.
Hinshaw, J. R.
Hodge, H. C.
Hodkinson, J. R.

Hogg, L., Jr.
Holaday, D. A.
Holler, J. W.
Hooper, D. C.
Horne, S.
Horton, C. A.
Howe, R. E.
Howland, J. W.
Hull, T.
Hunter, H. B.
Hursh, J. B.
Hurwitz, L.
Hutchinson, E. D.

Inda, F. A.
Ingram, M.
Innes, J. R. M.
Issac, S.
Izzo, J. L.
Izzo, M. J.

Jacobson, B. L.
Jenkins, D. W.
Jennings, D. H.
Jespersen, H. W., Jr.
Jespersen, J.
Jiminez, F.
John, D. W.
Johnson, K.
Johnson, L.
Johnstone, D. E.
Jones, E. B.
Jones, J.
Jordan, H. C.
Jorgensen, B.
Jung, C. Y.

Kanwisher, J. W.
Karr, J. W.
Katz, R.
Kaye, S. V.
Keary, F. V.
Kegan, L. S.
Keil, E.
Kendall, K. A.
Kennes, F.
Kertesz, Z. I.
Kesel, R. C.
Keutmann, E. H.
Keutmann, H. T.
Kimball, C. P.
Kingsley, H. D.
Knight, K.
Konnerth, A.
Konno, K.
Kosel, G. E.
Koszalka, J. M.
Koszalka, T. R.
Koval, L.
Kowlessar, O. D.
Krasavage, W. J.
Krebs, C. A.
Kreig, D. R.
Kremer, W.
Kresge, M.
Krolak, L. J.
Kurath, P.
Kurohara, S. S.
Kusnetz, H. L.

LaBelle, C. W.
LaCelle, P. L.
LaFrance, L. J.
Lamm, M.
Lamson, B. G.
Lan, T. H.
Lane, K.
Lankau, C. A.
Lankau, C. A., Jr.
Larrabee, C.
Laskin, S.
Laskowski, E. J.
Laties, V. G.
Lauenstein, K.
Laush, G.
Lauterbach, K. E.
Lavin, M.
Lawrence, J. S.
Leach, L. J.
Leary, D. E.
Leathem, J. H.
Lehmann, E. E.
Lehnert, S. M.
Leighton, A.
Lennox, E.
Leone, N. C.
Lerman, B.
LeSher, M. F.
Levi, H.
Levinskas, G. J.
Lewis, L.
Lie, R.

Light, A. E.
Little, K. D.
Little, M. F.
Lobene, R.
Loewenstein, B.
Lofstrom, J. E.
Looney, W. B.
Lovaas, A.
Lovejoy, F. W., Jr.
Low, R. J.
Lyon, J. L.

Maas, R.
Magos, L.
Maier, J. G.
Maillie, H. D.
Main, E. R.
Mann, W.
Manrodt, S.
Margoliash, E.
Marinetti, G.
Markham, J.
Marrack, D.
Marsh, A.
Marshall, V. F.
Marti, N.
Martin, A. E.
Martin, B. A.
Martin, G. R.
Mason, K. E.
Mason, W. B.
Masters, R. E.
Matthews, W. B.
Mattoon, J. R.
Maynard, E. A.
McCauley, H. B.
McConnell, K. P.
McCredie, R.
McDonald, E.
McDonnel, G. M.
McGovern, G. R.
McKane, A.
Megirian, D.
Megirian, R.
Mehrhof, E.
Meier, D. W.
Meier, R. C.
Meisenzahl, C. J.
Mercer, T. T.
Mermagen, H.
Metcalf, R. G.
Metzger, G. V.
Michaelson, S. M
Milani, R. E.
Miles, E. M.
Millar, F. K.
Miller, F. J.
Miller, G. J.
Miller, J.
Miller, L. L.
Miller, R. W.
Milley, P. S.
Mills, C. M.
Minor, J.
Minto, W. L.
Mitchell, J.
Mitola, J.
Mixter, G., Jr.
Mohney, J. B.
Monture, E.
Monty, K. J.
Moore, R.
Morales, R. L.
Morgan, B. H.
Morgan, H. R.
Morken, D. A.
Morrisey, J.
Morrison, M.
Morrow, P. E.
Morton, J. H.
Morton, J. J.
Moss, A. J.
Mulryan, B. J.
Murden, C. H.
Murlin, J. R.
Murphy, N.
Murphy, G. W.
Mutschler, L. E.
Myers, H. M.

Neidlinger, R. L.
Neufeld, H. A.
Neuman, M. W.
Neuman, W. F.
Nevin, R. B.
Nielsen, G.
Noonan, A. M.
Noonan, T. R.
Norgren, P. E.
North, C. A.
Novitski, E.
Nussbaum, E.

Nyholm, R. S.

Oberg, H. A.
O'Brien, J. A.
O'Brien, J. F.
O'Brien, M.
O'Connell, P. W.
Odland, L. T.
Okada, S.
O'Leary, J. C.
O'Leary, J. F.
O'Leary, J. J.
Olson, J. P.
Orcutt, J. A.
Orthey, G. F.
Osterhoudt, J.
Otis, E. M.
Overslaugh, C.
Overton, D. E.

Panner, B. S.
Papadopoulou, Z.
Papageorge's, N., Jr.
Parker, J.
Parks, H. F.
Passow, H.
Patterson, F. S.
Payne, F. W.
Payne, J. T.
Peachey, L. D.
Pearse, H. E.
Pearson, R.
Pekola, J. S.
Penikas, V. T.
Penney, D. P.
Perkins, J. B.
Perry, J. K.
Peters, P. A.
Petropoulos, M. C.
Pettengill, A. G.
Piatt, D.
Piccirilli, A.
Pifer, J.
Pillemer, L.
Platt, J. B.
Plosscone, R. P.
Polley, H.
Pories, W. J.
Potter, J. L.
Potter, J. P.
Pozzani, U. C.
Prankerd, T. A. J.
Predmore, C.
Preston, K., Jr.
Pretlow, T. P.
Provoost, A. T.
Pulliam, J. A.
Putnam, T. E.

Quinlan, W. J., Jr.
Quinn, G. P.

Raabe, O. G.
Radakovich, M.
Rahn, H.
Ramsey, G.
Randall, C.
Rausa, G. J.
Reed, C. F.
Reilly, C.
Reinhardt, G. E.
Rekers, P. E.
Remsen, N.
Remy-Defraigne, J.
Rene, R. M.
Reuter, A. M.
Reynolds, R. C.
Reynolds, W. F.
Rhodes, R. C.
Richmond, J. E.
Rieder, A.
Riley, R. F.
Roberts, C. J., Jr.
Roberts, E.
Robinson, R. A.
Robscheit-Robbins, F. S.
Rodgers, J.
Rohwer, P. S.
Roncone, A.
Root, R. E.
Rose, R. G.
Rosenzweig, W.
Ross, M. H.
Rossi, H. H.
Roth, R. E.
Rothe, W. E.
Rothermel, J. J.
Rothstein, A.
Rothstein, M.
Rouser, G. L.
Rouvina, J.
Rowe, V. K.

Rowe, W. B.
Rowland, R. E.
Rowley, J.
Rubin, P.
Rugh, R.
Rushing, D. E.
Russel, E. R.

Sacher, G. A.
Sadoul, P.
Salerno, L. L.
Salisbury, P.
Salomon, K.
Salvatore, J.
Same, E.
Samloff, I. M.
Sanders, A. P.
Sanders, C. L., Jr.
Sanfilippo, S. J.
Sanford, R. A. C.
Sarcione, E. J.
Saunor, P.
Scharff, T. G.
Scheer, K.
Schepartz, A. I.
Schilling, J. A.
Schlamowitz, M.
Schlegel, B.
Schlesinger, M. J., Jr.
Scholes, C.
Scholes, G.
Schreier, K.
Schreiner, B., Jr.
Schulman, M.
Schwartz, S. I.
Scott, D. C.
Scott, J. K.
Scott, R. G.
Sears, D. A.
Seeger, J.
Segal, H. L.
Siejffers, M. J.
Seth, H. S.
Shaber, G. S.
Shaeffer, J. R., III
Shandley, P. D.
Shapiro, J. V.
Shaver, A.
Shaver, S. L.
Sherman, F.
Sherman, R. E.
Shilen, J.
Shively, J. N.
Shourie, K. L.
Shrier, J.
Siegal, G.
Siegel, L.
Sikov, M. R.
Silberstein, H. E.
Simon, G. A.
Sippel, T. O.
Slater, I. H.
Slonimski, P. P.
Smith, C. G.
Smith, D. S.
Smith, D. W.
Smith, F. A.
Smith, G. A.
Smith N. B.
Smith, P. H.
Smith, W. K.
Smith, W. W.
Smull, K.
Snape, W. J.
Spar, I. L.
Sparks, A. F.
Spencer, W. P.
Spiegl, C. J.
Sobkowski, F. J.
Sognnaes, R. F.
Sokal, J. E.
Solomons, C. C.
Spertzel, R. O.
Sprague, G. F., Jr.
Spraragen, S. C.
Sproul, J. A., Jr.
Staib, W.
Stannard, J. N.
Steadman, L. T.
Steinberg, C. L.
Steinhard, T. H.
Stern, C.
Stern, E.
Stewart, C. C.
Stewart, J. W.
Stokinger, H. E.
Stoll, W. R.
Stotz, E.
Strain, W. H.
Strates, B.
Strong, L. H.
Stroud, C. A.

Struthers, A.
Stuart, B. O.
Suhrland, L. G.
Sultzer, M. R.
Sundvall-Hagland, I.
Sunier, A. A.
Suter, G. M.
Sutherland, R. M.
Swisher, S. N.
Sylvester, G. E.
Szekerczes, J.

Tabechian, H.
Taber, H.
Tanooka, H.
Tarbell, A. T.
Taves, D. R.
Taylor, J. M.
Terepka, A. R.
Terry, J. L.
Terry, R.
Thale, T.
Thomas, D. M. C.
Thomas, R. G.
Thompson, H. E.
Thomson, R. A. E.
Thornley, M. J.
Tidball, C. S.
Tiedeman, D. V.
Tihen, J. A.
Tishkoff, G. H.
Titthasiri, N.
Toole, S. R.
Toporek, M.
Toribara, T. Y.
Toyooka, E. T.
Traelnes, K. R.
Traynor, J. E.
Trunnell, J. B.
Tsinga, E.
Tsion, W.
Turner, M. D.
Turner, R. A. N.
Tuttle, L. W.
Tuxill, J. L.

Uber, D. C.
Underwood, A. L., Jr.
Underwood, E. E.
Uphoff, D.

Valentine, W. N.
VanAlstine, H.
VanSlyke, F.
VanSlyke, H. N.
VanSteveninck, J.
VanValkenburg, P. A.
Varon, M. I.
Vasile, N. J.
Velasquez, T.
Vittum, E. K.
Voegtlin, C.
Voss, M. J.
Vosteen, R. E.
Vyverberg, R. G.

Wachholz, B. W.
Walker, P. M.
Wanta, R. C.
Wantman, M. J.
Ward, W. F.
Ware, E.
Warner, H.
Warner, R. S.
Warren, S. L.
Watanabe, I.
Waterhouse, C.
Watman, R. N.
Watson, M. L.
Watson, R.
Watton, E.
Watts, N. P.
Wedd, A. M.
Weed, R. I.
Weikel, J. H., Jr.
Weil, C. S.
Weiss, A. B.
Weiss, B.
Weiss, C.
Weiss, J. J.
Weiss, L.
Welton, J.
Whedon, G. D.
Wheeler, C. M.
Whipple, G. H.
Whipple, G. H., Jr.
White, F. A.
White, N. G.
Whitmore, W. F.
Wiberg, J. S.
Wichser, F. W.

Williams, A. I.
Williams, D. B.
Williams, L. B.
Wills, J. H.
Wilson, D. E.
Wilson, H. B.
Wilson, J. G.
Wilson, R. H.
Wing, D.
Wirts, C. W.
Witter, R. F.
Wolf, B. S.
Wolfe, D. E.
Wong, L. C. K.
Wood, D.
Woodsum, H. C.
Woodard, H. Q.
Woodward, K. T.
Woolrich, P. F.
Wraight, N.
Wright, M.

Yaeger, R. G.
Yettewich, G.
Yoon, S. H.
Young, L. E.
Young, H. Y.
Yu, N. G.
Yu, P. N.
Yuile, C. L.
Yurkstas, E. P.

Zaldivar, R. S.
Zizzo, S. G.

FACULTY MEMBERS

Aser Rothstein

Co-Chairman of Department and Co-Director of Project

William F. Neuman

Co-Chairman of Department and Co-Director of Project

J. Newell Stannard

Associate Director for Education, Atomic Energy Project, and Associate Dean for Graduate Studies

PROFESSOR

Howard L. Andrews
William F. Bale
Henry A. Blair
George W. Casarett
Isaac Feldman
*Harold C. Hodge
Joe W. Howland
John B. Hursh
Leon L. Miller
Paul E. Morrow
Taft Y. Toribara
Bernard Weiss
Charles L. Yuile

ASSOCIATE PROFESSOR

*Kurt I. Altman
*Thomas T. Bannister
George G. Berg
Thomas W. Clarkson
Robert L. Collin
Arthur M. Dutton
Marylou Ingram
Victor G. Laties
Thomas T. Mercer
Herbert Mermagen
Solomon M. Michaelson
Donald A. Morken
*Shigefumi Okada
Fred Sherman
Frank A. Smith
Irving L. Spar
Luville T. Steadman
Werner Stoeber
*Donald R. Taves
A. Raymond Terepka
*Robert I. Weed

ASSISTANT PROFESSOR

*William G. Aldridge
James R. Coleman
David A. Goldstein
Eric W. Hahn
Betty J. H. Hopkins
Robert W. Kilpper
*Paul L. LaCelle
Leonard J. Leach
H. David Maillie
*Jack Maniloff
Morton W. Miller
Margaret W. Neuman
John W. Stewart
*Harry W. Taber
John S. Wiberg
Robert H. Wilson

RESEARCH ASSOCIATE

Bernard R. Gifford

INSTRUCTOR

Hubert A. Eddy
Ruth L. Goodland

SENIOR TECHNICAL ASSOCIATE

Robert Baxter
M. A. Contreras
F. Raymond Gibb
J. Russell Hayes
Ruth M. Howard
William J. Quinlan, Jr.
Louis Siegel
Roderick A. E. Thomson
Florence VanSlyke

TECHNICAL ASSOCIATE

Mildred A. Carr
Dwight E. Gardner
Mary Jane Izzo
Betty J. Mulryan
Ann B. Weiss
Herbert B. Wilson

* *Primary appointment in another department.*

PH.D. DEGREE IN BIOPHYSICS

NAME	YEAR
ANDERSON, LOWELL L.	1958
BICKMORE, JOHN T.	1956
BLACK, STUART C.	1957
BONNER, JOHN F.	1948
BOSMANN, H. BRUCE	1966
BURKI, HENRY J.	1967
CROSS, FREDRICK T.	1967
CUDDIHY, RICHARD G.	1967
DAHL, ADRIAN H.	1953
DAVIS, THOMAS PEARSE	1959
JONES, WILLIAM BARRIE G.	1965
JORDAN, HARRY C.	1959
KANWISHER, JOHN W.	1951
KRIEG, DAVID R.	1957
MILLAR, FLORENCE K.	1954
MOORE, RICHARD	1956
MORKEN, DONALD A.	1954
PUTNAM, THOMAS E.	1954
RAABE, OTTO G.	1967
ROBERTS, CARLYLE J., JR.	1954
SHAEFFER, JOSEPH R. III	1962
SHAPIRO, JACOB	1954
TANOOKA, HIROSHI	1962
WATSON, MICHAEL L.	1952
WATT, THOMAS B., JR.	1962
WHIPPLE, GEORGE H., JR.	1953

M.S. DEGREE IN BIOPHYSICS

NAME	YEAR
GAVIGAN, FRANCIS X.	1955
HAMBLEN, DAVID P.	1966
LEWIS, LIONEL	1955
MINTER, FRANCES M.	1967
SANDERS, AARON PERRY	1952
SCHLESINGER, MILTON J.	1953
SHANDLEY, PAUL D.	1954
STEWART, CARLETON	1964
SULTZER, MARY ROBB	1954
WILKINS, SALLY DELANCEY	1963
WOODSUM, HUBERT C.	1953

PH.D. DEGREE IN RADIATION BIOLOGY

NAME	YEAR
ANGEL, CHARLES R.	1960
BAIR, WILLIAM J., JR.	1954
BOECKER, BRUCE B.	1962
BRAND, JOHN SWEENEY	1966
BRUCE, ALAN KENNETH	1956
CARSTEN, ARLAND L.	1957
CASARETT, ALISON P.	1957
COOPER PHILIP H.	1966
COPELAND, EDMUND S.	1964
CRAIG, DOUGLAS K.	1964
DELLA ROSA, ROCCO J.	1959
DEWEY, WILLIAM C.	1958
EDDY, HUBERT A.	1964
EL-TAMAMI, MOHEI-ELDIN Y.	1965
GOKSEL, SELAHATTIN A.	1962
GOLDMAN, MARVIN	1957
GORDON, ELLEN R.	1958
GREEN, MORRIS	1958
HANSEN, CARL LUDWIG	1960
HARRIS, JOHN WAYNE	1965
HARRIS, MILFORD D., JR.	1960
HENDERSON, BETTY JO H.	1961
HEWITT, ROGER ROY	1963
JUNG, CHAN YONG	1964
KAYE, STEPHEN V.	1966
KUROHARA, SAMUEL S.	1964
MAIER, JOHN GAIL	1963
MAILLIE, HUGH DAVID	1963
MILLER, EDWARD J.	1964
MUTSCHLER, LETITIA E.	1963
NUSSBAUM, ELMER N.	1957
ODLAND, LAWRENCE T.	1962
OKADA, SHIGEFUMI	1956
PENIKAS, VINCENT T.	1966
PRETLOW, THERESA P.	1966
PULLIAM, JAMES A.	1967
ROHWER, PAUL S.	1967
ROTH, RAYMOND E.	1963
ROWLAND, ROBERT E.	1964
SANDERS, CHARLES ., JR.	1966
SCHULMAN, MURRAY	1959
SIKOV, MELVIN R.	1955
SOBKOWSKI, FRANCIS J.	1966
SPROUL, JAMES A., JR.	1962
STEWART, CARLETON C.	1967
STRONG, LORETTA HIGGINS	1966
STUART, BRUCE OWEN	1963
SUTHERLAND, ROBERT M.	1966

NAME	YEAR
TAVES, DONALD R.	1963
THOMAS, ROBERT GLENN	1955
TRAYNOR, JOSEPH EDWARD	1965
VARON, MYRON I.	1965
WACHHOLZ, BRUCE W.	1967
WARD, WILLIAM F.	1967
WOODWARD, KENT THOMAS	1966

M.S. DEGREE IN RADIATION BIOLOGY

NAME	YEAR
AARESTAD, NORMAN O.	1966
ADCOCK, BOBBY RAY	1964
AHMAD, S. MANSOOR	1964
AHMED, JASIM UDDIN	1959
AHUJA, MEVI	1965
ALLEN, RICHARD O.	1966
ALVARADO GRANDI, SERGIO	1962
AMUNDSON, PAUL I.	1956
ANCONA-HERRERA, MARICARMEN	1961
ANDERSON, CHARLES GUSTAV	1962
ANDERSON, CLAUDE TAYLOR	1963
ANDERSON, DONALD L.	1963
ANDREWS, JANET ELIZABETH	1959
ANGLETON, GEORGE MCC.	1952
ARMSTRONG, ROBERT L.	1965
BARKER, ROBERT FRANCIS	1954
BARLETTA, FRANCIS P.	1963
BARONE, GREGORY J.	1964
BARR, ISABELLE A.	1951
BARRALL, RAYMOND C.	1957
BAUM, JOHN WILLIAM	1954
BELLUSCIO, PHILIP R.	1966
BENSON, RICHARD E.	1956
BLOOM, JOSEPH DUITCH	1960
BOECKER, BRUCE B.	1960
BOEKER, ELISABETH H.	1960
BOYDEN, DOUGLAS GREGG	1960
BRAND, JOHN S.	1964
BRUCE, ALAN KENNETH	1954
BUCCI, THOMAS J.	1962
BURHAM, WILLIAM A.	1967
BURKE, KATHLEEN A.	1966
BURNETT, WILLIAM DAVIS	1960
CABLE, JOHN WILLIAM	1963
CAHILL, DANIEL FRANCIS	1962
CARSTEN, ARLAND L.	1956

NAME	YEAR
CHAMPAGNE, ROBERT J.	1963
CHANDLER, ROBERT PAUL	1962
CHAPUT, RAYMOND L.	1965
CLEARY, STEPHEN FRANCIS	1960
CLOUTIER, PAUL FREDERICK	1959
CLOUTIER, ROGER, J.	1957
CONTI, ENRICO F.	1957
COOL, WALTER S.	1951
COOPER, PHILIP H.	1960
COPELAND, EDMUND SARGENT	1961
CRAIG, DOUGLAS KENNETH	1961
CROSS, FREDRICK THOMAS	1961
CUDDIHY, RICHARD G.	1964
DALY, JAMES C.	1964
DAPOLITO, JOHN A.	1962
DAVIDSON, DAVID EDWARD, JR.	1962
DAVIS, JOYCE P.	1956
DEAN, EDWARD E.	1958
DESHPANDE, MADHURI V.	1964
DETTOR, CHARLES M.	1964
DONAHUE, NANCY S.	1966
DONOVAN, MARTIN S.	1957
DOUGLAS, GEORGE P.	1964
DUCKWORTH, JAMES W.	1956
DUDZIAK, DONALD J.	1957
EARLS, JULIAN M.	1966
EL-TAMAMI, MOHEIELDIN Y.	1961
EWING, DEAN E.	1962
FARRIS, RICHARD D.	1965
FAULKNER, DONALD ERNEST	1962
FAUST, JACK CHARLES	1959
FEOLA, JOSE MARIA	1961
FOELIX, CHARLES FERDINAND	1959
FRANKEL, ROBERT	1964
FRECHETTE, MURIEL A.	1962
FROOM, CHARLES PHILIP	1960
GALLIMORE, JOHN C., JR.	1952
GANGADHARAN, POODI	1966
GARCIA-TRIAS, NILDA (PARKINS)	1959
GARDNER, HORACE B.	1967
GEORGE, ROBERT EUGENE	1961
GERTZOG, JACK	1965
GIBB, FLOYD R.	1961
GIPSON, E. NEAL	1962
GODDEN, WILLIAM R.	1962
GOKSEL, SELAHATTIN A.	1959
GORDON, ELLEN R.	1954
GREEN, JEROLD PAUL	1963
GREENHOUSE, NATHANIEL	1967
GRENNEN, RUTH M.	1959
GROTENHUIS, IVAN MERLE	1959

NAME	YEAR
HAERTJENS, BERNARD L.	1961
HALKO, ARLENE A.	1957
HAMMOND, WARREN E.	1952
HARRIS, STANLEY C.	1964
HASTINGS, CATHERINE M.	1956
HAUVER, ROBERT C.	1965
HAYDOCK, IRENE C.	1961
HENDERSON, BETTY JO	1957
HETZNECKER, WILLIAM T.	1959
HEWITT, ROGER ROY	1960
HIGGINS, LORETTA M.	1960
HILL, LARRY W.	1966
HOKE, BOB	1961
HOWELL, WILLIAM D.	1961
JIMENEZ-BARBER, CARLOS M.	1959
JOHNSON, JAMES EDWARD	1959
JOHNSON, MERRILL C.	1963
JONES, W. BARRIE G.	1958
KEARY, FRANK V.	1958
KENNEKE, ALBERT P.	1957
KENNEY, ARTHUR LESLIE	1959
KERN, JOHN DWIGHT	1960
KESHAGUPTA, VITIT	1966
KHAN, RAFIQ AHMED	1959
KINNAMON, KENNETH E.	1961
KINSLEY, EARL LESLIE	1964
KIRCHNER, ROBERT A.	1964
KIRK, WILLIAM P., II	1965
KLAPPER, MICHAEL H.	1959
KNOSPE, WILLIAM H.	1962
KOLB, WILLIAM H.	1962
KRASAVAGE, WALTER J.	1963
KWAENGSOBHA, SUREE	1965
LALLIER, CLAIRE LOUISE	1960
LAPORTE, DONALD J.	1965
LAURER, GERARD ROBERT	1959
LAVALETTE, DAVID R.	1957
LEBOURDAIS, WALLACE R.	1963
LESACA, REYNALDO M.	1961
LEVY, LOUIS BOBBY	1962
LIDDLE, CHARLES G.	1963
LIE, RANDI	1961
LITTLEFIELD, PETER S.	1963
LIU, KUO-YUEH	1967
LOGIUDICE, JOSEPH M.	1957
LOIZEAUX, PETER ST. JOHN	1963
LOURIE, IRVIN M.	1960
LOVAAS, ARVIN I.	1956
MAHONEY, FRANCIS J.	1958
MAILLIE, H. DAVID	1956
MAMMEN, HELEN LOUISE (BOYDEN)	1960

NAME	YEAR
MARKOE, ARNOLD M.	1966
MARTIN, BARBARA A.	1965
MARTIN, MORRIS L.	1955
MARTIN, RICHARD J.	1958
MARTONE, MARGARET T.	1964
MARTONE, RONALD J.	1964
MCBAIN, JOHN K.	1966
MCCLINTOCK, ROBERT O.	1958
MCCLURE, JOHN A.	1957
MCCONNON, DANIEL	1960
MCDERMOTT, FRANK E.	1963
MCFADYEN, DOROTHY F.	1966
MCGREW, CLINTON J., JR.	1957
MCKANE, ANDREW	1958
MCRANEY, WILLIAM K.	1964
METALLI, PIETRO	1967
MILANI, ROBERT E.	1954
MILLER, ROGER I.	1958
MILLER, VANDY LEONARD	1962
MILLINGTON, RICHARD A.	1961
MINX, RAMON PASCHAL	1961
MITCHELL, THOMAS G.	1956
MURPHY, THOMAS D.	1957
MURRAY, JAMES LEWIS	1963
MUTSCHLER, LETITIA E.	1958
NEIDLINGER, ROBERT W.	1961
NELSON, RONALD BRUCE	1962
NGAN, TRAN THI	1966
NICASTRO, LAWRENCE J.	1956
NOONEY, THOMAS W., JR.	1961
NOSAN, MARTIN M.	1963
NYO, U HTIN	1966
O'BRIEN, JAMES A.	1958
O'BRIEN, JOSEPH F.	1955
OCHS, CHARLES W.	1961
ORTHEY, GEORGE F.	1964
PABON-PEREZ, HEIDI	1961
PAGE, NORBERT P.	1963
PALACIOS-FABREGAS, MARIA M.	1961
PANGRAZE, MILDRED A.	1964
PANYARJUN, BHIYAYO	1960
PARKOS, GERALD R.	1956
PELLETIER, CHARLES A.	1957
PENIKAS, VINCENT T.	1959
PERSING, RONALD L., JR.	1961
PHILLIPS, LEIGH F.	1956
PIZZUTO, JOSEPH S.	1958
POTTER, JOHN P.	1960
PREDMORE, CAROL ELLEN	1964
PROVOOST, ALISON T.	1953
PULLIAM, JAMES A.	1963

NAME	YEAR
QUAIFE, MERTON A.	1961
RAUSA, GERALD J.	1953
REED, ROBERT F.	1962
REESE, ISAAC CLINTON	1961
REITLER, EDWARD K., JR.	1964
REUBEN, JOHN P.	1956
RICHARDSON, FRED W.	1958
RICHMOND, JONAS EDWARD	1951
ROESSLER, CHARLES E.	1956
ROHWER, PAUL S.	1961
ROONEY, KEVIN L.	1956
ROSA-GARCIA, MARIO E.	1962
ROSENBERGER, EUGENE A.	1962
ROSENZWEIG, WALTER	1952
ROTHE, WILLIAM E.	1958
ROWE, WILLIAM BRUCE	1959
SCHOLES, SUSAN QUIRICONI	1964
SCHULTHEIS, JAMES J.	1956
SEIBYL, WALTER L., JR.	1956
SEIGNEUR, LESLIE J.	1958
SHABER, GARY S.	1961
SHATTERLY, LUTHER W.	1965
SHIVELY, JAMES N.	1956
SILVERSTEIN, LAWRENCE G.	1956
SIMON, GEORGE A.	1951
SMITH, AUDREY VIVIAN A.	1957
SMITH, DAVID SAUDERS	1953
SMITH, PHILIP HARDY	1953
SPAHN, JAMES A., JR.	1961
SPERTZEL, RICHARD O.	1962
SPRARAGEN, SANFORD C.	1952
STANGER, PAUL	1958
STANLEY, RICHARD E.	1964
STARA, JERRY FRANK	1961
STARK, JAMES E.	1958
STEADMAN, BRUCE LUVILLE	1961
STEWART, MARY LOUISE	1964
STILL, EDWIN TANNER	1964
STROMBERG, LAWAYNE R.	1963
STUART, BRUCE OWEN	1959
SUNTA, CHINTAMANI	1961
SUZUKI, MASASHI	1958
TELLES, NORMAN C.	1959
THOMAS, JOSEPH J., JR.	1964
THOMPSON, ROBERT ELLIOT	1961
TODD, PAUL WILSON	1960
TROKEL, STEPHEN L.	1956
TSINGA, ELPINIKI	1963
TYLER, PAUL E.	1964
VARON, MYRON IZAK	1963
VICHITRANONDA, SUTEERA	1963

NAME	YEAR
VON HAZMBURG, ROMULUS S.	1964
WACHHOLZ, BRUCE WILLIAM	1959
WAGNER, MURPHY THOMAS, JR.	1962
WALKER, JESSE P., JR.	1962
WALKER, P. MACK	1963
WALLACE, JOHN MILBURN	1964
WAMPLER, STANLEY N.	1961
WANGEMANN, ROBERT T.	1964
WEBSTER, JOHN BLAIR	1964
WELTY, CARL G., JR.	1956
WEST, JOE E.	1961
WHITE, CARLETON BENJAMIN	1962
WINANS, LAWRENCE F.	1966
WISSINK, ROBERT G.	1958
YODER, VIRGIL EDWARD	1957
YOUNG, JAMES BOWMAN	1959

PH.D. DEGREE IN PHARMACOLOGY

NAME	YEAR
BOYD, EUGENE S.	1953
CASARETT, LOUIS J.	1958
CHEN, PHILIP S., JR.	1954
DEMIS, DERMOT J.	1954
DISTEFANO, VICTOR F.	1953
DRESEL, PETER E.	1952
GABOUREL, JOHN D.	1957
HEIN, JOHN W.	1953
HILCKEN, JOHN A.	1954
HURWITZ, LEON	1953
LEVINSKAS, GEORGE J.	1953
LITTLE, KATHARINE D.	1957
MEGIRIAN, DAVID	1954
MERCER, THOMAS T.	1957
MORROW, PAUL E.	1952
MYERS, HOWARD M.	1958
O'LEARY, JOHN F.	1951
SCHARFF, THOMAS G.	1956
SHOURIE, KANWAR L.	1949
STOLL, WILLIAM R.	1956
TISHKOFF, GARSON H.	1951
WEIKEL, JOHN H., JR.	1954
WHITE, NORMAN G.	1954
WIBERG, JOHN S.	1956
WILLIAMS, LUCILLE B.	1950

M.S. DEGREE IN PHARMACOLOGY

NAME	YEAR
ADAMS, SAUL	1955
ARMSTRONG, ROBERT D.	1958
BERKE, HARRY L.	1948
BLAKE, ROBERT L.	1957
CASARETT, LOUIS J.	1955
DAGIRMANJIAN, ROSE	1954
DALE, PETER P.	1948
DANLEY, ROBERT A.	1950
DAVIS, KATHARINE H.	1954
DOWNS, WILLIAM L.	1953
GREENBERG, LEONARD	1954
HURWITZ, LEON	1950
KOSEL, GEORGE E.	1951
LABELLE, CHARLES W.	1950
MEGIRIAN, DAVID	1951
MEGIRIAN, ROBERT	1954
STRATES, BASIL S.	1956
TAYLOR, JEAN M.	1956
TIDBALL, CHARLES S.	1952
UNDERWOOD, ELIZABETH E.	1950