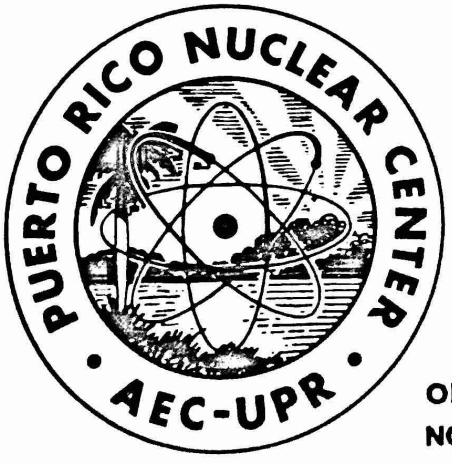
PRNC - 140

PUERTO RICO NUCLEAR CENTER

ANNUAL REPORT 1969

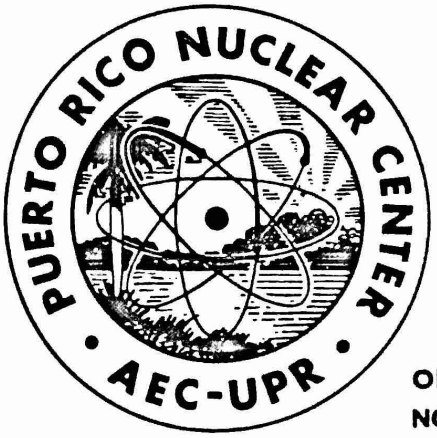


OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT
NO. AT (40-1)-1833 FOR U. S. ATOMIC ENERGY COMMISSION

PRNC-140
GENERAL, MISCELLANEOUS, AND
PROGRESS REPORTS (TID-4500)

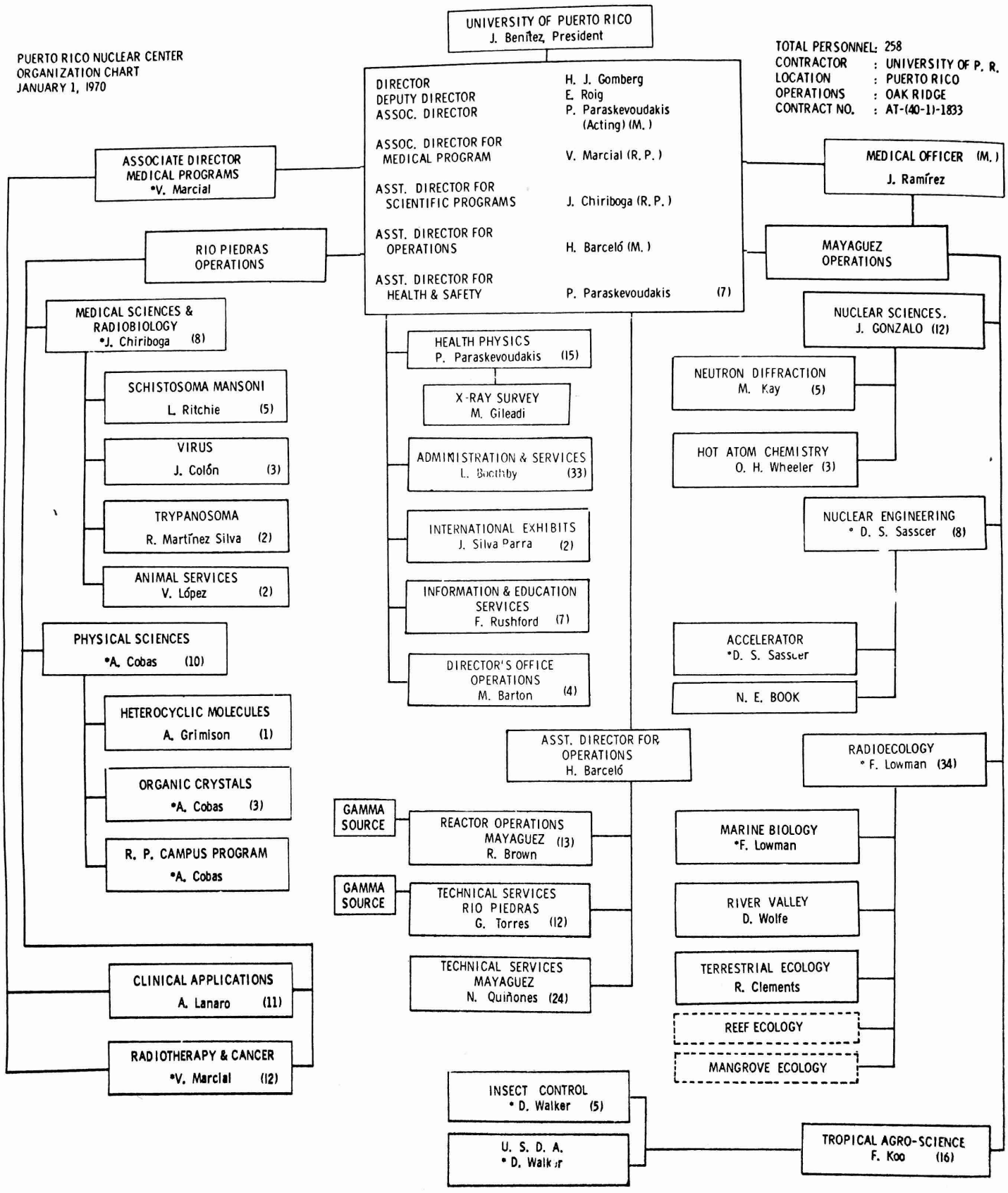
PUERTO RICO NUCLEAR CENTER

ANNUAL REPORT 1969



OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT
NO. AT (40-1)-1833 FOR U. S. ATOMIC ENERGY COMMISSION

PUERTO RICO NUCLEAR CENTER
ORGANIZATION CHART
JANUARY 1, 1970



APPROVED FOR AEC

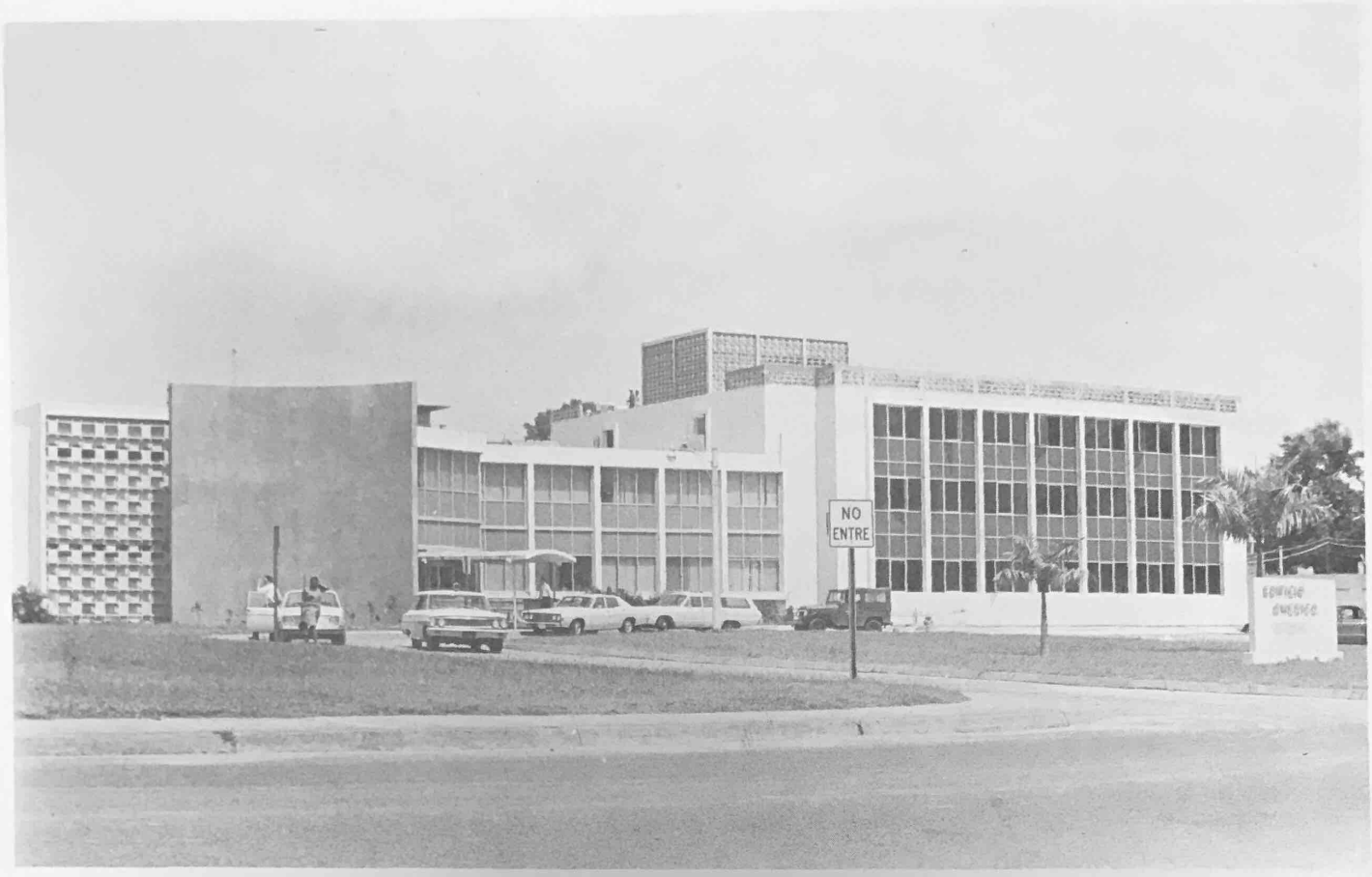
AREA MANAGER
PUERTO RICO AREA OFFICE

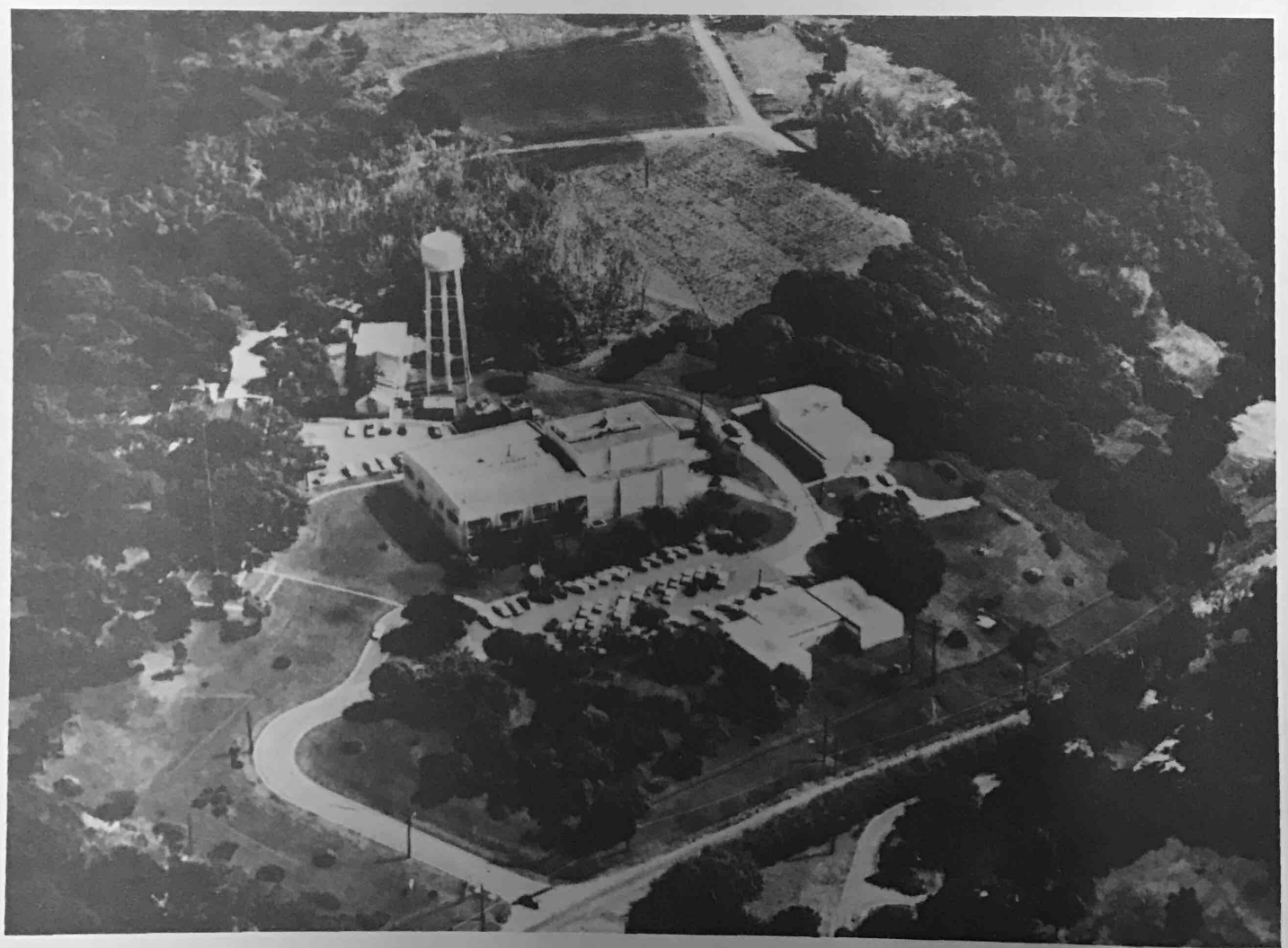
* Multiple Function
---- Planned Projects

APPROVED FOR CONTRACTOR

DIRECTOR
PUERTO RICO NUCLEAR CENTER

TABLE OF CONTENTS





Top: facade of the PRNC Bio-Medical Building, showing the new wing at right.
Bottom: aerial view of the PRNC installation in Mayagüez.

PREFACE

The Puerto Rico Nuclear Center, founded in 1957, is operated under contract for the U.S. Atomic Energy Commission by the University of Puerto Rico, whose student body of over 34,000(which has doubled in each of the past three decades) makes it the island's largest university.

The Nuclear Center, known as PRNC, engages in training and research in the peaceful use of the atom, with special emphasis upon the needs of Puerto Rico and Latin America. The idea for a nuclear center on this Caribbean island stemmed from President Dwight D. Eisenhower's historic "Atoms for Peace" address before the United Nations General Assembly in 1953.

PRNC has grown rapidly since its foundation. Its first year staff of 43 has multiplied to nearly 300, including 80 scientists. Student enrollment last year was 199, nearly four times the amount during its first year. About one-sixth of its 1886 alumni are foreign nationals, from 18 Latin American republics as well as other nations.

The Center is small compared to major nuclear labs on the U.S. mainland, but its modern facilities are excellent. One of PRNC's major installations is at the University's Mayagüez campus on the west coast. In Mayagüez, PRNC has three reactors(one pool-type research reactor and two training reactors), a subcritical assembly, a 14 MeV neutron generator, neutron spectrometers, a laboratory for work with high- and low-level radioactivity, a large gamma facility, a chemistry laboratory, and separate buildings for plant sciences, nuclear engineering and marine biology. A new oceanographic research vessel, the Palumbo, fully equipped with laboratory, is being constructed for the Marine Biology program. Expanded laboratory and pier facilities are planned for the Marine Biology program at Guanajibo Point, adjacent to new laboratories being built by the Commonwealth of Puerto Rico government in order to develop the island's fishing industry. A new neutron generator building in Mayagüez is also under construction.

Another major facility is at the new Medical Center in Río Piedras, on the outskirts of San Juan. The Bio-Medical Building in Río Piedras is equipped for research in several fields. Irradiation facilities include a cobalt-60 teletherapy unit, a 300 KVP X-ray therapy unit, and a cobalt-60 irradiator. An animal house next door is stocked with colonies of mice and snails for experimental use. By 1970 a new $1 million wing for the Bio-Medical Building will be completed, providing additional laboratory and office space. A solid state physics laboratory is located at the University's College of Natural Sciences on the nearby UPR Río Piedras campus; terrestrial ecology field laboratories are located in the Luquillo National Forest.

The Nuclear Center's academic program is closely linked with the master's degree programs of the UPR in the physical and life sciences, agriculture and engineering. Students enroll at the university and receive academic credit through the corresponding university department. Their professors are scientists who have joint appointments at both PRNC and the UPR. Inroads are also being made at the doctoral level. New doctoral programs are now offered in biochemistry, microbiology and physiology; a new doctoral program in chemistry has started in Rio Piedras, and a physics program is under study at Mayagüez.

PRNC also gives non-credit training courses. It provides facilities for graduate research and offers courses in the nuclear field, with students receiving credit from the university they are attending.

The Center's bi-lingual policy--most formal lectures are in Spanish--has encouraged enrollment by Puerto Rican and South American students. Spanish-speaking scientists come from abroad to teach, or to take advanced level courses. For example, PRNC's Physical Sciences Division--in addition to supporting the UPR's M.S. degree programs in chemistry and physics--provides four-week basic courses in radioisotope techniques which are often taken by working professionals--doctors, engineers, biochemists--who wish to augment their knowledge.

The Nuclear Center also participated for several years in the USAEC's "Atoms in Action" exhibits which were held twice yearly in different South or Central American republics. The exhibit provided data on the peaceful uses of atomic energy for scientists, teachers, and the general public. PRNC's scientists lectured, worked on graduate thesis projects with local students, and cooperated with institutions in the country being visited. During one exhibit in Ecuador, for example, research dealt with radiation preservation of agricultural products, including the banana, Ecuador's biggest money crop.

Although PRNC started as primarily a training institution, its research program has become equally important, with projects aimed at solving problems germane to Puerto Rico and/or Latin America.

PRNC's marine biologists took part in a feasability study for a new sea-level Isthmus of Panama Canal, with possible excavation by nuclear devices. Its research ships spent seven months in the waters off Panama and Colombia, collecting tons of marine samples. The results are being used to evaluate possible hazards caused by incorporating radionuclides into food webs leading to humans. The same team of scientists will in the near future embark on an environmental and ecological study of the Bay of Jobos on Puerto Rico's southeast coast, where two fossil-fired electrical generating plants are being built, and where a new nuclear power plant will also be located.

PRNC's terrestrial ecology specialists have irradiated a small section of the Rain Forest in eastern Puerto Rico. Preliminary and follow-up studies show how radiation affects the total environment (plants, animals, insects, soil, water, mineral cycling, etc.).

The main thrust of PRNC's research in medicine and radiobiology examines the impact of radiation upon the host and parasite in various parasitic di seases which cripple millions of persons, particularly on the South American and African continents. Studies are being made of Schistosomiasis(also known as Bilharzia), of Trypanosomiasis(also called Chagas' Disease), of coxsackie virus, and of Fascioliasis(cattle liver fluke).

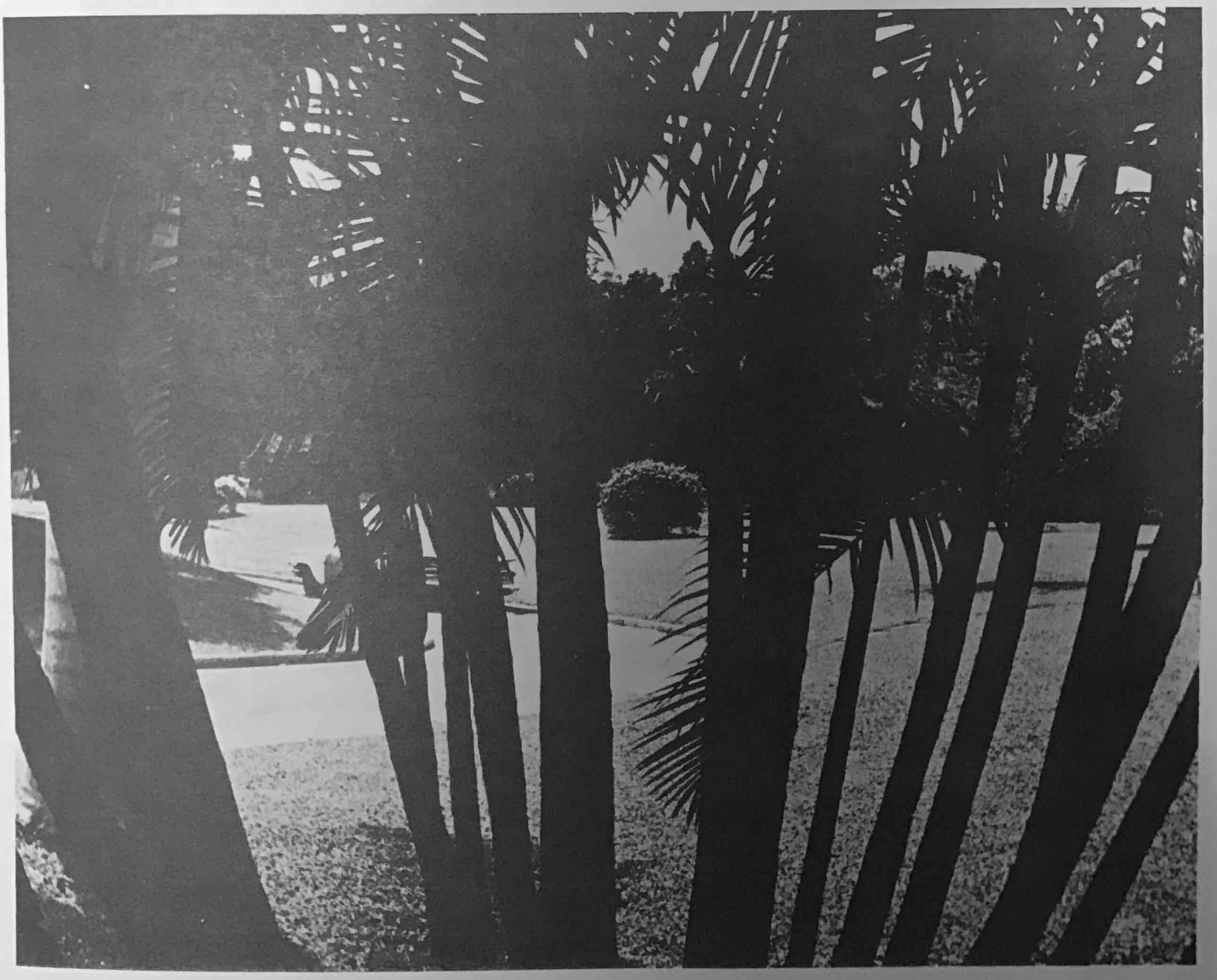
An insect called the sugarcane borer(*Diatraea saccharalis)* causes losses in Puerto Rico alone of $2 to $3 million a year. It is also a serious pest in the U.S. and Central and South America. A PRNC project begun in 1963 hopes to eradicate the sugarcane borer by breeding sterile or partially sterile adults and releasing them to mate with pests in the cane fields.

Food irradiation is another of PRNC's interests. Many areas of South and Central America produce abundant fruits and vegetables, but poor roads slow delivery to distant markets and cause severe spoilage losses. The technique of extending the shelf life of tropical fruits by radiation, without damaging flavor or nutritional value, is now being studied.

The Center has also studied whether underground atomic explosions can be used in mining to leach copper ore from deep in the earth. If feasible, this technique reduces time and labor costs, and eliminates the pollution problems found in opencut mining.

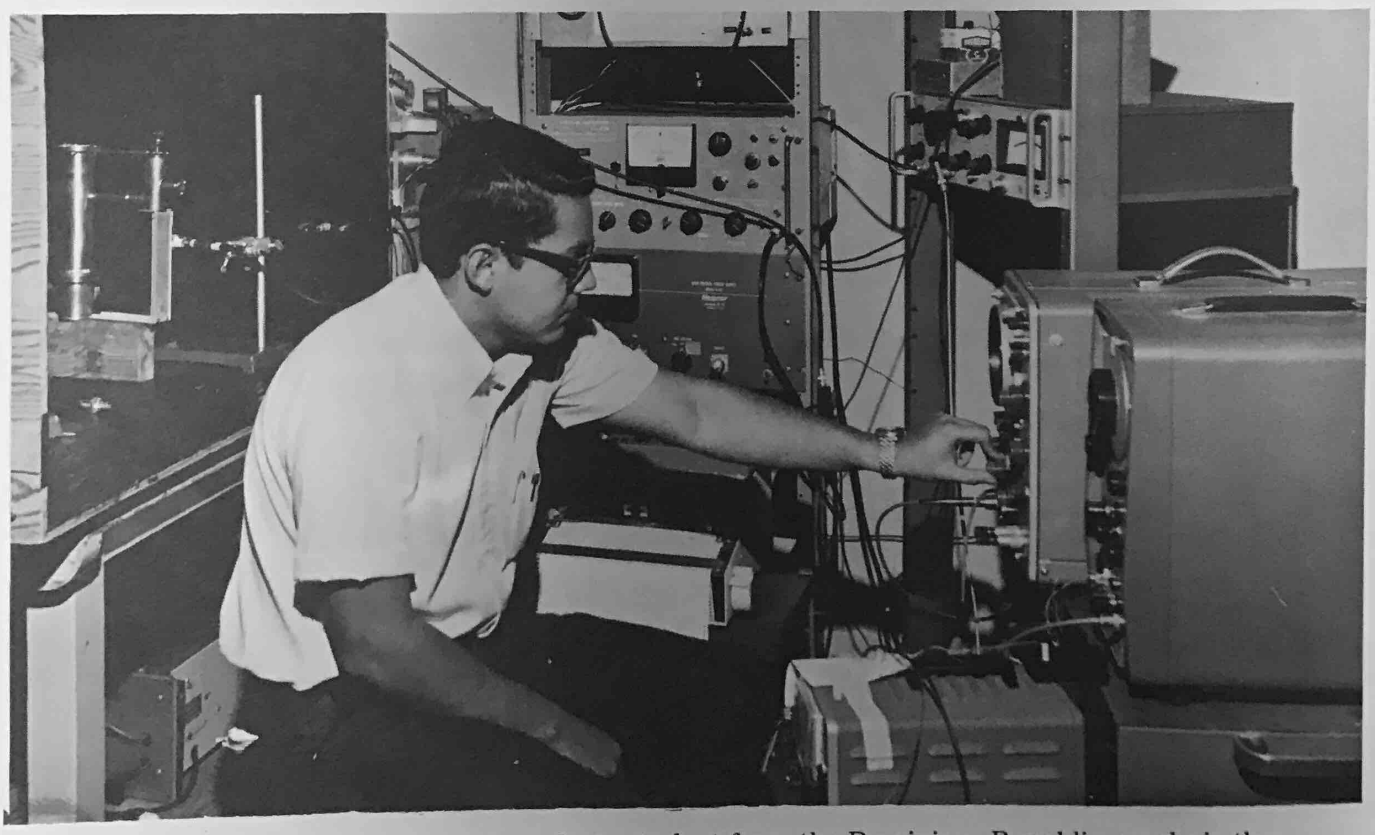
In the area of "pure" research, PRNC has programs in solid state physics, neutron diffraction, hot-atom chemistry and radiation chemistry.

The Puerto Rico Nuclear Center has been productive in its first 12 years. Its alumni work in laboratories and hospitals throughout the hemisphere. Its scientific staff produces an impressive amount of research papers. In 1969, PRNC was able to significantly expand its training for Latin American students thanks to scholarship funds granted by the University of Puerto Rico and by the Organization of American States. The Center also assumed a greater role in Puerto Rico's developing economy, by participating in studies on needs for university-level science education, on environmental pollution, and on the feasability of a major energy center in the southern region of the island.



View of the grounds at PRNC Mayagüez

Dr. Julio A. González observes while Colombian graduate student Luis Carlos Hernández works with the electron spin resonance spectrometer in the Nuclear Science Division.



Francisco Hernández Enchaustegui, graduate student from the Dominican Republic, works in the Nuclear Science Laboratory with the system to measure electroreflectance as a function of wavelength. The recorded spectra provide information on the band structure of semiconductor materials.

NUCLEAR SCIENCE

The Nuclear Science Division supports the M.S. degree programs in Chemistry and Physics of the University of Puerto Rico at Mayagüez by providing research opportunities for graduate students and faculty to teach specialized advanced courses. Research facilities are also made available to graduate students of Nuclear Engineering and Electrical Engineering as well as for pre- and post-doctoral students of other universities interested in working at PRNC.

One of the most important commitments of the Division is to promote and encourage co-operative research efforts among our scientific staff and science teaching staff at the UPR, Mayaguez.

EDUCATIONAL ACTIVITIES

Graduate Courses

During 1969 the following six graduate courses were taught by PRNC personnel, with academic credit given by the UPR:

Course	Professor	Enrollment
Nuclear Chemistry	Dr. O. H. Wheeler	12
Chemical Kinetics	Dr. O. H. Wheeler	8
Introduction to Solid State Physics	Dr. J. A. Gonzalo	6
Radiation Chemistry	Dr. R. A. Lee	5
Introduction to Quantum Theory	Dr. B. A. Cruz	3
Solid State Electronics	Dr. F. Vázquez	4

Thesis Research

The following students have completed thesis research under Nuclear Science Division staff supervision:

Student	Thesis Title	Advisor
Ileana Casanova	Synthesis of pyrimidin labeled with radioiodine	Dr. O. H. Wheeler
Gabriel Infante	Mechanism radiolysis of peptides	Dr. O. H. Wheeler
Cándida Rosa de Jesús	Incorporation of radioisotopes in pharmacological compounds	Dr. O. H. Wheeler Dr. L. Feliú
Iván Nazario	Radiation damage in KDP and ADP single crystals	Dr. J. A. Gonzalo
Raquel Rodríguez	Copolymerization of vinyl compounds with crotonic acid induced by gamma radiation	Dr. R. A. Lee

Laureano Niño	F center formation in potassium chloride at 78°K during exposure to monochromatic X-ray energies around the chlorine K edge	Dr. B. A. Cruz

The following students from Puerto Rico, Colombia, Chile, Dominican Republic, Nicaragua and United States are doing thesis research under Nuclear Science Division staff supervision:

Student	Thesis Title	Advisor
Manuel Lagunas	Radiolysis of organic compounds in aqueous solution	Dr. R. A. Lee
E. Lyons	Radiation protection studies by ESR	Dr. R. A. Lee
Nelson Peña	Recoil reactions of tritium in liquid organic acids	Dr. O. H. Wheeler
Genaro Coronel	Critical behavior of the specific heat anomaly in ferroelectric TGS	Dr. J. A. Gonzalo
Carlos Basora	High frequency behavior of ferroelectric Rochelle Salt	Dr. J. A. Gonzalo
Luis C. Hernández	ESR spectra from ferroelectrics	Dr. F. Cesaní

RESEARCH COMPLETED

Labeling of Iodocytosine and Iodouracil - O. H. Wheeler and Ileana C. de Brás (PRNC Mayaguez). The rate of exchange of iodocytosine and iodouracil with radioiodine (^{131}I) was studied. Optimum conditions were pH at 100° for 2 hr for iodocytosine and 30 mins for iodouracil. The rate constant for exchange of iodouracil was greater than that for iodocytosine. The method was used to prepare ^{128}I and ^{132}I labeled compounds.

Synthesis of Labeled 0-Iodohippuric Acid - O. H. Wheeler, M. S. Verter, L. A. Feliú and C. R. de Jesús (PRNC Mayaguez and Chemistry Departments, Interamerican University, San Germán and UPR Mayaguez). The reaction of o-iodohippuric acid with labeled iodide gave exclusively labeled o-iodohippuric acid. The same compound has been synthesized from anthranilic acid. The rate of exchange was sufficiently rapid to permit the preparation of ^{132}I and ^{128}I labeled o-iodohippuric acid.

Mechanism of the Radiolysis of Peptides - O. H. Wheeler and G. A. Infante (PRNC Mayaguez). The G values for the radiolysis of carbon-14 labeled glycylglycine and glycine anhydride have been determined at different pH, in the presence and absence of oxygen at different doses, and in the presence of chloroacetate as hydrogen atom scavenger and formate as electron scavenger. The products formed largely resulted from hydroxyl and perhydroxyl radical reactions.

Radiolysis of Phenylalanine and Tyrosine in Aqueous Solution - O. H. Wheeler and R. Montalvo (PRNC Mayagüez). The radiolysis of phenylalanine, tyrosine, and dopa (dihydroxyphenylalanine) in water, of phenylalanine and tyrosine in 0.5N hydrochloric acid and of phenylalanine in 0.5N sulfuric acid have been studied using carbon-14 labeled compounds. Phenylalanine formed tyrosine, tyramine, dopa and phenylpyruvic acid, while tyrosine afforded dopa, dopamine and p-hydroxyphenylpyruvic acid. The final product in all cases was an insoluble polymer. A linear relation was found between log G_{-M} and the absorbed dose, and the relative rate constants for radiolysis were obtained.

Preparation of Diphenylamines via the Chapman Rearrangement - O. H. Wheeler, F. Román, M. V. Santiago, and F. Quiles (PRNC and Chemistry Department, UPR Mayaguez). The optimum

conditions have been determined for preparing substituted diphenylamines using the Chapman Rearrangement. The rearrangement was best carried out in boiling tetraglyme. Phenyl N-phenylcinnamidate rearranged at a lower temperature than the corresponding benzimidate.

The Intramolecular Nature of the Rearrangement of Benzimidates - O. H. Wheeler, F. Román, and O. Rosado (PRNC and Department of Chemistry, UPR Mayaguez). The Chapman Rearrangement of a mixture of ^{14}C-4-bromophenyl N-phenylbenzimidate and 4-bromophenyl N-4-tolylbenzimidate showed that the reaction was intramolecular. Tritium-labeled allyl N-phenylbenzimidate similarly rearranged exclusively intramolecularly with inversion of the allyl group.

Ferroelectric Behavior of KH_2PO_4 in the Critical Region - I. Nazario and J. A. Gonzalo (PRNC Mayagüez). The temperature dependence of the hysteresis loops and the dielectric constant of KH_2PO_4 has been accurately determined in the neighborhood of the Curie temperature, T_c. No evidence has been found of a discontinuous jump (indicative of a lst order transition) in the spontaneous polarization at T_c. The critical exponents $\beta = 0.50 \pm 0.03$, $\delta = 2.95 \pm 0.10$ and $\gamma' = 1.00 \pm 0.05$ have been determined. These values are close to those found in other ferroelectric transitions (f.1. TGS) and are consistent with the mean field model predictions for the critical exponents.

Ferroelectric Specific Heat of Triglycine Sulfate - M. J. Tello and J. A. Gonzalo (Institute of Modern Sciences and PRNC Mayagüez). The ferroelectric specific heat of triglycine sulfate (TGS) powder has been measured. The experimental results indicate a more pronounced anomaly than that previously reported by Hoshino et al. [1] The transition energy and entropy are ΔQ=337 cal./mol. and ΔS=1.07 suggests a critical exponent $\alpha \simeq 0$, consistent with the mean field model. The values for fundamental parameters in the dipolar theory for TGS calculated from specific heat data are consistent with those obtained from dielectric measurements.

Equation of State for the Cooperative Transition of TGS Near T_c -J. A. Gonzalo (PRNC Mayagüez). Measurements of polarization versus field in the vicinity of the Curie temperature from triglycine sulfate, both below and above T_c, allow firstly, the determination of a number of critical exponents and secondly, the characterization of the ferroelectric equation of state. The relationship, below and above T_c, between the "scaled" variables $P/\ 1-(T/T_c)\ \beta$ and $E/\ 1-(T/T_c)\ \beta\ \delta$ was determined from a log-log plot which showed clearly a well defined asymptotic behavior for the small and large "scaled" field. Comparison of the scaled data with the results from the mean field theory showed good agreement. A phenomenological expression for the equation of state which matches all the empirical and homogeneity requirements has been formulated. Evidence for the validity of this equation of state for other transitions for which accurate data are available is discussed.

Gamma Induced Copolymerization of Crotonic Acid and Vinyl Acetate - R. A. Lee and Raquel Rodríguez (PRNC Mayagüez). Mixtures of crotonic acid and vinyl acetate in various mole fractions were irradiated in pyrex glass vessels using Co^{60} gammas. A reactivity ratio of 0.33 for r, was determined in agreement with a radical mechanism. Scavengers water, CCl_4 and DPPH were used. Water raised the monomer reactivity ratio to 0.60. CCl_4 had no effect and DPPH inhibited the formation of copolymers.

Radiolysis of Aqueous Solutions of Thiourea and Tetramethylthiourea - R. A. Lee and Manuel Lagunas (PRNC Mayagüez). $G(H_2)$ were measured in the above aqueous solutions irradiated in the absence of air. These values were lower than the molecular yields of hydrogen and not very much different in solutions of the two compounds. The products were determined by paper chromatography and G_{-M} calculated from UV measurements.

Formation of F-Centers by Excitons in MgO - J. Castro and I. Cantarell (Institute of Modern Science and PRNC Mayagüez). A model of F-center formation by exciton mechanism is proposed consisting of an exciton and an anion vacancy in the field of the crystal. Starting from

the definition of the many-body formulation and introducing appropriate approximations, we developed a method of calculating the energy level of an electron trapped at an anion vacancy in MgO. The physical model assumed was the dissociation of the exciton into an electron and a hole by electrostatic potential energy near the negative ion-vacancy. The results obtained using this model supported the theoretical value of 4.7 eV predicted by Kemp and Neeley, which is in agreement with experimental results.

The Role of K-Shell Ionization in the Formation of F Centers in Alkali Halides at 78°K
I. KBr - B. A. Cruz and H. J. Gomberg (PRNC Mayagüez). Within the uncertainty of the experiment, the rate of F center formation per unit energy retained in Harshaw KBr irradiated at 78°K at equal energy flux is the same (0.78 ± .02 F center/keV) whether the incident-photon energy is 13.4 keV or 14.1 keV. (The K edge of bromine is at 13.5 keV). Since a large background of multiply ionized atoms is expected whether the incident-photon energy is 13.4 keV or 14.1 keV, the above result is not sufficient evidence to conclude that a Varley mechanism of F center formation is not operative. Each of the monochromatic beams was the x-ray fluorescent output either of powdered RbCl filtered with a thin layer of NaBr or of powdered $Sr(NO_3)_2$ filtered with RbCl. The half-width of each monochromatic beam was 330 eV. An air ionization chamber used to measure the flux was calibrated with a calorimeter.

The Role of K-Shell Ionization in the Formation of F Centers in Alkali Halides at 78°K
II. RbBr - B. A. Cruz, F. Díaz-Hernández and H. J. Gomberg (PRNC and UPR Mayagüez). Within the uncertainty of the experiment, the rate of F center formation per unit energy retained in freshly cleaved RbBr (grown from purified material under a bromine-argon atmosphere by Professor R. O. Pohl, Cornell University) irradiated at 78°K at approximately equal energy flux is the same (0.342 ± .005 KeV^{-1}) whether the incident-photon energy is 13.4 keV, 14.1 KeV, 14.9 KeV, or 15.7 KeV. (The K edge of bromine is at 13.5 KeV and the K edge of rubidium is at 15.2 KeV). Each of the monochromatic beams was the X-ray fluorescent output of RbCl filtered with a thin layer of NaBr, of $Sr(NO_3)_2$ filtered with RbCl, of $Y_2(CO_3)_3 3H_2O$ filtered with $Sr(NO_3)_2$, or of Zr filtered with $Sr(NO_3)_2$. The half-width of each monochromatic beam was 330 eV.

The Role of K-Shell Ionization in the Formation of F Centers in Alkali Halides at 78°K
III. KCl - B. A. Cruz, L. Niño-Rojas and H. J. Gomberg (PRNC and UPR Mayagüez). Within the uncertainty of the experiment, the rate of F center formation per unit energy retained in Harshaw KCl irradiated at 78°K at equal energy flux is the same whether the incident-photon energy is below (2.62 keV and 2.81 keV), between (3.31 keV and 3.59 keV), or above (3.69 keV and 4.01 keV), the chlorine (2.82 keV) and potassium (3.61 keV) K edges. Since an initial photoionization in the L_{II} or L_{III} subshell of a chlorine ion is expected to result in an average loss of 2.3 electrons, while an initial photoionization in the K shell is expected to result in an average loss of 4.2 electrons, the result reported here indicates that the multiple ionization of the halogen (Varley mechanism) is not the dominant mechanism of Frenkel defect formation in KCl at 78°K. Each of the beams used was the x-ray fluorescent output of LiCl, or of $K_2C_2O_4 \cdot H_2O$, or of CaO.

RESEARCH IN PROGRESS

Scavenger Effects on the Radiolysis of CH_3F and CHF_3 - R. A. Lee (PRNC Mayagüez). The effect of dose, pressure and scavengers (SF_6 and C_2H_4) or the radiolysis of CH_3F and CHF_3 are presently being investigated.

Radiation Protection Studies - R. A. Lee (PRNC Mayagüez). Mixtures of glycylglycine with thiourea and cysteine hydrochloride separately are irradiated at liquid N_2 temperature. ESR studies are being carried out to see if spin transfer occurs as in other similar studies.

Critical Behavior of Ferroelectric Rochelle Salt - J. M. Rivera and J. A. Gonzalo (PRNC Mayagüez). Hysteresis loops measurements near the transitions which appear at around -18°C, and 23°C in Rochelle Salt have been carried out. A few tenths of a degree apart from every transition within the ferroelectric region asymptotic behavior of P vs T and P vs E indicates classical values for the critical indices, $\beta \simeq 1/2$ and $\delta \simeq 3$. However, closer to the transition the spontaneous polarization decreases much more slowly than expected according to the mean field theory for long-range order only. The difference between the observed and the extrapolated polarization might be attributed to short range order effects. The temperature dependence of the squared remnant polarization shows a rounded peak, approximately $(\Delta P_s)^2 \alpha (\Delta T)^{-1}$, which would correspond to a critical index-$\nu^1 = \log(\Delta P_s) / \log \Delta T \simeq -1/2$, in agreement with the Ornstein-Zernike theory except in the very close vicinity of the extrapolated Curie point. Complementary data on ε vs T will be taken in the near future.

High Frequency Behavior of Rochelle Salt - C. Basora and J. A. Gonzalo (PRNC Mayagüez). Recent measurements of the dielectric constant of Rochelle Salt in the GH_2 region indicate that the relaxation process can be described by a simple Deby model. An experimental system consisting of a special sample chamber, oscillator, slotted line and detector is being set up to determine the behavior very close to T_c, under accurate temperature control conditions. Preliminary measurements have been performed.

Specific Heat Anomaly of Ferroelectric TGS and Isomorphous Crystals - G. Coronel and J. A. Gonzalo (PRNC Mayagüez). An adiabatic calorimeter, with provisions for applying variable d.c. fields to the single crystal samples has been set up. The analysis of specific heat data for zero and variable d.c. fields in the critical region as well as in the neighboring ordered and disordered phases will provide additional information on the order-disorder mechanism of these important ferroelectrics.

Natural Radioactive Materials in Puerto Rico - F. Rivera (IMC-PRNC), A. Suárez (IMC), G. Ramos (IMC), E. López (IMC) and I. Cantarell (IMC-PRNC). Uranium and Thorium families were found in the north of the island, being in a 2 to 1 relative proportion, and in small absolute proportion (smaller than that required for economic exploitation). Difficulties with proper equipment location and maintenance at PRNC caused interruption of the measurements for eight months and damages to the equipment.

Changes in Electric and Optic Characteristics and Surface Effects in Semiconductors and Dielectrics Under Irradiation - F. Rivera and I. Cantarell (IMC and PRNC). In the initial step, ultra-high vacuum equipment is being set up. A visiting professor, Dr. Richard M. Stern, Director of the Low Energy Electron Diffraction Program at Brooklyn Polytechnic Institute, came as a consultant by arrangement with the Institute of Modern Sciences.

Iodine-128 and -132 Labeled Rose Bengal and Thyroxine - O. H. Wheeler, J. E. Trabal and H. López-Alonso (PRNC Mayagüez). A kinetic study using iodine-131 indicated that Rose Bengal and thyroxine could be labeled by exchange with radioiodine at 100° in about 10 minutes. Methods were developed for preparing these compounds labeled with ^{128}I and ^{132}I, in radiochemically pure form in 1/2 hour.

Radiation Protection by Thioureas - O. H. Wheeler and R. A. Ribot (PRNC Mayaguez and Chemistry Department, UPR Mayagüez). The "protecting activity" of substituted thioureas was measured in the radiolysis of labeled glycylglycine. One methyl group in thiourea reduced the effectiveness by a factor of 5, and 1,3-dimethylthiourea and tetramethylthiourea were similarly ineffective. The reduction in protecting activity seemed to be due to the inductive effect of the methyl groups, and thioacetamide also showed a low activity.

Infrared Thermoreflectance in Mg_2Si, Mg_2Ge and Mg_2Sn -F. Vázquez (PRNC Mayagüez). Thermoreflectance, the measurement of the modulation in the reflectivity induced by a temperature modulation, is a powerful technique for studying structure in the optical spectra of solids. It has advantages over other modulation techniques, in that it could be applied at low temperatures and could be extended to the infrared. We are applying this technique to study the visible and infrared spectra of Mg_2Si, Mg_2Ge, and Mg_2Sn that allow us to correlate the energy band properties of this family of materials with the same crystal structure, mainly the spin-orbit splitting.

Piezo-thermoreflectance in Ge and Si - F. Vázquez and J. L. Súñez (PRNC and Department of Elec. Eng., UPR Mayagüez). Thermoreflectance technique applying a uniaxial stress is going to be used to study some of the prominent peaks of the germanium and silicon to further clarify the interpretation of its spectra.

Electro-thermoreflectance in Ge and Si - F. Vázquez and F. Hernández (PRNC and Dept. of Elect. Eng., UPR Mayagüez). Thermoreflectance technique applying a static electric field is going to be used to study some of the prominent peaks of germanium and silicon to further clarify the interpretation of their spectra.

STAFF

Miss Raquel Rodríguez, after completion of the M.S. degree in Chemistry, left PRNC to begin studies toward the Ph.D. at University of California, Santa Barbara.

Mr. Antonio Mock, after completing all courses for the M.S. in Physics, and having initiated thesis research work on calorimetric measurements in ferroelectrics, left PRNC to return to the Physics Department of the University of Panamá. He plans to continue research work along the same line in his home university.

Mr. Iván Nazario, after completion of courses and thesis research, joined the Physics Department of the Catholic University of Puerto Rico, at Ponce.

Dr. F. Cesaní, from the Physics Department, UPR Mayagüez, has been granted an "ad honorem" appointment in our Division. He plans to work on ESR studies of solids.

The following guest investigators have performed research work in collaboration or in consultation with our staff.

Guest	Research Problem	Consultant
Dr. Harold W. Fenrick	ESR Studies of Radiation Damage in Ferroelectric Selenites	Dr. R. A. Lee and Dr. J. A. Gonzalo
Miss Angela Vallejos	Chemical Effects Produced in Activation of Thio-compounds of Germanium, Tin and Antimony	Dr. O. H. Wheeler
Miss Carmen C. Motta	Synthesis of radiopharmaceuticals labeled with short half-life isotopes	Dr. O. H. Wheeler

Dr. R. A. Lee was a research participant (July-August, 1969) at the Sloan Kettering Institute in N.Y. where he carried out research on ESR application to radiation protection studies.

Dr. B. Cruz joined the Maier-Leibnitz Institute of the Munich School of Technology in

Germany for one year as a research participant, working on the interaction of radiation and matter.

Dr. I. Cantarell attended the Atoms in Action Exhibit of the USAEC at Sao Paulo, Brazil from October 25 to November 7, 1969. Work on time dependent field emission on photo-multipliers with a surface BeO at the dynodes was performed with the collaboration of Mr. Juan Silva Parra and the following undergraduate students: 6 from Mackenzie University, 20 from the Catholic University of Sao Paulo (Sedes Sapientiae Campus).

Mr. Gabriel Infante completed the requirements for a M.S. degree in chemistry in May and is now teaching at the Catholic University of Puerto Rico in Ponce. Mrs. Ileana Casanova de Brás also completed her M.S. degree in Chemistry in May, 1969.

Mr. José Sequeira, from Nicaragua, a graduate student in Chemistry, was awarded a UPR Student Aid Scholarship, to carry out research in the Division.

MEETINGS

Dr. R. A. Lee attended the Fifth Caribbean Chemical Conference held in Barbados (January 6-11, 1969).

Drs. O. H. Wheeler and R. A. Lee attended the Tenth Latin American Congress on Chemistry held in San José, Costa Rica (February 2-9, 1969).

Dr. B. Cruz attended the American Physical Society Meeting in New York City, (February 3-6, 1969).

Dr. O. H. Wheeler attended the Junior Technical Meeting of the P.R. Section of the American Chemical Society in San Juan (August 30, 1969).

Dr. O. H. Wheeler and Dr. R. A. Lee attended a meeting of the Colegio de Quĭmicos (Chemists Association) in San Juan (October 11, 1969).

Dr. J. A. Gonzalo attended the Second International Meeting on Ferroelectricity in Kyoto, Japan (September 4-9, 1969).

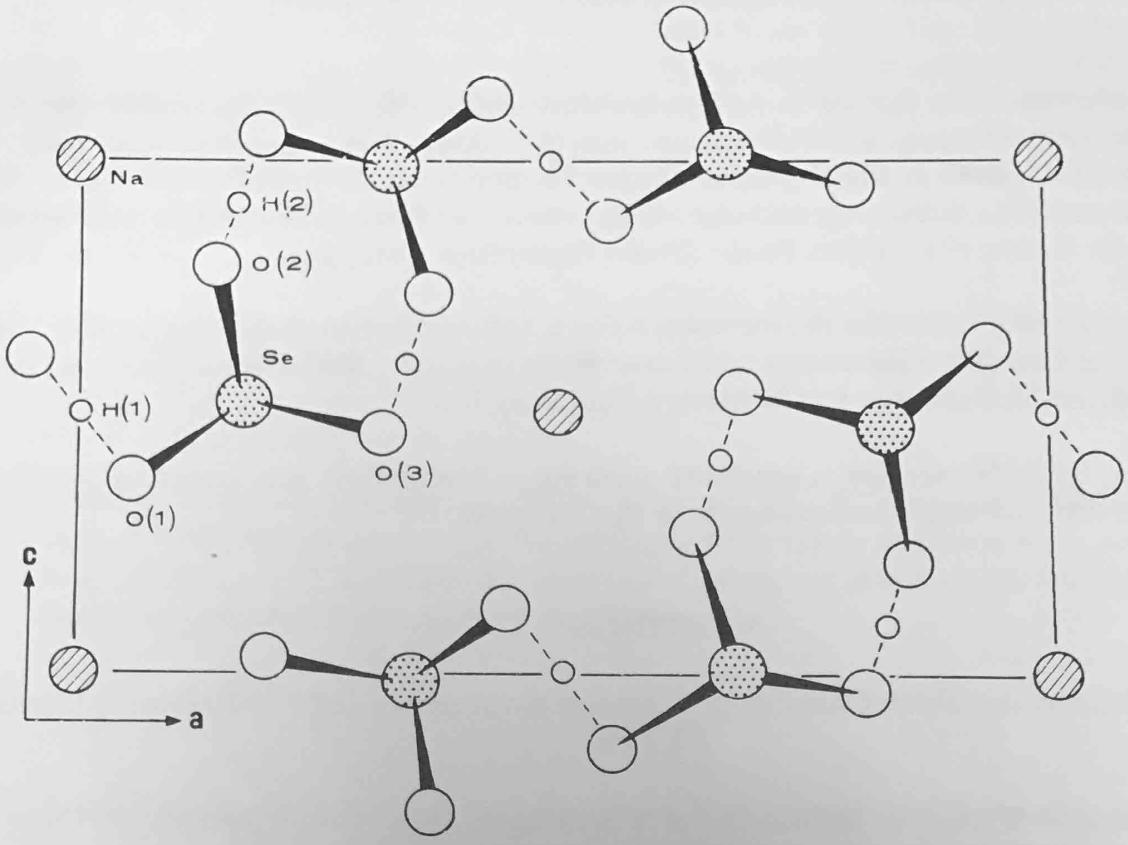


Fig. 1. A schematic representation of the crystal structure of $NaH_3(SeO_3)_2$ viewed down the b axis.

Dr. Mortimer Kay(foreground) and research associate Braulio Mercado at work on the Neutron Diffraction project, located in PRNC Mayagüez.

NEUTRON DIFFRACTION

The neutron diffraction group at the Puerto Rico Nuclear Center is working on two types of problems: (1) the chemical binding of atoms in crystals and molecules; (2) the nature of ferromagnetism. Both are related to the spatial arrangement of atoms in molecules.

If either x rays or neutrons are scattered from crystals, patterns can sometimes be analyzed that show the arrangement of atoms in the crystal. Since the amplitude of x rays diffracted is proportional to the atomic number of the scattering atom, if both light and heavy atoms occur in the same compound, the contribution of the light atom is very weak and its position can be determined only with great difficulty. Neutrons, however, are scattered by the nuclei of the atoms. Diffraction of neutrons by light elements compares favorably with that from heavier elements, and the coordinates of the lighter atom may be determined with greater precision than with x rays. In compounds having atoms with unpaired electrons, a neutron-electron spin interaction is also present. Since the magnetic properties of substances are related to the way the electron spins are arranged within the crystal, determination of such spin arrangements by neutron diffraction provides information about magnetic structures.

RESEARCH PROGRESS

I. The Magnetic Structure of Vivianite $Fe_3(PO_4)_2 \cdot 8H_2O$. At the time the present work was initiated, both x-ray experiments at room temperature, and nuclear magnetic resonance (NMR) experiments on antiferromagnetic vivianite had been performed. The present neutron diffraction study was undertaken because x-ray and NMR experiments did not yield sufficient information for a unique determination of the antiferromagnetic structure of vivianite.

The room temperature crystal structure had been determined by Mori and Itoh. Vivianite, a naturally occurring mineral, belongs to the monoclinic system and has space group C 2/m. The unit cell at room temperature has the dimensions a = 10.08, b = 13.43, c = 4.70Å, and $\beta = 104^\circ\ 30'$, and contains two molecules of $Fe_3(PO_4)_2 \cdot 8H_2O$. There are two types of iron ions (labeled I and II) that are unrelated by symmetry.

The two type I ions are at the cell corners and in the center of (001) faces. The four type II ions are located on the twofold symmetry axis, and on either side of, and close to, the mirror plane between adjacent ions of type I. One may think of the iron ions stacked along the symmetry axes in the order $Fe_I(y=0)$, $Fe_{II}(y=1/2-\epsilon)$, $Fe_{II}(y=1/2+\epsilon)$, $Fe_I(y=1)$.

The local magnetic fields at the proton positions have been measured by van der Lugt and Poulis using NMR. By assuming that the chemical space group in the antiferromagnetic state is also C 2/m, and by applying magnetic symmetry theory to the NMR data, they found that two, and only two possible magnetic space groups were compatible with the experimental data. These groups are P_C2_1/a, and C_c2/c. The latter group generates two possible structures, depending on the choice of the nonunique axes. Since extinction conditions for nonzero magnetic Bragg scattering from the $h0\ell$ zone are different for each of the three possible structures, the correct structure and space group may be determined by simply indexing magnetic reflections in a neutron diffraction experiment. Conditions for nonzero magnetic Bragg scattering

from the h0ℓ zone for P_C2_1/a, are that h,ℓ must be odd-even, but for the two structures generated by C_c2/c, h,ℓ must be even-odd, or odd-odd. The indices h,ℓ are based on a cell which is double the chemical unit cell along the c direction.

The experiment suggested by the data given above was performed by the Neutron Diffraction Group, at a temperature of 4.2°K, using liquid helium as the refrigerant. Magnetic reflections measured at 4.2°K showed the structure to have space group C_c2/c with ferromagnetic (001) planes, which are coupled antiferromagnetically, i.e., for a given type of iron ion (I or II) all the spins in the plane at z=0 are aligned in the same direction and sense, while the spins in the adjacent planes are also aligned in the same direction but with opposite sense.

The exact determination of the spin directions of the two types of iron ions from the measured magnetic reflections is in progress. This analysis is hampered by the fact that there are two magnetic systems, and that the magnetizations of the two systems are different. But a qualitative preliminary inference has been made about the magnetization directions of the two iron systems from the fact that the reflections (403), (203), and (205) had nonmeasurable intensities. If the magnetization and scattering vectors for a given reflection are parallel, then the reflection will have zero intensity. Thus, the absence of a measurable intensity for the reflections given above indicates that the possible spin directions for the two types of iron systems lie approximately within the angle of 25° formed by the scattering vectors (403), and (205).

Results of the quantitative analysis of the spin directions will be presented in future reports as soon as they become available.

II. Sodium Trihydrogen Selenite $NaH_3(SeO_3)_2$. Sodium Trihydrogen Selenite undergoes a transition to a ferroelectric phase (I) at -79°C and to a second ferroelectric phase (II) at -173°C. These transitions are of interest because the two ferroelectric phases have different electric polarizations and because the hydrogen bonds play a very important role in the phase changes, as indicated by the complete suppression of phase I, if the hydrogen atoms are replaced by deuterium atoms.

X-ray diffraction studies on the paraelectric phase of sodium trihydrogen selenite, $NaH_3(SeO_3)_2$, have been made by three different groups. Although the gross structures determined by these studies are similar, even the position of the heaviest atom, selenium, differs by over 0.04Å when any two studies are compared. Recently the deuteron resonance rotation patterns of Soda and Chiba suggested that the space group $P2_1/n$, selected by Unterleitner and by Vijayan, is the correct one rather than the noncentrosymmetric choice Pn selected by Kung-tu and Yu-Ch'i The lattice constants are a= 10.3450(4), b=4.8440(2), c= 5.7866(2) Å, and β = 91.133(4)°, and there are two formula units per unit cell. A projection of the structure along the b axis is shown in Fig. 1. Bond distances and angles are given in Table 1.

Some of the more significant features of the structure may be discussed with the aid of the bond lengths and angles given in Table 1. Unlike the results of previous investigations of the material we find that all Se-0 distances are about equal (1.71 ± 0.01Å). One might expect that Se-0 distances would reflect differences in hydrogen bonding by amounts on the order of 0.01 or 0.02 Å, rather than the approximately 0.05 Å found in previous work.

From the experimental data there are two possible ways to interpret the position of hydrogen (1). These two choices are designated H(1), and $H_d(1)$. In Fig. 1, we see that H(1) is located on the center of symmetry between two oxygen (1) atoms which are related by that center. $H_d(1)$ is slightly displaced from that center. Distances and angles for the atoms close to H(1) and $H_d(1)$ are given in Table 1. The reliability factor $R = \sum (F^2_{obs} - F^2_{calc}) / \sum F^2_{obs}$,

which measures the goodness of fit of a given model with a set of experimental data was identical for the model having the hydrogen at the center of the O(1) - H(1) - O(1)' bond, and the model having the hydrogen atom placed slightly off the center in the disordered position.

We prefer the disordered model because: the O(1) - O(1)' distance of 2.60 Å is very slightly too long for a centered bond when compared to many other experimental results; the Fourier map calculated from the diffraction data shows the maximum hydrogen mass density to a bit off the center of the bond; and the deuteron magnetic resonance data of Soda and Chiba, and Anderson, and Blinc, et al indicate some disorder as well as a non-180° bond angle.

The second hydrogen atom (H(2)) seems to be in a shallow, slightly skewed potential well. However, even here possible disorder cannot be eliminated.

Further work should include a study of the low temperature phases and the deuterated material.

EDUCATIONAL ACTIVITIES

During the past year, a beginning has been made to better integrate the neutron diffraction program with the University of Puerto Rico graduate school. The division staff offered two graduate courses during the year: *Introduction to X-Ray Diffraction* - Dr. M. I. Kay taught this one semester course during the summer of 1969. Basic principles and experimental methods of x-ray diffraction and reciprocal lattice theory were covered. *Theory of Electricity and Magnetism*- Dr. R. Kleinberg taught this two semester course during the 1969-1970 academic year. Green function methods for electrostatics and electrodynamics, Maxwell's equations, electromagnetic wave theory, scattering theory, and electron theory were covered.

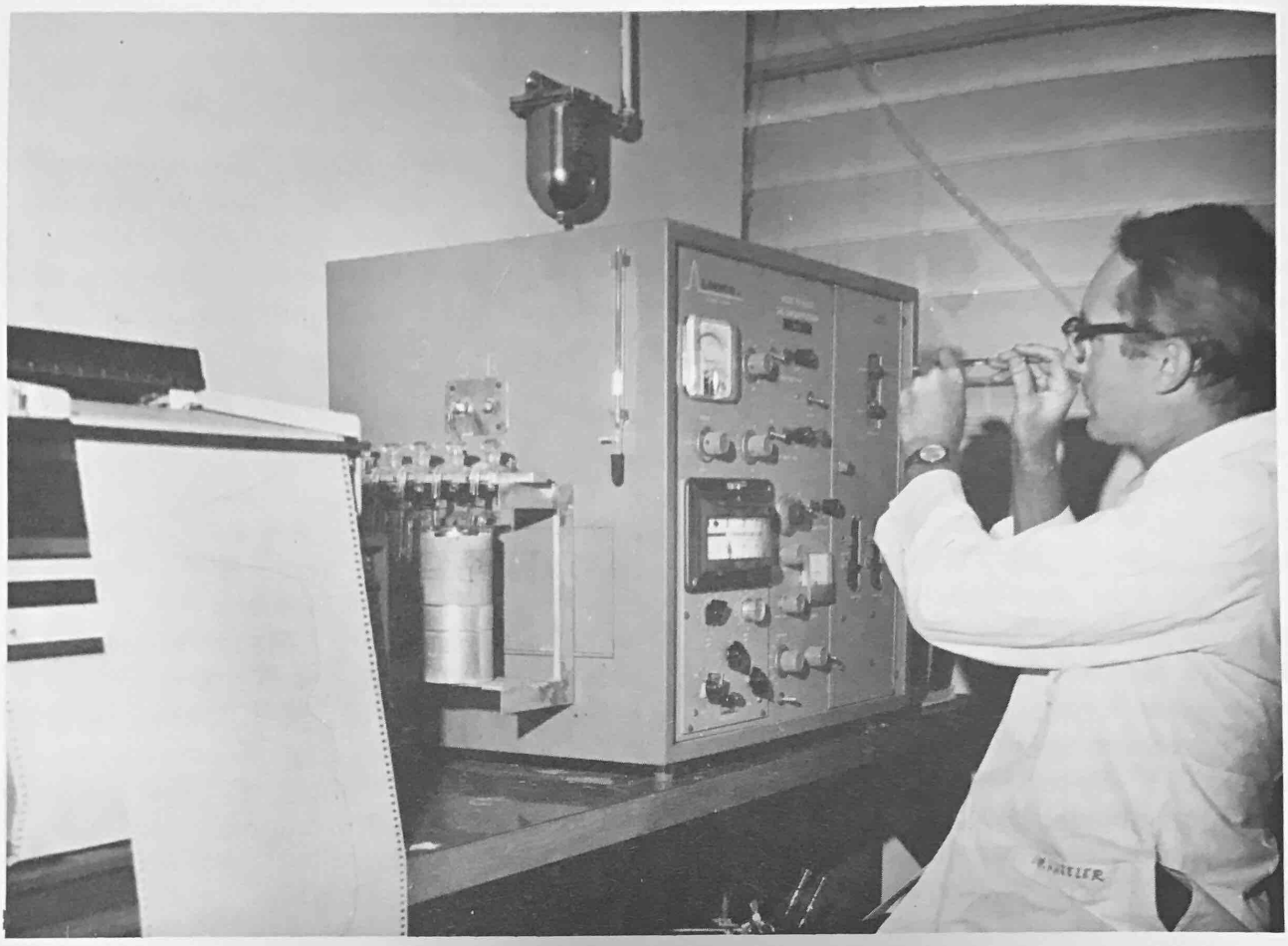
PERSONNEL

Mr. A. Camnasio, technician from Argentina, has joined the project in place of Mr. A. Fabregas. Mr. Camnasio is studying at the CAAM during non-working hours.

Dr. M. I. Kay is spending six months at Brookhaven National Laboratory working on the phonon spectra of Selenium.

Table 1
Interatomic separation and angles in $NaH_3(SeO_3)_2$

a)	involving oxygen atoms about the sodium ion			
	Na-0(1)	2.407(4)Å	0(1)-Na-0(2)	84.2 and 95.8(2)°
	Na-0(2)	2.413(4)	0(1)-Na-0(3)	87.0 and 93.0(2)
	Na-0(3)	2.462(4)	0(2)-Na-0(3)	83.7 and 96.3(2)
b)	involving selenite group			
	Se-0(1)	1.700(5)Å	0(1)-Se-0(2)	99.3(3)°
	Se-0(2)	1.716(5)	0(1)-Se-0(3)	102.7(3)
	Se-0(3)	1.707(5)	0(2)-Se-0(3)	100.6(3)
c)	involving hydrogen bonds			
	0(1)-H(1)	1.301(5)Å	0(1)-H(1)-0(1)	180°
	0(1)-0(1')	2.602(9)	0(2)-H(2)-0(3)	176.1(9)°
	0(2)-H(2)	1.24(1)		
	0(3)-H(2)	1.31(2)		
	0(2)-0(3)	2.556(6)		
	0(1)-H_d(1)	1.11(8)	0(1)-H_d(1)-0(1)'	170(4)
	0' (1)H_d(1)	1.50(8)		



Dr. O.H. Wheeler injects a sample into the radio-gas chromatograph.

Miss Hilda López-Alonso, research assistant, processes radioactive samples

Miss Angela Vallejos, graduate student from Paraguay, counts strips from a paper electrophoretic separation.

HOT ATOM CHEMISTRY

PRNC's hot-atom chemistry studies involve the investigation of the products formed when an atom covalently bound to carbon undergoes nuclear recoil. The recoiling nuclei have included the transition metals and heavy metals, as well as non-metallic atoms. The carbon compounds employed have been phenyl derivatives, metallocenes and metal carbonyls. The purpose of these studies is to determine the mechanism of high energy reactions in organic compounds through a study of the products formed under different activation conditions. The possibility of directly preparing labeled compounds and of obtaining radioisotopes of high specific activity by recoil methods is also being investigated.

The equipment available for handling unstable compounds includes vacuum systems and glove boxes. The experimental techniques used for separating the radioactive products include various methods of chromatography and electrophoresis.

WORK IN PROGRESS

Metallocenes - The retention in dicyclopentadienyltitanium dichloride was 17%. Dicyclopentadienylvanadium dichloride and cyclopentadienylvanadium tetracarbonyl showed 16 and 45% retention, respectively. Rapid separation methods were developed to handle the short half-life isotopes.

Metal Carbonyls - The retention in cobalt carbonyl $Co_2(CO)_8$ was found to be about 8%. Both iridium carbonyl ($Ir_2(CO)_8$) and rhenium carbonyl ($Re_2(CO)_{10}$) gave about 25% retention, comparable with that found for ruthenium carbonyl. However, nickel carbonyl ($Ni(CO)_4$) showed 98% retention resulting from recombination, both for the liquid and vapor. The retention was not decreased in heptane solution, although the addition of iron carbonyl ($Fe(CO)_5$) reduced the retention due to competition.

Tritium - The products formed in the tritiation of liquid propionic acid are being studied, using a solution of lithium-6 enriched lithium propionate. The labeled propionic acid and other products are being degradated to determine the positions of tritium labeling.

WORK COMPLETED

Phenyl Tin Compounds - The study investigated ^{125}Sn, resulting from neutron activation of phenyl tin compounds. Tetraphenyltin and triphenyltin chloride gave largely radioactive triphenylstibine and phenylstibinic acid, while diphenyltin dichloride afforded predominantly phenylstibinic acid and phenyltin trichloride formed a mixture of activities. The products arose through elimination from more complex phenyltin-125 intermediates, which were formed by recombination following recoil fragmentation.

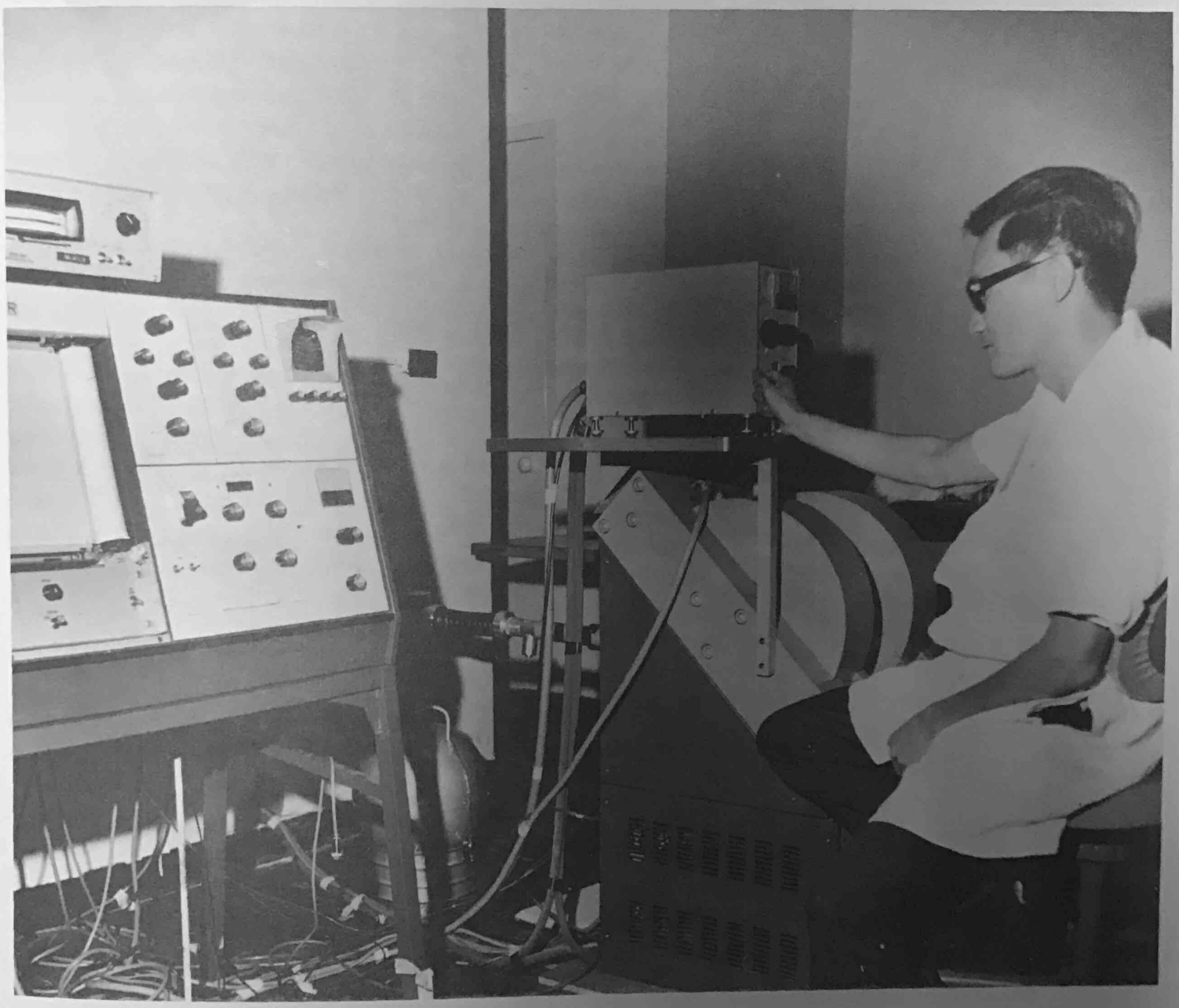
Mr. José Seguiera analyzes the products formed in the radiolysis of carbon-14 labeled succinimide.

STAFF

The group consists of Mrs. María Luisa McClin, M.S.; Miss J. Elisín Trabal, B.S. (part-time); Miss Hilda López Alonso, B.S.; Miss Angela Vallejos (Paraguay) and Mr. Nelson Peña (Dominican Republic), recipients of UPR Student Aid Fellowships, carry out their research in the project. Miss Carmen Cecilia Motta, an IAEA fellow, was also working in the group.

MEETINGS

Dr. O. H. Wheeler attended the 10th Latin American Congress of Chemistry in San José, Costa Rica (February 2-9, 1969). He also participated in the Atoms at Work exhibit in Sao Paulo, Brazil, and attended the International Symposium on Chemical Effects in Nuclear Transformations in Cambridge (July 1-3, 1969); the 5th Informal Hot Atom Chemistry Meeting, Cambridge (July 3-5, 1969) where he read a paper on "Recoil Reactions in Metal Carbonyls," and the International Symposium on Isotope Effects, York England (July 8-10, 1969).



Dr. R.A. Lee performs radiation studies by ESR.

Electronics technician Richard Hufty operates the new spectrum analyzer in the Nuclear Engineering laboratory.

NUCLEAR ENGINEERING

The Nuclear Engineering Division teaches graduate courses at UPR Mayagüez and conducts research in nuclear engineering. The staff also directs thesis research of nuclear engineering students from UPR and from other universities in the United States and Latin America. In addition, the Division offers short courses for scientists, engineers, and technicians, and for staff members engaged in individual research.

EDUCATIONAL ACTIVITIES

Master of Science Degree Program

UPR at Mayagüez, in close cooperation with PRNC's Nuclear Engineering Division, offers the Master of Science degree in Nuclear Engineering. The closeness of this relationship is illustrated by the fact that the faculty of the UPR Department of Nuclear Engineering is composed largely of staff members of the PRNC Nuclear Engineering Division; the director of the UPR department is head of the PRNC division as well. The Division also provides the classrooms, offices, laboratories, equipment, and administrative personnel necessary for the education and training of UPR nuclear engineering students. The Master's degree in Nuclear Engineering requires 30 hours of graduate work and the satisfactory completion of a thesis. A bachelor's degree in engineering is a prerequisite.

The basic pedagogical method is the presentation of lectures, strongly reinforced by laboratory work with various types of radiation counting equipment, the subcritical reactor, the L-77 low power reactor, and the PRNC one megawatt reactor. The student is encouraged to use both an analog and a digital computer and to present a seminar on his research to the PRNC staff. Students are guided to choose research topics related to their specific interests and those of their sponsoring countries or organizations. Courses included in the nuclear engineering curriculum are Nuclear Reactor Technology, Nuclear Measurements and Instrumentation, Elements of Nuclear Engineering, Graduate Seminar, Reactor Theory, Advanced Reactor Theory, Reactor Laboratory, Nuclear Engineering Application of Wavemechanics, Special Problems, and Mathematics. Supplementary courses include Nuclear Reactor Metallurgy and Introduction to Nuclear Engineering.

STUDENTS

During 1969, 10 students participated in the Master of Science Degree Program(Table 1); 5 of these students have completed all course work for the degree and are presently working on their thesis; 5 others are engaged in course work for their M.S. degree; no student received the M.S. degree during 1969. Fifteen additional students took semester-length courses taught by the Division staff(Table 2). Five thesis research projects were in progress(Table 3).

RESEARCH PROJECTS

The research projects of the Division, in progress or completed during the year:

1. **Determination of Certain Neutron Kinetic Parameters by Means of Stochastic Methods** (A. E. Gileadi). The applicability of stochastic methods including Rossi-α, variance to mean auto correlation to determine reactor transfer functions and certain neutron kinetic parameters, is studied, using a fast response time analyzer. The obtained data are processed on the IBM 360/40 computer. In progress.

2. **Fuel Burn Up Studies.** (A. E. Gileadi). A computer code was written and used to determine the burn up in a water moderated reactor fueled with a mixture of U^{235}/U^{238}. To date this code has been used for two reactor models. In progress.

3. **Gas Evolution of Borated Concrete in a Neutron Environment** (D. S. Sasscer, A. Castro Rosario). The rate of gas produced as a function of the boron content in heavy concrete is determined by placing a sample of concrete in the pool of the PRNC reactor and monitoring the amount of gas produced as a function of nvt. In progress.

4. **Activation Analysis in Water Pollution Studies** (K. B. Pedersen). Determination of aluminum content by activation analysis has been used to measure the pollution of Mayagüez Bay. In progress.

5. **Calculation of Time and Space Dependent Neutron Densities Following a Point Burst in an Infinite Medium** (A. E. Gileadi, M. Rodríguez Perazza). The time and space dependent contaminant concentration due to a three dimensional block-shaped instantaneous source diffusing within an infinite medium is being computed. In progress.

6. **Measurement of Fluorescent Radiation in Various Substances Induced by Radioisotope Gamma Ray Sources** (E. Ortíz, K. Pagán de Ramírez). Gamma rays from a 57Co source fall on a radiator, exciting its characteristic X-ray spectrum. The X-rays are detected by a proportional chamber and the electric pulses from the chamber are analyzed by a Multichannel Analyzer. In progress.

7. **Escape Peaks From a Proportional Chamber** (E. Ortíz). When the energy E_r of the incident radiation is larger than the activation energy, $E_{(K)}$, of the gas in a chamber, a spurious line appears in the spectrum. A study of the spurious lines is being made. In progress.

8. **Effects of the Temperature and Time of Heating on the Leaching of a Copper Chalcopyrite Type Ore in Sulfuric Acid Solutions** (F. J. Muñoz-Ribadeneira). A copper ore identified by X-ray diffraction techniques as chalcopyrite ($CuFeS_2$) was heated to different temperatures for various times. The heated samples showed an increased leachability of copper from samples heated up to 350°C as well as sharp reduction in solubility from ore samples heated at higher temperatures. Completed September 1969.

9. **Technological Studies on the Leaching of Chalcopyrite** (F. J. Muñoz-Ribadeneira). Studies have been initiated as to the possible technological importance of the long-term increasing solubility of chalcopyrite when it has been heated to 350°C. Different concentrations of sulfuric acid, sulfuric acid plus oxidants, and other leaching agents are used. In progress.

10. **Effect of Gamma Radiation on Non-biodegradable Wastes** (K. B. Pedersen). The effect of gamma radiation on the chlorine oxidation of organic materials is being studied to find ways to enhance the degradation of organic materials found in the effluent of waste treatment plants. In progress.

11. **An Application of the Neutron Reflection Technique to the Analysis of a Large Petroleum Cracking Tower** (D. S. Sasscer and K. B. Pedersen). Neutron Reflection Technique was used with success in determining the location of the trays in a 20 foot diameter ethylbenzene distillation column. Presented at the American Nuclear Society, Radiation and Isotope Division Topical Meeting. San Juan, Puerto Rico, May 1969.

12. **Mathematical Models Used to Compute Time and Space Dependent Contaminant Concentrations in Seawater** (A. E. Gileadi and G. Lowman). This study described a simple analytical model, using physical and biological data, to simulate the variation of radioactive contaminant concentrated in water and plankton due to the vertical migration of the plankton. Presented at the American Nuclear Society, Radiation and Isotope Division Topical Meeting. San Juan, Puerto Rico, May 1969.

STAFF ACTIVITIES

Dr. Arliss D. Ray, Professor of Civil Engineering on sabbatical leave for one year from the University of Missouri, joined the Division in August 1969 as a Visiting Scientist. Dr. Ray has also been given an Ad Honorem professorship at UPR Mayagüez. His primary field of interest is sanitation and he is working very closely with Mr. Pla and Dr. Pedersen on the enhancement of organic degradation by gamma radiation.

A book, "Applied Nuclear Power Engineering for Practicing Engineers," to be published by Barnes & Noble, Inc., is being prepared jointly by Drs. Pedersen, Plaza, Gileadi and Sasscer of the Division of Nuclear Engineering and by Mr. Brown of the Reactor Division. A rough draft of the book, excepting two chapters, has been completed and sent to the publishers. Publication is expected during FY-1971.

Dr. Sasscer was a Guest Research Collaborator with the Nuclear Engineering Division of the Brookhaven National Laboratory (June and July).

Drs. Gileadi, Pedersen, Plaza, Ortiz and Sasscer attended the American Nuclear Society Radiation and Isotope Topical meeting in San Juan and Drs. Gileadi, Pedersen and Sasscer presented papers (May).

Drs. Pedersen and Plaza attended the American Nuclear Society Annual Winter meeting in San Francisco (December).

Mr. Fausto Muñoz-Ribadeneira presented a paper at the Third Congress of the Pan American Meeting of the Institute of Mechanical and Electrical Engineering held in San Juan (June).

Drs. Gileadi and Sasscer attended the American Nuclear Societys' Fifteenth Meeting in Seattle, Washington (June).

Drs. Pedersen and Sasscer attended the Ninth Annual AUA-ANL Nuclear Engineering Education conference held at the Argonne National Laboratory (March).

Drs. Gileadi and Plaza attended the ANS Reactor Operators Conference in San Juan (October).

Dr. Gileadi presented a talk to the Annual Meeting of the American Technion Society (October).

Table 1

Students Enrolled in the Master of Science Degree Program in Nuclear Engineering

Name	Citizenship	Sponsoring Organization
Rafael Alcalá Quesada	U.S.	UPR
Antonio Castro Rosario	"	Self
Braulio Mejías Avilés	"	UPR
Rafael Luis Ufret	"	Self
Fernando Plá Barby	"	AEC
Vicen Alvarez Encarnación	"	AEC
Juan R. Caro Moreno	"	UPR
Julio Ortiz Torres	"	AEC
Rafael A. Ríos Dávila	"	UPR
Rafael Herminio Sardina	Cuba	UPR

Table 2

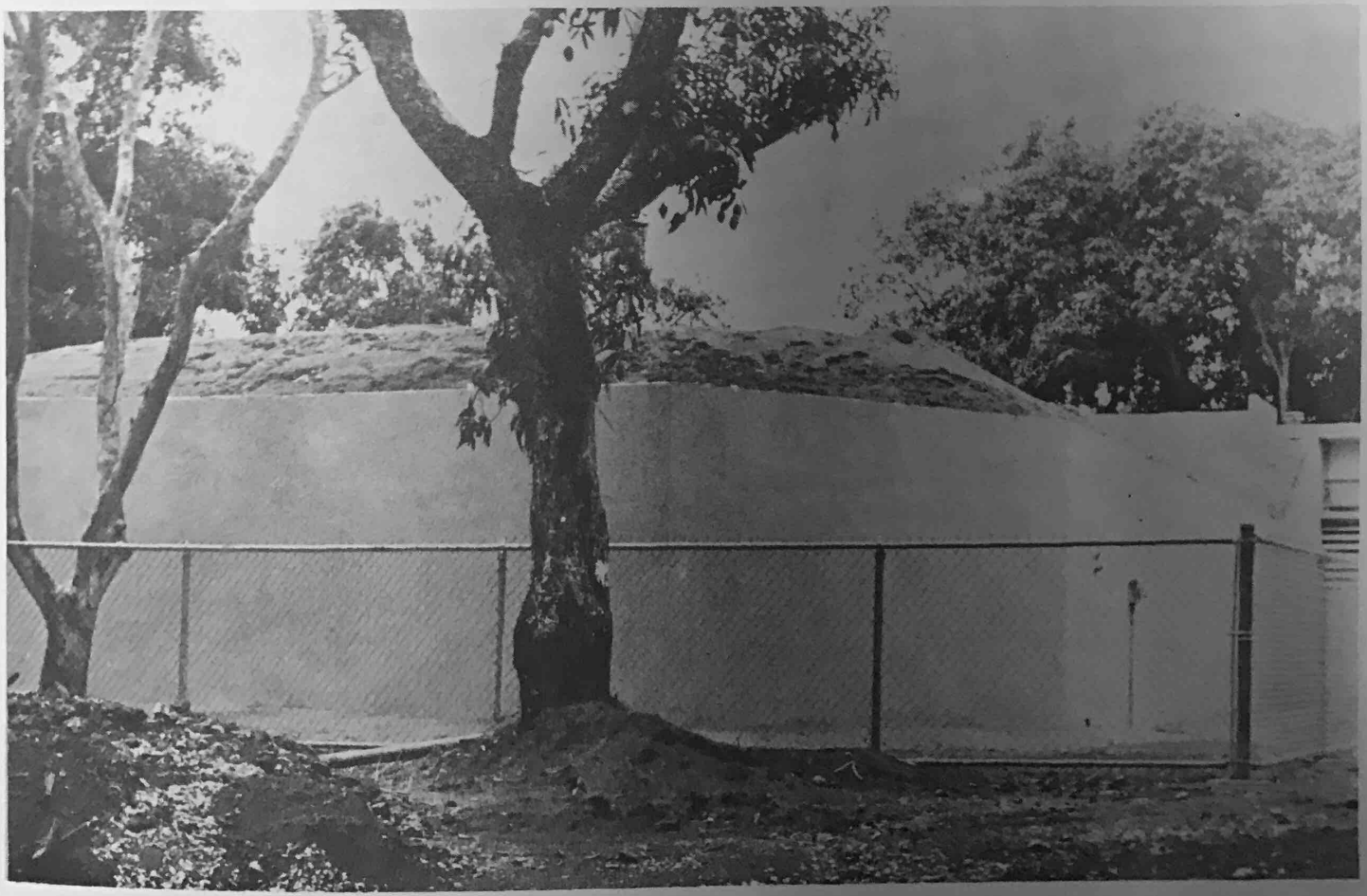
Students Not in Degree Program Who Have Taken Courses Offered by Nuclear Engineering

Name	Citizenship
Juan Alcaraz Vázquez	U.S.
José A. Cruz Alvarado	"
Miguel S. Descartes Vilard	"
Máximo A. Grano de Oro	Dominican
David Markus Rodríguez	U.S.
Michelen A. Musalem	Dominican
Guy Riboul Saliba	U.S.
Ralph Rodríguez Nazario	"
Héctor Santiago Chamorro	"
Rafael Morrillo Grullón	"
Ismael Guzmán López	"
María M. Irizarry	"
Francisco Monllor Zambrana	"
Rolando Roque Martínez	"
José Braulio Dueño	"

Table 3

Student Thesis Research Projects

Name	Title of Thesis	Major Professor
Fernando Plá Barby	Effect of Gamma Radiation on Organic Materials in Aqueous Solution	K. B. Pedersen
Rafael Luis Ufret	Determination of the Prompt Neutron Decay Constant by Means of Stochastic Methods	A. E. Gileadi
Braulio Mejía	Instrumental Methods in Neutron Activation Analysis	K. B. Pedersen
Antonio Castro R.	Investigation of Gas Production in Irradiated Barytes-Boron Concrete as a Function of Temperature	D. S. Sasscer
Rafael Alcalá	Measurement of Reactor Shutdown Activities by the Asymmetric Source Method	H. Plaza



Exterior view of the new neutron generator building at PRNC Mayagüez, construction of which began in late 1969.

Dr. Bruce Graybill synthesizes an organic compound. Dr. Graybill, from Graceland College in Lamoni, Iowa, worked at PRNC as an Oak Ridge Summer Research participant.

PHYSICAL SCIENCES

The long range objective of the Physical Sciences Division is to offer advanced training opportunities for Puerto Rico and Latin American trainees primarily through participation in research projects involving the use of high energy radiation and radioisotopes. Since this program is geared to regional needs, it includes an introductory training course in the use of radioisotopes, and requires participation of the scientific personnel in the academic activities of the natural sciences departments of the University of Puerto Rico, Río Piedras campus. The latter cooperative effort is encouraged through joint appointments. The Division also participates in the AEC "Atoms in Action" exhibits.

EDUCATIONAL ACTIVITIES

The educational activities of the division range from a four-week non-credit training course in the techniques of radioisotope applications to research training in the laboratories of the Center.

a) The Radioisotopes Techniques Course was offered three times during 1969. The distribution of the 31 trainees by geographical origin (Table 1) shows 17 from Puerto Rico, four from United States, one from Ecuador, one from Spain, two from Greece, two from Cuba, one from Uruguay, two from Argentina and one from Dominican Republic.

b) University courses:

1. Radiochemistry (Chem. 465, four credits). A one semester graduate course. Taught by Dr. José P.A. Castrillón.

2. Advanced Mechanics I (Physics 412). The first semester of a two semester graduate course. Taught by Dr. Amador Cobas.

3. Graduate Research (Chem. 599 or Phys. 501, one to six credits). Graduate students supervised by PRNC personnel. Their geographical origins are shown in Table 2.

4. Undergraduate Research Training. Six undergraduate science students took advantage of PRNC's research training opportunities during 1969; Felipe Cardona, César Cordero, José Marrero, José L. Muñoz, José L. Ramos and Christopher Reed with Drs. A. Cobas, S.Z. Weisz, and J. Levinson.

PARTICIPATION IN "ATOMS IN ACTION" EXHIBIT

Dr. Eberhardt participated in the "Atoms in Action" exhibit in Sao Paulo, Brazil (October 13-November 18, 1969). He presented two lectures at Sao Paulo on: "Steric effects in radiation chemistry" and "Homolytic and radiolytic aromatic substitution", and two research projects were initiated on the "Homolytic and radiolytic aromatic hydroxylation" and the "Radiolysis of aqueous solutions of uracil and dimethylsulfoxide".

TABLE 1

Participants in Basic Course in Radioisotopes Techniques, 1969

Name	Country	Field of Interest	Financial Sponsor
Robert O. Petersen	United States	Experiment Pathology	National Inst. of Health
Benjamin H. Stanley	United States	Medicine	National Inst. of Health
Kenneth J. Khan	United States	Neurology	National Inst. of Health
Aida Hernández Corsi	Puerto Rico	Medical Technology	Self
José A. Berlingeri	Puerto Rico	Radiology	University Hospital (UPR)
Emilio A. Reyes Villar	Dom. Republic	Radiology	University Hospital (UPR)
Carlos Roldán	Argentine	Radioisotopes	UPR-President's Fund
Bernardo Marqués	Puerto Rico	Radiology	University Hospital (UPR)
Julio C. Arroyo Otero	Puerto Rico	Medicine	Oncological Hospital
Adelaida Elias de Alonso	Puerto Rico	Medicine	School of Medicine (UPR)
Blanca S. Jiménez	Puerto Rico	Biology	University Hospital (UPR)
María Arací Medeiros	Uruguay	Nursing	I.A.E.A.
Violeta Napoleón	Puerto Rico	Medical Technology	School of Medicine (UPR)
Miguel A. Ortiz Vega	Puerto Rico	Biology	Oncological Hospital
Juan B. Reñé Ferrero	Argentine	Radiotherapy	Oncological Hospital
Nivia Reyes Deliz	Puerto Rico	Technology	Oncological Hospital
Carmen I. Rivera Ortiz	Puerto Rico	Medical Zoology	Self
Reineiro Rodríguez	Spain	Radioisotopes	UPR-President's Fund
Joaquín Segarra Gerena	Puerto Rico	Zoology	School of Medicine (UPR)
Angel J. Torres Noya	Puerto Rico	Medicine	San Juan City Hospital
María de los A. Vales	Puerto Rico	Physiology	School of Medicine (UPR)
Richard Clements	United States	Ecology	PRNC
Myrta López de Victoria	Puerto Rico	Clinical Pharmacology	School of Medicine (UPR)
Luis G. Rodríguez Medina	Puerto Rico	Medical Zoology	UPR
Isabel Ríos Duchesne	Puerto Rico	Microbiology	Self
Georgina García Muns	Cuba	Radiobiology	P. R. Medical Center
Alberto Palma Bonilla	Ecuador	Radioisotopes in Medicine	I.A.E.A.
Luis Bonnet Alemar	Puerto Rico	Radiology	P. R. Medical Center
Evangelina Pimenidou	Greece	Microbiology	I.A.E.A.
Constantina Tryfona	Greece	Health Physics	PRNC
Omar Salazar Acosta	Cuba	Medicine	Oncological Hospital

TABLE 2

Thesis Research Supervised by Division Personnel During 1969

Student	Country of Origin	Supervisor
Hilda Aledo	Puerto Rico	J.P.A. Castrillón
Jaime Colón	Puerto Rico	J.P.A. Castrillón
Agnes Costa	Puerto Rico	J.P.A. Castrillón
Elsa Gómez	Venezuela	J.P.A. Castrillón
Juanita Freer	Costa Rica	J.P.A. Castrillón
Hernando Guerrero	Colombia	J. Levinson, S.Z. Weisz
Julio A. Mainardi	Argentina	S.Z. Weisz
Rafael Pereira	Colombia	J.P.A. Castrillón
José Revuelta	Cuba	G.A. Simpson, A. Grimison
Gladys Rodríguez	Puerto Rico	A. Grimison
Antonio Rolón	Puerto Rico	J. Levinson, A. Cobas
Myrtha Trujillo	Cuba	G.A. Simpson, A. Grimison
Sonia Vázquez	Puerto Rico	J.P.A. Castrillón

VISITING LECTURERS

Prof. C.N. Yang, Nobel Prize in Physics 1957, "Very High Energy Collisions", "Some Recent Exact Solutions in Statistical Mechanics" (January 16-17, 1969).

Peter Avakian, E.I. Dupont de Nemours and Co., Central Research Dept., "Triplet Excitons in Anthracene Crystals" (January 21, 1969).

Dr. Arthur Paskin, Brookhaven National Lab., "Superconductivity-General Theory ". "Superconductivity-Recent Developments", "Dynamical Structure of Liquids" (January 21-23, 1969).

Dr. H.E. Duckworth, Vice President, University of Manitoba, Winnipeg, Canada, "Focusing of Positive Ions by Electromagnetic Fields", "Double Focusing for Mass Spectrometer", "The Significance of Atomic Mass Measurements" (January 28-30, 1969).

Dr. G.J. Dienes, "Enhanced Diffusion in Alloys", "Radiation Damage in Lithium Hydride" (February 17-19, 1969).

Dr. Bland Houston, U.S. Naval Ordnance Lab., "Chemical Physics of Non-stoichiometric Binary Compounds", "Crystal Growth and Evaluation" (March 3-4, 1969).

Prof. Jan Kommandeur, Washington University, St. Louis, Mo., "Electron Spin Resonance of Defects in Molecular Crystals", "Ionic Conductivity of Iodine" (March 6-7, 1969).

Dr. R.G. Kepler, Sandia Laboratory, N.M., "Photoconductivity in Anthracene" (March 20-21, 1969).

Dr. A. Many, The Hebrew University of Jerusalem, Israel, "Semiconductor Surfaces I" (March 25-27, 1969) and "Semiconductor Surfaces II" (April 1-2, 1969).

Dr. Howard Andrews, Rochester University, "Health Physics as a Career for Physics Majors", "The Physics of Whole Body Counters" (June 27, 1969).

SCIENTIFIC MEETINGS AND COURSES OUTSIDE PUERTO RICO

Dr. Alec Grimison attended an international symposium on Quantum Aspects of Chemistry and Biochemistry of Heterocyclic Molecules at Jerusalem, Israel. He presented the following paper: "Absorption Spectra of Azine Radical Ions" (April 1-5, 1969).

Dr. José Castrillón, attended a three week course on Liquid Scintillation Counting at Oak Ridge, Tennessee (June 2-20, 1969).

Drs. S.Z. Weisz and J. Levinson attended the Third International Conference on Photoconductivity at Stanford University . Dr. S.Z. Weisz presented a paper on "Interaction of Triplet Excitons with Trapped Electrons in Anthracene Crystals" (August 25-30, 1969).

Dr. S.Z. Weisz visited the Solid State Physics Laboratories at New York University, Yeshiva University, Massachusetts Institute of Technology, Pennsylvania State University and the RCA Research Laboratories in Princeton (November 6-13, 1969).

Dr. M. Eberhardt and Dr. G. A. Simpson attended the American Chemical Society meeting in Minneapolis. Dr. M. Eberhardt was co-author of a paper presented by Dr. H.H. Szmant on: "Radiation induced addition of thiophenols to indene" by H.H. Szmant, M.K. Eberhardt and I.Y. Zea Ponce (April 14-18, 1969).

Dr. M.K. Eberhardt visited IVIC (Instituto Venezolano de Investigaciones Científicas) by invitation from Dr. G. Chuchani. Dr. Eberhardt gave two lectures on: "Steric Effects in Radiation Chemistry" and "Molecular Orbital Calculations on Aminophenols and Aminobenzenethiols" (June 2-3, 1969).

Dr. M. K. Eberhardt attended the Winter Institute in Quantum Chemistry at the University of Florida at Gainesville (December 8, 1969).

RESEARCH

Division research can be classified under the following headings: Radiation Effects, Radioisotopic Studies, and Supporting Research. The projects are described briefly below, with the senior investigators and graduate student trainees.

Radiation Effects

These projects study the effect of high-energy deposition in chemical systems. Some of the projects emphasize the initial, or primary, products of radiations; others emphasize the initial, or primary, products of radiation; others emphasize the final products subsequent to secondary chemical reactions. However, the aim is always to trace the detailed mechanism by which radiation-induced changes occur.

a) Tritium Recoil Labeling (J.P.A. Castrillón). The study of the distribution of the activity in neutron irradiated lithium phenylacetate has been completed. A comparative study is now in progress of the results obtained on irradiation of a mixture of phenylacetic acid and lithium carbonate under exactly the same conditions. Graduate student trainee: Agnes Costa de Dubey.

b) Steric Aspects of Recoil Labeling (J.P.A. Castrillón). α -phenyl butyric acid has been resolved in its enantiomers and the corresponding lithium salts prepared. The main point to

elucidate is whether hot atom substitution takes place with retention on inversion of configuration of the asymmetric carbon. Preliminary results indicate that retention prevails. Graduate student trainees: Agnes Costa and Rafael Pereira.

c) **Rotational Excitation of Carbon Monoxide by Low-Energy Electrons** (A. Grimison). The Electron scattering in e^--CO collisions at low energies has been studied in the fixed molecule representation. The LCAOMO's of Nesbet were transformed to a numerical single-center expansion.

$$\Phi_i(\bar{r}) = \sum_{L=0}^{\infty} \frac{1}{r} U_L^i(r) Y^{m_i}(\hat{r}) \qquad (1)$$

The static molecular potential for the diatomic molecule in the field of the external (N + 1) electron was then obtained in the form

$$V(\bar{r}_{N+1}) = \sum_{\lambda=0}^{\infty} V_\lambda(r_{N+1}) P_\lambda(\cos\theta) \qquad (2)$$

The theoretical values of the dipole moment and quadrupole moment of the CO wave reproduced within 4% by retaining terms up to L = 15 in (1), providing a check on the accuracy of the single center expansion.

The above static potential, using all terms up to and including $\lambda = 4$, was then used in the close-coupling method to study shape resonances in the elastic scattering on the ground state of CO. The calculations were carried out for the $^2\Sigma$, $^2\Pi$ and $^2\Delta$ states, and the convergence of the results with the number of partial waves included was explored. Satisfactory convergence was found for all states. The effect of including exchange with the(3σ, 4σ, 5σ and 1π) molecular orbitals was then examined. Preliminary calculations showed that exchange with the 1σ and 2σ molecular orbitals was negligible. The results at low energies are a sensitive function of the inclusion of exchange terms, as expected.

The final results for the $^2\Sigma$, $^2\Pi$, $^2\Delta$ states, with the inclusion of full exchange, show a $^2\Pi$ CO^- resonance occurring naturally in the results near 0.1 Rydbergs. This is in good agreement with experiment, and since only the ground state configuration of CO was included, suggests that this resonance is a shape resonance. The results will be used to obtain rotational excitation cross sections for e^--CO collisions.

d) **Matrix Isolation Studies of the Gamma-Radiolysis of Heterocyclic Molecules** (A. Grimison and G.A. Simpson). This project receives support from the AEC Division of Biology and Medicine, and studies the nature of primary species formed by gamma-irradiation of heterocyclic molecules. The work is described fully elsewhere in this Annual Report under the 06 Program. Graduate Student trainees: Myrtha Trujillo and José Revuelta.

e) **Radiation Damage in Organic Crystals** (A. Cobas, S.Z. Weisz). This project receives support from the AEC Physical Sciences Division. Radiation damage in well-defined crystalline organic materials is studied by conductivity and spectroscopic measurements. The work is described fully elsewhere in this Annual Report under the 05 Program. Graduate student trainees: Hernando Guerrero, Julio A. Mainardi, León Pereira, Antonio Rolón and Lisandro Vargas. Undergraduate student trainees: Felipe Cardona, César Cordero, José Marrero, José L. Muñoz, José L. Ramos and Christopher Reed.

Radioisotopic Studies

These projects include the use of incorporated radioactive tracer atoms, as a diagnostic aid to the study of reaction mechanisms, as well as studies of counting techniques.

a) Oxidation of diarylethanes (J.P.A. Castrillón). This study has been essentially completed. By using ^{14}C labeled p,p' -diiodo diarylethane it can be neatly determined how much of the anomalous product, p-iodobenzoic acid, originates in the molecular rearrangement, and how much is formed by destructive oxidation of one of the benzene rings. Product analysis has also been done by isotope dilution techniques. Graduate student trainee: Jaime Colón.

b) Oxidation of monoarylethanes (J.P.A. Castrillón). A preliminary study has been started to establish whether the previous rearrangement also takes place in monoarylethanes. Graduate student trainee: Juanita Freer.

c) Liquid scintillation counting (J.P.A. Castrillón). This consists of various projects which aim to improve the present techniques by the use of better solvents and solutes and quench control:

(1) The influence of chemical structure on quenching. The effect of a series of different substituted benzophenones and of another series of substituted diphenyl sulfoxides on the β -spectrum of ^{14}C are being studied. Graduate student trainee: Elsa Gómez.

(2) The effect of both series of compounds on the internal conversion electrons spectrum of ^{139}Ce is also being examined. Graduate student trainee: Hilda Aledo.

(3) New solvents and solutes. Studies with the purpose of obtaining better scintillation solvents or media for aqueous and polar samples are in progress. Graduate student trainees: Elsa Gómez and Juanita Freer. It is hoped to enroll an undergraduate student trainee for this project in 1970.

Supporting Research

The projects described under this heading do not directly involve the use of radiation or radioisotopes. However, they exist to provide support for the previous projects by producing essential information on the systems of interest.

a) Structure of phenanthrene (A.Grimison). As a result of the refinement of the phenanthrene geometry completed by the Neutron Diffraction Program, and described elsewhere, a series of theoretical studies have been carried out to determine the origin of the effects observed. Particularly important is the role of the overcrowded H-H potential in the observed out-of-plane distortion of the molecule. All-valence electron self-consistent field calculations have been made on phenanthrene in a large variety of conformations, using the Complete Neglect of Differential Overlap (CNDO) formalism. The final results were obtained on an IBM 360/91 computer. For all the geometries tested (ideal, distorted, experimental neutron diffraction, and X-ray diffraction), scaling the out-of-plane distortion gave a minimum energy for the planar configuration. This suggests that the small out-of-plane distortion observed experimentally may be due to crystal packing forces. A valid alternative is that there is a considerable anisotropy in the H-H potential, which is not accounted for in the CNDO method because of the restrictions following from the requirement of rotational invariances. This is to be tested by further calculations in the Extended Huckel Theory (EHT) formalism.

The effect of maintaining a planar geometry and scaling the distortion vector of Coulson and Haigh was tested with a variety of assumptions for the relative magnitude of the vector components (essentially force constants of different types). If the relative magnitudes from

Dr. José P.A. Castrillón of the Physical Sciences Division weighs a one milligram sample on the Cahn Microbalance.

the experimental diffraction results were used, scaling gave a minimum energy near a scale factor of 1.0, as expected. This proves that the Coulson-Haigh approach is capable of reproducing distortions in such a complicated system. Its potential importance lies in the reduction of the number of independent variables to be considered. However, use of the original Coulson-Haigh distortion vector gives less good agreement with experiment, indicating the need for a refinement of the force-constant values.

The effect of varying the C-C-H dihedral angle from 118° to 126° was shown to give a minimum at 121°. This is in good agreement with the experimental value of 121.6°, while angles up to 126° have been observed in other overcrowded systems.

b) Thioxanthone and related compounds (J.P.A. Castrillón). In addition to thioxanthone and its derivatives, thiantrene and its oxides, and corresponding metallic complexes have been prepared. They are stable compounds that analyze well. Graduate student trainee: Sonia Vázquez.

c) Aromatic Substitution (M.K. Eberhardt).

(1) Triphenylmethylation. A paper on the triphenylmethylation of aminophenols and animobenzene thiols has been accepted by Tetrahedron for publication. This work has been carried out in cooperation with Dr. G. Chuchani of the Instituto Venezolano de Investigaciones Científicas (IVIC) in Caracas, Venezuela. The experimental part of this work was carried out at IVIC; the MO calculations were done by the author at PRNC.

(2) Hydroxylation. The radiolysis of aqueous solutions of chlorobenzene and nitrobenzene was carried out together with two graduate students at the University of Sao Paulo, Brazil as part of the USAEC Atoms in Action Exhibit (Oct.-Nov. 1969). The results obtained so far show that the data in the literature J. Weiss et. al. *J. Chem. Soc.* 1949, 2074; 1950, 2704; 1951, 405; 1951, 3275, are incorrect, but are in agreement with theoretical predictions. Work on this subject will be continued.

d) Aminomethylation of Lactam-Lactim Tautomers. Lactam-Lactim tautomers are very important building blocks in biological systems (DNA, RNA) and it is of great interest to learn more about their chemical reactivity. MO-calculations were carried out on a series of lactam-lactim tautomers, and the results were correlated with the aminomethylation of these compounds. The calculations lead us to propose a new mechanism for the reaction. The aminomethylation of pyridine-2 does not take place at the nitrogen, but at the oxygen, followed by rearrangement to the N-aminomethyl-pyridine-2. This work was submitted for publication, but has to be rewritten to comply with the comments of the referees.

RADIATION CHEMISTRY PROJECT: MATRIX ISOLATION STUDIES OF PRODUCTS OF GAMMA-RADIOLYSIS OF HETEROCYCLIC MOLECULES

The project aims at the trapping and subsequent characterization of the species formed by gamma-radiolysis of heterocyclic molecules of possible biological importance. Emphasis is therefore placed on direct observation of the normally labile intermediates formed after the absorption of high-energy radiation. This is made possible by utilizing the matrix isolation technique, in which the molecule is irradiated in some form of rigid matrix, normally at low temperatures. Under appropriate conditions, radicals and radical ions can be stabilized for extended periods of time by using this method, and studied by spectroscopic techniques. An important part of the program involves the quantum-mechanical calculation of electronic properties of heterocyclic radicals and ions. These results are used in conjunction with the experimentally measured properties to help identify unknown intermediates.

A brief description of the current research topics follows:

1. Absorption Spectra of Radiolytic Intermediates at 77°K. The experimental and theoretical observations on the electron attachment to pyridine and the diazines under gamma-radiolysis have now been published.

2. Photoionization in Rigid Matrices at 77°K. The study of the photoionization mechanisms of indole, imidazole, purine, and tetraphenylpyrrole mentioned last FY has now been completed, and this work is being prepared for publication.

3. Photoluminescence at 77°K after gamma-irradiation. Using the newly acquired grating spectrometer, the infrared stimulated emission at 77°K from gamma-irradiated pyrazine, pyrimidine, pyridine, pyridine d-5, 2 methylpentene 1, pentene-2, 2-picoline and 3-picoline were studied in 3-methylpentene glasses. Pyridine d-5 was used to study the effect on the luminescence of a change in the stretching vibration frequencies. The olefins were all chosen as having assigned $\pi \rightarrow \pi^*$ excitations, but no previously reported emission. Since the solutes have lower ionization potentials than 3-methyl pentane the gamma-irradiation is expected to lead to localization of the positive charges on the solutes, by charge-transfer. Infrared stimulation of trapped electrons produced by gamma-irradiation then promotes radical cation-electron recombination processes, yielding the neutral molecule in an excited state, and the possibility of emission to the ground state.

In all cases the maximum emission wavelength was in the same region as the thermoluminescence (*see below*), although in some cases only very low intensities were recorded, making observation difficult. As before, pyrazine has the most intense emission on IR stimulation. Experiments were also made to measure the lifetime of the observed emission from pyrazine. This appears to agree with the literature value for the lifetime of the emission stimulated conventionally by optical absorption.

4. Thermoluminescence after gamma-irradiation at 77°K. As mentioned above, thermoluminescence gave emission bands in the same region of the spectrum. A comparison of the integrated luminescence for the two processes shows that thermoluminescence has an intensity of 10 to 100 times the photoluminescence intensity. Changing the delay between gamma-irradiation and stimulation decreases the photoluminescence, but does not change the thermoluminescence intensity. This confirms earlier reports in the literature, suggesting that the electron trapping sites stimulated by the two processes are independent.

5. Self-consistent Field Calculations on Heterocyclic Radical Ions. The theoretical absorption spectra of the neutral molecules, radical cations, and radical anions of pyridine, pyrazine, pyrimidine, and pyridazine have been recalculated by the same Parisier-Parr-Pople-Configuration-Interaction method. The modified calculations involved: (1) the use of Mataga-Nishimoto repulsion integrals; (2) coordinates derived from the experimental geometries of the neutral molecules; and (3) improved values of other parameters. These modifications bring the theoretical spectra into even better agreement with the experimental transition energies, particularly for the radical anions. The inclusion of additional excited configurations has been found not to affect the results appreciably. Calculations have also been made by the same method on pyrrole, thiophene, furan, and imidazole molecules and radical ions.

All-valence electron calculations on pyrrole, pyridine and the diazines, and their radical cations and anions have been completed, using the Complete Neglect of Differential Overlap method.

STAFF

Dr. George Simpson resigned in September 1969 after working with the Physical Sciences Division, the Solid State Physics project, and the Gamma Radiolysis of Heterocyclic Molecules project for three years. He has taken a position with Aero-Chem Research Laboratories, Princeton, N.J.

Dr. Alec Grimison spent the calendar year 1969 working with the Atomic and Molecular Physics Group, Theoretical Physics Division, Harwell Atomic Energy Research Establishment in England, under assignment from PRNC. While continuing work on the theoretical side of the Gamma Radiolysis project, he also completed work on the resonance capture of electrons by molecules, and completed a study started at PRNC on the electronic structure of phenanthrene, in collaboration with the Neutron Diffraction program.

Mr. James Frost, visiting student associate from Washington University, St. Louis, adjusting the flash photolysis apparatus.

SOLID STATE PHYSICS

The primary interest in this project is to study the effects of radiation on organic crystals. It is felt that such studies on well defined crystalline structures can provide a firm foundation for a later study of more complex materials, including those of direct biological interest. Anthracene was chosen as the initial material to be studied because: (1) large, very pure anthracene crystals can be obtained; (2) much is known about its electrical and optical properties; (3) radiation damage due to high doses of neutron and gamma irradiation in anthracene has been studied.

Radiation damage in anthracene after gamma irradiation in the high dose range (larger than 10^5 rad) was studied by measuring the degradation of its fluorescence. Radiation damage due to neutron irradiation was studied by measuring the changes in the photoconductivity properties.

This project is housed at the Natural Sciences Building on the UPR Rio Piedras campus. Physics Department graduate and undergraduate students are encouraged to do their thesis work under the guidance of our staff using this project's laboratory facilities.

Graduate Participants

The following students participated in our research activities by doing their required M.S. thesis work between the months of July and December. Names are followed by country of origin and sponsor:

Hernando Guerrero, Colombia, Ford Foundation; Julio A. Mainardi, Argentina, OAS; León Pereira, Colombia, OAS; Antonio Rolón, Puerto Rico, OAS; Lisandro Vargas, Colombia, OAS.

Undergraduate Participants

The following students, all from Puerto Rico, worked as undergraduate research participants. Names are followed by sponsor and type of participation.

Felipe Cardona, UPR, summer research; César Cordero, self, honor's student research; José Marrero, UPR, undergraduate research; José L. Muñoz, UPR, summer research; José L. Ramos, UPR, undergraduate research; Christopher Reed, UPR, summer research.

Thesis Research

Double Injection in Anthracene Crystals, Hernando Guerrero. Double injection in anthracene may lead to the determination of the free hole trapped electron interaction rate constant. Electrons are injected from a sodium amalgam electrode and steady state space charge limited current is achieved. The transient hole current injected by a light pulse is then measured. If the Langevin approximation for the free hole - trapped electron recombination is valid then this value can be obtained experimentally from the changes in the hole lifetime due to the trapped electrons.

Singlet Exciton Trapped Electron Interaction in Anthracene, León Pereira. The spectral response of the photoenhanced space-charge limited current was interpreted to be partly due to singlet exciton trapped electron interaction. Such an interpretation appears incompatible with the fact that the diffusion length of the singlets is short compared to the distance between the trapped electrons. If such an interaction exists it should be observed in transient measurements.

Triplet Exciton Trapped Electron Interaction in Anthracene, Antonio Rolón Santiago. The interaction between trapped electrons and triplet excitons was studied from the enhancement of the triplet-singlet intersystem rate constant in the presence of trapped electrons. The interaction rate constant was found to be $R_X = 3.2 \times 10^{-11}$ $cm^3\ sec^{-1}$.

Optical Properties of Irradiated Anthracene, Lisandro Vargas. The nature of the radiation induced centers will be studied from the changes in the optical properties of the crystal.

A Study of the Effects of Gamma Radiation on the Electron Trap Density of Anthracene by the Method of Space Charge Limited Current Measurement, César Cordero. Electron traps are induced in anthracene single crystals by gamma irradiation. The density and the trapping characteristics of these radiation induced traps were studied from electron space-charge limited current measurements using sodium amalgam electron injecting electrode.

RESEARCH

(a) **Annealing of Singlet and Triplet Quenching Centers in Anthracene.** As reported previously, by irradiating anthracene with gamma rays, singlet and triplet quenching centers are introduced. These centers increase the singlet and triplet monomolecular rate constant linearly with dose. It was found that these centers can be partially annealed. An experimental method was used by means of which the annealing of the triplet and singlet quenching centers can be studied simultaneously. The blue fluorescence emission in anthracene due to an intense red light flash—Q switched ruby laser—originates from singlets obtained from triplet-triplet-annihilation- delayed fluorescence. For a light pulse with a long duration compared to the singlet lifetime, the fluorescence originating from the singlets excited by two photon absorption follows the temporal shape of the light pulse while the delayed fluorescence decays with a time constant equal to half the triplet lifetime. The annealing of the triplet quenching centers was studied from the time dependence of the delayed fluorescence and the annealing of the singlet quenching centers was studied from the intensity measurements of the luminescence in the two photon absorption region and also from the UV excited steady illumination fluorescence.

The degree of annealing is expressed as the ratio of the annealed centers to the centers introduced by irradiation. The dependence of the degree of annealing on the annealing temperature was measured. For triplet quenching centers it was found that annealing does not occur up to 70°C. For higher annealing temperatures there is a fast increase in the degree of annealing reaching 55% at 93°C. From this annealing temperature up to 150° the degree of annealing remains constant. Additional annealing does not increase the degree of annealing. If after annealing a crystal is irradiated, then reannealing the crystal results in a smaller degree of annealing. It was also found that the degree of annealing does not depend on the radiation dose. Singlet quenching centers can be annealed; however, the margin of error in these measurements was too large in order to obtain the degree of annealing with reasonable accuracy.

It was suggested [1] that fast carrier traps in anthracene are due to molecules being slightly out of place in the crystal lattice. The distortions visualized correspond to translation or rotations of individual molecules by an amount comparable to molecular dimensions. The

[1] S.Z. Weisz, R.C. Janagin, M. Silver, M. Simhony and J. Balberg, J. Chem. Phys. 40, 3365 (1964).

distortions, also small in magnitude,cause local disturbances and thus behave as potential wells for charged carriers. Large-amplitude molecular vibrational motion could reduce the distortions. The fast carrier traps could be annealed at 120°C. A thermochronic red shift due to population of higher molecular vibrational levels occurs at around 80°C, hence at this temperature the distortions could be annealed. Trapped electrons increase the triplet monomolecular rate constant. It is suggested that gamma radiation can fill these traps with electrons and perhaps also increase the density of such traps. The fact that additional annealing does not increase the degree of annealing indicates that more than one type of triplet quenching centers are introduced by gamma irradiation.

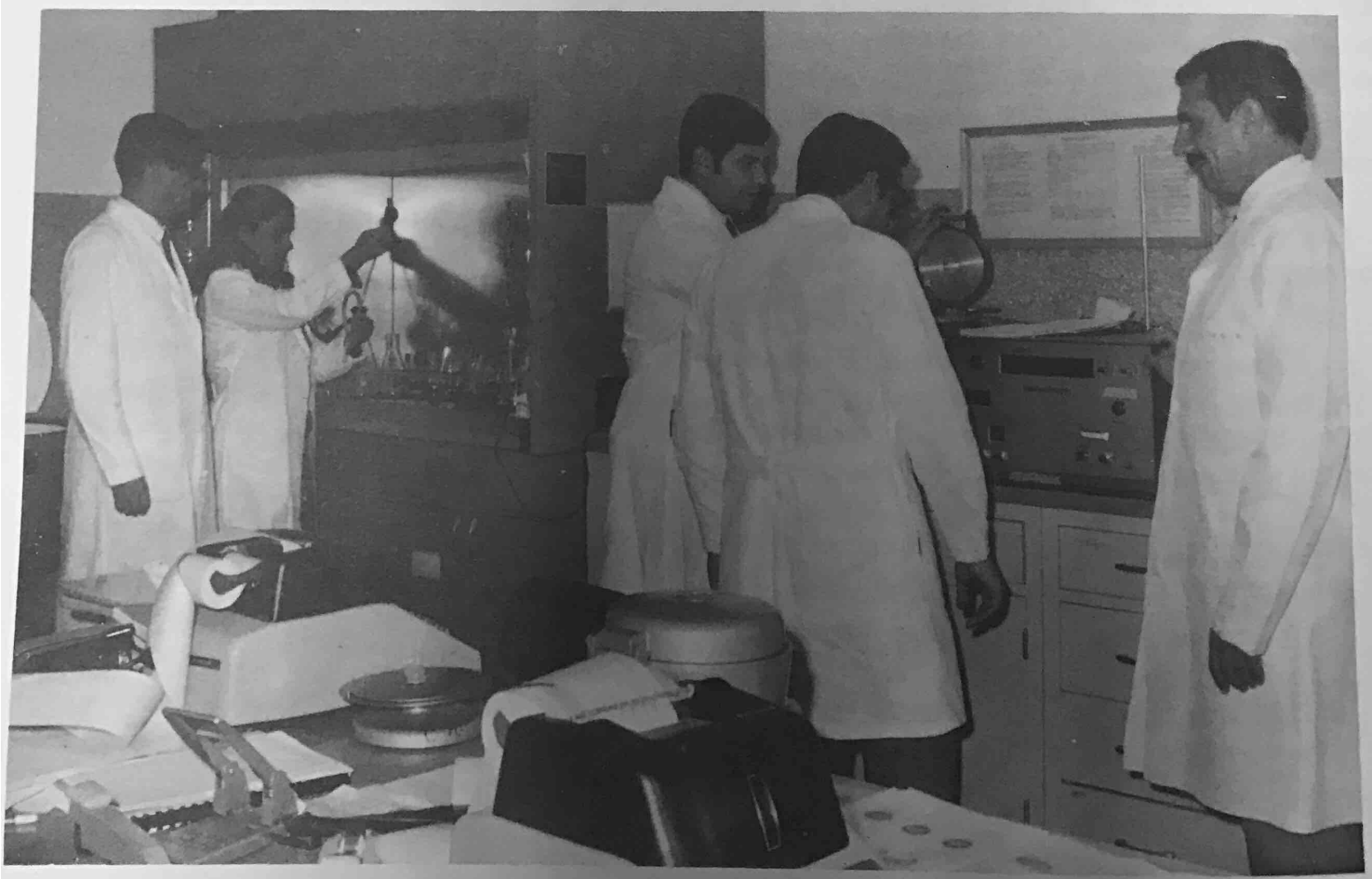
(b) **Determination of Photon-Trapped Electron and Triplet Exciton-Trapped Electron Interaction Rate Constant in Anthracene Crystals.** In order to explain the spectral dependence of the photoenhanced space charge limited current in anthracene, several authors suggested that three different processes of optical carrier release can be distinguished:
(1) direct detrapping by light; (2) detrapping by triplet excitons; and (3) detrapping by singlet excitons. Trapped carriers form paramagnetic centers similar to the radiation induced centers, hence the understanding of their interaction with excitons can be a link in analyzing the exciton quenching centers induced by radiation.

Photoenhanced electron space-charge limited currents due to excitation from a discrete set of traps in vapor grown anthracene crystals were studied. Direct evidence was given that interaction between trapped electrons and triplet excitons exists and that free electrons are produced by this interaction. The conclusion that this interaction exists is based on the experiment showing an enhancement in triplet-singlet intersystem rate constant when the traps are filled with electrons. Using a light pulse technique the current could be decomposed into two components; one originating from direct photoexcitation and one from detrapping by triplet excitons. The spectral dependence of the capture cross section A of the electron filled traps for photons in the energy range 1-2.8eV was measured. For excitation photon energy 1.833V, $A = 2.2 \times 10^{-18} cm^2$. The interaction rate constant between the trapped electrons and triplet excitons was obtained from the enhancement of the triplet-singlet intersystem rate constant and found to be $R = 3.2 \times 10^{-11} cm^3 sec^{-1}$. The electron lifetime was calculated $\tau_s = 1.5 \times 10^{-7}$ sec. This value is in very good agreement with the value obtained by other investigators by an independent method.

Experiments are in progress to determine the singlet-trapped electron interaction rate constant.

(c) **Gamma-Ray Induced Electron Traps in Anthracene.** Gamma Ray induced electron traps in solution grown anthracene crystals were studied by steady-state space-charge limited current method. The method was described in former reports on radiation induced hole traps. Sodium amalgam was used as an electron injecting electrode. For radiation doses higher than 10^4 rads, the changes in the log j vs log V curves are similar to those for hole currents. From the similar changes in the curves it can be deduced that electron and hole traps are produced by gamma irradiation with the same yield.

Dr. Alberto Palma Bonilla(Ecuador), Dr. Evangelina Pimenidou(Greece), Dr. Eduardo Rodrĩguez-Maisano(Argentina) and Technician Adriana Calderón(Puerto Rico calibrating the scanning equipment.



Drs. Palma Bonilla, Pimenidou, Omar Salazar(Cuba), Rodrĩguez Maisano, and Dr. Aldo Lanaro, who heads the Clinical Applications Division, work on blood samples in the counting room.

CLINICAL RADIOISOTOPE APPLICATIONS

The primary mission of the Clinical Radioisotope Applications Division is to train physicians and technicians in the diagnostic uses of radioisotopes. The bulk of the trainees are from Puerto Rico and various Latin American nations.

The division also disseminates data on the utility, applications and benefits of the clinical uses of radioisotopes; develops clinical research plans to be incorporated in division training courses; offers service to community hospitals which lack radioisotope facilities. The latter activity assures the division of all the patients necessary for the development of courses and research plans.

EDUCATIONAL ACTIVITIES

The Division offers the following courses:

Basic Clinical Radioisotope Application Course

This 8 week course consists of clinical conferences which stress the usefulness of radioisotopes in the resolution of a diagnostic problem. Therapy with internal emitters is also included. Laboratory procedures are keyed to the clinical material which is selected to provide a wide variety of clinical states which come into the trainee's consideration, to cover general presentation of the various applications available in current practice in nuclear medicine.

Subject matter treated in this course includes: thyroid disorders, cardiovascular system, liver and kidney function, gastrointestinal absorption, hematological applications, analysis of fluid compartments and electrolyte turnover, tumor localization, organ visualization, and radioisotope therapy of thyroid disorders.

Trainees and teaching staff correlate points of clinical interest with the various tests performed. Teaching is based on demonstrations, laboratory performance of tests, discussions of results, conferences and audiovisual presentations..

The course is satisfied when the student completes at least 80 adequately performed diagnostic procedures and evaluates and treats 3 patients with thyroid disorders. This year, 11 students took the course (Table 1).

Informal Courses

Practical training is offered for extended periods to students wishing to acquire more clinical and laboratory experience working with patients under the guidance of the laboratory staff. Opportunities are available in thyroid diseases, hematology, radioisotope localization studies, and other areas. After finishing her Basic Course, Dra. Dalia F. de López remained for a month, carrying out studies in special tests of thyroid and renal function.

Table 1

Basic Course in Clinical Applications of Radioisotopes
(gives student name, country of origin, and sponsor)

January 7 - February 28, 1969

César Soto Ramos, Puerto Rico, UPR Medical School
José A. Nassar, Puerto Rico, UPR Medical School

March 31 - May 23, 1969

Dalia F. de López, Paraguay, IAEA
Carlos Roldán, Argentina, self
Bernardo Marqués, Puerto Rico, UPR Medical School
José A. Berlingeri, Puerto Rico, UPR Medical School
Antonio Reyes Villar, Puerto Rico, UPR Medical School

July 7 - August 29, 1969

María Arací Medeiros, Uruguay, IAEA
Nivia Reyes de Deliz, Puerto Rico, Oncological Hospital
Reinerio Rodríguez, Spain, self
Juan E. Rizek, Puerto Rico, self

Participation in Courses Offered by Other Institutions

Nuclear Medicine Course for Medical Technologists. This course is offered to students of the UPR Medical School. The participation of this division consisted of nine conferences and eight demonstrations of radioisotope applications in medicine. There were 51 students, whose names follow. All except the first(*from the Dominican Republic)* are from Puerto Rico:

Beras Cardenas, Livia A.; Betancourt Aquino, Elba; Betancourt López, José J.; Bisbal Vázquez, José Eddie; Colón Cabrera, Francisco; Castro Irizarry, Sandra; Costa Luna, Irma; Cruz Ortiz, Nivia; Dávila Igaravidez, Carmen; Fernández Ortiz, Ana María; García Llorens, Eunice; García Ramírez, Nivia; González Caraballo, Migdalia; González Caraballo, Zulma; Gueits Matías, Ana; Gutiérrez del Arroyo, Susana; Guzmán Soto, Carlos; Hernández Richard, Carmen; Marcano Cuevas, Marian; Marrero Vázquez, Edith; Martínez Diaz, Lourdes; Minaya de la Cruz, Argentina; Miranda Reverón, Carmen Julia; Miranda Reyes, Nelly; Natal Pagán, Annie Luz; Negrón Padilla, Migdalia; Ocasio Matos, Carmen Iris; Osorio Vélez, Edna; Pérez López, Rosa N.; Prado Rodríguez, Aida; Prados Vázquez, María I.; Quiñones Pérez, Rosa I.; Rentas Rodríguez, Wanda; Rodríguez Betancourt, Lillian; Román Figueroa, Carmen; Rosario del Torres, Myriam; Rosario Martínez, Norma; Rosario Vega, Nilsa; Roura Torres, Edmés; Ruiz Pacheco, Zaida; Sánchez Figueroa, Priscilla; Santana Sanjurjo, Sonia; Sepúlveda Matos, Solange, Sevilla Ortiz, Lydia Esther; Sojo Morales, Lily; Tosado Hernández, Juan A.; Vázquez González, Violeta; Velázquez Loperena, María Teresa; Villamil Olivero, Aida.

Pathology Course for Medical Students. A conference and a practical demonstration were offered on general applications of radioisotopes in medicine.

Course for Neurology Residents. Two conferences on brain scanning were offered to neurology residents at the UPR Medical School. A one-hour lecture was given on May 28, June 4, and June 11, 1969. This course was given in response to an invitation by Dr. Luis P. Sánchez Longo, Professor and Head, Department of Neurology, UPR Hospital.

Conferences

Eight students and two instructors from the Bella Vista Nursing School in Mayaguez, visited this Division and heard a conference on the Uses of Radioisotopes by Dr. Sergio Irizarry. Two pictures, "Iodine 131" and "Radioisotopes Scanning in Medicine", were shown and demonstrations in I-131, Uptake, Protein Bound Iodine Conversion Ratio, Thyroid Scanning and Blood Volume were also given (October 10, 1969).

Dr. Eduardo Touya of the Centro de Medicina Nuclear, Escuela de Medicina, Universidad de Montevideo, Uruguay presented two special seminars (May 6, 1969):

a. La Serio-Centelleografía Renal (Serial Renal Scanning)
b. La Centelleografía del Encéfalo y del Espacio Sub-Aracnoideo (Scanning of the Encephalus and Sub-Arachnoidal Space).

Dr. Irizarry spoke at the regular staff seminar on "Pulmonary Embolism Problems" (September 19, 1969).

Dr. Irizarry presented a special seminar entitled "Tratamiento del Cancer de Tiroides con I-131 (Treatment of Cancer of the Thyroid with I-131) (October 10, 1969).

RESEARCH ACTIVITIES

Effects of External Irradiation on Thyroid Gland

Observations of variations in thyroid function in 50 patients whose normal gland is irradiated with radiotherapy for non-thyroid causes were begun three years ago. The immediate and short-term results have already been reported and published. The thyroid function drops 50 percent after irradiation and then slowly recovers, but without reaching initial values. During the final year, periodic control was continued of the surviving patients who still attend the hospital--nine in all--to observe possible long-range effects. No major variations were found with respect to the controls last year. These patients will continue to be observed.

Prolonged Survival of Red Corpuscles in Patients with Hodgkins Disease

Together with Dr. Antonio Bosch, the Radiotherapy Department studied red corpuscle survival with Cr 51 in a group of patients suffering Hodgkins Disease.

The test was made in 24 patients in different states of sickness, most of them just beginning treatment, with only seven showing moderate anemia.

Results reported in the literature on these patients refer to isolated cases or very small groups and all show a marked shortening of red corpuscle life. Results obtained in this Division are as follows, in terms of days:

13*	26	29	34	41/(37)
23	26.5	30	35.5	44 (38)
24	28*	30	37	44.2
24	28	31	40	45
25	28.5	33	40	

Total average	31.6	± 1.6
Standard Dev.	± 8	
Median	30	

* Patients treated with chemicotherapy

( ) Value of test repeated after treatment

These results are generally high norms. Five patients with lymphoma were also studied with similar results.

No definite correlation was observed between survival and the other clinical and hematological factors present. There could only be a certain relation between the result obtained and the state of the sickness, since the most advanced stages showed shorter life. Given the small number of patients in each state of sickness, these conclusions are not definitive.

It is felt that the discrepancy between these results and those previously reported in other centers is due to the fact that the patients who had been studied before were studied because of a rather serious aggregate anemia. Studies will continue on this type of patient.

Evaluation of Antithyroid Drug Effect with Radioiodine Tests in Hyperthyroid Patients

Four patients with clinical and laboratory evidence of hyperthyroidism averaging a baseline 24-hour RAIU(Radioiodine uptake) of 71.0% were tested by various modifications of thyroid I-131 accumulation under the influence of thyroid function inhibitors. Results: The tapazole thyroid-inhibited 24-hour RAIU was given to three patients, resulting in the detection of a highly non-responsive patient; a similar result was found in one of two patients tested with the propylthiouracil-inhibited 24-hour RAIU. The tapazole thyroid-inhibited KCNS discharge test in two patients demonstrated poor thyroid blockade in one, and a single KCNS discharge test in a propylthiouracil-blocked gland was ineffective in a patient with previously known good response to the tapazole, and poor response to the propylthiouracil-inhibited 24 hour RAIU tests. Comment: Group too small for conclusions. Present results and those in previous annual reports appear to indicate that drug unresponsiveness to pharmacologic control of hyperthyroidism may be more prevalent than ordinarily suspected.

Table 2

Antithyroid Drug Effect - Results - RAIU (Radioiodine Uptake)

Test	24 Hr RAIu Baseline %	Modified 24 Hr RAI u %	
		Responders	Non-Responders
Tapazole Inhibited 24 Hr RAI uptake	55.9	2.0	-
	70.7	9.3	-
	89.0	-	43.2
Propylthiouracil Inhibited 24 Hr. RAI uptake	55.9	3.5	-
	38.2	-	14.2
Tapazole Inhibited KCNS discharge test	9.7	2.9	-
	46.0	-	18.6
Propylthiouracil Inhibited KCNS discharge test	16.9	-	6.8

Review of I-131 therapy experience in 18 patients with Carcinoma of the Thyroid.

Eighteen patients with clinical and histopathologic evidence of carcinoma of the thyroid in various stages of the disease have been treated at this laboratory with I-131. Eight of the patients had a mass or nodule in the neck, and eight others had already undergone surgical treatment for this problem. Previously operated patients showed an average 24 hour radioiodine thyroid uptake of 8.6%; non-operated patients averaged 31.3%. Scanning of the neck detected 8 cold nodules, 5 active nodules, 11 thyroid remnants, 5 absent thyroid glands and 19 metastatic lesions of which 18 were radiographically evident.

Complete surgical ablation of the thyroid was given to 15 patients, one received hemithyroidectomy and 2 had no surgical treatment. Three patients stage I (localized disease) received an average dose of 8 mc of I-131, with good results in 2, insufficient in one; five patients stage II (disease spread to neck) were treated with an average dose of 36 mc I-131 with immediate response in 4 and insufficient in one; and ten patients stage III (distant metastases) were given an average dose of 69 mc with good immediate results in 5, 2 good partial responses and 3 insufficient responses. The minimum doses given for soft tissue lesions in the neck were 5 mc to stage I lesions, 10 mc to stage II and III lesions, whereas, the maximum dose for soft tissue lesions was 10 mc to stage I, 50 mc to stage II and 180 mc to stage III. Minimum dose for a bone lesion was 23 mc and maximum 75 mc. Five year survival was similar in the three stages, despite different overall prognosis.

It appears that the therapeutic response is good for the rather low average doses given to these patients. Radiosensitivity of carcinomatous tissue in these patients is not too dissimilar to that of normal thyroid gland which may require between 30 - 200 mc I-131 for diminution of normal activity or complete ablation of thyroid tissue.

Lung Scanning in Pulmonary Embolism

During the last year 63 new patients were referred to this laboratory for isotope scanning evaluation of pulmonary circulation. A total of 68 scannings were performed, as some patients needed more than one evaluation. The isotopic patterns of a variety of pulmonary diseases were compared with the pattern of avascularity seen in patients with pulmonary embolism. Abnormal perfusion (vascular) patterns of the lung were found in the following conditions: acute bronchial asthma, bronchiectasis, pneumonia, pleural effusion, pulmonary schistosoma arteriovenous fistulae, cardiac patients, granulomas of the lung, carcinoma (focal or multiple), post splenectomy thromboembolic disease, concurrent viral and thromboembolic disease, and thromboembolic disease of the lungs with or without pulmonary infarction.

Radionuclide scanning of the lungs is a highly sensitive but non-specific tool to detect vascular changes of the lungs secondary to a great variety of conditions of pulmonary or non-pulmonary origin. Because of its high sensitivity it may be the only diagnostic tool which may be positive for microarterial embolization from 2 mm caliber arterial vessels down to the pre-capillary bed. Yet because of its non-specificity it must be interpreted in the light of the clinical picture and other ancillary laboratory data.

New Applications of Radioisotopic Techniques in Medical Practice

A. Determination of Volumes of Subdural Effusions. Subdural effusions result from the accumulation of a transudate in the subdural space. They may occur as a complication of meningitis, dehydration, electrolyte imblance, craneocerebral trauma, and subdural hematomas. These effusions usually disappear spontaneously or after repeat needle aspirations of the fluid, in several days or weeks. Occasionally the effusions fail to disappear and even continue to increase in size, requiring surgical removal of the pseudocapsule that eventually develops. We have found it useful to determine the volume of the subdural spaces, using the

isotope dilution technic with RISA, first early in the course of the disease, and again a few weeks later,,to f ind out if the space is diminishing in volume and healing. In this way we can identify early the patients that most likely will need neurosurgical correction of the disease.

Three patients have been studied by the administration of RISA (1 uc) into the subdural space, without any untoward reactions. None have required surgery.

B. Recurrent Intracraneal Infections after Craneocerebral Trauma. Small fractures of the base of the skull and of the cribiform plate may be missed by radiographic examinations, but they may cause a communication between the craneal cavity and the ear canal, and/or the upper nasal cavity, permitting the entrance of germs into the craneal cavity, resulting in recurrent meningitis and/or brain abcesses.

During the past two years two children who had suffered recurrent intracraneal infections were discovered to have leakage of cerebrospinal fluid through thin fractures not detected by x-ray studies. The cases were detected by the demonstration of abnormally high increase of radioactivity in the nasal cavity and in the ear canal, respectively, after the administration of RISA intravenously. We plan to expand our experience using these techniques.

Table 3

Total Diagnostic and Therapeutic Tests

Work carried out in the Division in its different activities is summarized in the following table.

Service Procedures		1548
Thyroid Studies	1299	
Gastro-Intestinal	8	
Blood	19	
Liver	71	
Heart	24	
Renograms	99	
Tumor Localization	28	
Training Procedures		2771
Grand Total		4313

STAFF

Dr. Sergio Irizarry resigned his position as Head of the Division, but remains as a staff member.

Dr. Aldo E. Lanaro was named Acting Head of the Division, replacing Dr. Irizarry.

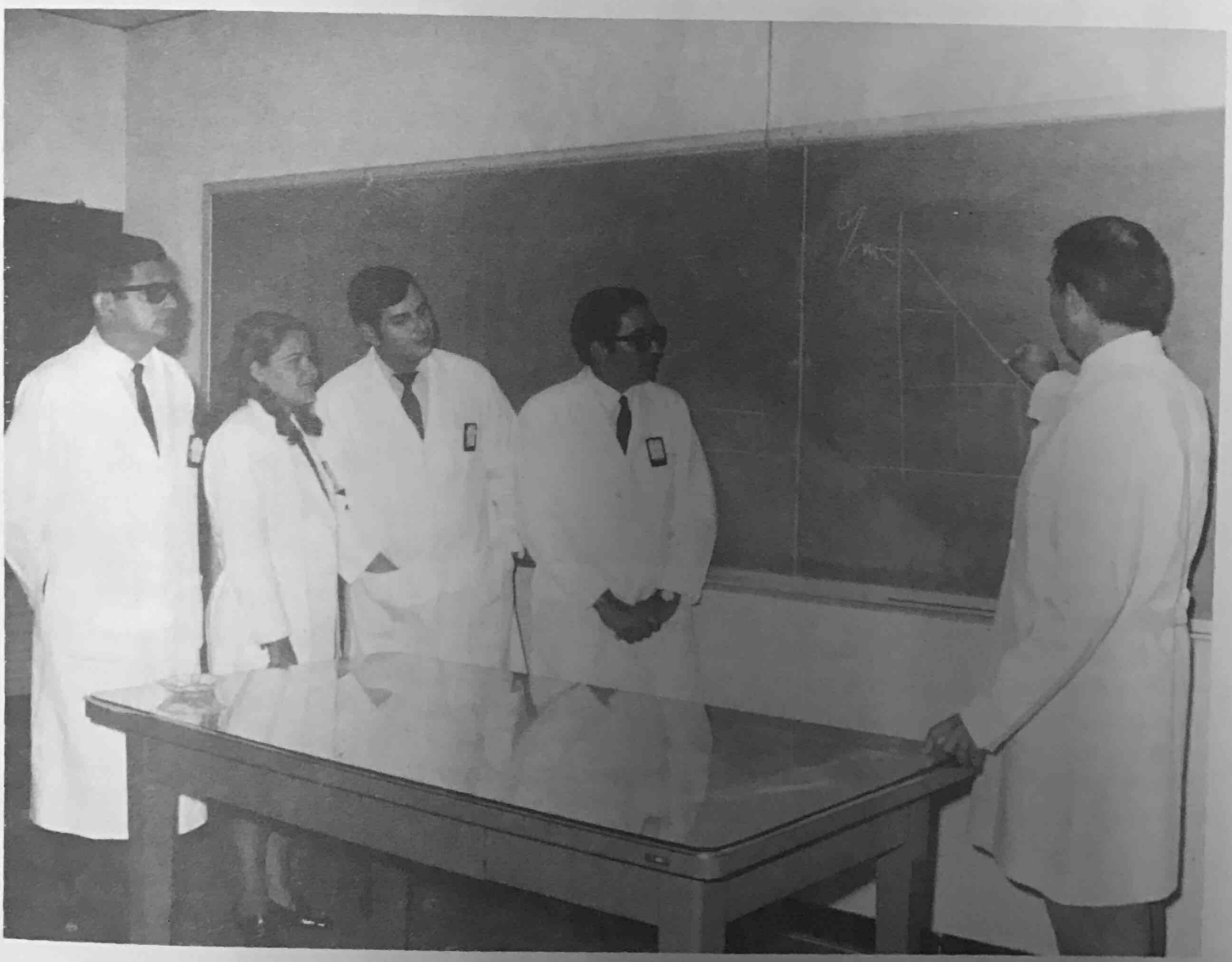
Dr. Eduardo Touyá of the Nuclear Medicine Center in Montevideo, Uruguay, spent part of the month of May at PRNC. He is a former Division trainee.

SCIENTIFIC MEETINGS AND CONFERENCES

Dr. Lanaro attended: the Integrated Cancer Congress in Sao Paulo, Brazil(September 7-13, 1969); the Jornadas Rioplatenses de Endocrinología in Salta, Argentina(September 23-27, 1969); the 16th annual meeting of the Society of Nuclear Medicine at New Orleans, Louisiana (June 21-29, 1969) and the American Nuclear Society Topical Meeting in San Juan at the San Jerónimo Hilton(May 4-6, 1969).

Dr. Irizarry attended: the first annual Nuclear Medicine Seminar on Fundamentals of Pulmonary Investigation with Radionuclides in Miami, Florida (March 7-11, 1969) and the American Association of Physicists in Medicine, and the meeting of the Radiological Society and Nuclear Medicine section, held in Chicago, Illinois.

During his trip to South America, Dr. Lanaro gave three conferences: "Our Current Work at the Puerto Rico Nuclear Center," at the Endocrinology and Metabolism Clinic in Buenos Aires, Argentina; "Our Experience in Thyroid Studies with Radioactive Isotopes" to the staff at the Hospital Maciel in the Montevideo (Uruguay) Medical School; "Biological Effects of Radiation and Protection" to a group of doctors of the Society of Hygiene and Protection in Sao Paulo, Brazil.



Dr. Lanaro(right) offers a lecture to physicians who are taking the basic course in clinical applications of radioisotopes.

Dr. Victor Marcial, head of the Radiotherapy and Cancer Division, discusses an X-ray with two residents: Mrs. Luz Toro de Berrios and Mr. Omar Salazar.

RADIOTHERAPY AND CANCER

The Radiotherapy and Cancer Division has a three-fold objective: education, research, and service.

The Division functions as part of the radiotherapy department of the I. González Martínez Hospital, adjacent to the Biomedical Building at the Puerto Rico Medical Center. The Oncologic Hospital provides some of the paramedical personnel, equipment and space, operating rooms, hospital beds, out-patient facilities, clinical laboratories, and medical services essential to the care of cancer patients.

The hospital renders services to over two-thirds of Puerto Rico's indigent cancer cases. Since May 1966,it has also provided the radiotherapy services to patients of the Puerto Rico Medical Center.

At the academic level, the Radiotherapy Division operates as the radiotherapy section of the University of Puerto Rico School of Medicine. It also works closely with the Cancer Control Program of the Puerto Rico Department of Health.

Partial support for this program is obtained from a National Cancer Institute training grant through the University of Puerto Rico School of Medicine.

EDUCATION PROGRAM

The educational program includes the radiotherapy residency program (long term training), short-term radiotherapy training course, in-service cancer training for medical students, in-service training for radiological physicists and radiotherapy technicians, and a series of lectures in radiotherapy and cancer offered to third-year medical students.

The radiotherapy residency program, designed to prepare qualified radiation therapists, meets the requirements of the American Board of Radiology. The trainees are physicians with a year of internship or equivalent clinical experience. The training period is three years, but trainees are required to take an additional fourth year of supervised practice (preceptorship) before admission to the specialty examinations. Diagnosis of cancer, determination of the extent and radiosensitivity of tumors, selection of appropriate treatment, and the planning and conducting of radiological therapy are included in the curriculum. Residents acquire background in clinical oncology through supervised work with new, follow-up, and hospitalized cancer patients. Radiation therapy experience is acquired by working with roentgentherapy machines of various voltages, cobalt and cesium teletherapy units, and the internal application of radioactive material in solid sources (needles, tubes, wire), such as radium, strontium, cobalt, iridium, and cesium.

The short-term radiotherapy training course for persons with previous radiotherapy experience is prepared according to the needs of the individual requesting the training.. Participants may engage in research and in all division training activities; however, they are not extended the privilege of patient responsibility. A minimum of one month of training is required.

In-service cancer training for medical students acquaints future physicians with clinical

problems and current research in cancer and radiation therapy. The minimum length for this course is one month. In-service training for radiological physics personnel and radiotherapy technicians is provided as the demand calls for it. Trainees are allowed supervised practice in the division's facilities.

The radiotherapy of cancer lecture course for third-year medical students is offered yearly as part of the medical school curriculum. Twelve lecture hours highlight epidemiology of cancer, radiological physics, radiobiology, clinical radiotherapy, and radioisotopes in therapy.

EDUCATIONAL ACHIEVEMENTS

Formal programs and courses were offered regularly to physicians and medical students. These included lectures, seminars, demonstrations, and patient care under supervision with rotation through the various sections of the division (PRNC treatment area, follow-up, and radiological physics). Resident physicians in the program also rotated throught the Pathology Department of the Oncologic Hospital, the PRNC radioisotope courses, and the PRNC Medical Sciences and Radiobiology Division for radiobiology training.

TRAINEES

Short-term Radiotherapy Training

1. Residents in Radiology at the Veterans Administration Hospital in the Bronx, New York have spent one month of training at the Radiotherapy Division, by special arrangements with Dr. B. Roswit, Chief of Radiation Therapy Service at the V. A. Hospital. Since July 1969 the period of training was increased to two months.

Name	Country	Date
Dr. William E. Agrait	Puerto Rico	January 1969
Dr. Prathuang Angkeow	Thailand	February 1969
Dr. James Custer	U.S.A.	July-Aug 1969
Dr. Richard Bradley	U.S.A.	Sept.-Oct 1969
Dr. Galileo Ramírez	Puerto Rico	Nov.-Dec. 1969

2. Other

Dr. Juan B. Reñé	Argentina	March-Oct 1969
Dr. Julio E. Vita	Argentina	Oct.-Nov. 1969

Dr. Omar Salazar, Intern, began four months of training on November 3, 1969.

Long-Term training

Dr. Augusto Llamas, from Colombia, a fourth year radiotherapy resident from the University of Chicago, continued his residency here from July to December 1969.

Dr. José A. Avila and Dr. Pedro J. Villanueva, from Puerto Rico, started their training as residents in radiotherapy in January 1969.

Dr. Juan B. Reñé, from Argentina, started his training as resident in radiotherapy in November 1969.

RESEARCH PROGRAM

Research of Residents

Dr. José A. Avila - Cancer of the Pinna - in progress
Dr. Pedro J. Villanueva - Retinoblastoma - in progress
Dr. Juan B. Reñé - Cancer of the Vagina - in progress

Research Done by the Group

A. Current Research Projects at End of Year

1. Dose-time relationships in the external irradiation of carcinoma of the uterine cervix: Comparison of 4500 rads versus 5000 rads.

This project tries to determine curability and complication rates obtained with two dose levels in the external irradiation of carcinoma of the uterine cervix when using an internal dose of 4000 rads at point A. Up to July 1968, the dose was stated in roentgens and since then it has been expressed in rads. Initial observations revealed that the complication rate is higher when a dose of 5000 rads is used, particularly if the weekly fractionation is three times per week.

2. Fractionation in radiation therapy of carcinoma of the uterine cervix: 3 vs. 5 fractions per week.

This project tries to determine curability and complication rates with two fractionation regimes (3 vs 5 fractions per week) of the external irradiation in carcinoma of the uterine cervix. An inital evaluation, with exposures of 4500 roentgens calculated in the mid-pelvis, followed by intracavitary irradiation of 4000 roentgens at point A, showed that the curability and complication rates were identical at 3 years in a group of 260 patients. More recently, when the dose is expressed in rads, particularly when reaching total dose levels of 5000 rads, the complication rate appears to be higher in the 3 fractions per week group.

3. Fractionation in radiation therapy of inoperable breast cancer: 1 vs. 5 fractions per week.

This study aims to determine the effectiveness (tumor control) of 1 vs. 5 fractions per week for inoperable carcinoma of the breast. Both groups receive a tumor dose of 5000 rads with an evaluation of the breast tumor one month after therapy. If tumor is still palpable at one month post-therapy, the patient receives a boost of 2000 rads in 2 weeks at the rate of 200 rads 5 times per week.

4. Surgical adjuvant breast project.

This study, to determine the effectiveness of radiation therapy for the regional lymph nodes areas as an adjuvant to surgery for carcinoma of the breast, is in the follow-up phase. A recent report of the national experience reveals that no increase in survival has been observed with the utilization of radiotherapy for the regional lymph nodes areas after surgery for carcinoma of the breast. However, regional tumor control is better in the patients submitted to radiation therapy versus surgery only.

5. Radiotherapy for carcinoma of the prostate - Stage C.

This study aims to determine the effectiveness of radiotherapy for carcinoma of the prostate versus hormonal therapy. Accession of cases depends on the urology group; this has not been adequate to contribute a significant number of patients to this national study.

6. Study of the incidence of leukemia in patients with cervical cancer treated with radiation.

This is a national study in the follow-up phase, to determine the incidence of leukemia in patients who have received treatment (surgical or irradiation) for carcinoma of the cervix. Information is provided to the national study on the fate of the patients registered. Reports show no increase in incidence of leukemia in patients who have received radiotherapy for carcinoma of the cervix.

7. Study of optimal irradiation in carcinoma of the esophagus: A boost of irradiation 2 weeks post-radiotherapy.

This study tests whether a boost of irradiation (2000 rads in 2 weeks at a rate of 200 rads 5 times per week) added to a dose of 5000 rads in 4 weeks for carcinoma of the esophagus is of value regarding the survival in this disease. Half of the patients received the standard dose of 5000 rads in 4 weeks and the other half also received the boost of 200 rads in 2 weeks. An initial revision by Dr. Jeanne Ubiñas of the 60 cases in the study showed that the survival, up to 18 months, was better in the group that received the boost.

8. Fractionation in radiation therapy of post-surgical breast cancer; 3 vs. 5 fractions per week.

This study aims to evaluate local tumor control and tissue damage from irradiation of carcinoma of the breast after radical mastectomy. The irradiation is directed to the regional lymph node areas, with half of the patients receiving 3 fractions per week and the other half 5 fractions per week. The initial finding is that tissue reactions are more severe in the 3 fractions per week group when the total tumor dose is 5000 rads in 5 weeks. Tumor doses of 4500 rads in 5 weeks result in acceptable tissue changes. It is too early in the study to evaluate long term tumor control in the irradiated areas.

B. Projects Terminated During the Year.

1. Study of tumor regression in carcinoma of the cervix.

Tumor regression in patients with carcinoma of the cervix treated by external cobalt 60 teletherapy followed by intracavitary irradiation was studied. Time of complete tumor regression is noted for the different stages. A correlation between time of complete regression and histologic picture, tumor volume, age, fractionation, interval between external and internal irradiation, and 3 year survival is discussed.

Tumor volume, as determined by the stage classification, and age, were found to be related to tumor regression. Regression was faster in early stages and in patients over 50 years of age.

Patients with tumors regressing completely by the end of external irradiation showed an excellent 3 year survival. Patients developing complete tumor regression during the period between external and intracavitary irradiation showed a tendency towards lower 3 year survival.

A late complete tumor regression is not associated with a different prognosis than when this happens early after therapy.

2. Complications of treatment in cancer of the cervix uteri from 1958-1965.

This study by Dr. Antonio Bosch analyzes the degree and incidence of normal tissue complications in patients with carcinoma of the cervix uteri who have received radiotherapy. Complications are related to tumor dose and other treatment parameters.

STAFF

At year's end, the Radiotherapy Division had four radiotherapists, one physicist, an assistant physicist, and a biostatistician. The services of a research medical records librarian, three graduate nurses, three clerical persons, and a photographer-electronic technician, were also available. Personnel is still insufficient for the needs of the division, particularly at the radiotherapist level; the present patient and teaching load requires at least six radiotherapists.

Dr. Arturo Valencia, from Colombia, who received his training in radiotherapy at our institution, joined our staff as attending physician in radiotherapy in August 1969.

Dr. Jeanne Ubiñas acted as Director of the Cancer Control Program of the Puerto Rico Department of Health from January to September 1969.

Dr. Antonio Bosch was Member of the Emergency Committee of the Puerto Rico Medical Center and Secretary of the Medical Faculty of the I. González Martínez Hospital.

VISITING SCIENTISTS

The following visiting scientists acted as consultants to the program: Dr. William E. Powers, Program Director for Radiation, Extramural Activities of the National Cancer Institute, Bethesda, Maryland (November); Dr. William Walters, Associate Director, Extramural Research of the National Cancer Institute, Bethesda, Maryland (November); and Dr. Luther W. Brady, Professor of Radiation Therapy, Hahnemann Medical College, Philadelphia, Pennsylvania (December).

A patient is positioned for treatment with PRNC's cobalt-60 teletherapy unit by technician Irene López de Velázquez.

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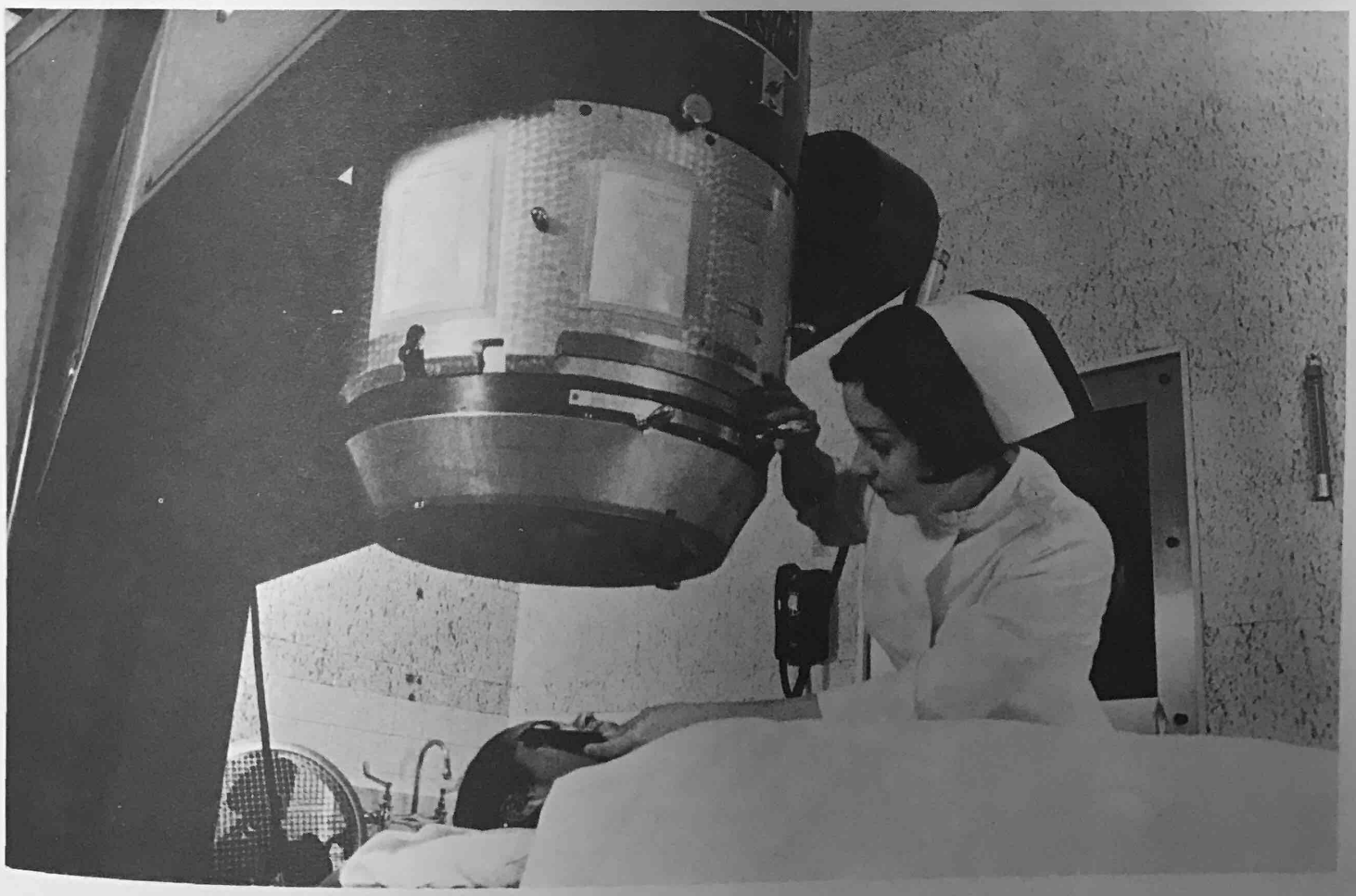


A patient is positioned for treatment with PRNC's cobalt-60 teletherapy unit by technician Irene López de Velázquez.

SERVICE

A. Distribution by site of new cases treated - January to December 1969.

Oral Cavity		**85**
Anterior 2/3 of tongue	15	
Floor of mouth	24	
Other	46	
Oropharynx		**76**
Base of tongue	34	
Tonsil	22	
Other	20	
Hypopharynx		**33**
Nasopharynx		**3**
Respiratory System		**82**
Paranal sinuses	9	
Larynx	29	
Bronchus and lung	40	
Other	4	
Digestive System		**104**
Esophagus	90	
Other	14	
Breast		**98**
Female Genital Organs		**216**
Cervix uteri	162	
Endometrium	29	
Ovary	19	
Other	6	
Male Genital Organs		**13**
Urinary Organs		**37**
Bladder	26	
Kidney	11	
Skin		**98**
Brain and Nervous System		**20**
Bone and Connective Tissue		**22**
Lymphatic & Hematopoietic System		**45**
Hodgkin's Disease	18	
Other	27	
Other		**40**
Total		**972**

B. Teletherapy Applications (^{60}Co, X-Rays, 137 Cs) **26,518**

C. Intracavitary and Interstitial Therapy **219**

D. Follow-up **5,305**

OTHER

The following five protocols for the national Collaborative Study of the Value of Split Course Radiation Therapy were prepared: Carcinoma of the Base of the Tongue; Carcinoma of the Nasopharynx; Carcinoma of the Tonsillar Fossa; Carcinoma of the Uterine Cervix; Carcinoma of the Urinary Bladder.

SCIENTIFIC TRIPS OF STAFF

Dr. Victor A. Marcial: Attended a meeting of the Committee for Radiation Therapy Studies, Bethesda, Maryland (January 10).

Presented a paper at the World Conference of Cancer of the Uterus, New Orleans, Louisiana (March 2-5).

Presented papers at the American Radium Society meeting, Philadelphia, Pennsylvania (April 27-30).

Presented a paper at a Symposium on Cancer of the Cervix Uteri; Stage I and II, Nashville, Tennessee (May 1-5).

Attended and participated in a meeting of the Committee for Radiation Therapy Studies, Bethesda, Maryland (May 27).

Attended Harvard Medical School Alumni Day, Boston, Massachusetts (May 30).

Attended and participated in a meeting of Computers for Dosimetry, Chicago, Illinois (July 18).

Attended and participated in a meeting of the Methotrexate Study, Chicago, Illinois (September 12).

Attended and participated in the conference "Time and Dose Relationships in Radiation Biology as Applied to Radiotherapy", Carmel, California (September 15-18).

Presented papers at the XII International Congress of Radiology, Tokyo, Japan (October 6-11).

Presented papers at the Eleventh Congress of the Pan-Pacific Surgical Association, Honolulu, Hawaii (October 14-22).

Presented a paper at the Radiological Society of North America annual meeting, Chicago, Illinois (November 30-December 5).

Dr. Jeanne Ubiñas: Attended the American Radium Society annual meeting, Philadelphia, Pennsylvania (April 27-30).

Dr. Antonio Bosch: Attended the American Radium Society annual meeting, Philadelphia, Pennsylvania (April 27-30).

Presented a paper at the Congresos Integrados de Cancerología, Sao Paulo, Brazil (September 7-13).

Attended and participated in the Carmel Meeting on Time and Dose Relationships in Radiation Biology as Applied to Radiotherapy, Carmel, California (September 15-18).

M. M. P. de Lozano: Attended the Health Physics Society annual meeting as representative of the P. R. Chapter, Pittsburgh, Pennsylvania (June 8-12).

Miss Zenaida Frías: Attended the American Radium Society annual meeting, Philadelphia, Pennsylvania (April 27-30).

Made an official visit to the Division of Epidemiology and Biostatics of the Institute of International Medicine of the University of Maryland, Baltimore, Maryland (May 1-6).

Dr. Arturo Valencia: Attended the Radiological Society of North America annual meeting Chicago, Illinois.

Nuclear Techniques course laboratory exercise with plant material by graduate students in biology or agriculture, CAAM of UPR. Mr. J. Cuevas (left) Research Associate of the Tropical Agro-Sciences Division supervising the laboratory session.

Miss Carmen Asencio, Research Assistant, makes titration determination as one of the steps in the kinetics studies of pectic enzymes in tropical fruits.

TROPICAL AGRO-SCIENCES

The purpose of the Tropical Agro-Sciences Division remains two-fold: first, to train students in agricultural and biological research with emphasis on nuclear science applications in these investigations; and second, to conduct basic research programs which are particularly concerned with problems in tropical agriculture that can uniquely be studied by nuclear techniques.

Educational and Training Activities

During 1969, the emphasis on education and training continued to be directed toward the graduate and post-graduate level. These activities were frequently related to the Division's basic research activities which are outlined in a later section.

The Division staff, holding ad honorem or joint appointments at the various science departments of the University of Puerto Rico, offered the following courses during the year:

Cytogenetics	Dr. F.K.S. Koo (Rio Piedras Campus).
Cytogenetics	Dr. J.A. Ferrer-Monge (Mayagüez Campus).
Food Chemistry	Dr. S.N. Deshpande.
Radiochemistry	Dr. S.N. Deshpande.
Nuclear Techniques in Biological Research	Dr. S.N. Deshpande, Dr. J.A. Ferrer-Monge, and Mr. J. Cuevas-Ruiz.

The staff also contributed lectures and laboratory sessions to the PRNC basic courses in radioisotope techniques and radiobiology.

Graduate Research

A number of graduate students were active in thesis research leading to the M.S. degree in biology or in agriculture under the supervision of the Division staff members. Research topics reflected the broad interests of the Division. During the year of 1969, one graduate student completed and four initiated their thesis research programs.

1. The effect of temperature on the mitotic cycle in *Vicia faba*-- Carmen Elena Cintrón, Puerto Rico. Seeds were germinated at O°C, no mitotic activity was noted as indicated by a mitotic index (MI) of 0.0% even after 94 hrs. of germination. At 10°C, cell division began around 50 hrs. from the beginning of germination with an MI of 5.2% and reached a maximum of 56.4% at hour 74. At 20° C (considered as ambient), mitosis began about 48 hrs. from germination with an MI of 9.9% and reached a maximum of 44.8% at 78 hrs. At 30°C, mitosis began at hour 36 with an MI of 2.7% and reached a maximum of 27.2% at 72 hrs. At 40°C, no cell division was observed, even after 56 hrs. of germination. It may be concluded that with an increase in temperature from 10° to 30°C there is an increase in cell division. At 0°C, the absence of division may be attributed to a reduction in metabolic activity of the cells. The lack of cell division at 40°C, however, could be attributed partially to a denaturation of cell proteins (Research completed under Dr. Ferrer-Monge's guidance).

2. Effect of gamma radiation on the peroxidase isoenzymes of *Glycine max*--Aida R. de Mari, Puerto Rico. Techniques and procedures for electrophoretic analysis of the peroxidase isozymes in soybeans were tested and standardized. Main work is expected to be completed

by March, 1970. The objectives of this investigation are (1) to study the effect of ionizing radiation on the peroxidase isozymes, and (2) to study the age and tissue or organ specificities of isozyme production (Dr. Ferrer-Monge serves as thesis advisor).

3. Effect of gamma rays on isozyme patterns of malate dehydrogenase in soybean seedlings--Isabel Bulla Dueñas, Colombia. Disc-electrophoresis has been used to study the changes in isozyme patterns of the MDH extracted from 6-day and 12-day old soybean seedlings grown from irradiated and control seeds under light and in the dark. Completion of the experimental work is expected in April, 1970 (work performed under Dr. Koo's direction).

4. Comparative mutagenic effect of target atom irradiation and N-methyl-N' -nitro-N-nitrosoguanidine on histidine operon of *Escherichia coli* strain C--Carmen Baerga Santini, Puerto Rico. Protocol and other special techniques for raising and identifying various genetic stocks were tested. Experiments on mutation induction, isolation, and identification by complementation test are to begin in January, 1970 (investigation supervised by Dr. Koo).

5. Comparative study of radio-pasteurization and freezing on lipoxidase activity in soybeans--Oscar Aragón, Nicaragua. The lipoxidase-catalyzed oxidation of lipids is assumed to be one of the primary causes of off-flavor during prolonged frozen storage of many vegetables. Objective of this research is to determine and characterize the principal lipids and lipoxidase activity under different preservation conditions. The techniques of enzyme assay, and characterization of the lipids by means of gas liquid chromatography and thin layer chromatography are being standardized. It is expected that the thesis research would be completed by August, 1970 (research conducted under the supervision of Dr. Deshpande).

Special Training

The Division participated actively in technical and scientific training programs. Training in radiation preservation of food was provided for Miss Vachira Jiravatana of Thailand, International Atomic Energy Agency Fellow, and for Mr. Luis Cabrera Mosqueda of Mexico. Technical assistance on the same subject was also given to the Instituto Centro Americano de Investigación y Tecnología Industrial (ICAITI) of Guatemala.

Miss Jiravatana, a scientific staff member of the Office of the Atomic Energy for Peace in the Ministry of National Development in Thailand, joined the Division in August, 1968 and completed her training in July, 1969. She received a technical orientation first and was then assigned to conduct independently the specific research problems closely related to the needs of her homeland. The shelf-life extension, biochemical changes and kinetics of pectin methyl esterase of the irradiated papaya and mango fruits were investigated to a degree of thoroughness.

Mr. Cabrera Mosqueda, Assistant Professor of Chemistry, National University of Mexico, arrived at PRNC in August and expected to complete his training including a master's thesis research on the subject of radiation effect on the activities of pectic enzymes in papaya fruits by the end of January, 1970. The thesis is to be submitted to the National University of Mexico.

The Technical Assistance Program in Food Preservation by Radiation has been supported financially by the USAID. The Program was initiated in November, 1968 with active participation of two ICAITI scientists, Dr. Pedro Solé and Mr. Carlos Rolz, in the studies of radiation effects on papaya fruits at PRNC. Their investigation was mainly concerned with the changes in respiration, flavor, and pectic enzyme activity following irradiation using infrared spectrophotometry, gas chromatography and other analytical methods. In May and again in August of 1969, two Division staff members each spent two weeks at ICAITI to review research progress there and to assist in developing new programs

Miss Vachira Jiravatana of Thailand, International Atomic Energy Agency Fellow, making selections of mango fruits for irradiation preservation experiment which involves studies of shelf-life extension, changes in fruit chemical constituents and kinetics of pectin methylesterase action.

in food irradiation. In early 1970, plans to organize an overall research program using radiation will be formulated by taking into consideration the needs of Guatemala and the other Central American Common Market countries.

Dr. Ira Jones, Professor of the Inter-American University in San Germán, P.R., spent three months (June through August) as an Oak Ridge Research Participant in the Division to study the nuclear structure and life cycle of *Sporozoa* of Caribbean *Sipunculidae*.

Research Activities

The major research activities may be outlined under the following categories:

1. Mutation breeding

The main objective of this project is to adapt soybean crops to tropical environmental stresses by mutation breeding. In the summer of 1969, M_2 progenies together with the controls of the varieties Hill and Lee were grown in the field and the late-flowering and late-maturing variants among others were harvested. The late or day-length neutral mutations are considered important for high yield in these early varieties being adapted to cultivation in the tropics. To verify and to effect further selection for these traits in M_3, a group of selections were sown again in December. Mutants tolerant to higher temperatures are also of prime importance to tropical adaptation. A hot-water dipping test has been developed for making mass screening for heat-tolerant M_2 seedlings. During the same 1969 summer crop season further adaptation and yield trials of 9 varieties were conducted at four locations where different environmental stresses prevailed. From these tests the high-yielding varieties best adapted to different types of stresses will be selected for improvement by mutation breeding method. Also in the summer of 1969, more intense selection pressure was applied to the lines derived from the high protein crosses. The other breeding objective of equal importance is the improvement of quality of the seed protein. Methionine in soybean protein is known to be the limiting amino acid with a narrow range of natural variation. Here application of mutation breeding technique may prove to be most appropiate. To facilitate selections for mutants with high methionine content, a nuclear assay technique has been developed which obviates the limitations of microbiological and colorimetric methods for methionine determination. By this improved method pulverized soybean seeds were first subjected to hydrolysis. The hydrolyzates were then filtered and made to volume. Aliquote of C^{14}-labelled methionine solution with known specific activity was added to a definite portion of the hydrolyzate solution, and the volume adjusted to 1 ml accurately. A definite amount of aliquote of this mixture was spotted on to a thin layer film one half square centimeter in area, dried, and the radioactivity of the spot was assayed by liquid scintillation counting. Methionine concentrations of these hydrolyzates were also determined by colorimetric methods. The results were comparable. The isotopic dilution technique was advantageous in that further clarification of the hydrolyzates or adjustment of the pH was not necessary as in the case of colorimetric determinations. As a further refinement, the amino acids were separated by thin layer chromatography. The methionine spots were cut out from thin layer films and assayed by scintillation counting. Further experiments to standardize the technique are being pursued.

For the sugarcane improvement program, some 1,000 samples were assayed for sucrose content. A few from the high-sucrose stocks selected previously appeared to have high sucrose content. However, further studies are needed to determine the true merit of these selections.

2. Food preservation

The Division activity in this field has been intimately integrated into the training programs. During 1969, research has been directed to the underlying processes associated with

radiation preservation of tropical fruits. In the studies of the effect of ionizing radiation on the kinetics of pectin methylesterase the crude enzyme was extracted from papaya fruits by standard procedures, dialyzed against borate phosphate buffer, and the kinetics of the action of pectin methylesterase was determined by estimation of the methoxyl groups liberated from the pectinic acid used as substrate. The results indicate a distinct increase in the activity of this enzyme with increasing radiation doses, as compared with the control treatments. Further proof of this increase in enzyme activity came with the plot of the logarithm of the ratio of initial concentration to the prevailing concentration of the substrate against time. This plot resulted in approximately parallel straight lines, but the slope increased with increasing doses of radiation.

In studies of shelf life extension and biochemical changes in the irradiated papaya fruits during the post storage period, it was found that fruits stored for a week showed an increase in the pectic content,followed by a decrease in the pectic content after 2 and weeks. These changes were undoubtedly caused by conversion of protopectin to pectin and its degradation by the activity of pectic enzymes. Although there was a higher activity of pectin methylesterase in the irradiated fruits as compared with the control, no evidence was found for the activity of pectin polygalacturonase. Also there was no appreciable change in the total content of sugar, carotenoids or the external color of fruits. The damage caused by microbial infection was reduced and the shelf life of the fruit was increased.

3. Insect sterility

Research carried out under a special program supported by the Division of Biology and Medicine, USAEC,concentrated on the elucidation of transmission of sterility factors and protein complements in inherited sterility. Examinations were also made for chromosomal aberrations in the larvae from outbred strains carrying inherited partial sterility factors. Details are reported elsewhere in this report, under "Insect Sterility."

4. Experimental control of mutagenesis

It has long been the aim of the geneticists and plant breeders to harness the mutation process so that any particular mutation may be artificially induced at will. The present investigation exploits the following principles and facts: Since bromine as in 5-bromouracil deoxyriboside (BUDR) can be incorporated in the genetic material during DNA synthesis and the genes in a genome follow a definite time sequence for replication, it is possible to incorporate Br in a specific gene or genes by treating the material at a specific stage of DNA synthesis. Moreover, the monochromatic X-ray of the energy at or slightly above the Br K-absorption edge is known to be preferentially absorbed in Br atoms and therein it produces inner-shell multiple ionization. Thus, it is conceivable that mutations at any selected locus could be specifically induced by such X-irradiation in the material incorporated with Br at a specific synthetic stage. Seeds of *Arabidopsis thaliana* were soaked in distilled water at 24°C for various lengths of time before being subjected to one of the 4 treatments, namely, BUDR plus X-ray, BUDR alone, X- ray alone, and control. The pre-germination soaking for various lengths of time was designed to advance the DNA synthesis in the shoot meristem cells to different stages. Treatments involving BUDR(concentration:100ug/ml) were performed at 24°C for a duration of 1 hour. For X-ray treatments seeds were arranged in a single layer and irradiated at 12°C for 1 hour with fluorescent X-rays mainly of 14.10 and 14.16 keV energies (total dose: 5.1 krads). Seeds were planted in the soil immediately after treatment and plants were grown to maturity in the laboratory at 24°C under 18-hour illumination. Seedlings in the second generation were classified at the first leaf stage for mutations of various morphological and pigment-deficient types. Results indicate that mutation frequency for the material treated at different times during pre-germination soaking appears to increase with soaking time and then to decrease. The specificity of mutation

as a function of treatment period (pre-germination soaking time) was analyzed by observing the occurence of individual mutant types at various treatment periods. Results indicate that in the BUDR plus X-ray combination treatment, 3 mutant types, namely, light green cotyledon, yellow first leaf, and light green cotyledon and first leaf, were recovered in high frequencies, each at a particular treatment period. For other mutant types there were no apparent clusterings at any specific treatment period. Further studies including assays for mutants tolerant to chemicals are being pursued.

5. Seed radiobiology

To assist in furthering a world-wide program on seed irradiation coordinated by the International Atomic Energy Agency, the Division continued to investigate the comparative effect of gamma rays and neutrons on soybean seeds.

Studies using seedling growth retardation and changes in malate dehydrogenase isozyme pattern as end points were carried out in 1969. Six doses (1-5 krads) of fast neutrons and 5 doses (10-50 krads) of gamma rays were used for seedling growth study. Seeds were planted in flats at a uniform depth of 3/4 inch in the growth chamber where a constant temperature (24°C) and illumination (16 hours daily) were kept. Measurements on growth of seedling parts below and above the cotyledons were made at intervals. Growth inhibition increased with increasing dose. This effect was found more pronounced on shoot than on hypocotyl growth. At high dose levels, shoot growth was completely arrested in most seedlings.

Disc-electrophoresis was used to study the changes in isozyme pattern of malate dehydrogenase extracted from soybean seedlings grown from irradiated seeds (1.5 krads of fast neutron and 15 krads of gamma rays). Five and twelve-day old seedlings grown under light and in the dark were divided into 5 parts--roots, hypocotyl, cotyledons, epicotyl and leaves, for the analysis. Differences in isozyme pattern were observed between the control and the irradiated materials and also between the materials exposed to the two different radiations. Tissue and developmental stage specificity for isozyme pattern was also evident when the controls or the irradiated materials were compared. Light and dark growth conditions also caused a change in isozyme pattern. It is interesting to point out that only in a few comparisons the radiations showed no or negligible effect on the isozyme patterns. Changes in isozyme pattern include increase, rarely decrease, in number of major and minor bands, staining intensity and width of the bands.

In addition to its own research activities, the Division has been interested in promoting cooperative investigations with scientists of other institutions. Several programs were continued in 1969, including a) adsorption studies of ^{14}C-labeled herbicides by different types of Puerto Rican soils, and b) breaking of dormancy and mutation induction by radiation in the root crop yautía *(Xanthosoma atrovierens)*. A new program on the study of pectic enzyme activity in relation to fungal infection in vanilla roots was initiated during the year.

STAFF

Change in the Division's roster was minor in 1969. On February 1, Dr. Flavio Padovani joined the Division as Associate Scientist, assuming responsibility for the Sugarcane Borer Project during Dr. Walker's leave of absence. Dr. Padovani also holds a joint appointment at UPR as Assistant Professor.

Miss Barbara Saylor joined the Division in September as Research Assistant, filling the position vacated earlier by Mrs. Myrta C. de Pagán.

Dr. Walker returned in mid-December, from a special assignment by the International

Atomic Energy Agency to serve as Scientific Expert to the Atomic Energy for Peace Program at the Nuclear Center in Bangkok, Thailand where he provided for the Thai scientists advanced training in insect mass rearing methods and nuclear techniques related to sterilization control of important rice pests. He also organized several other insect control research projects and gave numerous seminars at universities and research institutions and also a series of lectures to the Regional Rice Borer Training Group jointly sponsored by IAEA, FAO, and the Office of Atomic Energy of Thailand.

Dr. N. Virkki, cytogeneticist of the Agricultural Experiment Station, UPR, was appointed Scientist (Ad honorem) to the Division, participating in cytogenetic studies of sugarcane borer.

Dr. Deshpande was promoted to the rank of Associate Professorship in the Department of Chemistry, UPR Mayagüez Campus.

Dr. Ferrer-Monge was appointed Liaison for the group of state-side scientists offering a special course in Molecular Biology and Microbial Genetics in the Biology Department, UPR Mayagüez Campus during the second semester. The Division provided laboratory and teaching facilities and staff assistance.

Mr. Cuevas on May 13-25 and Dr. Deshpande on August 4-17 went to Guatemala to serve as Scientific Consultants to the staff of the Instituto Centro Americano de Investigación y Tecnología Industrial as required by the Technical Assistance Program in Food Preservation by Radiation sponsored by USAID.

Dr. Deshpande spent about six weeks in early summer at the Max Planck Institute, Munich, West Germany to engage in enzymological studies.

In August, Dr. Ferrer-Monge was appointed member of the Radiation Advisory Group to the Puerto Rico Commission for Radiation Control by the Secretary of Health, Commonwealth of Puerto Rico.

Several Division staff members attended scientific meetings during 1969. Dr. Graham and Dr. Deshpande attended the Tenth Latin American Congress of Chemistry in San José, Costa Rica (February 2-9); Dr. Graham presented a paper on "Reaction of Desoxy Sugar With Sulfuric Acid and Sulfuric Acid Reagent" and Dr. Deshpande a paper on "Effect of Ionizing Radiation on the Activity of Pectin Methyl Esterase". Dr. Koo attended as an official participant the FAO/IAEA Symposium on the Nature, Induction, and Utilization of Mutations in Plants in Pullman, Washington and delivered a paper on "Potential Use of Target Atom Irradiation in Control of Mutation Induction" (July 14-18). Dr. Koo attended the Symposium on Neutrons in Radiobiology in Oak Ridge (November 11-14) and subsequently he was invited to participate in the FAO/IAEA Research Coordination Meeting on the Use of Seeds as Biological Monitors for Neutron Irradiations in Knoxville, Tennessee (November 17-20) where he presented a paper on "Effect of Fast Neutrons and Gamma Rays on Seedling Growth and Malate Dehydrogenase Isozyme Pattern in Soybeans".

Lab technician Carmen Lydia Rodrĩguez transferring insect, in the Induced Sterility of Insects program.

Dr.David D. Walker, head of the Induced Sterility of Insects Program, in his office at PRNC Mayagüez.

INSECT STERILITY PROGRAM

The sugarcane borer, *Diatraea saccharalis* (Fab.) (Lepidoptera, Crambidae) causes serious destruction to gramineous crops in the new world and in parts of Asia. Principal crops damaged are sugarcane, maize, sorghum, rice, citronella and lemon grass, and pasture grasses. Loss of sugarcane in Puerto Rico is in the range of $2.5 million annually. Total world loss is on the order of 100 to 200 times this value.

The original purpose of this program was to determine if steriles could be used to overflood the natural population so that the species could be eradicated from Puerto Rico and other cane-producing areas. Adult males can be effectively sterilized without adversely affecting mating behavior by exposure to 27 kr. of gamma radiation. Females can be sterilized at 25 kr. These data are being confirmed under natural conditions in field tests at the UPR Mayagüez campus.

One of the greatest problems inherent in this method is the high cost of mass-producing the insects. Efforts to develop cheaper diets and more efficient rearing methods have not been successful in reducing production costs to a practical level (less than $30./million adults).

IPS: One alternative is the introduction of lethal factors into the natural population by releasing laboratory-reared adults that have been given a substerilizing dosage of gamma radiation. This method has been under investigation at PRNC during the past four years. It has the advantages of much reduced cost (about one tenth the cost of a mass-release of sterile adults), because fewer individuals would need to be raised, sterilized and released. Surveillance, regulatory and quarantine costs would also be slightly less. We have called this inherited partial sterility (IPS).

This phenomenon has been observed in other lepidoptera, including the cabbage looper, the codling moth and navel orange worm. It is thought to be related to the nature of the lepidopteran chromosome. These chromosomes are holokinetic, as opposed to the monokinetic chromosomes that are found in most other animals and plants.

Using the sugarcane borer, we have confirmed in three series of laboratory experiments that IPS has the potential to suppress population. In the first series, outbreeding to the F_2 confirmed our preliminary test that lethal factors are inherited. In the second series of experiments four types of treatments were made. Adults of the P generation were irradiated and the following lines were established: (a) both parents irradiated and inbreeding four lines were established that sibling matings in each successive generation; (b) both parents irradiated and the successive generations were outbred to non-siblings of similar treatment in the P generation; (c) the male parent was irradiated and his offspring were outbred in successive generations. Each line was established at 4 dosage levels: 2 kr, 4 kr, 6 kr and 12 kr, using the Puerto Rican strain of *D. saccharalis.*

The results of these tests indicated that: (1) females could not transmit lethal factors for over two generations at the dosages used, i.e. the females themselves were victims of the lethal factor that they were transmitting; (2) inbreeding had the greatest effect, and concentrated the lethal factors to such an extent that populations could not be perpetuated; (3) the outbred lines from male and females could maintain themselves through the male offspring

Lab technician Carmen Lydia Rodrĭguez prepares diet for insects.

Container with sugarcane borer insects in the PRNC lab.

to the eighth generation (F_7).

In the third series of tests only outbreeding was practiced using one irradiated parent in the P generation. The Louisiana strain of these species was used on a wheat germ diet. Three dosages were used: 2, 6 and 12 kr. These lines were outbred to the F_7. Results were similar to those obtained in the second experiment.

Rearing: Improved vial washing methods are being developed, but even these improvements will not be adequate for solving the problem of mass-rearing i.e. one hundred thousand or more adults per day.

Improved rearing methods included testing disposable one-ounce medicine cups as rearing containers. These are sterile, and have snap-on recessed cardboard lids. Formerly they were not suitable because the larvae escaped by tunnelling through the sides and tops. These cups were surface-sterilized with 70% alcohol before use. With the wheat germ diet, tunnelling through the sides was less than with the PRNC diet. However there were escapes through the lids. Larvae apparently migrate to the lid due to moisture condensation and to air leaks in the cap. Further tests are in progress to solve this problem, principally by coating the lids with paraffin wax before using. If this is successful we may have a much superior rearing method since we can eliminate the time-consuming vial washing operation.

Bacterial contamination of diet was traced to three organisms: the fairly common *Escherichia* and *Proteus* and an unidentifiable spore-forming gram positive bacteria. Contaminated wheat germ and contamination of larvae themselves are the major sources of the infection. A more rigid protocol is being followed whereby the vials, dry ingredients, and eggs are all sterilized before use. Vials and dry ingredients are sterilized by autoclave. Eggs are surface-sterilized by a prehatching wash with 70% ethanol or 0.1% solution of mercuric chloride. Egg hatch is reduced by this treatment.

Lipid study: Lipid content and quality were assayed in larvae of IPS line of the F_6 and compared with larvae and pupae from normal lines. Third and fourth instars and two day pupae were used in this experiment. After macerating, lipids were extracted with chloroform-methanol and separated by the method of Wood and Snyder.

Total lipid content was equal in the two lines, i.e. IPS versus normals. Phospholipids were higher in normal pupae than in normal larvae. On the basis of total lipids it appears that there are some small qualitative differences in lipid between IPS and normal lines.

Field tests: Preliminary population surveys on the Island of Vieques are being continued by Dr. Sanford of the USDA. He is using traps based on the attractant of female phermone as well as light traps. Five surveys have been made during the past year. He estimated that there were 77 male moths per day emerging in February, 25 in April, 30 in May, 28 in September, and 7 in December. This survey will be continued if funds are available. Additional information and funds will be necessary before a trial eradication program based on integrated control can be started in Vieques.

Dr. Raymond A. Brown uses the spectrophotometer to analyze sucrose density gradient at the Medical Sciences and Radiobiology Division lab in the Bio-Medical Building.

MEDICAL SCIENCES AND RADIOBIOLOGY

The Medical Sciences and Radiobiology Division offers training and research opportunities in fundamental nuclear energy aspects of biology, radiation biology, biochemistry, molecular biology, virology, and medicine. Research is directed in large part toward biological problems encountered in tropical areas such as Puerto Rico. Facilities include a tissue culture unit, an animal house containing a mouse colony and a snail colony, a biochemistry laboratory and other modern equipment and laboratory facilities.

This report covers educational, training, and research activities involving Division personnel. Also included are projects sponsored by the AEC Division of Biology and Medicine:

1. Studies of the host-parasite relationship in Schistosomiasis;
2. Radiation activation of latent virus in wild arthropods and vertebrates;
3. Radiation effects on the host-parasite relationship in *Trypanosoma cruzi* infections.

Other research projects include the study of *Fasciola hepatica* (cattle liver fluke), and radiation effects at the cell and molecular levels (the effects of Poly I-C, an inducer of interferon).

EDUCATIONAL ACTIVITIES

During 1969 the following courses were offered:

a. Tissue culture and radioisotopic techniques at the cellular level. Offered under the direction of Dr. Ramiro Martínez-Silva. Participants were: Dr. Reinerio Rodríguez-Fernández (Spain); Dra. María Arazi Medeiros (Uruguay); Miss Tanya Druck (USA).

b. Graduate course in virology. Sponsored by the UPR School of Medicine's Department of Microbiology and offered at PRNC under the direction of Dr. Julio I. Colón. The participants, all from Puerto Rico, were: Mr. Jaime L. Cancel Lugo; Miss María Santaella; Mr. Carlos R. Lao Vélez; Mr. Jorge L. Suria Colón.

c. PRNC 510, Radiation Biology. Given for academic credit by Doctors Jorge Chiriboga, Ramiro Martínez-Silva, and José N. Correa. The students were: Mr. Angel R. González Arvelo (Puerto Rico); Mr. Juan Angel Gil Borgos (Puerto Rico); Mr. José E. Pacheco (Puerto Rico); Mr. Ricardo F. Gerdingh Landin (Mexico); Mrs. Agness Weiss (Israel).

d. PRNC 515, Radiation Effects on Mammals and Humans. Given for academic credit by Doctors Jorge Chiriboga, Ramiro Martínez-Silva and José N. Correa. Participants were: Mr. Aquiles Santana (Colombia); Mr. Ramón Cruz (Puerto Rico); Mr. Daniel Torres (Puerto Rico); Mr. Luis Rodríguez (Ecuador); Mr. Heriberto Torres (Puerto Rico).

e. Special course in Virology, taken by Miss Tanya Druck (USA).

f. Special seminars on Molecular Biology (from October 16 to November 25, 1969). The following Puerto Rican students from the Biology course of the UPR participated (Under Dr. Jorge Chiriboga's direction.): Mr. Carlos B. Pagán; Mr. Antonio Alegría-Gandía; Miss Norma Cruz; Mr. Antonio G. Sotomayor.

g. Thesis research

Dr.Roger Ramos-Aliaga, a predoctoral student from Perú, finished his thesis in the PRNC Medical Sciences and Radiobiology Division, under Dr. Jorge Chiriboga, advisor. He was awarded a doctoral degree in biochemistry by the National University of San Marcos, Lima, Peru, on September 1969. He is continuing his studies at PRNC as a post doctoral fellow.

Mrs. Carmen M. Rivera passed the thesis oral examination for the M.S. degree in Microbiology. Her thesis is entitled "Effect of Gamma Irradiation on Interferon Production in Chick Embryo." Thesis research was directed by Dr. Julio I. Colón.

Mr. Gualberto L. Borrero, a graduate student in virology, started his thesis research for the M.S. degree in virology under the supervision of Dr. Julio I. Colón. His thesis is entitled "The Effect of Gamma Irradiation on Rats Actively Immunized with Sindbis, Wild Strain. Reactivation of the Latent Virus by Means of Radiation."

COOPERATIVE TRAINING AND RESEARCH

Assistance is given to other PRNC programs and divisions, especially those that are medically oriented. Cooperative research and training programs are maintained with the following institutions and agencies:

1. Division staff members assist in the teaching activities of the following PRNC divisions: Physical Science, Health Physics, and Clinical Applications.

2. School of Medicine, UPR:

   a) Department of Microbiology - Dr. Julio I. Colón, Virologist, continues as and "ad honorem" member of the PRNC staff and as Associate Professor of the School of Medicine.

   b) Department of Parasitology - The exchange of information and biological material with this department has been continued. Dr. Lawrence S. Ritchie continued as lecturer in this department.

   c) Department of Biochemistry and Nutrition - Dr. E. Toro Goyco, Professor of Biochemistry and Nutrition, continued to study the biochemistry of *Schistosoma mansoni;* he is receiving help from the Division.

   d) Dr. Jorge Chiriboga, Professor of Biochemistry (ad honorem) at the School of Medicine, has lectured at the Department of Biochemistry and continues as member of the Graduate Committee of the Medical Campus.

3. U.S. Public Health Service. Cooperation on schistosomiasis research with the group headed by Dr. Frederick Ferguson, from the Tropical Disease Section of the U.S. Public Health Service in San Juan, has continued. The work on schistosoma cercariae labeled with Se^{75} to study the cercariophagic activity of guppy fish in the laboratory and field conditions is in progress. It is hoped that these studies will eventually contribute to the better understanding of the ecology of this disease. Mrs. Wilda B. Knight continues as an "ad honorem" member of the PRNC staff.

4. Veterans Administration Hospital. Dr. Rafael Menéndez-Corrada, Associate Chief of this Hospital, and members of our Division continue a time lapse cinematography project on the penetration and development of *T. Cruzi* in DC_2 cells developed in our laboratory which began in 1968. Dr. P. Crosby, of this Hospital, is conducting research on xanthene-oxidase in mice infected with normal and irradiated cercariae provided

by PRNC. Doctors Jorge Chiriboga, Raymond A. Brown and Lawrence S. Ritchie comprise a study group of the Hospital.

5. P.R. Department of Agriculture. The Division is engaged in research on *Fasciola hepatica*, one of the most important parasitic problems in Puerto Rican and South American agriculture. This year our laboratory staff collaborated with the Department of Agriculture on this problem. In the future it is expected that there will be a joint effort to understand this disease and to develop methods to control it. A research proposal will be submitted this year to the USAEC Division of Biology and Medicine on *Fasciola hepatica* in which we propose to use radiation to improve our understanding of immunity of this disease and isotopes to study the biology of the snail and population dynamics of the vector.

6. UPR Agriculture Experimental Station. In November 1969, an agreement was made with the UPR Experimental Station by which Dr. Delfin D. de León, a Veterinarian with a Master's Degree in Parasitology and experience in *Fasciola hepatica* research, has been working full-time in this program as an "ad honorem" member of this Division during the present fiscal year.

7. Pan American Health Organization. This Division is one of the few institutions which systematically applies radiobiological techniques in parasitology, and which collaborates with other groups in Puerto Rico and abroad. For these reasons; we are proposing the creation of a multinational center in Puerto Rico for training and research. Dr. Jorge Chiriboga, Head of this Division, has initiated meetings with groups in Brazil, Peru, and the Pan American Health Organization. Such a center will provide a focus for the programs of parasitic diseases in the underdeveloped countries.

8. National Institutes of Health. We have started a cooperative program with Doctors Baron and Levy of the Laboratory of Biology of Viruses of the National Institute of Allergy and Infectious Diseases of the National Institute of Health, in Bethesda, Md., in which we shared information on the effect of polynucleotides and interferon inducer on American trypanosomiasis in cells and in animals. A paper with the results of this cooperation has been released for publication.

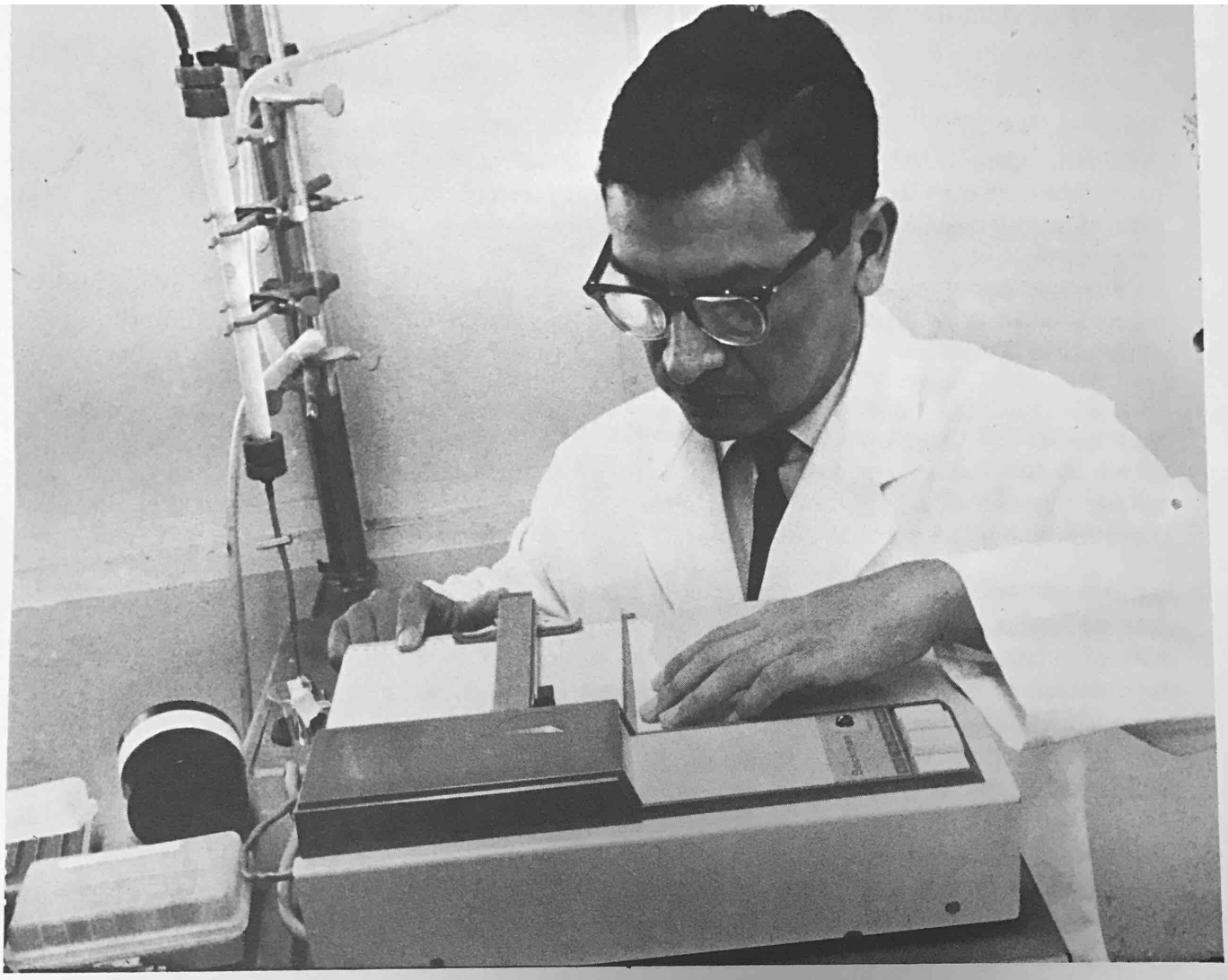
9. Brookhaven National Laboratory, New York. A cooperative program has been started with Dr. Leonard Hamilton, Head of the Department of Microbiology of the Medical Division of the Brookhaven National Laboratory. Tests have been made on the effect of polynucleotides prepared by Doctor Hamilton on parasitic diseases, such as *T. cruzi* in cells and in mice and *Schistosoma mansoni* in mice.

10. Columbia University and the Perinatal Department of the National Institutes of Health. In a joint cooperative program with the Perinatal Department of the NIH , Dr. Laslo Z. Bito, Professor of the College of Physicians and Surgeons of Columbia University, used our facilities in a study of analytical measure of cations in the development of brain barriers.

RESEARCH ACTIVITIES

Reports follow on the five research projects carried out under the auspices of the Medical Sciences and Radiobiology Division:

(1) Radiation Effects at the Cell and Molecular Levels; (2) Schistosomiasis; (3) Fascioliasis; (4) Radiation Activation of Latent Viruses; and (5) Trypanosomiasis.



Dr. Roger Ramos Aliaga uses the spectrophotometer to determine the spectrum of double strand polynucleotide solutions formed with different ions.

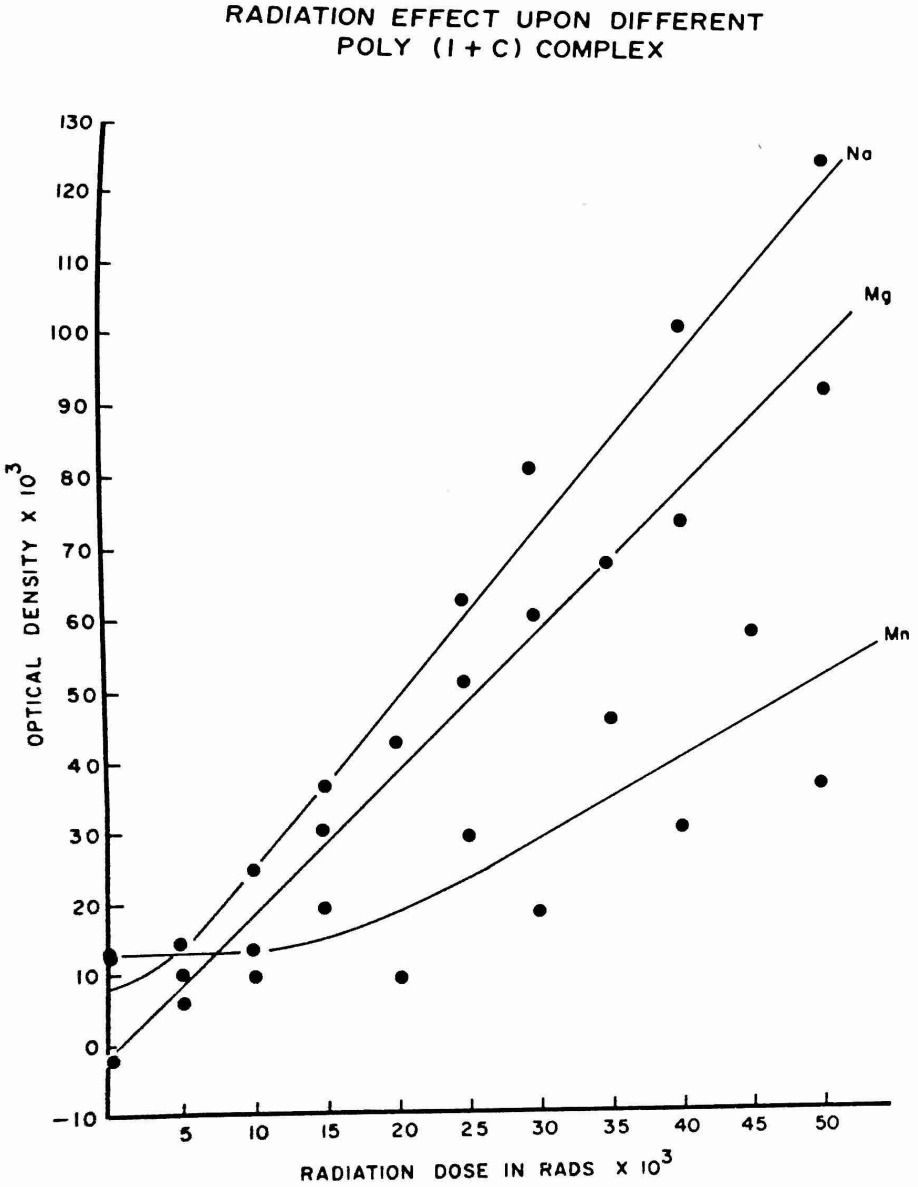
RADIATION EFFECTS AT THE CELL AND MOLECULAR LEVELS

Effects of Poly I-C, an Inducer of Interferon. The action mechanism of Poly I-C in the induction of interferon and the effect of irradiation on the production of interferon are not known. Poly I-C has been irradiated to learn about molecular changes connected with interferon induction.

Double stranded Poly I-C has been prepared in the presence of various metallic ions: Na^{+}, K^{+}, Li^{+}, Mn^{++}, Mg^{++}, etc. The double stranded polynucleotides had different radiosensitivities, depending upon the metallic ion present, with the manganese solution showing the least radio sensitivity.

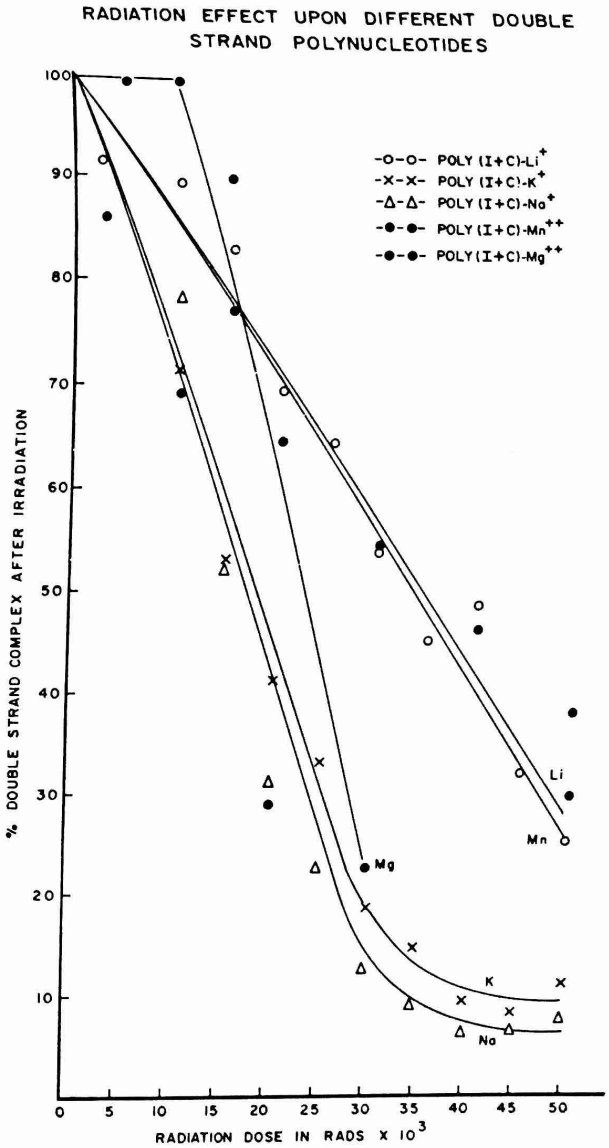
Furthermore, these solutions have different abilities to produce interferon in L cells. We are analyzing this effect at the molecular level by means of Tm determination, molecular sieve chromatography, paper chromatography, thin layer chromatography, sucrose gradient centrifugation, spectrophotometry, etc.

Fig. 1



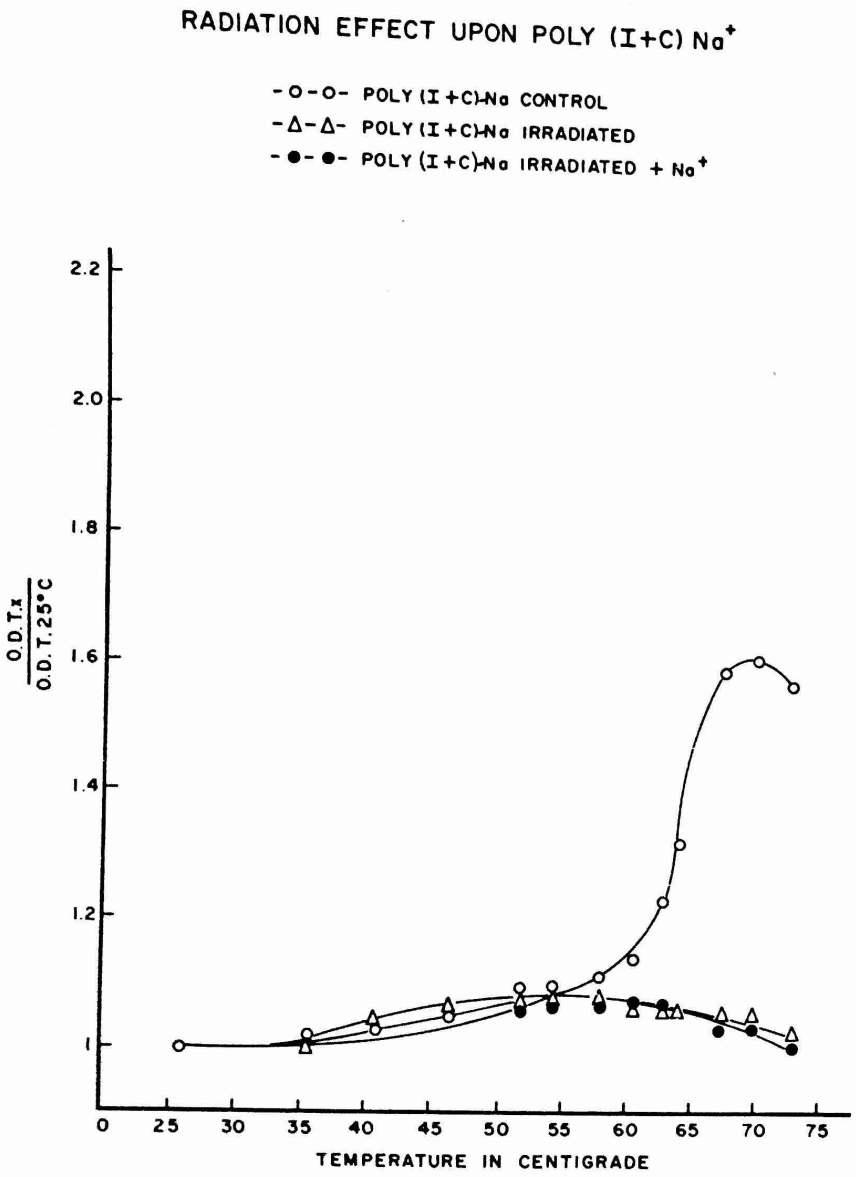
Gamma radiation effect upon solutions of Poly(I+C) complexes with different ions (Mg^{++}, Mn^{++}, and Na^{+}). Changes were evaluated at 248 and 275 mu and expressed as differences in optical density. A lesser radiosensitivity of Poly (I+C)-Mn^{++} is noted. A Co^{60} source was used at 3930 rads/min.

Fig. 2



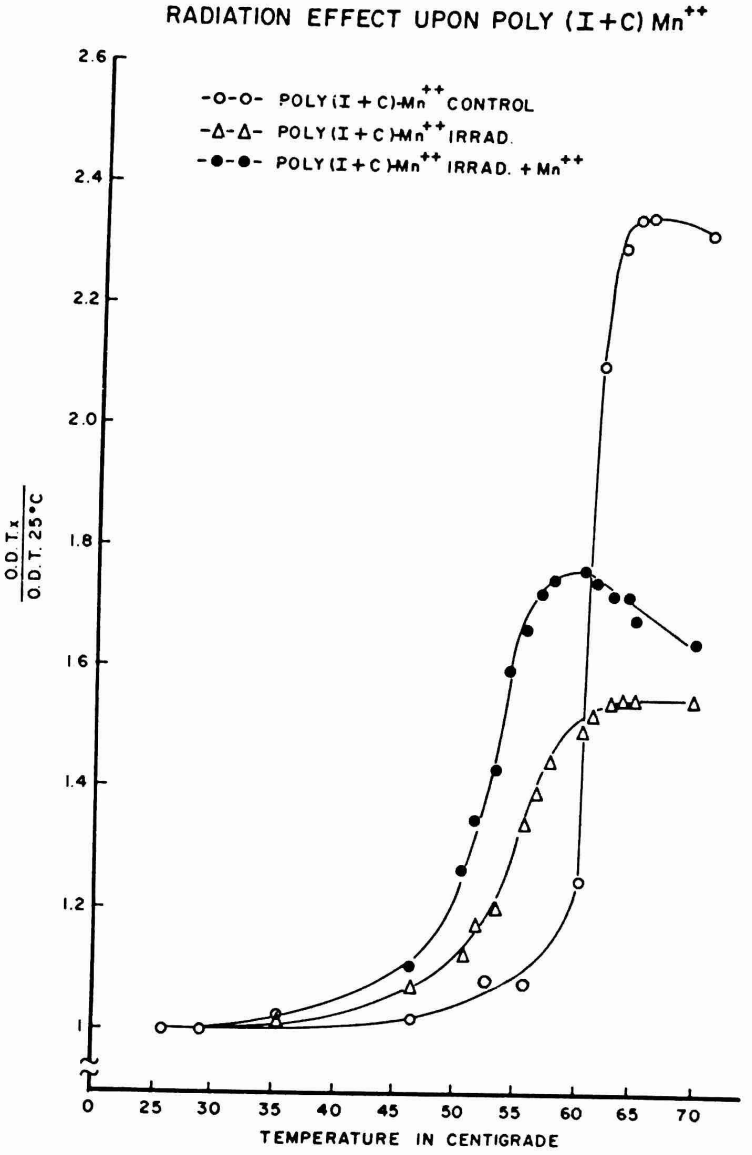
Different polynucleotide complexes formed with different ions (Mn^{++}, Mg^{++}, Na^{+}, Li^{+}, K^{+}) show different rates of radiosensitivity to gamma radiation. Lesser radiosensitivity of Poly (I+C)-Mn^{++} and Poly (I+C)-Li^{+}.

Fig. 3



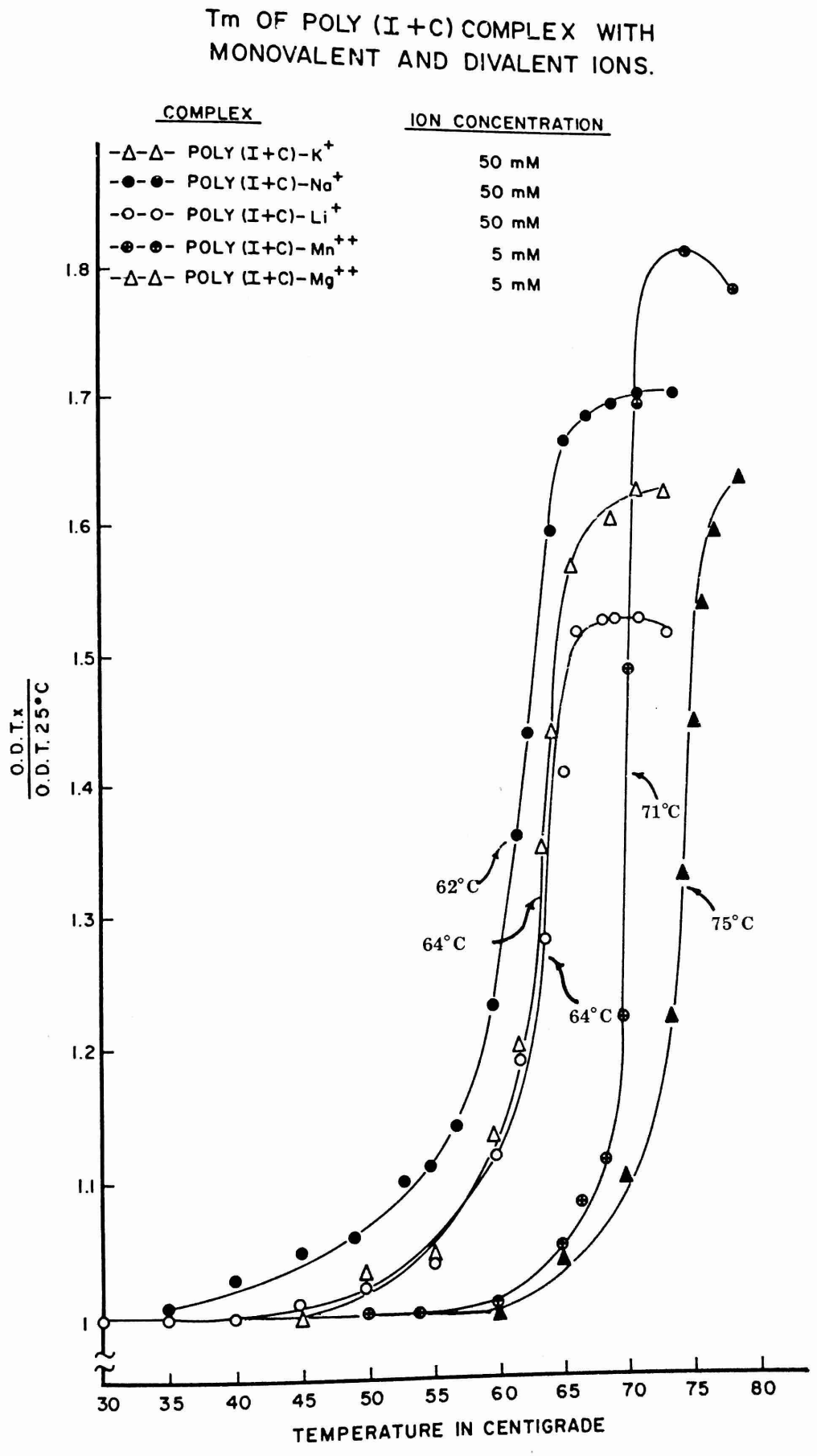
Radiation effect upon Poly (I+C)-Na^+. Gamma radiation dose was 100,000 rads. In order to check the damage of radiation on the double-strand complex, Na^+, was added until 100 mM concentration was obtained, and we next checked the amount of double-strand complex in relation to a control in same ion concentration.

Fig. 4



Radiation effect upon Poly (I+C)-Mn^{++}. Gamma radiation dose was 100,000 rads. In order to check the damage of irradiation on the double-strand complex, Mn^{++} was added until a 10 mM concentration was obtained and we next checked the amount of double-strand complex in relation to a control in the same ion concentration.
(Observe the difference between Poly (I+C)-Na^+ and Poly (I+C)-Mn^{++}, figure 3 and figure 4)

Fig. 5



Tm of Poly (I+C) complex with different cations. Changes were measured at 248 mμ in Beckman Instrument Model DU with Gilford attachment and thermo regulator of circulating water bath. The ratio of optical density at different temperatures (Tx) and optical density at 25°C ($T_{25}°C$) ($\frac{ODTx}{ODT_{25}°C}$) was plotted in abcisse versus temperature in cell.

SCHISTOSOMIASIS

Schistosomiasis, a parasitical disease transmitted by a snail, is a worldwide health problem which infects millions of persons. It is particularly serious in Latin America, and in some areas of the Caribbean, including Puerto Rico. This research project uses radiation and radioisotopes to help understand the natural history of schistosomiasis. Emphasis has been given to the immunological mechanism, and to biological control of the disease.

A. Quantitation of the ingestion of newly-hatched *Biomphalaria glabrata* snails by guppy fish (*Lebistes reticulatus*), using Radioselenium. We have quantitated this phenomenon under laboratory conditions by counting the number of snails that had been tagged with radioselenium (^{75}Se).

When male and female fish of varying sizes were fed radioactive snails, the juveniles were only slightly active, while males and females of 13-17 and 18-27 mm in length were equally radiated at a relatively low level. Females of 23-27 mm were 4-5 times more active than males of this size. It was found that snails over 1 mm in diameter were not eaten by the guppies. Marisa snails, the potential bug snail used for control of Biomphalaria, are so large they cannot be eaten by the fish at hatching.

We showed that guppy fish will consume large numbers of cercaria under laboratory conditions. The current finding gives the guppy a second possible role in the biological control of schistosomiasis.

B. The effect of whole-body radiation ^{60}Co on the host parasite relationship between mice and Schistosoma mansoni. In mice simultaneously exposed to *Schistosoma mansoni* and irradiated with 400 R, the resulting worm burden and worm sizes are unaffected. This work was replicated in 1969 using repeated exposure to radiation worm recovery rates and worm sizes were essentially the same for irradiated and non-irradiated mice. Moreover, the number of eggs in the liver and intestine do not appear to be affected. The experiment on the effect of radiation on granulowater formalin is also being repeated.

The sera from irradiated and non-irradiated mice infected with *Schistosoma mansoni* were tested with the circumoval and slides floculation serological procedures. Of 27 non-irradiated, 22 were positive with the COP (81%) while 15 of 27 non-irradiated mice were positive (52%).

C. Effect of Schistosoma mansoni infection on susceptibility to radiation. Present experiments show changes in the susceptibility of infection during radiation. Experiments are in progress to determine this point. So far we found that normal mice of our colony have an LD_{50} of about 700 R. Infected animals are being studied for changes in LD_{50}.

Cellular immunity against Schistosoma mansoni: Humoral immunity per se is virtually excluded as a basic mechanism of immunity against Schistosomiasis. Until recently little attention was given to the possibility of cellular immunity against this infection. Many experiments in vivo and in vitro were made. No conclusive results were obtained this year.

D. An attempt to demonstrate immunity in Schistosoma mansoni infected mice by passive transfer. Dr. Ritchie has developed a partial immunity in *Schistosoma mansoni*—infected mice by multiple injection of a small number of cercariae.

We have attempted to transfer immunity from these and infected mice by the use of spleen and mesenteric lymph node cells.

Table 1 shows the results of two experiments in which one mouse equivalent of cells was transferred and followed by an immediate challenge with 100 cercariae. Mice were sacrificed 6 weeks later and worms counted.

Table 1

Cells Transferred	Samples of Worms Recovered	S. D.	S. E.
	Experiment I		
Spleen cells, normal mice	57.4	29.45	4.81
Spleen cells, immune mice	81.6	34.05	13.88
Spleen cells, infected mice	101.0	24.70	8.20
No cells	67.1	19.09	6.35
	Experiment II		
Spleen cells, normal mice	17.5	11.4	4.31
Spleen cells, infected mice	26.9	10.7	3.10
Mesenteria node cells, normal mice	28.4	10.7	2.86
Mesenteria node cells, infected mice	32.5	16.9	4.65
No cells	21.7	11.4	4.31

There is no protection of the mice by the transferred cells; in fact, there is an enhancement of the infection significant at the 1% level. Preliminary experiments also suggest that the number of worms recovered can be enhanced by the transfer of serum from infected mice. Attempts are being made to characterize the active fraction.

Labeling experiments with normal and infected mice using C^{14} leucine and glucosamine as precursors established that the infected mice are synthesizing proteins at twice the normal rate. Ultracentrifugal and electrophoretic analysis show that qualitative differences in the synthesis of carbohydrate containing proteins by normal and infected mice. The infected mice are packing an active response to the infection but the net result does not appear to be an effective immunity.

E. The effect of snail hemolymph upon the Schistosoma mansoni in mice. The observation of Oliver-González that mice could be cured of *Schistosoma mansoni* infection by snail hemolymph was confirmed in the laboratory.

However, when we studied the in vitro effect upon the parasite of snail hemolymph, specifically the utilization of glucose labeled with C^{14}, we observed, in contrast with the control without hemolymph, many radioactive metabolites that made us suspect that glucose was metabolizing via pentose shunt, in addition to the lactic acid pathway. This led us to find that the hemolymph used in these experiments contains not only soluble protein but bacteria cells, and fungi. In many experiments, with erratic results, it appeared that bacteria on cells were the curative factors.

Bacteria was cultivated from hemolymph of wild and laboratory raised snails. From the first group we cultivated *Escherichia coli*, one specie of aeromonas, an alcaligenes fecales and a hemolytic micrococcus. When the bacteria (*Escherichia coli* and aeromonas) at 6 x 10^8 were inoculated in mice infected with schistosomiasis, the animals were killed in 24 hours.

From the laboratory snails, we isolated 2 species of proteus and a *Klebsiella* neumonies. Mice infected with this bacteria produced infection of the worm and a lethal effect and granuloma piogenes of the liver where the death of the parasites was reported.

Bacteria obtained from worm and granuloma after infecting hemolymph were recovered and reproduced the effect when isolated and injected pure into other schistosomiasis-infected animals.

Table 2

The effect of unaltered hemolymph on Schistosoma mansoni in mice.

Trial No.	Regimen ml x days	Days effective[2]	No. mice	Worms/mouse: reduced[3]	none	mean	Oogram altered (mice/No. examined)
1	0.1 x 5	19	5	4/5	0	14	4/5
	controls[1]	--	7	1/7	0	58	0/5
2	0.05 x 5	10	7	0	0	54	0/5
	controls[1]	--	8	0	0	86	0/5
3	0.05 x 5	27	12	8/12	3/11	10	8/10
	controls[1]	--	13	0	0	46	0/10

[1]—Controls injected with Hanks' solution
[2]—Interval between last injection and necropsy
[3]—Worms reduced by 75%

Table 3

The effect of filtered hemolymph (millipore 0.22 μ) on Schistosoma mansoni in mice.

Hemolymph	Regimen ml x days	Days effective[2]	No. mice	worms/mouse reduced[3]	none	mean	Oorgam altered Mice/no. examined	Trial No.
whole	0.1 x 5	27	8	2/8	0	31	4/8	
filtered	0.1 x 5	27	10	0/10	0	40	0/10	1
control[1]	—	—	6	0/6	0	42	0/6	
filtered	0.05 x 3	28	11	0/11	43	—	ND	2
control[1]	—	—	10	0/11	43	—	ND	

For footnotes see Table 2

Table 4

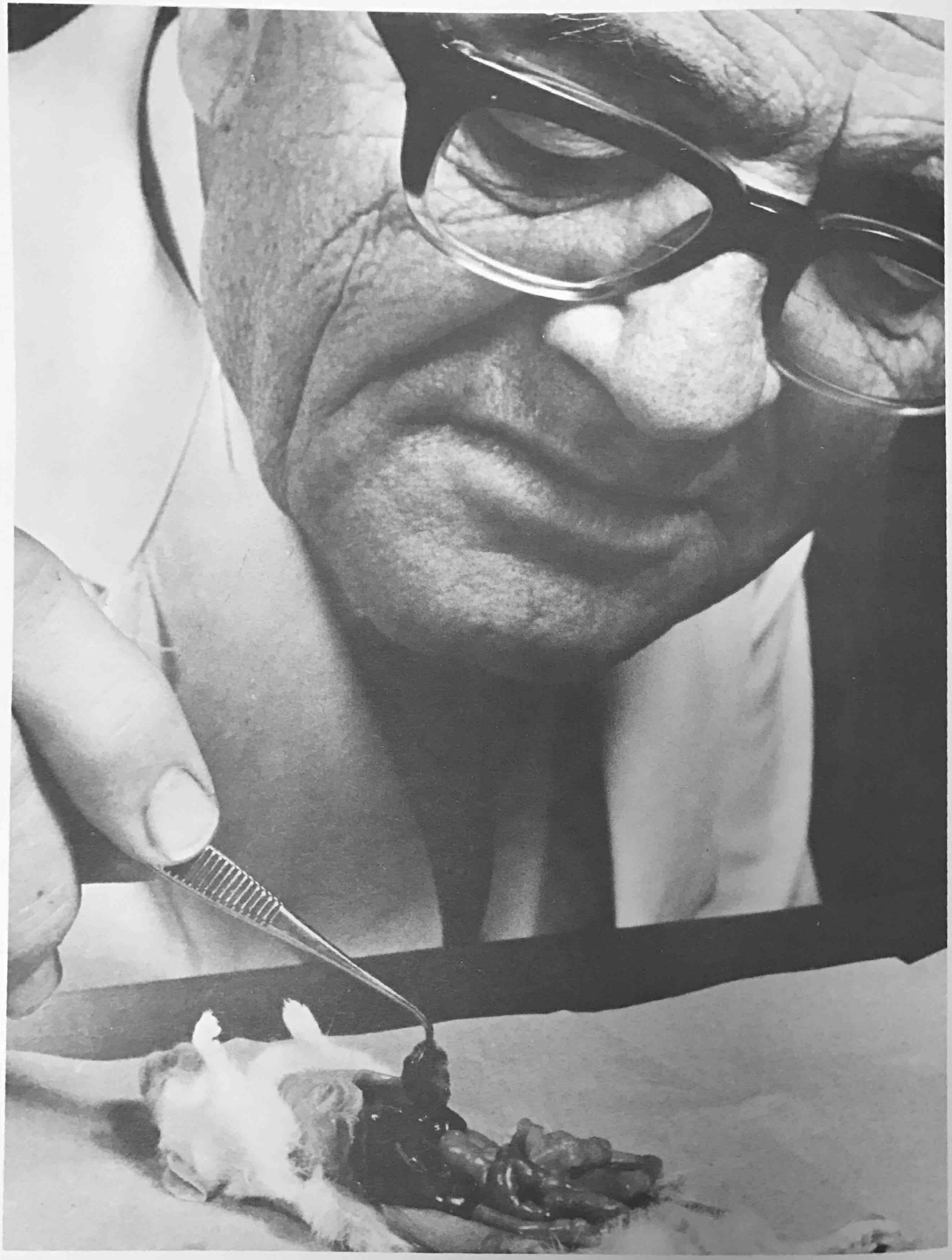
Effect of bacterial isolates from hemolymph on S. mansoni infections in mice[1]

Bacteria injected	No. of mice injected	Mean worm/mouse	No. of mice free of worms	Oorgam altered (No. of mice)	Bacterial Isolates from: worms (No.mice)	abscesses (No.mice)
Proteus mirabilis $(H)^2$	7	0.9	3	7	2*	7
Klebsiella pneumoniae $(S)^3$	6	5.4	2	4	2**	4
Ibid $(H)^2$	8	25.1	0	0	0	0
Untreated controls	6	18.2	0	0	0	0

[1] Infections of *S. mansoni* were 6 weeks old when treated and necropsies were made 28 days later.
$(H)^2$=Isolates from hemolymph, $(S)^3$=from unknown source.

± No abscess in 2 mice.

* Insufficient worms for culture in 2 mice; ** No bacteria from worms in 2 mice.



Dr. Ritchie removes a *Fasciola hepatica* worm from a dissected experimental mouse.

FASCIOLA HEPATICA

Fascioliasis (cattle liver fluke) causes millions of dollars in damage yearly in Latin America, and in Puerto Rico. Surveys show that it has also infected an appreciable number of humans. The Puerto Rico Nuclear Center is cooperating with the Pan American Health Organization in seeking ways to combat this disease, which is transmitted by a snail.

Our studies in progress include: (1) development of an effective laboratory cycle; (2) characteristics of the snail vectors; (3) population dynamics of the vectors; (4) natural occurrence of infection in the snail; and (5) epidemiological aspects of fascioliasis in one large herd of dairy cows.

A laboratory cycle of *Fasciola hepatica* was established involving two species of lab-research snails, and the mouse as the definitive host.

Two known vectors of *F. hepatica* occur in Puerto Rico: *Lymnaea columella* and *L. cubensis*. There are distinctive shell features; the maturation time (from hatching to egg laying) was shorter for *L. cubensis*, and *L. columella* attains a larger size before the onset of laying. Incubation time for the eggs of *L. columella* was about 10 days.

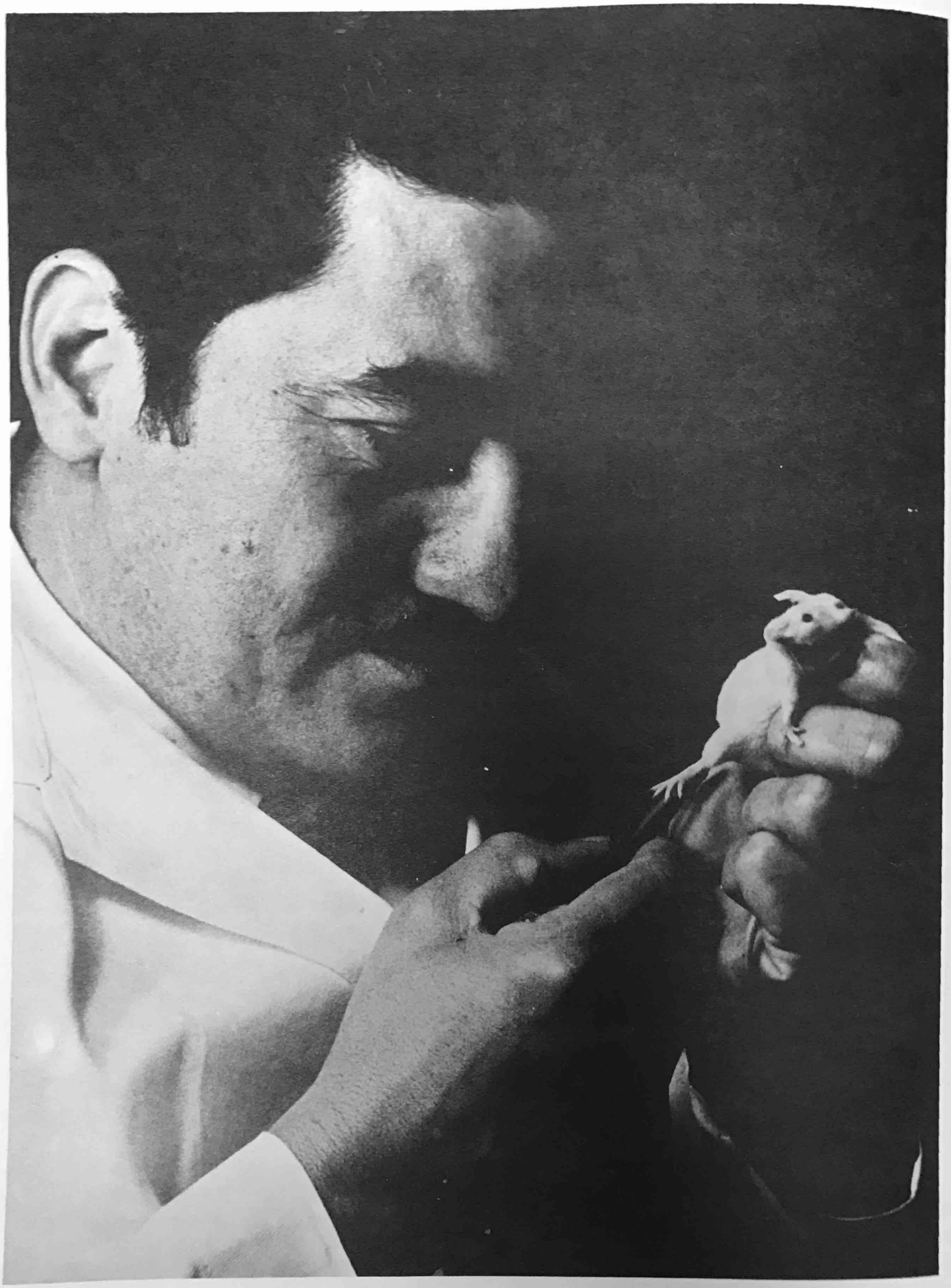
Periodic sampling of snail population has been started in a swamp habitat where both vectors occur. Standard samples of mud are taken from 18 collecting points (on a grid). The samples are diluted with water and passed through a series of sieves to recover the snails. Also, samples have been collected around each collecting point on the basis of time. Each method of sampling has merits and disadvantages, and they will be used for complementary benefits.

To date, 121 *L. columella* and 111 *L. cubensis* have been collected; 6% and 22%, respectively, were infected with *F. hepatica* in varying stages of development. It appears that the two snail species may not be equally effective in transmission of the infection. This is being studied by experimental exposures of snails of varying ages.

Infections in cattle have been detected by using an ether sedimentation procedure that was developed for recovery of schistosome eggs. With some modifications, the technique appears quite effective and egg counts per ml (1 gram) may provide a means of quantitating the intensity of infection. Experimental evaluations of the technique are being made.

To date, 71 cows from one herd have been examined; of these, 60 (85%) were positive, with egg counts ranging from 1-185 eggs per ml of feces (mean of 27 eggs for positives). The negative cases appear to be heifers that were recently added to the herd. Attempts will be made to see if egg counts can be interpolated as numbers of mature worms.

The dairy farm under study has 3 sections, one with about 150 milk cows, a second with about 300, while the third section provides "under roof" care for female calves until they are 20 months old. After insemination, the heifers are pastured separately until parturition and then are placed with one of the two milking herds. A complete history of each cow is kept, affording correlations of information for an epidemiologic study.



Dr. Colón inoculates a white mouse with a virus sample.

RADIATION ACTIVATION OF LATENT VIRUSES IN WILD ARTHROPODS AND VERTEBRATES

This project studies the impact of irradiation on virus infections. In PRNC's ecological studies of a tropical rain forest, it was observed that rats which inhabited a small irradiated portion of the forest became sick and died. The project seeks to find the mechanism of the host-parasite relationship, and in doing so answer fundamental questions in virology, particularly the latency of viruses(especially arboviruses, which are most common in the tropics).

A. Effect of Gamma Irradiation on the infection of mice and rats with coxsackie virus. Adult white mice are normally resistant to coxsackie virus infection, but when they were exposed to whole body gamma radiation and inoculated with coxsackie virus the blood and organs of these animals consistently showed a high concentration of virus; the concentration was directly proportional to the radiation dose (For details see Annual Report 1968).

Experiments with adult rats showed very similar results to those obtained with adult white mice. In all the animals tested the viremia increased with the radiation dose. However, when the rats were irradiated with 800 rads the animals showed a very low titer viremia that lasted for 7 days.

B. Activation of Coxsackie virus by radiation.

1. In Adult Mice. Mice irradiated and inoculated with 10^6 LD_{50} suckling mice coxsackie virus showed a viremia that lasted for several days, depending on the radiation dose. No viral activity was found in animals that were inoculated but not irradiated, or those that were irradiated, but not inoculated. After 25 days of infection, antibodies were found in the serum of inoculated animals, whether they were irradiated or not. No viral activity was found in the blood or in a selected group of organs of animals from these groups that were sacrificed. Thirty days after irradiation and inoculation, the surviving mice received a second dose of 400 rads. 24 hours later, the animals were bled, sacrificed and selected organs were harvested. Virus was isolated in the animals' spleen, heart, pancreas and liver. Only the original virus coxsackie virus Type A-10 was isolated. The important point here is that after a treatment with radiation, virus was isolated from mice whose organs previously showed no virus. Either the active virus was present in very low concentration, and could not be detected by our methods or the virus, in a "latent" state, was activated by the radiation.

2. In Rats. Similar experiments were performed with three different species of rats. The non-irradiated adult rats, regardless of species, when injected with coxsackie virus had a very low titer viremia for 24 hours; the virus disappeared from the blood and organs, and antibodies in the serum were detected after 15 days. Adult rats, regardless of the species, when irradiated with 400 or 800 rads, showed a viremia that lasted for 6 to 8 days, and antibodies were detected by the 15th day. No virus was isolated from the blood or organs of rats sacrificed 30 days after infection. A second radiation dose (800 rads) was given on the 31st day after animals were injected. The non-irradiated rats that were injected with the virus, were then irradiated (800 rads). As in the case of mice, we could again isolate

active virus from the pancreas and liver of rats of all species, which previously showed no active virus. This again indicates radiation activation of latent infection.

C. Isolation of virus from Immune Animals after Gamma Irradiation.

1. Immune adult mice. Non-irradiated adult mice could be immunized with coxsackie virus by inoculating intraperitoneally on three occasions at 7 day intervals. When these animals were irradiated with 400 rads 60 days after the last inoculation, active virus was isolated from the spleen and pancreas.

2. Isolation of virus from immunized animals with antibodies still present in the serum. Active virus was isolated from irradiated immunized animals with antibody present in the serum. No virus was isolated from immunized non-irradiated animals with antibody in the serum. No virus was isolated from irradiated immunized animals with no antibody in the serum. No virus was isolated from immunized non-irradiated animals that showed no antibody in the serum. It was concluded that coxsackie virus antibodies must be present in the mice or rat serum in order to obtain active coxsackie virus by radiation. This could indicate that viruses which confer a long-lasting immunity remain in a "latent" state in the animal.

D. Effect of radiation on the antibody titer of immune mice and rats.

1. Effect on the circulatory neutralizing antibodies of immune rats. Baby rats were immunized by inoculating intracerebrally at birth or before 24 hours of age. On the 18th day after infection, serum collected from these animals showed antibodies against coxsackie virus, but no active virus could be recovered. On the 47th day after injection the immune rats were divided in two groups. The animals were bled and the serum antibodies titrated. One group was irradiated with 800 rads and the other group served as an immune non-irradiated control. 29 hours after irradiation the rats were bled and the serum titrated for coxsackie virus neutralizing antibodies. The results indicated that 29 hours after irradiation the circulatory antibody titer of the immune rats remains unaltered. It was decided to repeat another series of experiments using adult mice due to the lack of radiation facilities for rats.

2. Effects of radiation on the circulatory antibody of immune mice. Adult white mice were immunized by inoculating three times at 7 day intervals. These animals were divided into two groups: immune, non-irradiated mice; immune mice given 400 rads. Active virus was isolated from the heart, pancreas and liver of animals from the second group.

E. Enhancement of interferon production by gamma irradiation in chick embryos.

1. Studies of the stimulation of interferon by radiation have been extended to other animals. In mice they show that gamma radiation inhibits the production of interferon, but as doses increase the degree of inhibition diminishes. This seems to indicate that an optimum dose exists for the stimulation of interferon production.

TRYPANOSOMIASIS

Work on the effects of gamma radiation on the host-parasite relationship with infections caused by *Trypanosoma cruzi* was started in 1966 before official budgetary support was received from DBM. The infection produced by this microorganism occurs only in the Western Hemisphere, with high prevalence both in wild and domestic animals. Man is involved only incidentally during the transmission cycle of the parasite; it is estimated that some 7,000,000 human beings are infected in the Americas, with a high rate of fatal sequelae.

Research on the effects of gamma radiation has been conducted on the parasite, on mice and on tissue culture. Considerable attention has been given to develop a methodology which would provide a sensitive, accurate measurement of radiation effects.

Tissue culture techniques developed to measure small amounts of parasites in the organs of infected animals (PRNC Annual Report 1968) allowed us to study the fate of parasites introduced in the animals.

RADIOBIOLOGICAL STUDIES

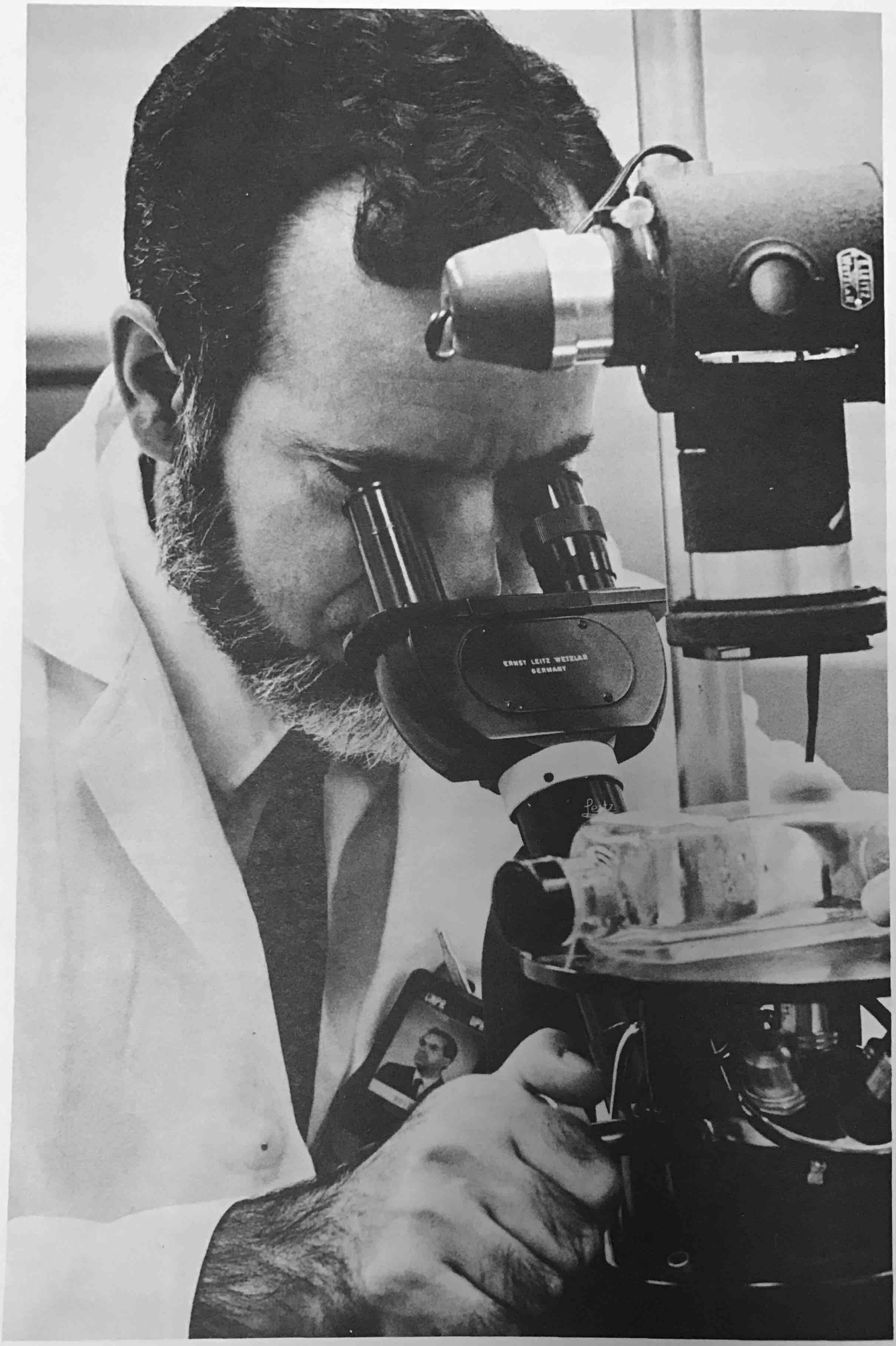
A. Effect of radiation on mice infected with T. cruzi. Two experiments were carried out; one with a virulent strain of *T. cruzi* (Tulahuen strain from Chile) and the other with a strain which has lost most of its virulence by repeated cultivation in laboratory culture media (Corpus Christi strain from USA).

Tulahuen strain: Mice 21 days old were subjected to 400 rads whole-body radiation. This group, as well as the control, were inoculated by the intracerebral route with 100 parasites from tissue culture. Five mice of the irradiated and non-irradiated groups were sacrificed daily. Parasite levels were constantly higher in the organs of irradiated mice than in those of non-irradiated. (Talbe 5).

Corpus Christi strain: Since this strain is less virulent, 7,500 parasites were inoculated. The results showed very slow parasite multiplication, the levels reached are very low (10 per 100mg) and the spread of infection much slower, without reaching detectable levels in most of the organs invaded by the virulent strains.

Whole body irradiation with an avirulent strain: The Maryland strain (isolated from a racoon in Laurel, Md.) produces a latency or latency-like phenomenon, i.e. the parasites are inside the cells but there is no liberation, and, apparently no harm to the infected cells. In one experiment it was decided to take tissue culture with latent infection; the supernatant, where microscopically no parasites were observed, was inoculated into new tissue culture and into newborn mice, both irradiated and without irradiation. The results suggest a latency phenomenon, and that even parasites so attenuated in their virulence that they normally do not produce death, are, nevertheless able to multiply and lead to death when the host has previously been subjected to radiation.

B. Effect of cell irradiation on T. cruzi infection. In PRNC 1966 it was reported that a cell line established in this laboratory from a mouse chondrosome and subjected to 800 rads was rendered more susceptible to infection by the *T. cruzi*. Four possibilities could account for the greater number of intracellular parasites: (1) Radiation depressed the formation of a substance inhibitory for division of the trypanosomes; (2) Radiation increased the syn-



Dr. Martĭnez Silva observes tissue culture inoculated with *T. cruzi*.

thesis of an essential metabolite for the trypanosomes; (3) Radiation altered membrane permeability, allowing many parasites to penetrate, and (4) Radiation affected the cellular membrane reducing the process of penetration into the cell. In order to determine which mechanism in the cell was responsible, an experiment was set up in which cell monolayers were irradiated, inoculated with parasites and incubated. The results suggest that radiation affects permeability, permitting earlier entrance of the parasite than in the non-irradiated cells. (Table 6).

BIOLOGY OF THE HOST-PARASITE RELATIONSHIP

A. Immunization of mice with inactivated T. cruzi. In general it is accepted that immunity to *T. cruzi* infections is accomplished only as result of parasite multiplication in the host. An experiment was carried out to determine if, and how much, resistance could be induced by different fractions of *T. cruzi* obtained from an *in vitro* medium and from infected tissue culture. For this purpose, 40 day old mice were given the protective dose by the i.p. route in 0.1 ml amounts. The 3 fractions (exoantigen, endoantigen, and somatic antigen) were suspended in equal amounts in DEAE, Freund's Incomplete Adjuvant and Hanks' solution. The same treatment was made with parasites from an LIT culture medium and a heavily infected monolayer. Seven days after inoculation, the mice were challenged also by the i.p. route with 1 x 10^5 blood forms of a virulent strain. The results (Table 7) suggest that the protection afforded by the parasites of infected tissue culture is higher (51%) than the one conferred by parasites from LIT (27%). Of the 3 different fractions, the one showing greater activity is the exoantigen (62%) as compared to the endoantigen (17%) or the somatic antigen (43%). Of the 3 vehicles, the most effective is DEAE (60%) as compared to Freund's adjuvant (14%) or Hanks (47%). The results of this experiment seem to confirm that immunity induced by the different fractions might be due to the presence of non-inactivated parasites.

B. Adsorption and penetration of T. cruzi into cells. It was reported in the 1968 PRNC Annual that adsorption and penetration of cells in tissue culture by viable virulent strains of *T. cruzi* starts immediately upon contact, increases gradually and reaches a maximum in about 12 hours.

It was observed that strains which have lost virulence through long periods of artificial cultivation geve consistently lower titers when tested in tissue culture.

The number of parasites needed to infect the cell monolayer is about 1 single parasite for the virulent strains (Tulahuen and Bertoldo) but requires about 10^3 to 10^4 for the avirulent ones (Corpus Christi and Maryland). These results have been so consistent and the virulence-infectivity correlation in tissue culture so close that we started to use this last parameter as a measure of virulence in animals.

The lack of intracellular infection when avirulent strains are inoculated can be due to:
1) Non-penetration of the parasites into the cell,
2) Penetration, but non-division of the parasite.

An experiment attempted to follow the dynamics of the infection. A set of Leighton tubes was inoculated each with 0.1 ml of a suspension (LIT) of the virulent strain (Tulahuen) and another set with the avirulent (Corpus Christi). The percentage of infected cells increased when inoculated with the virulent strain, whereas the avirulent one produced a very small rate of infection which does not progress. This seems to suggest that the factor responsible for non-infectivity is that avirulent parasites are unable to penetrate the cell, since infection, once the parasite is intracellular, progresses in the same pattern as with the virulent ones.

Hypothetically, it can be assumed that virulent parasites can penetrate the cell because they synthesize an enzyme that acts on the substratum in the cell wall. The nature of the enzyme is unknown. Studies continue.

C. Labeling of host-cells with C^{14}-glucosamine. Monolayers of DC_2 cells were seeded in mildilution bottles, incubated at 37°C and when 50% confluent, the medium (EBM) was replaced with C^{14} glucosamine (0.1 ml with 0.1 mc), and again incubated at 37°C until confluency was reached. The medium was replaced, the monolayers washed 3 times with Hanks' solution and then new nutrition medium added. The cells were then inoculated with culture forms of *T. cruzi*, and incubated. Samples of the medium counted in a liquid scintillation apparatus indicate that the glucosamine does not form part of the substratum making up the receptor of the cell for *T. cruzi.*

D. Multiplication of trypanosomes inside the cells. Host-cells for the parasites have a very high tolerance. Since cells can divide when they are infected, resulting in two daughter cells with parasite load split among them, an experiment was carried out in order to observe the formation of cellular clones from single infected cells. This was accomplished by seeding 100 cells in a petri dish, incubating them at 37°C in an atmosphere of 5% CO_2 during 3 hours and then inoculating with suspensions of *T. cruzi* in multiplicities to cells from 10,000/1 to 0.1/1. There is no statistically significant difference between the plates inoculated with the largest amount and the ones inoculated with least amount. This seems puzzling, since infected cells are destroyed; an explanation, however, can be offered by the difference between the generation time of the cells (24 hours) and the time needed to complete the intracellular cycle of the parasites and subsequent destruction of the cell; after the first 24 hours of incubation, the parasite which has penetrated the cell (a single parasite in our opinion) has undergone 2 divisions and is therefore in the 3rd generation with a total of 4 parasites. At this time, if nutritional conditions are suitable, the cell can divide the production of a clone.

E. Liberation of the parasites. The cell-parasite relationship comes to an end when the parasites become very active, disrupt the cell wall and become freed. This behaviour seems normal for most of the strains. However, in some cases the process seems to be interrupted and a latency-like phenomenon results.

Strain Md in tissue culture monolayers produced the normal cycle of intracellular infection with liberation of parasites. However, when the cells were further incubated with the usual changes of medium, production of free parasites ceased. When stained, the cells showed intracellular parasites. To resolve conflicting observations, infected cell monolayers that had ceased producing extracellular parasites were kept at 37°C during 1 month. No parasites were observed in the nutrient medium. With these cells, 3 fractions were prepared to determine infectivity: nutrient medium; trypsinized cells; supernatant of the trypsinized cells. The results, as shown in Table 8, seem to confirm that there is a latent phenomenon.

F. Infectivity by the crithidial stage of T. cruzi. A view widely held by parasitologists is that infection by *T. cruzi* is initiated only by the trypanosomal stages called metacyclic forms. When we inoculated newborn mice by the intracerebral route with suspensions of culture medium even a single parasite caused death. Since metacyclic forms comprise only 5% of the whole culture, it was concluded that any form present in the culture can produce death. However, when older mice were used, even if the i.c. route of infection was employed, the result was multiplication not resulting in death.

Similar results were obtained in tissue culture monolayers (reported under virulence of *T. cruzi*). A culture in the logarithmic phase was diluted so that a single parasite was present in each microdrop. With a micropipette the crithidia was transferred to a tissue culture monolayer. 45 roller tubes were inoculated.

These were observed daily until trypanosomes in the fluid expressing intracellular multiplication with disruption of the cells were seen. Table 9 shows the days post inoculation in which extracellular trypanosomes were observed.

G. Modifiers of the host-parasite relationship at the cellular level. This year, we tried many types of substances in order to investigate Trypanosoma infectivity at the cellular level. The process of *T. cruzi* penetrating into the cell(very active in the virulent strain) could be an enzymatic process. To test this possibility, cell monolayers previously infected with an avirulent form of the parasite were treated with an extract of the virulent strain. No changes occur in the penetration rate after this treatment. However, it is necessary to discard the possibility of an inhibitor present in the extract. When monolayers were treated with trypsin or neuraminidase, no changes were observed in the penetration of an avirulent strain. Hyperimmune serum was prepared in rabbits and its action on the prevention of infection was tested. No effect was observed.

EFFECT OF DRUGS ON T. CRUZI INFECTION

A. Effect of Poly l-C on T. cruzi infection in mice. In the 1968 PRNC Annual, it was reported that the polynucleotide Poly I.C., which is able to induce high levels of interferon both in animals and in tissue culture, did not exhibit any anti-*T. cruzi* activity. In order to determine whether this lack of activity would depend on the schedule followed, a new experiment was made in which the time relationship between the administration of Poly I.C. and the challenge inoculum of *T. cruzi* was changed. Mice 21 days old were infected with 200 ug of Poly A-U and 0.3 ml of PBS as controls. At different intervals, the animals were inoculated by the intraperitoneal route with 100,000 blood forms of the parasite. The animals were observed for parasitemia and the time of specific death recorded. No difference was observed with Poly I.C. or Poly A-U with respect to the controls. This confirms our previous findings and seems to rule out the use of polynucleotides as a preventive agent in Chagas' Disease. However, work continues, to determine whether these substances have any effect on the course of the chronic infection.

B. Therapeutic essays in tissue culture. There is no effective therapy for Chagas' disease. Although some substances are active on the blood forms of the parasite, none was able to act on the intracellular ones. Positive results of the mycostatic substance Amphotericin B have been reported on infections caused by *Leishmania donovani*, a parasite very closely related to *T. cruzi*. We tried this substance on *T. cruzi* in vitro and on infections both in mice and tissue culture with positive results.

(1) In vitro *T. cruzi* Tulahuen strain in LIT medium with a concentration of 3×10^7 parasites per ml were treated with 0.1 ml of decreasing amounts of Amphotericin B. The immobilizing activity of the drug is very quick. This is also accompanied by inactivation of the infectivity.

(2) **Effect in tissue culture.** Heavily *T. cruzi* infected cell monolayers were given dosages from 100 to 1 ug of Amphotericin B. The results show a very strong effect of the drug. However, the infection was not cleared even 10 days after treatment, since once the substance was removed the few parasites remaining in some of the cells resume their growth until a flourishing infection is observed.

(3) **Effect on mice.** Studies were carried out in both the acute and chronic phases of the infection. The results suggest that this might be a promising substance.

Table 5

T. Cruzi Infectivity Titers[1] in the Tissues of Acutely Infected Normal and Irradiated Mice[2]

Days after inoculation	NORMAL MICE					IRRADIATED MICE				
	Brain	Blood	Heart	Liver	Spleen	Brain	Blood	Heart	Liver	Spleen
1	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
2	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ	ϕ
4	1.5	1.3	ϕ	ϕ	1.3	2.5	1.3	ϕ	ϕ	1.5
7	4.0	2.0	1.5	3.5	3.0	4.7	2.7	1.5	4.0	4.0
10	5.0	3.0	2.5	2.5	3.7	5.7	4.5	3.0	3.5	4.5
15	5.3	4.5	4.5	3.5	5.0	7.5	5.7	5.0	4.0	6.0

[1] Titers expressed as the logarithm of the $TCID_{50}$ units contained in 100 mgm of tissue.
[2] Twenty-one day old mice received 400 R whole body irradiation and immediately inoculated intracerebrally with the Tulahuen strain.
ϕ Lower then detectable level.

Table 6

Intracellular Multiplication of T. cruzi in Normal and Irradiated DC[2] Cells.

	Days Post-Inoculation								
	1			2			3		
Generation	R	N	R/N	R	N	R/N	R	N	R/N
1	68	26	2.62	60	64	0.94	27	21	1.29
2	67	33	2.05	71	57	1.25	37	65	0.57
3	26	6	4.30	54	47	1.15	74	44	1.68
4	8	5	1.23	55	38	1.45	63	50	1.26
5				29	12	2.42	51	35	1.46
6				10	1	10.00	27	9	3.00
7							8	1	8.00
8							2	0	∞

Table 7

Immunization of Mice with Different Fractions of T. cruzi.

		SUSPENSION MEDIUM		
		DEAE	Freund's Adjuvant	Hanks'
LIT	Exoantigen	1/5	4/4	1/5
	Endoantigen	5/5	5/5	4/5
	Soma	4/5	5/5	3/5
Tissue Culture	Exoantigen	0/5	2/5	3/5
	Endoantigen	1/5	5/5	5/5
	Soma	1/5	4/5	0/5

Table 8

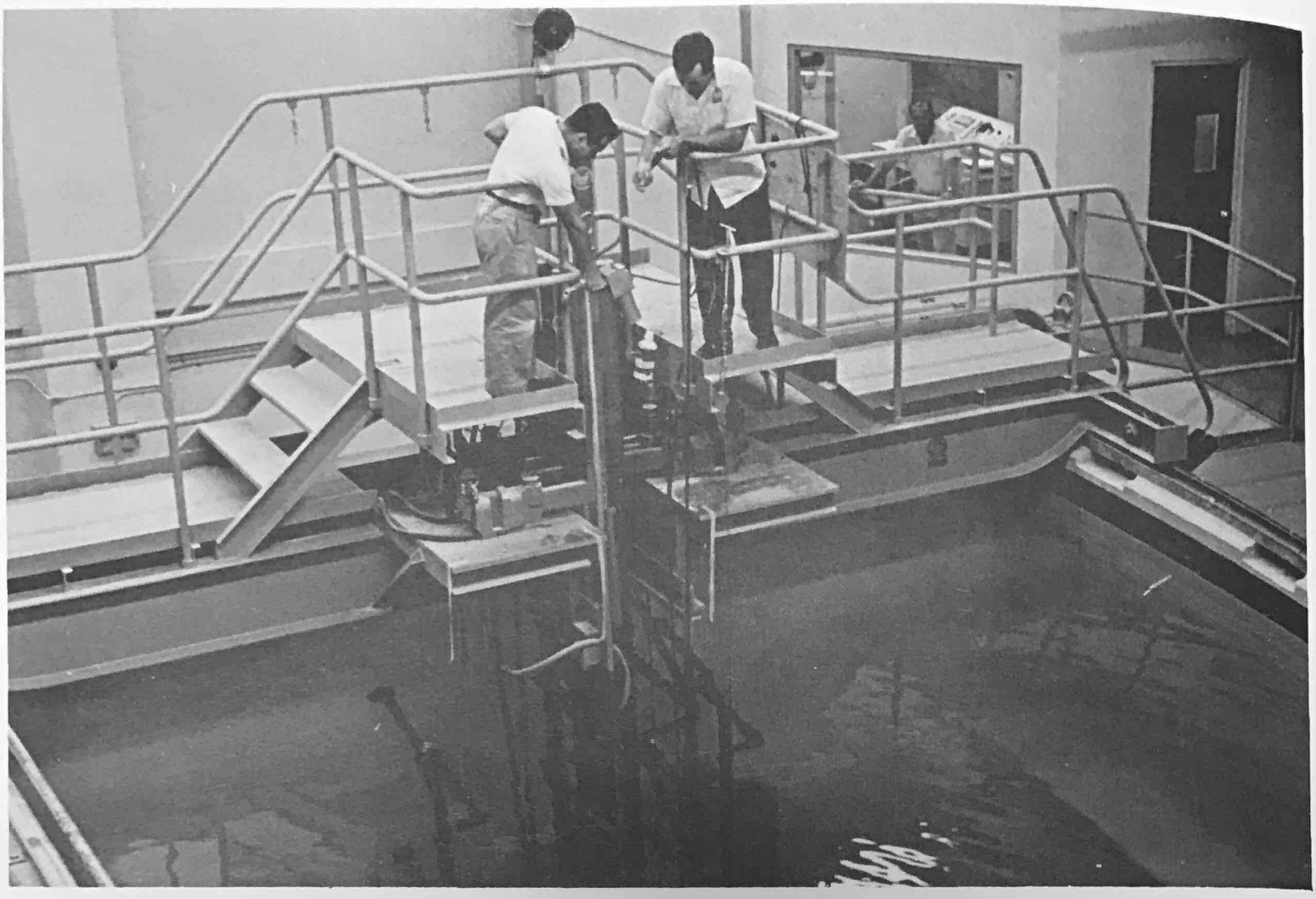
Detection of T. cruzi, strain Maryland with Tissue Culture and mice.

Inoculum From	Cells	Mice 1 Day Old	
		Non-Irradiated	Irradiated
Medium supernatant	0/10	0/17	0/19
Supernatant of tripzinized cells	9/9	1/17	2/15
Cells	10/10	3/15	1/7

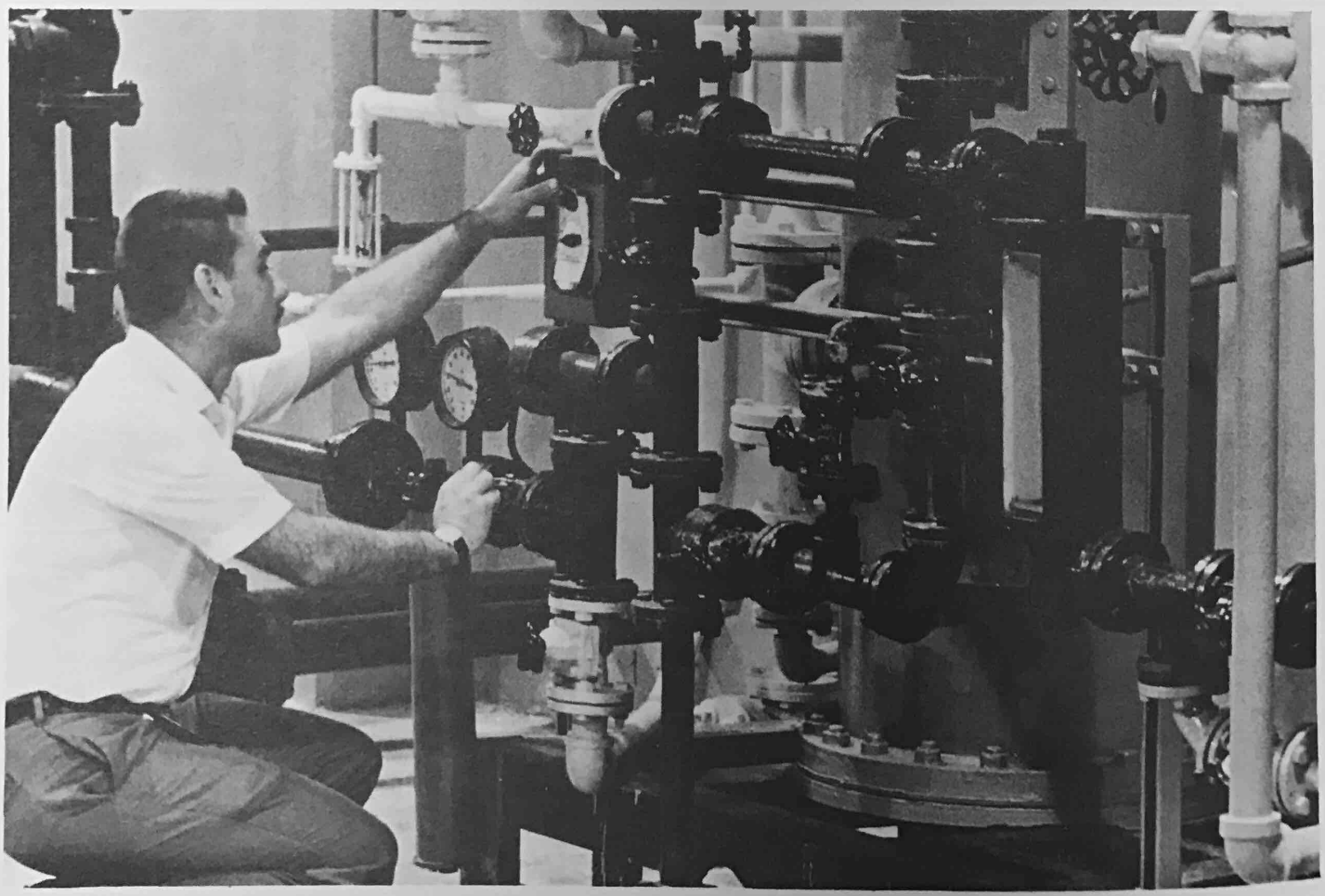
Table 9

Infectivity of Single Crithidial Forms in DC^2 Cells

Days after inoculation	Tubes showing growth	Mean
15	4	17.4
16	7	
18	13	
19	2	
20	3	
	29	



View of the research reactor pool at PRNC Mayagüez



Mr. Brown Campos examines the cooling system of the PRNC reactor

REACTOR

The Reactor Division provides support and services to other divisions of PRNC which require neutron and/or gamma irradiation. It operates and maintains: (1) a one megawatt, pool type research reactor; (2) a ten watt, aqueous-homogeneous L-77 reactor; (3) a cobalt-60 gamma irradiation pool; (4) a cobalt-60 gamma source in the reactor pool and; (5) high level hot cells.

The Reactor Division also operates and maintains all the auxiliary equipment associated with the reactor such as beam tubes, rabbit system, fuel element irradiator and gamma room, transfer port, etc., and all pool water cooling and purification equipment.

During the year, the one megawatt reactor operated routinely two shifts per day, five days a week, accumulating a total of 2,378.266 megawatt-hours. A total of 390 side-of-core irradiations were performed; 610 short duration irradiations were also performed utilizing the rabbit facility. In the 60-cobalt gamma pool facility, 264 irradiations were carried out. Also 43 long duration gamma irradiations were made utilizing the gamma source in the reactor pool.

The L-77 reactor was used for training, student experimentation and thesis work throughout the year. The reactor was operated a total of 107.22 watt-hours for operator training, research and testing purposes.

The conversion project for the one megawatt reactor is now well underway. The Safety Analysis Report has been submitted to AEC Washington headquarters for review and approval . Actual conversion, which will last about three months, will start near the end of 1970; initiation of operations with the Gulf General Atomics Triga Flip core is expected in the early part of 1971. Work on the one kilowatt reactor has been stopped until completion of the Triga conversion.

The 60-cobalt source which was located in Río Piedras in the gamma irradiator was transferred to Mayagüez and installed in the reactor pool north side, approximately 12 feet under water. The source is now utilized as another facility for long term irradiations.

EDUCATIONAL ACTIVITIES

The Division participated with the Nuclear Engineering Division in the preparation of the N.E. book. Drafts were submitted on two chapters covering the subjects of fuel management and plant maintenance.

Miss Isaura González reads the tracks produced on special film by neutron irradiation.

HEALTH PHYSICS

The Health Physics Division, which deals with health and safety problems, operates at both Río Piedras and Mayagüez with two main functions: it provides the services needed for safe operation of the Puerto Rico Nuclear Center and implements the radiation, industrial and fire safety regulations; it also contributes to PRNC's educational and research programs.

The services (*see Table 1*) include consultation and supervision, in all matters concerning safety and especially in radiation safety.

Table 1

The following services are offered by the Division to any other project at PRNC

a.	Personnel monitoring*	j.	General laboratory safety
b.	Area monitoring	k.	Industrial safety
c.	Calibration of radiation monitoring equipment	l.	Fire safety
d.	Radioactive materials handling	m.	Consultation on matters concerning all safety, especially on radiation and radioactive materials.
e.	Environmental surveillance	n.	Indoctrination of staff members in Health Physics, Industrial Hygiene, Industrial Safety and Fire Prevention.
f.	Dosimetry*		
h.	Decontamination		
i.	Waste disposal		

* This service is also offered to BONUS

To implement and enforce safety regulations, the Division instituted regular inspections in addition to existent monitoring practices, and established safety committees with members within each Division. Indoctrination on safety, especially on radiation protection, is offered to PRNC personnel through special courses, lectures, films and through the safety coordinating committee.

The education and research program includes:

1. Courses offered at UPR Mayagüez, and UPR San Juan, and the Medical Center, Río Piedras in basic Radiation Protection at the graduate level for students not specializing in the field.
2. An M.S. degree program in Health Physics at UPR Mayagüez. This program has been offered since 1959.
3. Six students have graduated from the new one-year program leading towards the M.S. degree in Radiological Health at UPR San Juan campus. This program is offered by the Department of Preventive Medicine and Public Health in conjunction with PRNC. Fifteen new courses were designed to meet the needs of the students, especially those from Latin America. Six of them were offered during the Fall Semester 1969.
4. Advice and supervision of student research theses.
5. Special training in Applied Health Physics.
6. Radiological Physics training for Radiology residents, UPR School of Medicine.
7. Basic research

Special emphasis was given this year to improving PRNC safety standards and in further developing the new graduate program in Radiological Health.

SERVICES

All service functions have been improved, with emphasis on promptness. Procedures have been revised and updated. The PRNC personnel exposure report, for example, is now distributed within two weeks after the collection of the film badges. Further improvements are expected since the computer program is now ready and will be effective in January 1970. Personnel monitoring films are now being supplied to the I. González Martínez Oncologic Hospital, University Hospital, the UPR School of Medicine and the BONUS power plant, as well as to PRNC personnel *(see Table 2)*.

Table 2

Health Physics Services 1969

1. Film Service to PRNC and BONUS:

	Beta Gamma	Neutron
PRNC	5,252	831
BONUS	574	581
Total	5,826	1,412

2. Radiation Survey Meters Calibrated:

a) Gamma	234
b) Neutron	46
Total	280

3. Area Monitoring Samples Analyzed:

Smears	1,330
Water	60
Air	15
Total	1,405

4. Environmental Surveillance Samples Analyzed:

a) Water	26
b) Air	0
c) Soil	9
d) Vegetation	9
Total	44

5. Review of questionnaires for reactor experiments: 516

6. Review of requests for use of irradiation facilities other than reactor: 23

7. Review of requests for radioisotopes procurement: 134

8. Medical Dispensary.No. of Cases seen:

a) Minor Accidents	45
b) Physical Exams	38
Total	83

The environmental surveillance program is now analyzing a few samples a month of soil, water, and vegetation in the vicinity of Mayagüez in addition to a water sample from the well of the India brewery. The laboratory, however, is completely capable of performing full surveillance when required.

A calibration facility for high exposures using a 20 Ci Cs-137 source was added this year. The facility is located in one of the hot cells which was modified into a calibration room. The old calibration facility is used for low-range calibration.

The film badge service laboratory was moved to the installation at Cornelia Hill where a darkroom was constructed for this purpose. It is planned to incorporate a digital voltmeter in the circuit of the densitometer. This adaptation will speed up the film density reading. Emergency lines were installed and the emergency power generator is functioning properly. The NAD laboratory is being transferred to the space provided at Cornelia Hill. A complete revision and updating of the NAD program is in progress.

The radiation safety program at the Oncologic Hospital continues at the same level. The program, except for the film badge service, includes regular radiation surveys at the wards and rooms used for patients with implanted radiation sources, advice and recommendations on radiation protection, training in radiation protection of the nurses in charge of the patients carrying radioactive sources, and indoctrination in Health Physics for new hospital personnel.

The new 4500 Ci ^{60}Co source was installed in Río Piedras and will be operated by Technical Services. A special operator will be trained by the Division. The old source in Mayagüez was placed in the reactor pool next to the gamma room. The gamma room will be used as a new radiation facility for moderate dose rates.

A special three-room building has been constructed behind the animal house to store radioactive, flammable and other hazardous materials. This building is now fully utilized to eliminate accumulation of these hazardous materials from PRNC laboratories.

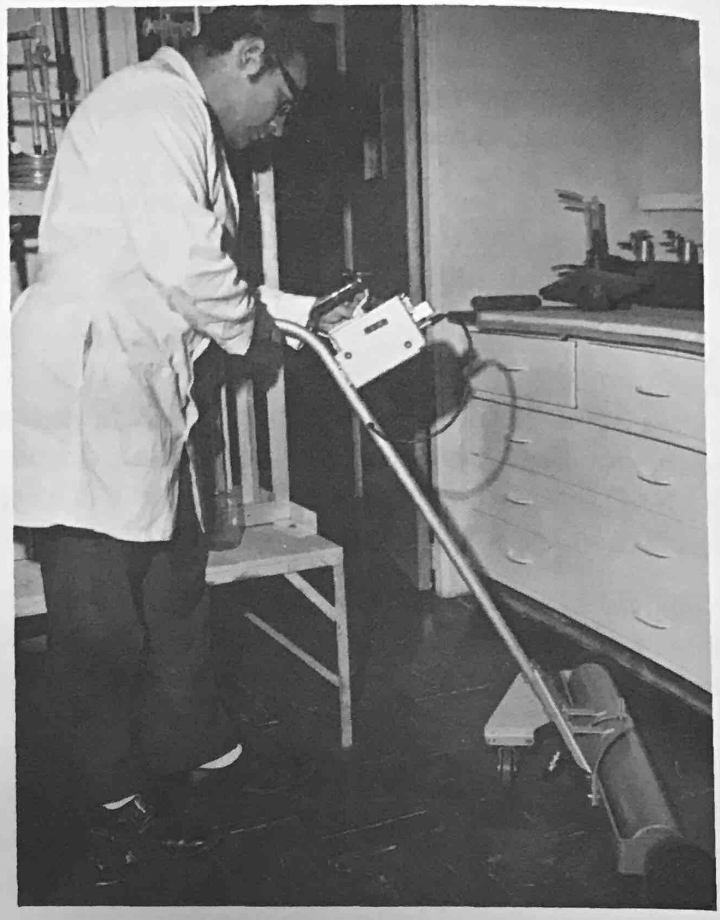
Plans to construct a special irradiation room for the Texas Nuclear Neutron Generator were made and approved. The safety features for this room were expedited by the Division and regulations and procedures will be prepared.

An emergency plan in case of any catastrophic event in Mayagüez was prepared, relating PRNC problems and competencies to the surrounding community.

Two committees deal with all safety problems, and have branches in Mayagüez and Río Piedras. The first consists of all division heads and one member from the Director's office. Through this committee, general safety policy and rules will be approved. The second consists of one member from each division who has supervisory or technical background. Through this committee, followup of recommendations are implemented. Indoctrination of personnel is offered in two ways: first, through safety institutes in Mayagüez and Río Piedras in conjunction with the Labor Department of the Commonwealth of Puerto Rico; and second, through lectures, films, personal contact and information pamphlets and posters supplied by the National Safety Council and through a newly developed newsletter called Safety Tips.

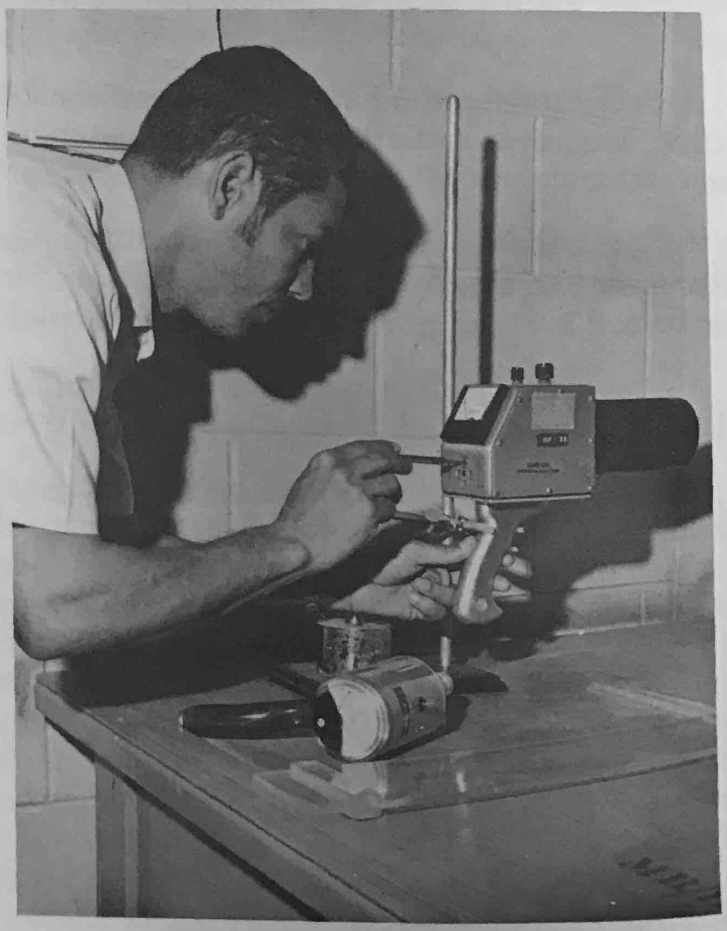
The Industrial Safety and Fire Protection program has greatly improved in Mayagüez and Río Piedras during the year. Personal safety and fire fighting equipment are provided by the Division as needed.

(a)



(b)

(c)



(d)

(a) Miss Mercedes Marty reads the optical density in beta-gamma film.
(b) Mr. Antonio Vega monitors the floor to detect possible radioactive contamination.
(c) Mr. Oscar Perez monitors the reactor, and (d) calibrates an instrument.

EDUCATION AND TRAINING

The education program has two main objectives. The first is to provide graduate programs leading to the M.S. degree and advanced training in Applied Health Physics for students who are planning a career in Health Physics. The second is to provide indoctrination in radiation safety and general safety for PRNC personnel, and courses for students who will be working with radiation sources, but who do not intend to specialize in Physics.

The Radiological Health graduate degree program was developed by the Division through the School of Medicine, Department of Preventive Medicine and Public Health (PMPH) in addition to the existing Health Physics program offered by the Department of Biology, UPR Mayagüez campus.

Three courses, one at UPR Mayagüez, and the others at the School of Medicine San Juan, are regularly scheduled for students not specializing in the field.

Table 3
Graduate Degrees Granted in 1969

Name, country and degree
1. Luis Rodrĭguez, Ecuador, M.S. in Radiological Health, PMPH, UPR, San Juan
2. Aquiles Santana, Colombia " " "
3. Daniel Torres, Puerto Rico " " "
4. Heriberto Torres Castro, Puerto Rico " "
5. Amalia Vélez Paradis, Puerto Rico " "
6. Michael Gileadi, Israel, M.A. in Sanitary Science " "

Each course covered such topics as : basic nuclear physics, radioactivity, interaction of radiation with matter, the biological effects of radiation, instrumentation and methods of measurement, and the principles of handling radiation in all its forms. Laboratory on Radiation Detection was included in the Mayagüez course, while the Public Health aspects of radiation were emphasized in the San Juan course since the students were either physicians or sanitary engineers. Lectures related to radiation protection were also given as part of the regular PRNC "Radioisotopes Techniques" course offered four times this year.

THESIS RESEARCH

Gamma-Ray Spectra Around the PRNC Reactor. Heriberto Cuebas. This work is incomplete. The purpose of this study is to determine the spectral distribution of gamma radiation around the reactor. Results indicate that the predominant gammas have an average energy of about 0.1 Mev. The student is not working at the present time.

Study of Exposure Received by Patients During Chest X-Ray Examinations. Amalia Vélez. The purpose of this study is to determine the dose delivered to the patients during routine chest X-ray exposure in Puerto Rico. The age and size of the patients, and the particular X-ray unit used, kVp, mA settings and the filtration used are considered. The entrance and the exit dose were determined, utilizing thermoluminescent dosimetry techniques. The data will be published as a PRNC report. This work was completed and the student was graduated.

Measurement of Neutron Spectra of the PRNC 1MW Reactor. Efigenio Rivera. A neutron spectrometer, consisting of Li^6 sandwiched between two surface barrier detectors of 214 mm^2

active area of 350 microns depletion depth, coincidence system and multichannel analyzer is set up for this experiment. Neutron spectra will be measured at the beam tubes and possibly in the pool at certain places.

Possibilities of the Existence of HRP (Horseradish Peroxidase) Molecule in a Partially Damaged Condition. George Perez Rivera. This work studies the changes taking place on enzyme molecules as a result of the application of monochromatic x-radiation, which may reveal a special kind of interaction of radiation with macromolecules. The general idea will be to apply a stress other than x-radiation, mainly heat, and study the inactivation pattern using radiated and non-irradiated enzymes (such as peroxidases, catalases). The radiation dose chosen will permit at least 90% of the enzymes to remain active. The enzymes will be irradiated both dry and in solution.

NEW PROGRAM IN RADIOLOGICAL HEALTH

The new program is offered through the School of Public Health, which is considered by many leading universities in USA to be the natural environment for a program in Radiological Health. All courses aside from the Public Health courses are new ones offered by PRNC, and are specifically designed for the students of Radiological Health.

The academic prerequisites for enrollment in the program are a B.S. and 6 credit hours each of university-level physics, chemistry, biology, and mathematics.

The duration of the program is one full year, including 2 months of field practice. The thesis was eliminated (as it is in many leading universities) and field practice was introduced since it appears to be more useful to the students. However, if there is a future need for a more sophisticated degree (including thesis) a course can be offered to students who prefer an academic career. During the summer the facilities of the Bio-Medical Building, PRNC Río Piedras, are made available for Hospital Physics-minded students, while the nuclear reactor and other facilities at PRNC Mayagüez are available for students interested in Health Physics. This training is arranged according to the needs of the students and their country.

There is also a possibility for future expansion of the program so that it may serve as a core for an M.S. program in Radiation Biology and in Hospital Physics.

Most of the instruction is given in Spanish (approximately 75%),with textbooks in English. This makes the program especially attractive for students from Latin America.

The curriculum is designed to provide integration of related disciplines as the most effective way to create Radiological Health Specialists. A minimum of 40 credit hours of course content is required. Table 4 is a list of the courses offered. Full description of the courses is given elsewhere.

BASIC RESEARCH

The Calorimeter Project. The calorimeter was reconditioned the latter part of this year. The teflon housing of the gold absorber was modified so that the top of the calorimeter vessel was sealed and the window system was used instead for introducing the housing into the calorimetric vessel. The housing itself was made out of Epoxy in a special mold to satisfy all required conditions including good thermal contact of the beryllium window. The calorimeter is operating now and measurements are taken for the calibration of the weak X-ray beams produced by crystal diffraction. The LiF dosimeter (LiF-Teflon) is being calibrated to be used as a secondary standard, its energy respond in the region of 5-15 KeV will also be determined in the near future. There are plans to construct a special ionization chamber to measure the W-values in air and other gases in the same energy region.

Table 4
Courses offered for the M.S. Program in Radiological Health

The following are Required Courses:		Credits*
PRNC 501 Radiation Physics	I**	2
PRNC 505 Radiation Chemistry	I	2
PRNC 510 Radiation Biology	I	2
PRNC 515 Radiation Effects on Mammals and Humans	II	2
PRNC 520 Radiation Detection	I	2
PRNC 525 Radiation Dosimetry	II	2
PRNC 530 Radiation Hazards and Protection	II	2
PRNC 535 X-Ray Protection	II	1
PRNC 540 Decontamination & Waste Management	II	1
PRNC 545 Laws and Regulations on Radiological Health	II	1
PRNC 565 Basic Nuclear Electronics	II	2
PMPH 470 Environmental Health	I	3
PMPH 556B Industrial Hygiene and Industrial Accident Prevention	I	2
PMPH 540 Biostatics	I	2
PRNC 599 Field Practice	S	4

The following are Elective Subjects:		
PRNC 550 Radioactivity of the Environment	II	2
PRNC 555 Safety in Reactor Operations	II	1
PRNC 560 Reactor Technology	II	2
PMPH 476 Seminar	I, II	1
PMPH 489 Basic Epidemiology		2
PMPH 420 Fundamentals of Public Health Administration		2
PMPH 430 Social and Cultural Aspects of Public Health		2
Phys. 325 Atomic Physics Laboratory		3
Phys. 326 Nuclear Physics Laboratory		3
Biol. 231 Genetics		4
Biol. 351 Cellular Physiology		4
Biol. 372 Nuclear Techniques in Biological Research		4
Chem. 221 Chemical Analysis		4
Chem. 465 Radiochemistry		4
Math. 152 Statistical Analysis		3
Math. 203 Mathematical Analysis		3
Math. 204 Mathematical Analysis		3
Math. 307 Ordinary Differential Equations		3
Met. 101 Introduction to Meteorology		3
Met. 103 Introduction to Climate		3

* One credit is equivalent to 18 hours of lectures or at least 36 hours of laboratory work.

** I = first semester, II = second semester, S = Summer.

The Neutron Dosimetry Project. This work has been reactivated recently. The solid state neutron spectrometer is being set up utilizing a coincidence circuit and a multichannel analyzer. The scope of the work was modified to include a student M.S. thesis. Primary importance will be given in measuring neutron spectra rather than special neutron dosimetry for chemical and biological studies in the beam tube. This data is pertinent and will be needed for the new TRIGA reactor.

The Enzyme Inactivation Project. This work was reactivated as described *(see Annual Report 1968)* and included a student M.S. thesis. Data is being taken now but there are no reportable results as yet.

The Phantom Dosimetry Project. This is a joint project with the Radiotherapy Division. The progress on the results is reported by the Radiotherapy Division.

Population Exposure Project. The study on population exposure in Puerto Rico, during routine medical X-ray exposures was continued. The first part dealing with chest X-ray exposure was completed for the western region of Puerto Rico and the results will be reported as a PRNC report. Further work in other regions was discontinued at the present time.

The second part dealing with abdominal X-ray exposures and direct measurements of the gonadal dose was developed into the X-ray Survey Program sponsored equally by the Commonwealth Department of Health and the Puerto Rico Nuclear Center. A report (PRNC-132) including the results of the western region was published. The work was continued this year with data taken in Southern region of Puerto Rico and is still in progress. Preliminary results be reported under the X-ray Survey Project.

The MTF of Radiologic and Scintigraphic Imaging Systems Project. This project was initiated this year and will consist of experimental and theoretical analysis of the factors effecting the transmission of diagnostic information in radiologic and scintigraphic systems and it assessment as measured by the Modulation Transfer Function (MTF). Work on finite exposure slit effects was reported at the International Conference on Medical Physics (Boston 1969). Likewise, work on finite microdensitometer scanning slit effects was given at the American Association of Physicists in Medicine Meeting (Chicago, 1969). Both of these presentations included, in part, work done by the author while at Johns Hopkins University. Studies continue in the areas of line source width effects in scintigraphic systems and scanning aperture configuration effects.

Table 5
Radiological Physics Conferences for radiology residents at UPR Medical School. given January 8-March 20, 1969.

1. Emilio A. Reyes Villar, Dominican Republic
2. Ilia Torres Marcano, Puerto Rico
3. Carlos R. Méndez, Puerto Rico
4. José M. Pizarro Lago, Puerto Rico
5. Jorge M. Haddock Cordero, Puerto Rico
6. Víctor M. Quiñones Fernández, Puerto Rico
7. Luis R. Rentas Magaz, Puerto Rico
8. Luis E. Bonnet, Puerto Rico

Table 6
List of Students

M.S. in Health Physics, Mayagüez
Efigenio Rivera, Puerto Rico
M.S. in Radiobiology, Mayagüez
Alice O. de Caraballo, Puerto Rico
M.S. in Radiological Health, PMPH, UPR San Juan
Agnes Weisz, Israel
José C. Pacheco, Puerto Rico
Ricardo F. Gerdingh, Mexico
José J. Gil, Puerto Rico
Angel R. González, Puerto Rico
PMPH 561, Principles of Radiological Health
Wilfredo Barreto
Angel Montañez
Pedro J. Rivera
Raymond Fournier
Pedro Fuentes
Eulalio Soto
Edna Rosado (all from Puerto Rico)

STAFF CHANGES

The Health Physics Division, in addition to its Radiation Protection program, has undertaken responsibility in other areas of safety as well, such as: Medical Care, Industrial Hygiene, Industrial Safety, and Fire Protection. It was felt that an appropriate name would be "Health and Safety Division." Steps are being taken to make this change official.

The Head of the Division was named Assistant Director for Health and Safety. The positions of Deputy Head and Assistant Head of the Health and Safety Division will be created under the new organization of the Division. Responsibilities including all safety areas will be reassigned.

Miss Heidi Pabón resigned to accept the position of Hospital Physicist at the Río Piedras Medical Center. Mrs. M. Soderstrom resigned in order to accompany her husband to the USA. Dr. Theodore Villafaña joined the staff in Río Piedras in August, as did Mr. Heriberto Torres. Dr. Villafaña received his Ph.D. in Radiation Physics from John Hopkins, and Mr. Torres earned his M.S. in Radiological Health from UPR. He was one of our graduate students.

Mr. Gileadi was awarded two projects (population exposure and X-ray machine survey in Puerto Rico), jointly sponsored by the Commonwealth Department of Health and PRNC. He was totally relieved of his duties in applied Health Physics in order to devote his time to the new projects. He remains with the Division as a researcher and will report the results of his work separately.

Dr. Ernesto Colón Yordan, Secretary of Health of Puerto Rico(second from right) receives the first report of the Joint Radiation Survey from its author, Michael Gileadi, a senior associate with PRNC. At far left is Undersecretary of Health Dr. Carlos Náter, and at far right is Dr. Henry J. Gomberg, Director of PRNC.

X-RAY RADIATION SURVEY PROJECT

The X-ray Radiation Survey Project evaluates health hazards due to unintentional irradiation of the gonads during routine abdominal x-ray diagnostic examinations of male and female patients in Puerto Rico. It also estimates average health hazards to offspring of unintentionally irradiated patients and recommends measures to avoid or reduce hazards to a minimum compatible with the diagnostic objectives involved. It has been established by authorities in this field that 85 percent of the unintentional gonadal irradiation dose caused by medical x-rays is due to a relatively small group of diagnostic abdominal x-ray examinations. This project considers primarily those irradiation hazards that are generally referred to as "genetically hazardous."

The following nine types of abdominal and pelvic x-ray examinations have been included in this group: (1) abdomen; (2) gallbladder (cholecystography); (3) upper gastrointestinal series ("barium swallowed and meal"); (4) lower gastrointestinal tract - barium enema; (5) lumbar spine; (6) pelvis (pelvic region); (7) hip joint (hip joint and femur upper third); (8) retrograde or intravenous pyelography (I.V.P.); (9) pelvimetry.

Except for examinations labeled "gastro-intestinal series" and "barium enema", which are performed in conjunction with fluoroscopy of variable duration all others can be performed under rather well-defined uniform standard conditions concerning KVP, MaS, filtration, collimation, T.F.D. (Target Film Distance), positioning, central beam direction, and the quality of the beam.

To evaluate magnitude and frequency of occurence requires extensive data collection, statistical analysis and accurate, reproducible dose measurements, using several different methods of dosimetry.

Statistical Data and Analysis

The collection and analysis of the statistical data is best done by region, following the Puerto Rico Planning Board System. The Island of Puerto Rico is divided into three regions, which in turn are subdivided into eight areas:

(a) Northern Region, population 1,776,830, including San Juan, Arecibo, Bayamón, Caguas and Fajardo.
(b) Western Region, population 415,400, including Mayagüez with eight municipalities, and Aguadilla with five municipalities
(c) Southern Region, population 483,440, including Ponce and 16 municipalities.

Because of geographic convenience, the first part of this survey evaluated health hazards in the Western Region.

This part of the project was completed in the first half of 1969 and the findings published in a report (PRNC-132) titled: "Evaluation of Health Hazards Due to Unintentional Irradiation of the Gonads During Routine Abdominal X-ray Examination of Male and Female Patients in Puerto Rico," and reprinted in a joint radiation survey of the Puerto Rico Nuclear Center and the Puerto Rico Health Department.

Results

The most significant results of this work are enumerated below: (all data refers to the Western Region of Puerto Rico, 1967):

Population of the Western Region: 415,400
Number of diagnostic X-ray units: 78 (excluding dental x-ray)
Total number of abdominal X-ray diagnostic examinations termed genetically hazardous: 47,459
Total number of diagnostic x-ray examinations (estimated): 200,000
Global gonadal dose to the total population of the region: 20,067,110 mrads.
Per capita annual gonadal dose: 48.3 mrads per person per year

The survey found obsolete Coolidge tubes being used in some general practitioners' offices, presenting undue radiation hazards for patients, and exposed personnel.

The operation of x-ray units in certain public institutions was discontinued a few years ago (1967 or before) by the Radiological Health Program of the Health Department because of undue technical hazards. As of this date there are no public x-ray facilities operating in the following municipalities: Aguada (population 26,400); Rincón (population 10,100); Moca (population 24,000); Hormigueros (population 10,000); Sábana Grande (population 18,200); Añasco (population 19,200).

There were 94,766 x-ray examinations in all medical institutions and radiologists' offices in the Mayagüez area in 1967. In the Aguadilla area, there were 56,387, out of which the District Hospital in Aguadilla contributed 39,339, including 24,664 abdominal x-ray examinations that are considered "genetically hazardous".

It can be estimated that including the examinations performed in the general practitioners' offices (50 of them having x-ray facilities), approximately 200,000 x-ray examinations were performed in the Region during 1967. These figures indicate the significance of the problem.

Statistical analysis of data shows that additional patient protection was only used in a negligible number of cases (approximately .3%).

The most conspicuous feature of the Census: Available Diagnostic X-ray Units in the Western Region, Puerto Rico, 1967, is the lack of uniform geographic distribution; there is a diagnostic x-ray unit for each 2,650 inhabitants in the city of Mayagüez, but only one for all 19,200 inhabitants in Añasco; one unit for all 26,400 inhabitants in Aguada and none in Hormigueros, Las Marías, Maricao and Rincón. There are almost twice as many diagnostic x-ray units per 10,000 population in the Mayagüez area than in the Aguadilla area.

The number of x-ray examinations per 100 patients also varies very strongly, even among facilities of similar character: e.g., 73.6 in the Public Health Unit in Mayagüez, but only 13.6 in the Health Center of San Germán and only 5.6 in the Health Center of San Sebastián.

Dosimetry and Intercalibration

Complete details on dosimetry measurements and intercalibration procedures are contained in the previously mentioned report, PRNC 132.

Dose measurements were carried out under conditions closely simulating individual diagnostic procedures. These measurements try to establish average testicle and ovary dose associated with each type of abdominal diagnostic x-ray procedure, together with the total number of procedures of each type. This permits evaluation of the global gonadal irradiation doses and the average dose due to all procedures considered, weighted with the annual number of cases, as well as the per capita annual gonadal doses.

The x-ray units chosen as sources in this series of dose measurements were the three most common models: Picker, 200 mA; Picker, 500 mA; and k G.E., 300 mA. Two different Victoreen ionization chambers (from 1,000 mR to 5,000 mR range), especially calibrated for low energy, as well as thermoluminescent dosimeters containing powdered Li.F. capsules, and sensitive films were used. A Rando-Phantom in lieu of the patient with radio absorptivity equivalent to human tissues, simulating cross sectional sizes and contents typical of the human body was irradiated.

Conclusions

The per capita annual average irradiation dose to all the genetically significant diagnostic abdominal x-ray examinations in the Western Region of Puerto Rico in 1967 was computed as:

34.9 mrads per person per year for males
61.1 mrads per person per year for females
48.3 mrads per person per year for both sexes

Measurements indicate that testicular doses received in a pelvis x-ray examination can be reduced by a factor varying between 14.3 for 60 KVP and 8.6 for 90 KVP if a shielding of .5 mm lead is applied on the testes. This factor varies between 22.2 and 10.1 if a shielding of 1 mm lead is applied on the testes. Thus, the genetic hazard in male patients can be reduced to 6-11% of its original value by applying a lead shield of .5 mm thickness to the testes. By increasing the thickness of the shield to 1 mm, the hazard is reduced to 5-9% of its original value depending upon the KVP applied. Since such an extremely simple measure eliminates approximately 90-95% of the irradiation doses to the testes it seems only reasonable that the direct shielding of the testes during abdominal diagnostic x-ray examinations should be required by Commonwealth law.

Similar shielding factors will likely prevail in all abdominal diagnostic x-ray examinations. To corroborate this conjecture, the investigator plans to execute a series of "*in vivo*" irradiation dose measurements by means of miniature LiF TLD dosimeters applied to the lead shielded testes and to the adjacent unshielded area, during a series of diagnostic abdominal x-ray examinations.

By applying both accurate collimation and direct shielding to the testes, the genetic hazard associated with unintentional irradiation of the male population during diagnostic abdominal x-ray examinations can be practically eliminated.

Statistical data collected in each medical facility includes not only the number of genetically hazardous diagnostic abdominal x-ray examinations performed in a specified period of time, but also the type of examination as well as the age and sex of the patient. This data is needed to evaluate the so called "genetically significant dose," a computed indicator characterizing the magnitude of the average health hazard to the offspring of unintentionally irradiated patients.

Storing the collected statistical information on IBM-cards provides a versatile master file, suitable for any type of classification, statistical analysis updating and computation.

A system is being designed to record the cumulative x-ray irradiation doses of each patient treated in Puerto Rico's major medical facilities.

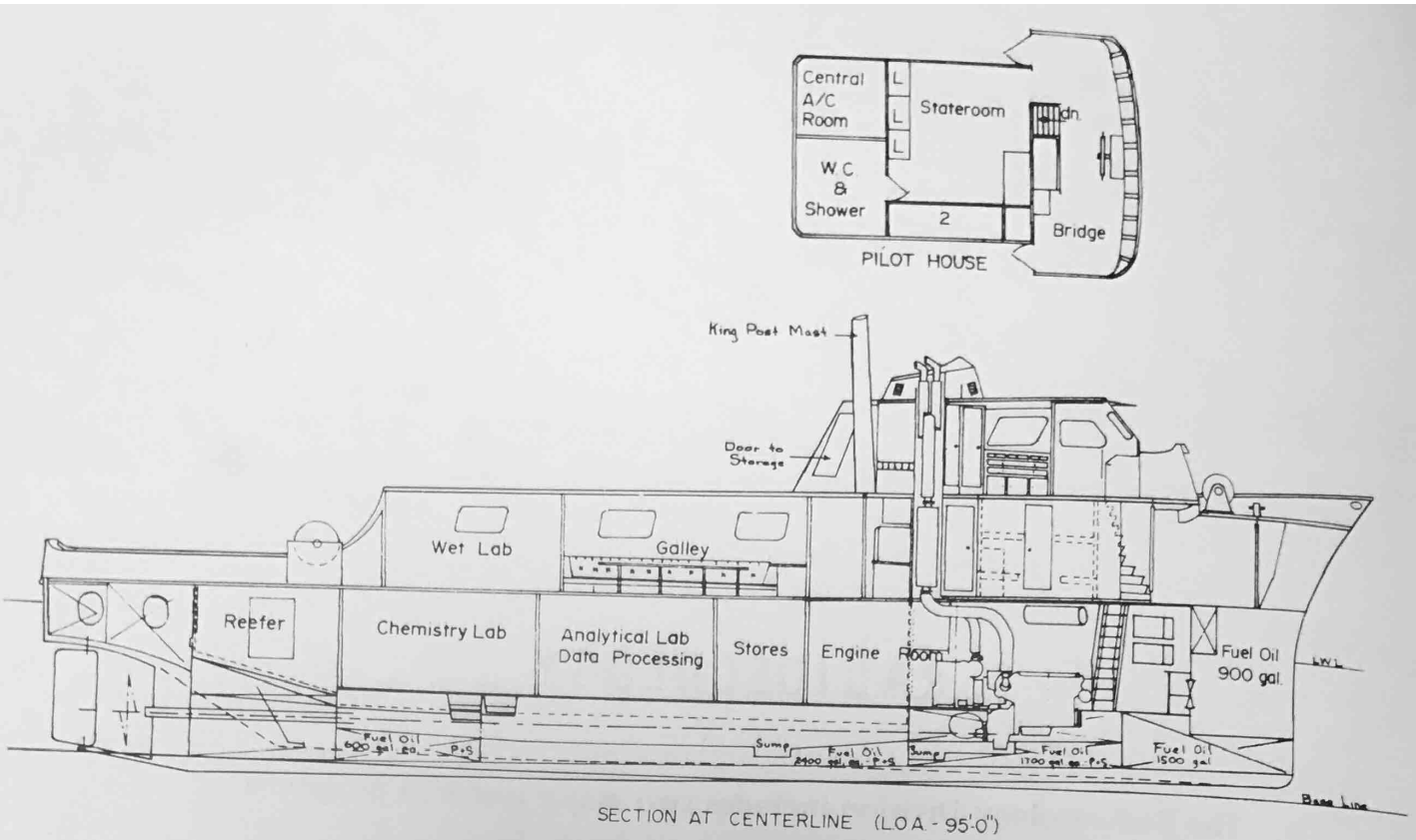
Partial results of this project were presented as a paper jointly with Dr. Jorge Carrera at the Medical Association of Puerto Rico meeting in San Juan, P.R., November 1969.

The present project is being extended into an island wide study under joint sponsorship of the PRNC and the Department of Health of the Commonwealth of Puerto Rico.

Data collection, statistical analysis, dose rate measurements (including the determination of "*in vivo*" doses) are now being completed for the Southern Region, 1968.

RADIOECOLOGY

The Radioecology Division includes two major research programs: Marine Biology and Terrestrial Ecology.



Sideview of the new ocean-going research vessel, the Palumbo, being constructed by the AEC for PRNC's Marine Biology Program.

Mr. Stephen Walsh of the Radioecology Division shows(left) samples of lead ingots extracted from a Peruvian mine, dated 1535, which were found off the west coast of Puerto Rico. Some of the lead was melted down for use as a cylindrical radiation shield in the Marine Biology program(right).

MARINE BIOLOGY

Some problems which arise from advances in nuclear applications and technology are concerned with the possible release of radionuclides into the environment from Plowshare operations, power reactors, accidents with nuclear-powered ships and disposal of high and low-level radioactive wastes. Were nuclear warfare to erupt, our present knowledge of the influence of food webs, ecosystems and environmental physical and chemical processes upon the transfer of widespread contaminants to man is inadequate for use in designing the countermeasures needed to minimize damage to the human population.

The investigations in the Marine Biology Program at PRNC are designed to determine the relative influences of biological and environmental mechanisms upon the transport and distribution patterns of trace elements and corresponding radionuclides in estuarine and other near-shore areas. The definition of the relative influence of environmental and biological processes upon the stable elements may be, and have been, used to predict the behavior of radionuclides of the same elements released into the system. However, the data now available allow only for the production of crude and simplified models, and these approximations of nature are often subject to serious question.

Some differences in behavior between the naturally occurring elements and the introduced radionuclides may occur, especially if the added material is in a different chemicophysical form. Investigations of these and other natural processes are included in field and laboratory studies now in progress on the west and south coasts of Puerto Rico.

The Marine Biology Program was started in the spring of 1962 to develop the methods and background data needed to apply the specific approach for the prediction of hazards to man from the release of radionuclides in the enivironment. One major effort is to develop laboratory and field methods to measure the amounts of elements which are represented by potentially dangerous radionuclides, if released in the environment. Many of these elements are also of interest in pollution problems resulting from the introduction of non-radioactive materials from mining, industrial and manufacturing operations and from disposal of municipal wastes. Elements which may be included in these categories are beryllium, phosphorus, manganese, iron, cobalt, copper, zinc, cadmium, mercury, lead, arsenic, and uranium. The development of methods for the analysis of these elements in rocks, soils, river water, marine waters and organisms and in bottom sediments has been continued.

RESEARCH PROJECTS

The program is composed of 6 projects which are interrelated and integrated into a team investigation of the interactions of mobile trace elements, organisms and the tropical marine environment. The projects include:

1. Basic marine ecological studies in anoxic, phosphorescent basins with mangrove fringes , in marine bays with high deposition rates of river sediments, in benthic foraminiferan assemblages of reefs, and investigations of food web relationships in turtle grass and plankton systems.

2. Measurements of concentration factors and turnover rates in selected organisms for radionuclides in ionic and chelated forms and in stable organic molecules.

3. Measurements of transfer of energy, biomass and trace elements between trophic levels in food webs.

4. Background measurements in physical and chemical oceanography and in rates of sedimentation in the areas of mixing of fresh and sea water. Included are investigations on changes in physical and chemical forms of elements added in ionic, colloidal and particulate form in the rivers and the influence of dissolved organic materials in the rivers upon these changes.

5. Development of accurate analytical methods for trace elements using neutron activation analysis, flame spectrophotometry, atomic absorption spectrophotometry, x-ray emission spectrography, colorimetry, fluorescence emission, arc spectrography, isotope dilution, coulometry and gas chromatography.

6. Determination of distribution patterns of "light" and "heavy" rare earths in marine ecosystems.

Geographic Areas

Work in two geographical areas is now in progress: (1) in areas of river outflows on the west coast, and (2) in mangrove forests on the south coast where little runoff from the land occurs.

On the west coast, three rivers draining limestone, volcanic and serpentinite substrates, respectively, empty into a 17-mile stretch of coast on Mona Pass. In the volcanic watershed are hydrothermal deposits of copper, in the serpentine area enhanced amounts of cobalt and nickel and in the limestone region, calcium and strontium. All rivers contain the same groups of major and trace elements, however the ratios of abundance vary significantly, each watershed delivers its characteristic assemblage of elements to the marine areas and organisms near the mouths of the rivers.

The Puerto Rico studies have been used for hazards prediction in the feasibility study for a sea-level Isthmus of Panama canal. Continued investigations of the transfer and distribution patterns of stable elements in a variety of marine environments and ecological systems will illustrate the mechanisms which govern the distribution of radionuclides introduced into similar systems. These results, coupled with controlled laboratory experiments will provide the basis upon which realistic mathematical models may be constructed in which the movement of the radionuclide through the near-shore marine environment and the food webs is treated as an isotope dilution process. The use of compartment-transfer route models cannot be realistically applied in the forseeable future because of the multitude of variables and feedback loops which must be accounted for. The specific activity approach, at present, appears to be the only practical approach.

Field data and descriptions of the mechanisms which control the biogeochemistry of the trace elements in near-shore areas are important in hazards considerations from nuclear contamination and are also of academic interest. The borders of the major seas and oceans constitute, in general, the more populated centers of the world and provide man's contact with the sea. Most of the nursing grounds for larval and immature stages of commercially important marine food animals are located in estuarine regions, and the adult forms of many species of edible marine animals as well as benthic algae inhabit the near-shore areas. Because human population densities are high at the sea-land interface, the chance of accidental (or purposeful) release of radionuclides is also high in these areas since the factors which result in large concentrations of humans also encourage the presence of

nuclear-powered ships, power reactors, industries utilizing radionuclides and the construction of military targets along the sea shores.

Investigators in radioecology generally agree that some radionuclides are accumulated by marine organisms in amounts which greatly exceed those in the water, on an equal weight basis, and that the near-shore areas are usually sites of intense biological, physical and chemical activity. Real disagreement exists, however, concerning the relative influence of environmental, physical, and chemical reactions and the biological activities upon the distribution patterns of the radionuclides in the biosphere, the hydrosphere and the bottom sediments.

In the near-shore areas iron, aluminum and silica, added in soluble or colloidal form by rivers, are precipitated, upon mixing with sea water, and often coprecipitate stable and radionuclides of many elements including Sc^{46}, Mn^{54}, Zn^{65}, Zr^{95}, and Ce^{144}. In some near-shore areas the production of faecal pellets by oysters and other molluscs may greatly increase the sedimentation rate of introduced radionuclides. The relative influence of the biological and environmental processes upon the trace element transfer and distribution may be determined by (1) controlled laboratory studies of chemical and physical interactions of fresh and salt water and the suspended sediments and (2) accurate measurements of distribution patterns of trace elements in the rocks and soils of watersheds, the river waters and sediments and the marine organisms, waters and sediments in near-shore areas.

Cooperative Projects

From its beginning, the PRNC Marine Biology Program has emphasized the use of distribution patterns of stable elements as the basis for understanding the fate of radionuclides released into biogeochemical systems. Within the last few years, increasing numbers of investigations in radioecology at other laboratories have been conducting studies on stable elements as well as radionuclides in organisms and their ecosystems.

Cooperative work with laboratories in the United States and Europe continues. During the past year joint research has been done with investigators from the Universities of Miami, North Carolina and Wisconsin; Oregon and Florida State Universities; Queens College; the Bureau of Commercial Fisheries Radiobiological Laboratory, and the U.S. Naval Radiological Defense Laboratory (now closed).

Technical Progress

1. Basic marine ecological studies in anoxic basins with mangrove fringes, in marine bays with high deposition rates of river sediments and in benthic foraminifera assemblages of reefs.

The work, started last year, on productivity and environmental characteristics at Phosphorescent Bay has been continued. Monthly samples of plankton, suspended particulates, water and bottom sediments as well as measurements of oxygen, salinity and water temperatures have been taken on a monthly basis. The area in and near Phosphorescent Bay contains mangroves in the natural state and a program has been initiated to study the physical, chemical and ecological features of the system. Mangroves are important, among other reasons, because of their abundance in some areas in which Plowshare operations are contemplated. A small research raft has been constructed with a diesel-electric generator and basic laboratory facilities. Collection of samples for chemical analysis and hydrographic measurements are made weekly at 5 stations, one outside the mangrove area in the open sea. Sources of phosphorus, iodine, iron, manganese, zinc and strontium are being investigated by following the concentration gradients of the elements in the water, sediments and organisms. The extremely low levels of phosphorus have made necessary the development of a preconcentration method, using liquid-liquid extraction from sea water followed by

colorimetry. A neutron activation analysis method for measurements of microamaounts of iodine has been developed for use in the analysis of the element in sea water and organisms.

Foraminiferan studies have been continued on the west coast of Puerto Rico in the near-shore marine areas of the outflows of the Añasco and Guanajibo Rivers. More than 100 samples of sediments were collected at depths 4 to 450 meters, and more than 300 species of foraminifers have been determined. Areas of investigation include:

(a) Assemblages in Puerto Rican submerged Pleistocene terraces and the description of several new foraminifers.

(b) Descriptions of arenaceous foraminifers in Pleistocene submerged reefs and terraces.

(c) The distribution of living and total foraminiferal populations in Mayagüez Bay and the influence of temperature, oxygen, salinity and bottom facies upon the assemblages.

(d) Distribution of foraminifers in the sediments of Añasco Bay and its nearby waters.

(e) Trace element composition of individual species of foraminiferans collected at different stations off the west coast of Puerto Rico.

Investigations on the C,H,N content of the marine copepod *Puntella mimocerami* have been related to size and sex of the organisms. Least squares regression analyses of the data have been completed. Analyses for fat and phosphorus content have been made on individual copepods of both sexes. Fat content was determined by extraction with a mixture of chloroform-methanol and phosphorus by neutron activation analysis. Male animals exhibit an increase in lipid content with increased size but the females show an initial increase in lipid up to a dry body weight of 0.26 mg. With further increases in size the lipid content decreases with size of organisms. Phosphorus analysis in females has not been done.

2. Measurements of concentration factors and turnover rates in organisms for elements in different forms.

During the past year investigations upon the relative uptake by algae of ionic Co^{60} and Co^{57} incorporated into vitamin B^{12} were completed by Dr. John Bunt, a visiting investigator to our laboratory from the University of Miami. The main results were as follows:

(a) Rates of uptake B^{12} and ionic cobalt were directly related although the algae sorted into two groups, one favoring uptake of B^{12} cobalt and the other ionic cobalt. The fleshy algae *Caulerpa racemosa, C. sertularioides* and *Laurencia corallopsis* discriminated in favor of uptake of ionic cobalt by a factor of two over the B^{12} cobalt when compared to the amounts of the two forms of the element in the water. The filamentous, fibrous algae *Enteromorpha lingulata, Grateloupia filicina, Gracilaria sjoestedtii* and *G. domingensis* Sonder accumulated B^{12} cobalt by a factor of two over the uptake of the ionic form from sea water.

(b) In the presence of sunlight *Laurencia* accumulated ionic cobalt at rates three times those in the dark but the rate of uptake of B^{12} cobalt was increased only 1.4 times by sunlight.

(c) Ionic cobalt was taken up in the presence of B^{12} cobalt in amounts greatly in excess of those apparently needed to satisfy requirements for B^{12}.

An investigation upon the uptake of mercury by the marine diatom *Chaetoceros costatum* was done by Dr. Walter Glooschenko, Florida State University, Research Participant of the Oak Ridge Associated Universities at PRNC, Marine Biology Program. Dividing cells were found to accumulate Hg^{203} longer than non-dividing cells but sunlight had no influence upon Hg^{203} uptake by non-dividing cells. Diatoms killed by formalin accumulated twice as much Hg^{203} when placed in the sea-water-solution of the radionuclides than did living cells.

3. Measurements of transfer of energy, biomass and trace elements between trophic levels in food webs.

Determinations of the concentrations of biologically important trace metals (Fe, Mg, Mn, Cu, Ca, Co) and other trace elements of no known biological function (Ni, Sc, Cd, Pb, Sr) in marine organisms of selected food webs have been continued. The food webs include:

(a) Plankton- herbivorous fish - carnivorous fish
(b) Clams - starfish
(c) Turtle grass - sea urchins - king helmet

Analysis of variance is being used to test for significant differences in, (1) individuals of a given species collected at one site, (2) individuals of a species collected at different locations, (3) individuals of different species with the same feeding habits collected at one site, (4) predators and prey and (5) different tissues and organs of selected individuals.

The trace elements are not concentrated with increasing trophic level except zinc and sometimes iron in food web number one. In food web number 3 the total transfer of trace element through the system is complicated by organ differences in the upper two trophic levels.

4.Background measurements in chemical and physical oceanography and in rates of sedimentation in areas of mixing of fresh and sea water.

Detailed investigations on the interactions of river water and sediments with sea water have been carried out under the joint direction of Dr. Douglas A. Wolfe, Bureau of commercial Fisheries Center for Estuarine and Menhaden Research, who is working with the Marine Biology Program on a BCF Training Assignment and Dr. William O. Forster, an Oak Ridge Post Doctorate from the Department of Oceanography, Oregon State University. Dr. Frank G. Lowman and Mr. Raul McClin are assisting on the project.

The partitioning of elements, added to river water in solution, between the water, suspended particulates and bottom sediments have been examined with neutral-pH tracer radionuclides. Cobalt-60, Zn^{65} and Mn^{54} were selected as biologically important elements and Ag^{110}, Sn^{113}, Sb^{125}, and Eu^{155} to represent soluble and insoluble trace elements. Preliminary results showed the following distributions:

	Sb^{125}	Ag^{110}	Zn^{65}	Co^{60}	Mn^{54}	Eu^{155}	Sn^{125}
% soluble	83	17	8	5	5	3	1
% with suspended particles	3	23	18	12	6	20	8
% with bottom sediments	14	60	74	83	87	77	91

Experiments were also made to determine the influence of sea water upon the distribution patterns of the tracers between the soluble form, suspended particles and the bottom sediments. Little influence of the sea water occurred until the salinity of the mixture reached 30°/₀₀. In this high salinity water the tracers increased in solubility, except antimony, for which the amount in solution decreased with increased salinity. The results were as follows:

	Sb^{125}	Ag^{110}	Zn^{65}	Co^{60}	Mn^{54}	Eu^{155}	Sn^{125}
% soluble, river water	83	17	8	5	5	3	1
% soluble, salinity 30°/oo	54	64	39	88	75	47	3
% soluble RW/% sol. 30°/oo	0.65	3.8	4.9	17.6	15	15.7	3

Experiments have been started to measure the rate and degree of coprecipitation of tracers and the corresponding stable elements from river water filtered through a 0.45 μ filter then added to different amounts of filtered sea water. Preliminary experiments suggest that, concurrent with the desorption of trace metals from river particles by the addition of sea water, precipitation and coprecipitation of many elements occur to form particles which will not pass a 0.4 μ filter.

Tests were made to determine the influence of epiphyton upon the adsorption of trace elements to bottom sediments in the river. In parallel experiments tracers were added to water (with suspended and bottom sediments) treated with antibiotics to destroy the epiphyton and untreated water (with suspended and bottom sediments). No difference in the distribution patterns of the "non essential" elements was noted, however, in the treated water biologically important elements were found in the soluble fraction 10 x for Mn^{54}, 6 x for Co^{60} and 3 x for Zn^{65} in comparison with the untreated water.

The laboratory experiments are matched by field studies conducted in the lower reaches of the Añasco River. The changes in the distribution and chemistry of trace elements that occur with the mixing of fresh water with sea water in areas where the current velocity of the river is decreased, the suspended particulates settle, and the ionic content of the water and the oxidation potential increases. The field investigations are divided into five sections:

(a) Distribution of Fe, Mn, Al, Sc, Co and Zn in the sediments, in suspended particles and in solution in areas of gradual horizontal and rapid vertical salinity change. Comparisons are being made of elemental content of the sediments throughout the lower 3 miles of the river and the shallow near-shore area of the bay outside the river. Interstitial water from the sediment samples are also analyzed for the six trace elements. A sediment squeezer utilizing compressed nitrogen has been constructed for 300g samples of sediments.

(b) Estimation of the total annual discharge of water, sediment load and trace elements from the Añasco River from quarterly measurements of current velocities made over 24 hour periods.

(c) Analysis of trace element content (including the elements listed above) in plants and animals near the mouth of the river. Ten species of plants and animals are being studied.

(d) Analysis of trace element content in plant leaves (sugar cane) immersed in river and sea water. Comparisons of the trace elements in these samples with the contents of the living leaves provide estimates of the total adsorption of trace elements to the leaves from precipitation and coprecipitation, adsorption of ionic elements and the activity of epiphyton. In the bay preliminary measurements show that some elements increase 500x in amount in the submerged leaves over those in the living leaves.

(e) Development of methods for field collection of assemblage of trace elements from water and suspended particulates in the river and in the bay. Standard ferric hydroxide precipitation, using high purified iron, has been tested for efficiency in removing normally-occurring elements and has been compared with recoveries from chelation and solvent extraction. Tests, using tracers, with chelating resins and with ammonium pyrolidine dithiocarbamate (APDC) in methyl isobutyl ketone (MIBK) was found to recover Co^{60}, Ag^{110}, Cr^{51}, Zn^{65} and Hg^{203} in reasonable yields if the pH of

the sea water was kept within narrow pH limits (± 0.2 pH unit). APDC extraction of cobalt and zinc was observed to have opposite yield efficiencies with change in pH so that batch extractions with good yields cannot be realized. For all samples of river and sea water, pretreatment to break down natural complexes of the elements must be done before chelation and extraction or variable yields result.

The filter-ion exchange unit developed by Battelle Northwest investigators for analysis of radionuclides in natural waters was loaned to us for a 1-year period. The equipment is capable of treating 1000 liters per hour in which the water is passed over a bed of $Al_2 0_3$. $SnCl_2$ and the trace elements adsorbed to the bed. Reduction-sorption experiments with the unit show good recoveries for scandium (83%), chromium (73%), antimony (90%) and silver (66%) from tap water, filtered sea water and sea water. The limitation of the method at the present time is imposed by contamination in the aluminum and tin reagents by the desired elements. For most elements the amounts in the filter bed prior to use are greater than the amounts collected from the water. Methods for obtaining high-purity aluminum and tin are being investigated.

5. Develpment of accurate analytical methods for trace elements.

Studies on interferences in atomic absorption analysis of environmental and biological samples in tropical, marine and terrestrial areas, show that large errors occur if the analyses are done on a single-beam instrument without prior removal of the interferents. Errors in trace element analysis by atomic absorption in a calcium carbonate matrix (clam shell) have been evaluated by comparison with analyses by neutron activation analysis. Investigations of matrix effects on errors in arc spectrography have been continued with neutron activation analysis being used to estimate true values.

A rapid method for the group separation of Zn, Fe, Cu, Ni, Co, Ca, Sr, Mg, Cd and Ag from sea water and solutions of biological ash has been developed, using chelating resins. The sample is eluted through the resin, the resin rinsed and irradiated, along with a control, in the reactor. Direct counting of the resin is done on a lithium-drifted germanium γ analyzer.

6. Determination of distribution patterns of "light" and "heavy" rare earths in marine ecosystems.

The major emphasis has been on the first five projects but increased emphasis in this area is anticipated during 1970 and 1971.

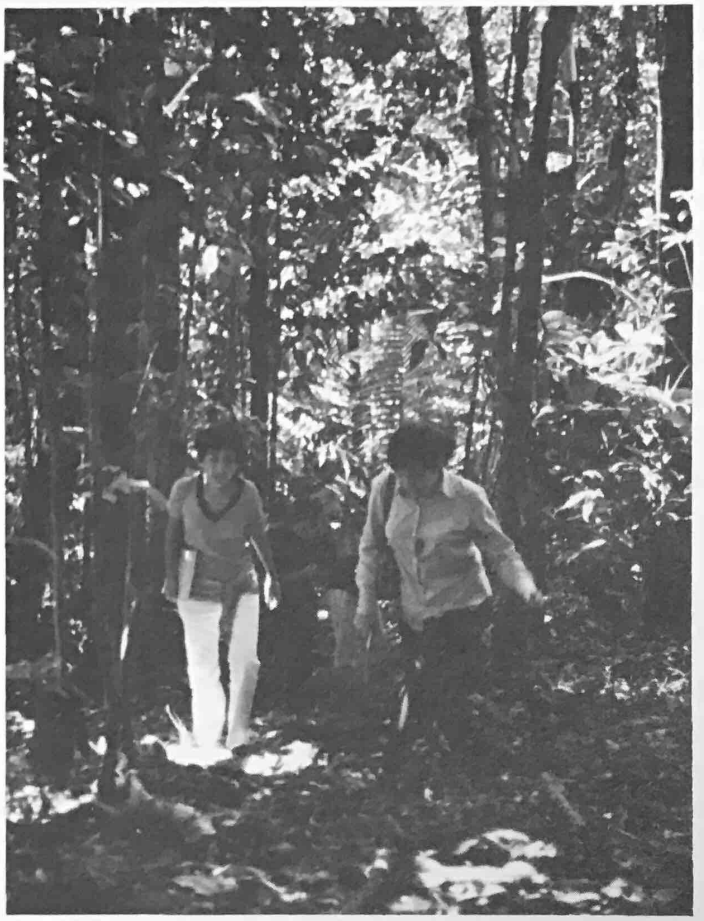
VISITING INVESTIGATORS

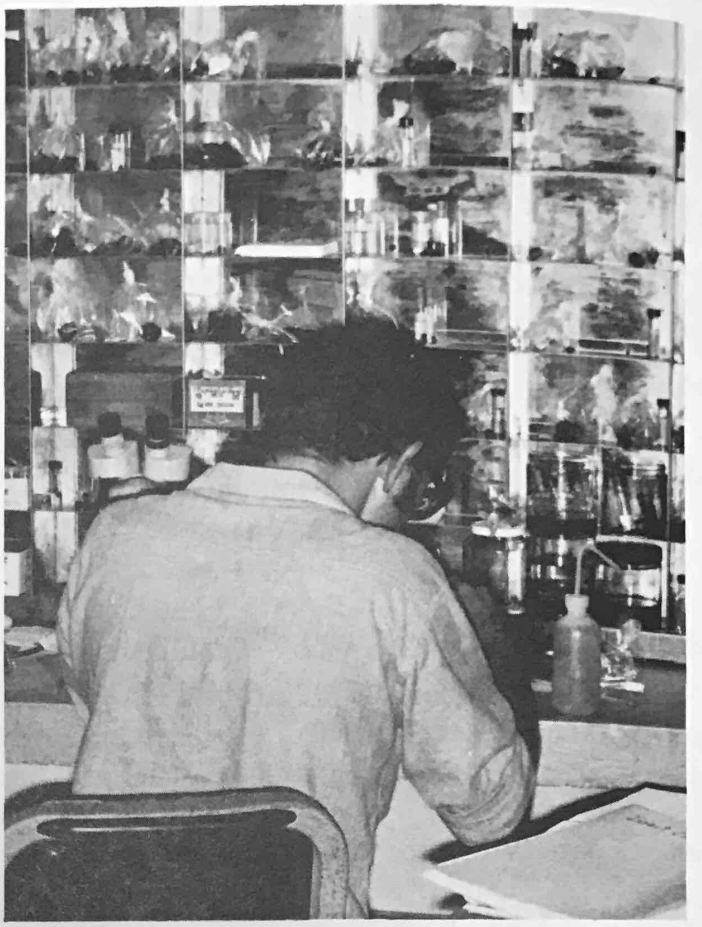
Several visiting scientists worked with staff members of the PRNC Marine Biology Program during 1969. Financial and/or laboratory and logistic support were provided for Dr. Daniel Habib, Queens College, N.Y.; Dr. Edward R. Tompkins, USNRDL; Mr. Edgar Gonzáles and Hugo Jiménez from the Instituto Venezolano de Investigaciones Científicas; Herman Cordova, a Colombian citizen at UPR Mayagüez; Dr. Graham Geise and Dr. Thomas Atwood, Dept of Marine Sciences, UPR Mayagüez; Dr. John Bunt, University of Miami; Dr. Douglas A. Wolfe, Bureau of Commercial Fisheries Center for Estuarine and Menhaden Research and Dr. William O. Forster, Department of Oceanography, Oregon State University.

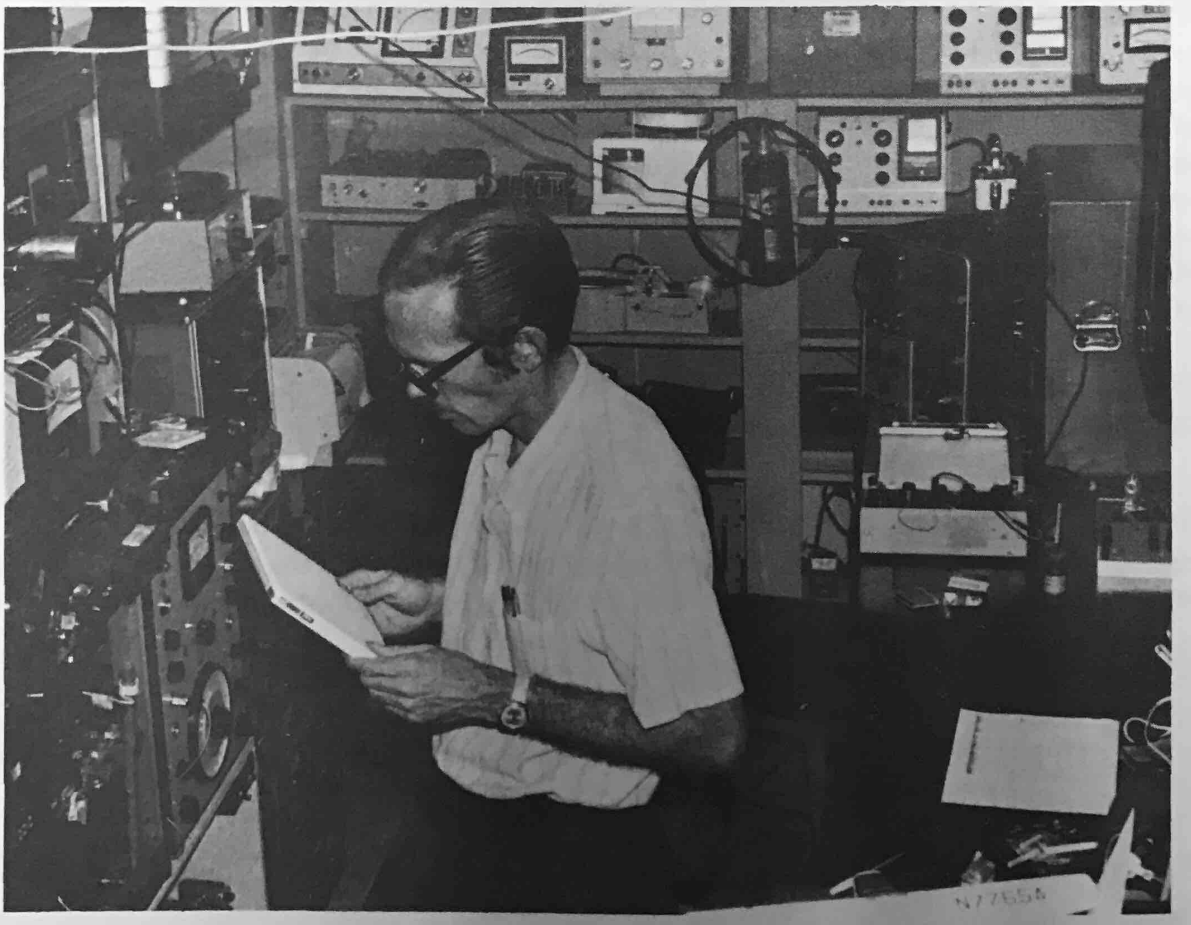
CHANGES IN STAFF

During the past year Dr. John H. Martin resigned to accept a position for one year at the Hopkins Marine Station, Pacific Grove, California. Dr. Steven S. Barnes left to accept a teaching appointment at Southampton College, Southampton, New York. Dr. Martin expects to rejoin the staff of the PRNC Radioecology Division during the next year.

Dr. Seppo E. Kolehmainen of Oak Ridge and the University of Tennessee, accepted an appointment as a senior investigator in the PRNC Marine Biology Program.







(a) Students on a guided tour of the Rain Forest at El Verde;

(b) Dr. Robert Lavigne in the Entomology Lab at El Verde identifies insects eaten by frogs and lizards as part of the study of food webs;

(c) Dr. George Drewry in the Instrument Room at El Verde conducts studies on the vocal organization of the Puerto Rican frogs.

TERRESTRIAL ECOLOGY

The main effort of the Terrestrial Ecology Program continues to be directed toward understanding the rain forest ecosystem. The study area, approximately 150 acres of montane forest, is located on the northwestern slope of El Yunque mountain in Eastern Puerto Rico at an altitude of 1500 feet. The original objectives of the program were to study: (1) the effects of gamma radiation on the tropical forest ecosystem; (2) the cycling of both radioactive and stable isotopes through the ecosystem; (3) the basic biological functions of this ecosystem, such as photosynthesis, respiration and transpiration in order to understand phenomena related to the first two objectives.

The first objective has been completed and the results are to be published in a separate volume which is now in press. With the project now in its seventh year, studies on the succession in the irradiated center consist of a complete census of plants, growth measurements and species diversity.

In 1967 emphasis was gradually shifted to the cycling of radioactive and stable isotopes though and within the ecosystem.

RESEARCH PROGRESS

Cycling Studies. Active research this past year has been primarily in the field of insect and amphibian ecology. Studies on radioactive and stable isotope movement in trees, litter and soil have been inactive most of the year due to completion of these studies during the first two months of 1969 and a change in staff. The results of these studies were summarized in the 1968 annual report (PRNC-131); a more detailed discussion was presented by Jordan in the 1969 annual report of the Terrestrial Ecology Program (PRNC-129).

A new experiment has been designed and initiated to quantify the input and dispersion of rainfall and its associated isotopes in the forest. The design is based upon studies made on the frequency and distribution of storm events. Analysis of rainfall data collected at the El Verde station from January, 1964 through May, 1966 showed that 68.8 percent of the rains were less than 0.50 inches. These data were tabulated by summing the total rainfall received in each 24 hour period (0600 hrs to 0600 hrs) and tabulating the number of rains by 0.10 inch classes (Table 1). It has been reported that 0.10 inch is sufficient to cleanse the atmosphere of particulate matter. Thus, rains in or near this amount may be very important in the input to the ecosystem. The experiment has been designed to yield data on the amount and chemistry of rain, throughfall and stemflow by 0.10 inch storm classes. Data collected will permit the development of predictive equations, through correlation-regression analysis, for rainfall-throughfall relationships and rainfall-stemflow- DBH relationships.

Table 1.
Distribution of rainfall by 0.1 inch classes
for the period January 1964 - May 1966.

Storm Class	Number of Events	Percent of Total Rains	Accumulative Percentage
less than 0.1	179	27.8	27.8
0.1	96	14.9	42.7
0.2	60	9.3	52.0
0.3	61	9.5	61.5
0.4	47	7.3	68.8
0.5	26	4.0	72.8
0.6	29	4.5	77.3
0.7	16	2.5	79.8
0.8	19	3.0	82.8
0.9	9	1.4	84.2
1.0	11	1.7	85.9
1.1	12	1.9	87.8
1.2	7	1.1	88.9
1.3	9	1.4	90.3
1.4	2	0.3	90.6
1.5	4	0.6	91.2
1.6	5	0.8	92.0
1.7	3	0.5	92.5
1.8	3	0.5	93.0
1.9	6	0.9	93.9
2.0	3	0.5	94.4
2.1	5	0.8	95.2
2.2	1	0.2	95.4
2.3	1	0.2	95.6
2.4	1	0.2	95.8
2.5	1	0.2	96.0
2.6	1	0.2	96.2
2.7	4	0.6	96.8
2.8	1	0.2	97.0
2.9	1	0.2	97.2
3.0	0	0	
greater than 3.0	18	2.8	100.0
Totals	643		

Succession. An area of rain forest was exposed for 3 months in 1965 to radiation from a 10,000 curies cesium 137 source. Study of the radiation damage and the subsequent recovery of the ecosystem has formed one of the three primary objectives of the Terrestrial Ecology program. During 1969 the major vegetational increases occurred in the sapling category of trees. There was a net decrease in the number of herbs and seedlings, limits on germination space available having been reached in late 1967. Effects of competition are now clearly visible, and theoretical aspects of this process are receiving the most intense study.

Results of this year's detailed mapping are still being processed but general trends emerge. Young individuals of the shade adapted species are beginning to enjoy a competitive advantage as the early successional species have matured and begun to shade the ground. As pre-

dicted in 1968, there is an increase in diversity without increase in individuals as the more abundant sun-adapted species are thinned more rapidly by competition than the less abundant shade-adapted species.

Amphibian Ecology. Preliminary investigations in amphibian ecology, reported last year, have been expanded to give considerable emphasis to this important component of the vertebrate fauna. The moist, moderate oceanic climate of Puerto Rico appears to combine with a relative scarcity of predators and competitors to give frogs on the island a larger share of vertebrate biomass and species composition than almost any place in the world. The frog fauna is so complex in its relationships that not until 1965 was the most familiar species on the island, *Eleutherodactylus coqui*, recognized to be distinct from the older montane species *E. portoricensis*. This genus comprises 14 of the 16 amphibian species now recognized here and its unique reproductive biology makes it well suited to exploit the ecological advantages to the fullest. Eleven species of the genus are common near PRNC's El Verde Field Station. *Bufo marinus* and *Leptodactylus albilabris*, the other two amphibians, also occur at El Verde, and two other *Eleutherodactylus* occur within 3 miles of the station. The remaining species, *E. cooki*, is restricted to the southeastern tip of the island and has been studied at intervals.

Reproduction in *Eleutherodactylus* is peculiar in that it is a non-amphibious amphibian; i.e. the eggs are not laid in water to hatch into swimming, gill-breathing tadpoles, but are placed, in the species observed so far, within the shelter occupied in the daytime by the male. They absorb water from the environment, and from the body of the male when conditions are dry, and he moves at night, when necessary, to a source of water for replenishment. The tadpole stage is passed within the eggshell and the hatchlings are fully formed miniature frogs which disperse for short distances about the male's shelter. Evidence is accumulating that the male performs an additional, subtle form of parental care by not locating his nest in the near vicinity of other calling males and by calling himself when established, which discourages other males from locating nearby. He thus provides his brood, which eat very small insects and probably compete very little with adults, with a ready-made feeding territory free of other beginning froglets.This possibility in frogs has ecological importance, for interspecific interactions between calling males should then reflect very closely the degree of potential interspecific competition, a factor that is often discussed but seldom measured by ecologists. The degree of competition is normally very difficult to quantify except under rigid laboratory conditions. As the social behavior of frogs is known to be strongly affected by acoustic cues, these factors can easily be studied under field conditions; sounds are relatively simple to record, store, analyze, reproduce in the field and even simulate.

Information for this study is being accumulated under five general headings. First is the attempt to measure feeding competition directly by analysis of stomach contents; this will be discussed elsewhere under insect ecology. Second is the use of radioactive tracers to identify the compartment of the ecosystem from which the food energy is derived; here the frogs are actually used as integrating devices to study insect energetics and are usually live-counted and returned unharmed to their territories. Third is an attempt to evaluate the evolutionary relationships of the frog species to each other; so far this has involved morphological study and the counting and structural comparison of each species' chromosomes. Fourth is the detailed analysis of the calls of each species, their organization in space and time from frequency through periodicity of notes, calls and call groups to daily and seasonal patterns of organization. Also documented are naturally occurring interactions, particularly of different species, where these can be proven. Fifth is experimental acoustics; equipment has been constructed which automatically exposes a calling frog to calls of his own species, other species and simulated calls having desired properties, while recording any responses he makes and plotting them against the stimulus.

Table 2
Summary of Amphibian Information Collected

Species	Habitat	Microhabitat	Diploid chromosomes	Adult size	Call ramps	Sharp canthus	Band-width	Number of bands	Center frequency (Hz)	Notes per call	notes	calls	call groups
1. *Bufo marinus*	outside forest	bare earth, gravel,-short grass	22	large	–	–	N	1	600	?	–	+	–
2. *Leptodactylus albilabris*	general	mud	22	large	–	–	M	2	1100,2200	1-20	+	+	–
3. *Eleutherodactylus richmodi*	forest only	tree roots, earth banks,-rockpiles	30	med.	–	+	W	1	3900	1-5	+	+	–
4. *E. unicolor*	mossy forest only	burrows	30	small	–	–	M	1	3600	8-13	–	+	–
5. *E. karlschmidti*	forest only	rocky streams	30	large	–	+	M	1	3200	5-25	+	+	–
6. *E. cooki*	Panduras mountains	caves	26	large	+	+	N	1	1800	3-7	?	?	?
7. *E. coqui*	general	tree trunks, shrubs-human buildings	26	med.	+	+	N	2	1400,2500	2	–	o	+
8. *E. portoricensis*	forest only	low shrubs, palms	26	med.	+	+	N	2	1700,2700	2	+	+	+
9. *E. antillensis*	outside forest only	weeds, low shrubs in-the open	26	med.	+	+	N	3	1900,2900-3300	2 5-10	+	+	+
10. *E. brittoni*	outside forest only	tall grass, vines	26	small	+	+	N	1	4800	1-6	–	+	+
11. *E. wightmanae*	forest only	litter	26	small	–	i	N	2	2400,4400	5-10	+	+	–
12. *E. hedricki*	forest only	tree holes only	26	med.	–	–	N	1	3200	7-19	+	+	–
13. *E. eneidae*	forest & forest edge	mossy banks & rocks	26	med.	–	–	M	1	3200	9-33	?	?	–
14. *E. locustus*	forest edge & mossy forest	steep grassy or fern slopes	26	small	–	–	M	1	5000	12-17	?	?	–
15. *E. cochranae*	lowlands only	wet meadows, marshes	26	small	–	–	M	1	4500	1-4	?	?	–
16. *E. gryllus*	forest edge & mossy forest	high shrubs, trees bromeliads	26	small	+	–	W	1	7000	1-20	+	+	+

Symbols:—

? - not yet studied
i - intermediate
o - occasional
+ - present
– - absent
W - wide
M - medium
N - narrow

Table 2 is a summary of some of the information accumulated during the study. The genus *Eleutherodactylus* seems to fall into three major groups based on chromosome number and the shape of the snout. The latter characteristic is backed up by chromosome morphology and a tendency to accelerate call rate within a call group (nicknamed ramping). Evidence for interaction of some species can be inferred from the simple distribution of dominant frequency bands. With the exception of *E. gryllus* and *E. cooki*, which have specialized calling sites, the former high in trees and the latter below ground, the remaining species have at least one band between 2500 and 5000 Hz. Larger species tend somewhat toward the lower limit and smaller ones toward the upper. Some species have been shown to respond to a variety of sounds in this band, increasing calling when sounds are louder than a certain threshold and abruptly ceasing or even moving away when they exceed a certain higher intensity. At the same time ample information is present in each call for the identification of the caller's species; presumably the females can use the sounds for mate identification and location. In this interpretation the calls of some species represent elegant solution to the opposing problems of species recognition and interspecific communication. In particular the species numbered 7, 8 and 9 have 2-note calls in which the first notes are low in frequency (outside the interspecific common band) and sharply fixed at specific frequencies, while the second notes sweep into broad overlap with one another. Species under 9, *E. antillensis*, whose habitat contacts that of every other species on the island, appears to be the amphibian equivalent of the mockingbird. It has 2 distinct calls exhibiting 3 frequency bands, and the ability to synchronize calling activity at several levels with various other species. It has been shown to respond to and affect several other species in the acoustic experiments. Figure 1 illustrates the method by which it synchronizes with the slower calling *E. coqui*.

A paper entitled "Communications Stratagems in Puerto Rican Anurans" co-authored with Dr. Austin S. Rand of Smithsonian Tropical Research Institute in Panama was presented to the Acoustical Society of America. A manuscript describing evolutionary trends in *Eleutherodactylus* chromosomes is in preparation.

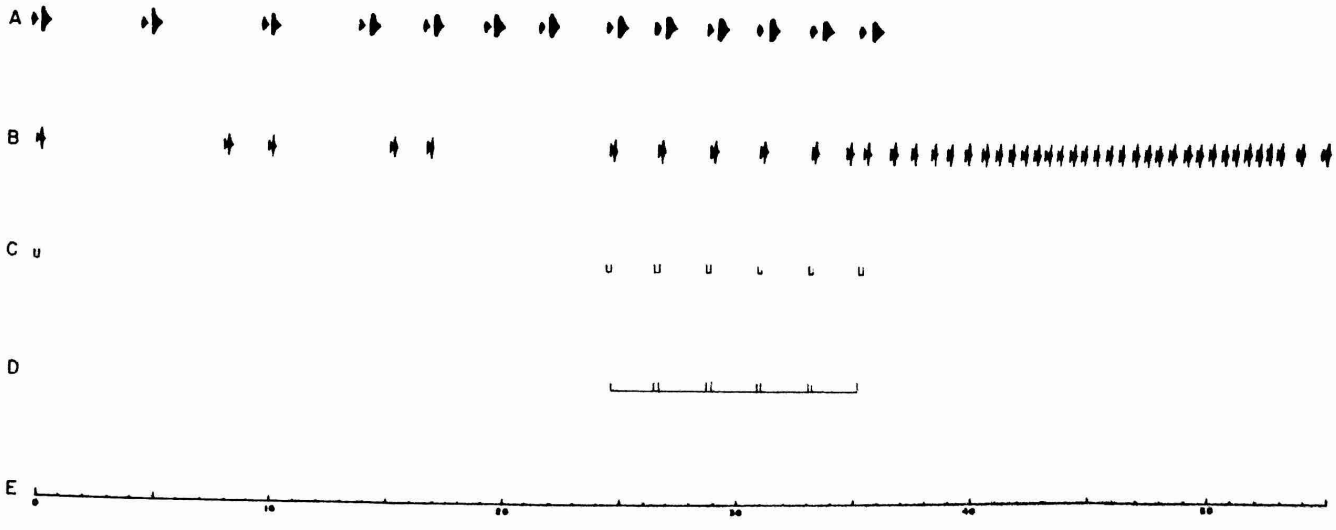


Figure 1 Interspecific interactions of the call level in *Eleuthrodactylus*. (A) Calls of *E. coqui*, invading. (B) Calls of *E. antillensis*, resident. (C) Apparent response times for B. (D) Probable response times for A. (E) Time in seconds. Figure shows one call group of each frog. Recorded at 0040, Dec. 23, 1969, temp. 21°C, El Verde field station, Puerto Rico.

Insect Ecology. Two main lines of research have been initiated at the El Verde Field Station in the past four months, both of which will eventually contribute to a basic understanding of the food web in the tropical wet forest. In one study, berlese samples were taken from existing Se^{75} and Fe^{59} plots to ascertain the fauna of the litter and to determine whether this fauna was picking up measurable amounts of radioactivity. Total samples were placed in the gamma well counter to check for radioactivity. Then they were separated into groupings according to habits and retested. Results thus far indicate that millipedes, isopods, collenbola, spiders and pseudoscorpions pick up the most radioactivity. Since the last two groups are predators, concentration of radioactive material must be due to consumption of radioactive prey. In addition, flesh fly adults (*Paraphrissopoda capitata* Aldrich) reared from dead radioactive lizards (*Anolis* sp.) were found to have picked up the radiation.

The second approach to the food web study has involved dissection of the digestive systems of 6 species of frogs and 3 species of lizards to ascertain what is eaten as well as in what segment of the forest feeding is occurring. Ants form a significant portion of the diet of all the species and a supplementary study has been initiated to determine the habits of forest ants which make some kinds available and some unavailable. One species of bark beetle (unidentified) which appears in the stomachs of *Eleutherodactylus wightmanae* *E. coqui*, *E. portoricensis* and *Anolis gundlachi* has been found to live and breed in the fallen fruits of the sierra palm, *Euterpe globosa.* In addition, litter collections have revealed that millipedes, sowbugs, pseudoscorpions, orobatid mites, *Forcipomyia* larvae and scale insects are common inhabitants of this strata. When these organisms appear in the stomachs of frogs or lizards it is probable that these animals have been feeding in the litter strata. Females and juveniles of *Anolis gundlachi*, both sexes of *Eleutherodactylus wightmanae richmondi* and the juveniles and females of *portoricensis* fall into this category. Orobatid mites are picked up by most lizards and frogs and only a study of species could provide data as to which mites occur only in the litter.

STAFF

Dr. Richard G. Clements, Soil Scientist, joined the staff in August as Chief Scientist I and Director of the Terrestrial Ecology Program. Dr. Clements was formerly with the Institute of Ecology, University of Georgia where he served as field director of Terrestrial Ecology studies in Eastern Panama and Northwestern Colombia in conjunction with the feasibility studies of a sea level canal. He was also one of the principal investigators in the Mineral Cycling Studies carried out at the Coweeta Hydrological Laboratory in North Carolina. Dr. Clements will continue his work with soil-plant relationships and the cycling of isotopes in the forest ecosystem.

Dr. Robert J. Lavigne, Entomologist, joined the project in September. Dr. Lavigne is on sabbatical from the University of Wyoming and will spend one year conducting studies on insect ecology in the Rain Forest.

Mr. William Dirk, electronic technician, joined the project in July and will be responsible for the operation and maintenance of the El Verde weather station and data logging system.

Dr. Carl F. Jordan resigned his position as Associate Scientist II in May to accept a position with Argonne National Laboratory.

Mr. Douglas Krom resigned his position as instrument technician in June.

Mr. Abel Rossy resigned his position as Research Technician to complete his degree at the University of Puerto Rico.

VISITING SCIENTISTS

Terrestrial Ecology served as host to several programs by visiting investigators in 1969.

Financial and logistic support were extended to Dr. Elizabeth McMahan of the University of North Carolina, Dr. Nellie Stark of the Desert Research Institute of the University of Nevada and Dr. Joe A. Edmisten of the University of Georgia. Dr. McMahan continued her long term studies of radiation effects on rain forest termite populations and the role of termites in ecosystem function. Recovery of termite populations following the 1965 gamma irradiation experiment accelerated with an increase during the year July 1968 to July 1969 from 24% of trees with termite tunnels to 55%. Much of the new activity seemed to come from areas adjacent to the radiation area, with two nests established and three old nests abandoned within the radiation area. The abandonment figure remains somewhat high in comparison to rates in control areas. The work on termite castes in *Nasutitermes costalis* was reported in a paper submitted to Insectes Sociaux.

Dr. Stark completed a program designed to serve as a feasibility study for similar large scale experiments. She measured uptake rates in forest plants and animals of Phosphorus 32, Selenium 75 and Iron 59, the latter 2 isotopes not previously having been studied in tropical ecosystems. She also performed several experiments designed to elucidate the role of mycorrhizal fungi in the rain forest and concluded that symbiosis between these fungi and the roots of forest trees is extensive and significant.

Dr. Edmisten continued his studies on the role of epiphyllae in nitrogen fixation and the nitrogen budget in the rain forest.

Logistic support and Ad Honorem appointments with PRNC were extended to Dr. J. H. Connell of the University of California, Santa Barbara for experiments on effect of parent trees on germination and seedling success in *Tetragastris balsamifera;* Dr. Robert Harris and assistant Mr. Anders Andren of Florida State University to study aerosols and particulate matter in the air and precipitation of eastern Puerto Rico; Dr. Robert Baker and assistant Mr. Jenaro López of Texas Technological College, Lubbock, Texas to study the chromosomes distribution and ecology of rain forest bats; Drs. Roland Seymour and Richard T. Hartman of University of Pittsburgh to investigate aquatic fungi in the rain forest; Dr. Alan Moore of the University of North Carolina to examine earthworm ecology in the rain forest; and Mr. L.A. Burns of the University of North Carolina who studied energetics of *Nasusitermes costalis,* working during part of his visit with Dr. McMahan; Miss Bess Haines, Rutgers University, investigated the effects of light on the ecology of mosses. The program provided labor to assist in the graduate research program of Mr. Jack Ewel of the University of North Carolina, who is investigating recovery capabilities of forest vegetation in several forest types of Puerto Rico and Costa Rica. Other scientific visitors who studied aspects of forest ecology were Drs. Austin S. Rand of Smithsonian Tropical Research Institute, Panama; Thomas Schoener of Harvard University, Llewelyn Williams of U.S. Department of Agriculture, Crop Research Division and Mr. John F. Addicott of the University of Michigan.

Mr. Juan Silva Parra(right) shows a radioactive sample to the U.S. Ambassador to Brazil(center) and the Sao Paulo Governor during the USAEC Atoms in Action Exhibit in Brazil.

Partial view at the Atoms in Action gamma irradiation facility used in research experiments in Sao Paulo, Brazil. Students are hearing a lecture in the gamma reactor classroom.

INTERNATIONAL EXHIBITS

Since 1965 the Puerto Rico Nuclear Center has been responsible for research conducted in conjunction with the Atoms in Action Exhibits in various countries in Latin America. The Oak Ridge Associated Universities is responsible for the Exhibit Training Programs and the USAEC operates a Technical Library as part of the Exhibit. The Exhibits provide information on peaceful applications of nuclear energy to persons of varying backgrounds. The general public is given guided tours of special displays which demonstrate the nature, applications and developments of atomic energy. Students, scientists and physicians are offered demonstrations, lecture courses and supervised participation in research involving applications of radiation to problems of regional origin and interest, with emphasis on the use of the gamma source and the reactor available at the Exhibit.

In October and November 1969, the exhibit visited Sao Paulo, Brazil.

RESEARCH ACTIVITIES IN SAO PAULO, BRAZIL

The Gamma Irradiation Facility with a source of 3,500 Curies of cobalt 60, the exhibit's reactor, and associated technical equipment were utilized by members of the Institute of Atomic Energy (IAE) of Sao Paulo, and students of Mackenzie University, the University of Sao Paulo (USP), and Catholic University. The projects were:

Applied Research

A graduate student from the IAE initiated a study of the separation of hafnium and zirconium, two elements which exist in the mineral Caldasite in Brazil. This study will be used to satisfy requirements for an advanced degree. To optimize the separation of hafnium and zirconium in Caldasite, samples of the same were irradiated in the reactor and then submitted to different types of chemical separation, the objective being to obtain the best yield possible.

The ultimate objective is to produce hafnium and zirconium at a considerably lower cost than is now possible in Brazil. This work will continue at the Institute of Atomic Energy.

Basic Research

a. Radiation Chemistry

Two graduate students of pharmacy at the USP began a study entitled: Radiolytic Aromatic Hydroxylation. Aqueous solutions of nitrobenzene (C^{14}) and chlorobenzene (C^{14}) were irradiated. The ratio of ortho, meta and para substitution by hydroxyl radicals was determined by isotope dilution. The results indicate that the major point of attack is the ortho position in agreement with the molecular orbital calculations, but are contrary to results of previously reported work in this field. The participating students had an opportunity to use equipment and isotopes which are not easily available to them and to progress toward fulfilling requirements for their Ph.D. in Pharmacy. The project will continue at USP. The results of this project may be published.

Three chemical engineering students of Mackenzie University initiated and completed a study entitled: Radiation Protection of Uracil and Dimethylsulfoxide. Uracil is part of the

DNA molecule which determines the heredity of an individual. It has been found that Dimethylsulfoxide (DMSO) protects rats and mice from death by overexposure to radiation. Aqueous solutions of uracil in the presence and absence of DMSO were irradiated. The G-value was found to be about 2.4 in the absence of DMSO and approximately 0.1 - 0.2 in the presence of DMSO. This work will be used to partially fulfill thesis requirements of the participants, who also had an opportunity to use equipment which is unavailable at Mackenzie University.

b. Solid State Physics

Five physics students from Catholic University completed a project on Fatigue in Photomultiplier Tubes. Fatigue, the abnormal variation in the yield of secondary electron emission of photomultiplier tubes, is a temporary phenomenon, the disturbing effects of which are important to the nuclear spectroscopist. The tubes are used in counters and other equipment essential to research. The response of such tubes is seriously affected by the fatigue factor. Using the results of research already accomplished at PRNC, the students studied the fatigue in a type of photomultiplier tube which had not been examined previously. The experimental part of this study has been completed. Calculations are now being done by the researchers.

c. Radiochemistry

Three chemistry students of Mackenzie University initiated a project on: Study of Nuclear Transformations in Organometallic Compounds. Samples of ferrocene, an organometallic compound, were irradiated utilizing the reactor. The object was to activate the iron molecule and to analyze the quantity of iron which appeared in the form of Fe^{++}, Fe^{+++}; and the ferocino ion. Also analyzed was the amount of iron that remains in the ferrocene. Additional samples were irradiated in the reactor to determine if the percentage of ferrocene remains constant after being activated. The project was completed and will be used to satisfy final requirements for undergraduate degrees. The data obtained contradicts data already published.

LECTURES IN SAO PAULO, BRAZIL

In conjunction with the research program, PRNC personnel gave the following lectures during the Atoms in Action Exhibit which were attended by 291 persons:

Dr. Ramiro Martínez, Senior Scientist I, PRNC, Rio Piedras: (a) Some factors of *Trypanosoma cruzi* infection in cell cultures, Microbiology Department, Federal University of Sao Paulo; (b) Isolation of *Trypanosoma cruzi* from blood by means of tissue culture, Instituto Adolfo Lutz, Sao Paulo; (c) Effects of Gamma radiation on experimental infection with *Trypanosoma cruzi*, School of Medicine, University of Minas Gerais, Belo Horizonte; (d) Use of Isotopes for the Labeling of *Biomphalaria glabrata*, Vector of *Schistosoma mansoni*, Department of Biology, Faculty of Minas Gerais, Belo Horizonte; (e) *Trypanosoma cruzi* Infections in Mice and at the Cellular Level, Institute of Microbiology, University of Brazil, Río de Janeiro.

Dr. Manfred Eberhardt, Scientist I, PRNC Río Piedras: (a) Use of Radiation in Chemistry, students from Faculty of Pharmacy Exhibit; (b) Steric Effects in Radiation Chemistry, Biochemistry and Pharmacy Faculty; (c) Homolytic and Radiolytic Aromatic Substitution, University of Sao Paulo.

Dr. Owen Wheeler, Senior Scientist I, PRNC Mayagüez: (a) Recoil Reactions in Ferrocene, students from Mackenzie University, Sao Paulo; (b) Mechanisms of Labeled Compound with Tritium, Atomic Energy Institute; (c) Nuclear Transformation in Organometallic Compounds, Faculty of Pharmacy; (d) Radiolysis of Peptides, Atomic Energy Institute.

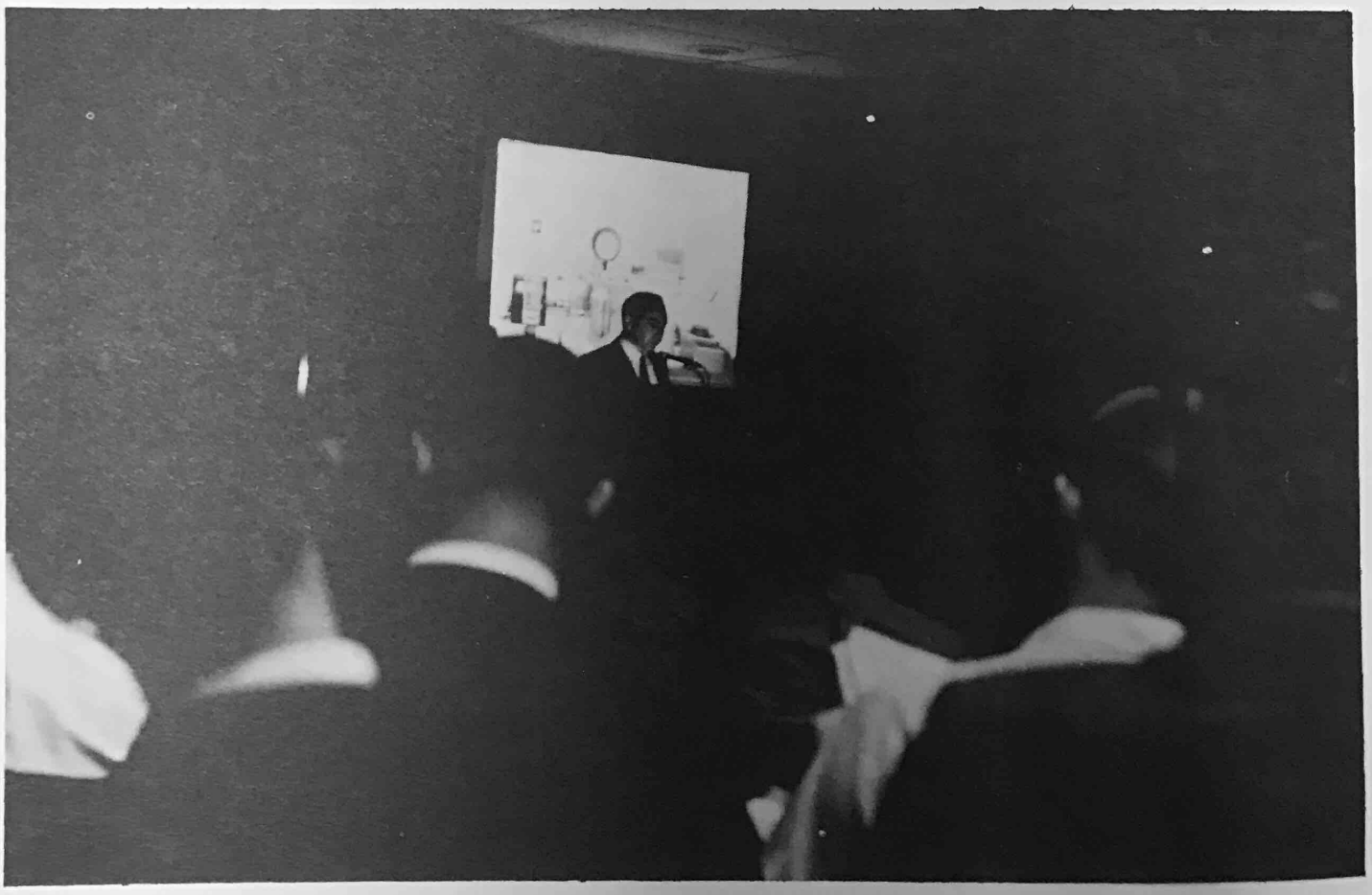
Dr. Ignacio Cantarell, Scientist I, PRNC Mayagüez: (a) Color Centers Energy Equations, Mackenzie University; (b) PRNC Research Program, Catholic University.

Sr. Juan Silva Parra, Senior Associate, PRNC Río Piedras: (a) Neutron Detection, Exhibit; Reactor Instrumentation, Exhibit.

Dr. Aldo Lanaro, Senior Scientist I, PRNC Río Piedras: (a) Lung Function and Lung Scanning, Exhibit; (b) Anemia and Blood Test Unit Radioisotopes, Exhibit; (c) Kidney Function and Kidney Scanning, Exhibit; (d) Biological Effects of Radiation and Protection, Exhibit.

Dr. Manfred Eberhardt of PRNC(right) and three students from the Central University of Sao Paulo, Brazil, work in the radiochemistry laboratory of the Atoms in Action exhibit.

Miss Ivette Minguela at the reading room, PRNC Mayagüez.



Slide lecture being given at the American Nuclear Society convention at the San Jerónimo Hilton Hotel.

OFFICE OF THE DIRECTOR

The Director's Office plans and coordinates the various educational and research programs carried out by the Puerto Rico Nuclear Center.

It is also the center for internal and external communications, for management of meetings and conferences, and for serving the needs of students and trainees from abroad. Staff members of the Director's Office also take part in the teaching and research activities of several PRNC divisions.

1969 was an active year on several fronts: there was expansion in the economic aid program for Latin American students and trainees; the new $1 million wing for the Bio-Medical Building in Río Piedras was nearly completed, and several of the new offices and laboratories were occupied; two major American Nuclear Society meetings were held in San Juan, with PRNC as the host organization; and, with growing interest in the United States(and in Puerto Rico) in the field of ecology,PRNC prepared for an expanding role in the study of tropical ecosystems. In Puerto Rico, whose energy needs are expanding rapidly, there is particular interest in the ecological impact of fossil and nuclear fuels.

During the year, PRNC--through the Director's Office--also collaborated with the University of Puerto Rico in evaluating future needs in college-level science education, and with the Commonwealth government in drafting a status report on air and water pollution in Puerto Rico. This report helped form the basis for a new executive level Environmental Quality Board, responsible directly to the Governor,and with substantial authority in its own right.

PRNC Impact Upon Science Studies in Puerto Rico

Late in 1969, PRNC carried out a study to examine the impact it has had upon graduate science studies in Puerto Rico, which has long been a consumer of imported technology. The results show that the impact has been quite significant.

Science still plays a relatively small role in Puerto Rico's universities. A recent survey shows that only 18.6 percent of the senior faculty in the island's colleges are involved in the natural sciences or in engineering, compared with 44.4 percent for Israel, and 45 percent for Japan.

In the past 30 years, the University of Puerto Rico has conferred only 194 Master of Science Degrees. However, 185 of these 194 were granted in the past ten years, and 48 of them were awarded in fiscal 1968-69, demonstrating a sharp upward trend. (See Table 1)

The Nuclear Center has played an important role in stimulating graduate level work. Significantly, the first student to earn a degree in the UPR's new doctoral program in chemistry did her work in PRNC's Radiation Chemistry project. Last year, of the seven graduate physics students at the UPR Río Piedras campus, five were working in PRNC's Solid State Physics laboratory.

Table 1

Master of Science Degrees at University of Puerto Rico

	1968-69	Last 10 Years 1959-69	Last 30 Years 1939-69
RIO PIEDRAS CAMPUS			
M. S. Physics	4	4	4
M.S. Biology	6	15	15
M.S. Chemistry	5	18	18
MEDICAL SCIENCES CAMPUS			
** M.S. Radiological Health	5	5	5
MAYAGUEZ			
M.S. Agriculture	9	40	40
M.S. Chemistry	4	25	25
M.S. Nuclear Technology	0	20	26
M.S. Nuclear Engineering	2	15	15
M.S. Radiological Physics	0	10	10
M.S. Physics	3	4	4
M.S. Biology	4	13	13
M.S. Civil Engineering	1	1	1
M.S. Electrical Engineering	1	1	1
M.S. Mathematics	8	56	59
	48	185	194

Note: For some idea of proportion, the University of Puerto Rico has conferred 68,716 degrees and diplomas in the past 30 years, 37,057 in the last 10 years, and 4,489 in 1968-69.

** All requirements completed for the M.S. Degree in August 1969.

Most encouraging of all, however, is that PRNC has in several cases served as a catalyst, resulting in the establishment of graduate programs outside its own laboratory, on the UPR campus itself. For example, in 1966, all five of the engineering graduate students at UPR Mayagüez did their thesis research in the PRNC Nuclear Engineering Division facility. By 1969, the number of students had expanded to 25, with 11 of these at PRNC and the other 14 at the university proper. Even more dramatic is the case of the graduate chemistry program at UPR Río Piedras. In 1962, out of a total of 10 graduate students, 9 were working at PRNC. By 1969, there were 44 chemistry students, with 32 of them working at the UPR campus, and 12 at PRNC. The total included 18 aspirants for the Ph.D., compared with none in 1962. (see Table 2)

Table 2

Graduate Students doing Chemistry Research at UPR - Rio Piedras

	1961*	1962	1963	1964	1965	1966	1967	1968	1969
Total Students	—	10	11	16	13	15	26	39**	44***
Total at PRNC	—	9	9	10	9	9	10	12	12

* M.S. Program begins August 1961

** Includes 15 Ph.D. aspirants and 15 M.S. candidates

*** Includes 18 Ph.D. aspirants and 26 M.S. candidates

Another interesting outcome of the study is the notable rise in educational activity for non-U.S. students at PRNC. In fact, 1969 was a record year, as PRNC enrolled 50 foreign students, compared with 35 in 1964, and 10 in 1958. Significant, too, was the longer average residence time per student--from 2.7 months in 1958 to 5 months in 1969--indicating a trend towards more intensive, in-depth training. (see Table 3)

Table 3

Educational Activity for Non-U.S. Students at the P.R.N.C.

Fiscal Years	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969*	1970
Total non-U.S. Students	10	18	27	17	21	32	35	13	32	37	46	50	50
Total Student Months	27	44	69	84	42	71	144	56	96	139	232	248	300
Average Residence Time (months)	2.7	2.4	2.5	4.9	2.0	2.2	4.1	4.3	3.0	3.8	5.0	5.0	5.0

* estimate

Student Economic Aid

PRNC continued to expand its Student Economic Aid Program, a new scholarship fund for Latin American students and trainees. In fiscal 1969, the University of Puerto Rico granted $10,000 for PRNC - administered scholarships, and the Organization of American States--under the Centers of Excellence Program--granted 10 fellowships for study at PRNC in the final three months of 1969.

During FY 1969, the $10,000 grant benefited 12 students; one from Spain and the rest from seven different Latin American republics. Some students worked towards their M.S. degrees, while others studied such varied topics as tritium labeling, hot atom chemistry and radiation therapy. In FY 1970, 13 students(one from Spain, the others from nine different South American republics) benefited from the $10,000 grant. Grant sizes ranged from $150 for a student from Barbados who studied neutron diffraction for two weeks, to $1775 for a Colombian, who will spend a year working towards an M.S. in Biology.

Under the OAS Regional Scientific and Technological Program 10 graduate students from 7 Latin American countries studied at PRNC during 1969, with most of them working towards their M.S. degree. (See Tables 4, 5 and 6).

New Bio-Medical Building Wing

By late 1969, some PRNC personnel had already moved to the new $1 million wing of the Bio-Medical Building in Río Piedras, which was scheduled for completion in early 1970. The new building offers 24,700 square feet of extra lab and office space. As the moving proceeded, renovations of the present building continued. PRNC's Technical Services Division assumed an expanding role in supervising and performing some of the renovation work, whereas an outside contractor had been responsible for construction of the new wing. Space has been set aside for the first time for a staff reading room. Facilities in temporary structures are being re-housed. Files and other gear once kept in crowded passageways have been returned to office and lab areas, vastly improving working conditions.

Expansion of Ecological Studies

Although budget cuts have checked growth in some areas of training and research, PRNC geared for expansion in the field of ecological studies. Contracts were confirmed for the Marine Biology program's new research vessel, the R.F. Palumbo, to replace the Shimada, which was used in the trans-isthmian canal study. The 95-foot Palumbo will be the first vessel built for the Atomic Energy Commission, and will be one of the newest marine research vessels of her type; it will be equipped with modern chemistry, biological and analytical laboratories and will be fully air-conditioned. Its mission will be to collect marine data and specimens for the Marine Biology and Oceanography program in the Caribbean and other Latin American waters. Construction was scheduled to begin in August 1970, with completion estimated by February 1971, after which it will be sailed to Puerto Rico by Marine Biology personnel from its building site in San Diego, California(See Figure 1).

Other goods news is the fact that the Marine Biology program will benefit from a new half million dollar research facility being constructed at Guanajibo on the west coast by the Puerto Rican government for development of fishing. PRNC owns 20 acres adjacent to this site, and has a laborátory type structure on the land. It is expected that many Marine Biology activities will gradually shift from Mayagüez to Guanajibo as the new facility comes into use. A new temporary pier to service this complex is being built by PRNC, to be replaced later by a more permanent ship berthing installation. This will be the home port for the new Palumbo, as well as for smaller fishing boats attached to the Commonwealth of Puerto Rico government laboratory.

SUMMER RESEARCH PARTICIPANTS

Three Oak Ridge Research Participants worked at PRNC during 1969, for periods of three months each.

. Dr. Herbert J. Lilling from the West Virginia Institute of Technology worked with Dr. Eberhardt in the Physical Sciences Division. He carried out research on the synthesis of co-polymers of styrene and 1-,2-vinylnapthalene. These co-polymers were gamma irradiated from a ^{60}Co source and the $G_{(H_2)}$ and $G_{(R)}$ values were measured.

.Dr. Harold W. Fenrick from Wisconsin State University worked with Drs. Lee and Wheeler in the Nuclear Sciences Division on Electron Spin Resonance of Irradiated Organic Compounds.

.Dr. Ira Jones from Inter American University, Puerto Rico, worked with Drs. Koo and Ferrer-Monge in the Agricultural Bio-Sciences Division, studying nuclear structures and meiosis of Sporozoa of Caribbean Sipunculida and its radiobiology.

MEETINGS

Among the significant events of the year were two meetings of the American Nuclear Society held at the San Jerónimo Hilton Hotel in Puerto Rico, in which PRNC served as the host installation.

The meeting, held on May 4-6, was the first official ANS topical meeting held in Puerto Rico, and was the second time that an ANS group had met anywhere in Latin America. The topic was Radiation and Isotope Technology in Latin American Development. The meeting brought together scientists of North and South America, and other world areas, for a joint consideration of: (1) isotopes and radiation technology which has been developed

and applied in Latin America, and (2) general developments in isotopes and radiation technology which may be useful in Latin America and other areas. Background sessions were also given on the present economic and technological situation in Latin America.

It seemed appropriate that Puerto Rico, with its midway geographic location, and bilingual capability, should serve as a meeting ground for scientists from both continents of the Western Hemisphere. Papers were presented in both Spanish and English, and simultaneous translation facilities permitted free discussion afterwards.

The meeting, attended by 125 persons, including 23 Latin American scientists, was sponsored by the ANS Radiation and Isotopes Division, the USAEC Divisions of Isotope Development and Nuclear Education and Training, and the Oak Ridge Associated Universities. As host institution, PRNC had a 7-man Local Meeting Committee of its personnel, and also provided other technical and secretarial support. PRNC staff members contributed five scientific papers to the meeting, and five members of the staff served as Session Chairmen.

After the meeting, PRNC's Editorial Services Division edited a bilingual 600-page Proceedings Volume of the meeting (PRNC-135), which in early 1970 was printed and distributed by the USAEC Division of Technical Information Extension.

On October 1-3 of 1969, the ANS Reactor Operations Division, with the cooperation of the Puerto Rico Water Resources Authority and PRNC, sponsored a Conference on Reactor Operating Experience. Approximately 275 persons registered for the meeting, also held at the San Jerónimo Hilton Hotel. Six executive staff members of PRNC served in various capacities, from general chairman to tasks such as registration, finance, hotel liaison, and public information. For two days prior to this meeting, Dr. Gomberg, Mr. Barceló(Assistant Director for Technical Operations) and Mr. Brown(Head of the Reactor Division) participated in portions of the USAEC Reactor Safety Conference at the same hotel.

The Advisory Committee to the University President on the Puerto Rico Nuclear Center met twice, as scheduled, during 1969 to review PRNC's programs. The first meeting was held at the Bio-Medical Building in Río Piedras on February 17-18.

In addition to a review of on-going programs, the committee considered, in depth, the role that PRNC might and should play in the developing economy of Puerto Rico and in assisting development in Latin America. These discussions raised many questions of the scope of and the limits on PRNC and AEC operations. To help resolve these questions, the next meeting was set aside for policy discussions.

The second meeting was also held in Río Piedras, on September 22-23. In addition to the committee and members of the U.P.R. staff, others attending were: Samuel R. Sapirie, Manager of Oak Ridge Operations; R.W. McCauley, Deputy Assistant Manager for Administration, ORO; and Dr. Spofford G. English, Assistant General Manager of AEC for Research and Development. The group also met with Puerto Rico's Governor, Luis A. Ferré, where development plans for Puerto Rican science and industry were discussed.

This meeting provided vital information and guidance to the committee and to the PRNC staff.

STAFF CHANGES AND ACTIVITIES

Dr. Edwin Roig joined PRNC as Deputy Director, succeeding Dr. Amador Cobas, who asked to be relieved so that he could devote full time to his duties as Head of the PRNC Physical Sciences Division, and as member of the faculty of the Physics Department, UPR Río Piedras. Dr. Roig was Dean of the College of Natural Sciences, UPR Río Piedras, prior to joining PRNC. From October 1957 until September 1966, he had worked with PRNC, during which time he headed the Radioisotopes Division.

Dr. Owen H. Wheeler asked to be relieved of his duties as Associate Director in Mayagüez in order to pursue his research and teaching activities at PRNC more effectively. Dr. Peter Paraskevoudakis was appointed Acting Associate Director for Mayagüez, effective August 1, 1969.

Dr. Gomberg was appointed Chairman of a Sub-Committee to study pollution problems in Puerto Rico, by the Advisory Committee to the Governor. On November 2, the sub-committee completed its written document, entitled "Pollution Report to the Governor's Advisory Council." This report was the catalyst for later executive and legislative action, creating an Environmental Quality Board.

Dr. Gomberg was also appointed advisor to the Energy Center Committee, a joint venture of the Puerto Rico Water Resources Authority and the USAEC, to study the feasability of developing a major energy center (including water desalination) for Puerto Rico. This study envisions the ultimate development of an energy center which was already started on the island's south coast and has scheduled for installation two 400MW oil-burning plants for 1973 and the first nuclear power plant in Puerto Rico--a 600 MW pressurized water reactor--by 1975.

During the year, Dr. Gomberg: attended a meeting of the Washington, D.C. section of the American Nuclear Society (March 24) where he spoke on "Nuclear Science Activities in Central and South America" and later met with the staff of the office of the Scientific Advisor to President Nixon; attended the Symposium on "Education for the Peaceful Uses of Nuclear Explosives" at the University of Arizona in Tucson (March 31-April 2) where he spoke on "Plowshare Studies at PRNC" and also acted as rapporteur for the whole conference; visited New York and Washington (May 13-16) to discuss PRNC's Latin America activities with AID officials and met with PRNC Advisory Committee members; consulted with AID officials in Bogotá, Colombia (June 2) regarding programs conducted by PRNC and the Colombian Institute of Nuclear Affairs; visited various agencies and institutions in Europe (June 7-29) to discuss training and scientific research activity of mutual interest with officials of the IAEA: participated in a meeting in San Diego, California (July 11) to finalize the Safeguards Summary Report for the TRIGA-Flip Reactor at the Puerto Rico Nuclear Center (PRNC-123); attended a meeting of the Executive Council of the American Nuclear Society in New York City (September 19); attended an IAEA Study Group Meeting on Isotope Production in Sao Paulo, Brazil (October 6-10) where he reported on Isotope and Radiation Uses in Latin America, and met with members of the Latin American scientific community; attended the Annual Winter Meeting and the executive board of the American Nuclear Society in San Francisco (November 30-December 4), after first visiting the TRIGA Reactor Installation at Texas A&M College.

VISITORS

Among the many visitors to PRNC's installations during 1969 were: AEC Chairman Dr. Glenn Seaborg, with Mrs. Seaborg, who visited the Bio-Medical Building in Río Piedras (February 7)..... Congressman John B. Anderson from Illinois, a member of the Joint Congressional Committee on Atomic Energy, who inspected facilities in Mayagüez and

Río Piedras (April 10)..... Dr. Spofford G. English, from USAEC headquarters in Washington, who visited PRNC Mayagüez (September 23)..... Robert C. Dreyer, Assistant Manager for Composition Processes and Manufacturing, DTIE, USAEC, who reviewed PRNC's editing, composing, reproduction and copying services (October 6-17).... Dr. Elliott Pierce, Director, USAEC Division of Nuclear Education and Training, Dr. Herman Roth, Director, Oak Ridge Operations Laboratory and University Division, and Mr. Earl Cook, DNET, USAEC, who reviewed PRNC's program and facilities (November 17-21)..... Mr. Arve Dahl and Mr. Allan Richardson of the Bureau of Radiological Health, and Dr. Charles Nice of Tulane University visited PRNC (November 24-25) to evaluate the M.S. Program in Radiological Health for a Radiological Health Specialist Training Grant. During the year, several local high school and university level student groups visited PRNC's laboratories in Río Piedras and Mayagüez.

It was gratifying to receive the following message at Christmastime, 1969:

I would like to take advantage of the Christmas season to thank you and the personnel that collaborate with you, for the magnificent cooperation that you have given to our international exchange program.

There is no doubt that the achievements in the field of technical cooperation are due in large measure to the active participation of institutions such as yours, that collaborate from day to day in favor of a better world and international understanding.

Fernando Chardón
Secretary of State
Commonwealth of Puerto Rico

Messrs. Rushford and Barceló examine the new printing facilities at PRNC Mayagüez.

Table 4

PUERTO RICO NUCLEAR CENTER — STUDENT ECONOMIC AID PROGRAM — FISCAL YEAR 1969 $10,000 Grant February 1st, 1970.

NAME	COUNTRY	TYPE OF TRAINING	DIVISION — LOCATION	INCLUSIVE DATES	AMOUNT ASSIGNED
1-Francisco Bernasconi	Chile	MS Degree in Chemistry	Physical Sciences - RP	Jan 1—Mar 31, 1969	$ 500.02
2-Isabel Bulla	Colombia	MS Degree in Biology	Tropical Agro-Sciences - RP	June 15--30, 1969	100.00
3-Genaro Coronel Martinez	Paraguay	MS Degree in Physics	Nuclear Science - M	Jan 1-June 30, 1969	1,350.00
4-Francisco Hernandez	Dominican Republic	MS Degree in Electrical Engineering	Nuclear Science - M	" " "	1,000.00
5-Antonio Mock	Panamá	MS Degree in Physics	Nuclear Science - M	" " "	1,000.00
6-Laureano Niño	Colombia	MS Degree in Physics	Nuclear Science - M	" " "	1,000.00
7-Rafael Pereira Ramos	Colombia	Tritium Labeling Studies	Physical Sciences - RP	Mar 15-June 30,1969	700.00
8-Emilio A. Reyes Villar	Dominican Republic	Radioisotope Techniques Clinical Applications of Radioisotopes	Physical Sciences - RP Clinical Applications-RP	Mar 1-May 31, 1969	600.00
9-Juan B. Reñe	Argentina	Short Term Radiation Therapy	Radiotherapy and Cancer-RP	Mar 1-Aug 31, 1969	1,275.00
10-Reinerio Rodrĩguez-Fernandez	Spain	Radioisotope Techniques Clinical Applications of Radioisotopes	Physical Sciences - RP Clinical Applications - RP	June 1-30, 1969	225.00
11-Carlos Roldán	Argentina	Radioisotope Techniques Clinical Applications of Radioisotopes	Physical Sciences - RP Clinical Applications - RP	Mar 1-May 31, 1969	680.00
12-Angela Eugenia Vallejos	Paraguay	Hot Atom Chemistry	Nuclear Sciences - M	Jan 1-June 30, 1969	1,350.00
				TOTAL	$9,780.02

Table 5

PUERTO RICO NUCLEAR CENTER — STUDENT ECONOMIC AID PROGRAM — FISCAL YEAR 1970 $10,000 Grant May 26, 1970

NAME	COUNTRY	TYPE OF TRAINING	DIVISION — LOCATION	INCLUSIVE DATES	AMOUNT ASSIGNED
1.Laureano Niño	Colombia	MS Degree in Physics	Nuclear Science — M	July 1-Aug 31, 1969	350.00
2.Antonio Mock	Panama	MS Degree in Physics	Nuclear Science — M	July 1-31, 1969	175.00
3.Reinerio Rodríguez Fernández	Spain	Radioisotope Tech., Clinical Applications	Physical Sciences — RP Clinical Applications — RP	July 1-Sep 30, 1969	675.00
4.Eduardo Rodriguez-Maisano	Argentina	Clinical Applications	Clinical Applications —RP	Jan 1-Feb 28, 1970	450.00
5.Nelson Peña Suarez	Dominican Republic	MS degree in Chemistry	Nuclear Science — M	July 1-Dec 31, 1969	1,200.00
6.Luis Carlos Hernández Pardo	Colombia	MS Degree in Physics	Nuclear Science — M	July 1-Dec 31, 1969	1,200.00
7.José E. Sequeira Sevilla	Nicaragua	MS Degree in Chemistry	Nuclear Science — M	July 1-Dec 31, 1969	1,200.00
8.Isabel Bulla	Colombia	MS Degree in Biology	Tropical Agro-Sciences — RP	July 1, 1969 - June 30, 1970	1,775.00
9.Leo Moseley	Barbados	Neutron Diffraction	Nuclear Science — M	July 1-15, 1969	150.00
10.Ricardo F. Gerdingh Landin	Mexico	MS Degree in Radiological Health	Health Physics — RP	Aug 1-Sept 30,1969	400.00
11.Juan B. Reñe	Argentina	Radiotherapy Training	Radiotherapy and Cancer — RP	Sept 1-Oct 31, 1969	400.00
12.Alberto Palma Bonilla	Ecuador	Radioisotope Techniques Clinical Applications Renal and Brain Scanning	Physical Sciences — RP Clinical Applications — RP Clinical Applications — RP	Dec. 1, 1969 Apr. 30, 1970	1,125.00
13.Ana María Revollo	Bolivia	Radioisotope Techniques Clinical Applications	Physical Sciences — RP Clinical Applications — RP	March 1-May 31,1970	675.00
				TOTAL	$9,775.00

Table 6

OAS REGIONAL SCIENTIFIC AND TECHNOLOGICAL PROGRAM * — Puerto Rico

February 1st, 1970.

NAME	COUNTRY	TYPE OF TRAINING	DIVISION — LOCATION	INCLUSIVE DATES
1. Manuel Lagunas	Chile	Radiolysis of aquatic solutions containing sulfurorganic compounds Chemistry	Nuclear Sciences -- Mayaguez	July 1, 1969—
2. Angela Eugenia Vallejos	Paraguay	Hot Atom Chemistry Research	Nuclear Sciences — Mayaguez	July 1, 1969—
3. Oscar Aragón	Nicaragua	MS Degree in Chemistry	Nuclear Sciences — Mayaguez	July 1, 1969—
4. Genaro Coronel Martĩnez	Paraguay	MS Degree in Physics	Nuclear Sciences — Mayaguez	July 1, 1969 —
5. Julio Alberto Mainardi	Argentina	MS Degree in Physics	Physical Sciences — Rio Piedras	July 1, 1969 --
6. Rafael Pereira Ramos	Colombia	MS Degree in Chemistry -Tritium Labeling	Physical Sciences — Rio Piedras	July 1, 1969 —
7. Juanita Freer Calderón	Costa Rica	MS Degree in Chemistry	Physical Sciences — Rio Piedras	July 26, 1969 —
8. León Pereira	Colombia	MS Degree in Physics	Physical Sciences — Rio Piedras	August 6, 1969 —
9. Lisandro Vargas Zapata	Colombia	MS Degree in Physics	Physical Sciences — Rio Piedras	August 13, 1969--
10. Ricardo Gerdingh Landĩn	Mexico	MS Degree in Radiological Health	Health Physics — Rio Piedras	Oct. 1, 1969 —
* Present program is limited by OAS to physical sciences and biology.				

APPENDIX

PUERTO RICO NUCLEAR CENTER
DIRECTORY

Advisory Committee

Chairman: Dr. Paul B. Pearson
President,The Nutrition Foundation
New York, New York

Dr. W. O. Baker, Vice President, Research
Bell Telephone Laboratories
Murray Hill, New Jersey

Dr. John C. Bugher
USAEC General Advisory Committee
Washington, D.C.

Dr. Juan A. del Regato
The Penrose Cancer Hospital
Colorado Springs, Colorado

Dr. Michael Ference, Jr.
Vice President Scientific Research Staff
Ford Motor Company

Dr. James G. Horsfall, President
The Connecticut Agricultural
Experiment Station

Dr. Frederick Seitz, President
The Rockefeller University
New York, New York

*Dr. John A. D. Cooper, President
Assoc. of American Medical Colleges
Washington, D.C.

Administrative and Technical Staff

Office of the Director

Henry J. Gomberg, Director, Ph.D., U. of Michigan (Physics)
Edwin Roig, Deputy Director, Ph.D., U. of Pennsylvania (Chemistry)
Peter Paraskevoudakis, Acting Associate Director and Assistant Director for Health and Safety, Ph.D., U. of Michigan (Radiological Health)
Victor A. Marcial, Associate Director, Medical Programs, M.D., Harvard U. (Radiotherapy)
Jorge Chiriboga, Assistant Director, Scientific Programs, M.D., U. of San Marcos, Perú (Biochemistry)
Héctor Barceló, Assistant Director-Technical Operations, M.S., U.P.R. (Nuclear Technology)
Marie Barton, Executive Assistant to the Director
Frederick E. Rushford, Technical Assistant to the Director
Kal Wagenheim, Editor

Administration and Services

Luis E. Boothby, General Administrative Officer
Ramón Nuñez, Jr., Administrative Officer II
Pedro Vélez Mendoza, Administrative Officer II
Nélida Banuchi de Gómez, Administrative Officer I
Peter A. Willman, Scientist I, M.S., Massachusetts Institute of Technology (Mathematics, Computer Programming)

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* Terminated before Dec. 31, 1969

Technical Services

Héctor M. Barceló, Head (See Office of the Director)

Mayagüez:

Nelson Quiñones, Engineering Associate III - General
Víctor Lequerique, Scientific Associate II - Glassblower
Germán Gaztambide, Technical Associate I - Photography
Alberto González Pérez, Technical Associate I - Machinist
Jean M. Dietsch, Technical Assistant III - Reproduction
Fermín Cámara Salazar, Technical Assistant III - Machinist

Río Piedras:

Guillermo Torres Carmona, Engineering Associate II - General
Domingo Fernández Aguayo, Engineering Associate II - Electronics
*Julio Gagot Mangual, Research Associate II
René Carrión Bonano, Technical Assistant III - Building and Ground

Scientific Staff

Nuclear Science Division

Julio A. Gonzalo-González, Head, Scientist II, Ph. D., U. of Madrid (Physics)
Owen H. Wheeler, Senior Scientist I, D.Sc., U. of London (Chemistry)
Florencio Vázquez-Martínez, Scientist II, Ph.D., U. of Madrid (Electrical Engineering)
Rev. Ignacio Cantarell, Scientist I, Ph.D., U. of Santiago de Compostela, Spain (Nuclear Physics)
Rupert A. Lee, Scientist I, Ph.D., U. of London (Chemistry)
Baltasar Cruz-Vidal, Scientist I, Ph.D., Harvard U. (Physics)
Josefa Elisa Trabal, Research Associate II, B.S., U.P.R. (Chemistry)
José M. Rivera, Research Associate II, M.S., U.P.R. (Physics)

Neutron Diffraction Program

Mortimer I. Kay, Head, Senior Scientist II, Ph.D., U. of Connecticut (Chemistry)
Robert Kleinberg, Scientist II, Ph.D., Michigan State U. (Physics)
Braulio F. Mercado-Ferrer, Engineering Associate II - Electronics, B.S., U.P.R. (Electrical Engineering)

Hot-Atom Chemistry Project

Owen H. Wheeler, Head (See also Nuclear Science Division)
Josefa Elisa Trabal, Research Associate II, (See also Nuclear Science Division)
María Luisa McClin, Research Associate II, M.S., U.P.R. (Chemistry)

Nuclear Engineering Division

Donald S. Sasscer, Head, Senior Scientist I, Ph.D., Iowa State U. (Nuclear Engineering)
Aviva E. Gileadi, Scientist II, Ph.D., U. of Budapest (Reactor Analysis)
Eddie Ortiz-Muñiz, Scientist II, Ph.D., Texas A & M College (Physics)
*José L. García de Quevedo, Chief Scientist I, Ph.D., Duke U. (Physics)
Knud B. Pedersen, Scientist I, Ph.D., Iowa State U. (Nuclear Engineering)
Heriberto Plaza-Rosado, Scientist I, Ph.D., Texas A & M College (Nuclear Engineering)

* Terminated before December 31, 1969.

Fausto Muñoz-Ribadeneira, Senior Associate, M.S., U.P.R. (Nuclear Engineering)
*Antonio Rivera Cordero, Research Associate II, M.S., U.P.R. (Nuclear Engineering)
*Erik Méndez-Veray, Research Associate I, M.S., U.P.R. (Nuclear Engineering)

Physical Sciences Division

Amador Cobas, Head, Senior Scientist II, Ph.D., Columbia U. (Physics)
**Alec Grimison, Scientist II, Ph.D., U. of London (Chemistry)
José P.A. Castrillón, Scientist I, Ph.D., U. of Buenos Aires (Organic Chemistry)
Manfred Eberhardt, Scientist I, Ph.D., U. of Lubingen (Chemistry)
*George A. Simpson, Scientist I, Ph.D., Notre Dame U. (Chemistry)
Rosa Santana de Tirado, Research Associate II, M.S. U.P.R. (Chemistry)
Dolores A. Julián, Research Associate I, M.S., U.P.R. (Chemistry)

Radiation Chemistry

**Alec Grimison, Head (See Physical Sciences Division)
*George A. Simpson, Scientist I (See Physical Sciences Division)

Solid State Physics Divísion

Amador Cobas, Head (See Physical Sciences Division)
Shmvel Zvi Weisz, Scientist II, Ph.D., Hebrew U. of Israel (Physics)
Jacob Yehuda Levinson, Senior Associate, Ph.D., Hebrew U. of Israel (Physics)

Clinical Radioisotope Applications Division

Aldo Ernesto Lanaro, Head, Senior Scientist I, M.D., U. of Buenos Aires (Nuclear Medicine and Endocrinology)
Sergio Irizarry, Senior Scientist I, M.D., U. of Buffalo (Internal Medicine)
Leila Crespo de García, Scientific Assistant III
Adriana R. de Calderón, Scientific Assistant III
Ada L. Rodríguez de Colón, Scientific Assistant III

Radiotherapy and Cancer Division

Víctor A. Marcial, Head, (See Office of the Director)
José M. Tomé, Scientist II, M.D., U. of Zaragoza, Spain (Radiotherapy)
Jeanne Ubiñas-Villeneuve, Scientist II, M.D., U. Nacional Autónoma de Mexico (Radiotherapy)
Antonio Bosch, Scientist II, M.D., U. Nacional Autónoma de Mexico (Radiotherapy)
María M. Palacios de Lozano, Research Associate III, M.S., U. of Rochester (Radiation Biology)
Zenaida Frías Monserrate, Scientific Associate II-Medical Statistics, M.P.H., U. of Michigan (Biostatistics)

Tropical-Agro Sciences Division

Francis K. S. Koo, Head, Scientist II, Ph.D., U. of Minnesota (Radiation Genetics)
**Robert A. Luse, Chief Scientist I, Ph.D., U. of California (Biochemistry)
José A. Ferrer-Monge, Scientist II, Ph.D., Louisiana State U. (Biology)
**David Walker, Chief Scientist I, Ph.D., Washington State U. (Entomology)
Shreekant N. Deshpande, Scientist I, Ph.D., Purdue U. (Food Technology, Biochemistry)
José Cuevas-Ruiz, Research Associate II, M.S., U.P.R. (Biology)
Angélica Muñiz de Otero, Research Associate I, M.S., U.P.R. (Biology)
Edith Robles de Irizarry, Research Associate I, M.S., U.P.R. (Genetics)
Adela Vidal de Alemañy, Research Associate I

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* Terminated before Dec. 31, 1969
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Radioecology Division

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Stephen H. Walsh, Senior Associate, B.S., U.S. Naval Academy, Annapolis (Marine Operations)

Marine Biology Program

Frank G. Lowman, Head (See Radioecology Division)
William O. Forster, Scientist II, Ph.D., U. of Hawaii (Chemistry, Oceanography)
Seppo E. Kolehmainen, Scientist I, Ph.D., U. of Tennessee (Marine Biology)
Robert Y. Ting, Scientist I, Ph.D., U. of Washington (Fisheries Biology)
George A. Seiglie, Scientist I, M.S., U. of Havana (Geology)
Henry L. Besselievre, Engineer I, B.S., U.P.R. (Physics)
Raúl McClin Escalera, Research Associate I, M.S., U.P.R. (Physics)
Rosa Julia Santiago, Research Associate I, M.S., U.P.R. (Health Physics)
Russell W. Davis, Research Associate I, B.A., Inter American U. (Chemistry)

Terrestrial Ecology Program

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George Drewry, Scientist I, Ph.D., U. of Texas (Zoology)
*Carl F. Jordan, Associate Scientist II, Ph.D., Rutgers U. (Botany)
Robert J. Lavigne, Senior Associate, Ph.D., U. of Massachusetts (Entomology)
José Antonio Colón, Research Associate I
William Dirk, Engineering Associate I - Electronics

Medical Sciences and Radiobiology Division

Jorge M. Chiriboga, Head (See Office of the Director)
Raymond A. Brown, Senior Scientist I, Ph.D., California Institute of Technology (Physical Chemistry)
Carmen Rivera de Campos, Research Associate I, B.S., U.P.R. (Biology)
Ramiro Martínez-Silva, Senior Scientist I, M.D., U. of Santiago, Spain (Bacteriology, Pathology)
Lawrence S. Ritchie, Senior Scientist I, Ph.D., Northwestern U. (Parasitology)
Víctor A. López-Santiago, Administrative Associate III;General
Roger Ramos-Aliaga, Research Associate I, Doctoral Degree, U. of San Marcos, Perú (Pharmacy, Biochemistry)
Mirta Toro-Gonzalez, Research Associate I, M.S., U.P.R. (Microbiology)

Schistosoma Mansoni Project

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Trypanosoma Cruzi Project

Jorge M. Chiriboga, Head (See Office of the Director)
Raymond A. Brown, Senior Scientist I (See Medical Sciences & Radiobiology Division)

Mouse Colony Section

Víctor A. López-Santiago, Head (See Medical Sciences & Radiobiology Division)

Reactor Division

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Alfredo Carmona-Trutten, Engineering Associate III-Electronics
José E. Rivera-Guzmán, Assistant Reactor Supervisor
Lorenzo Rosa-Graniel, Chief Reactor Operator
Miguel A. Rodríguez, Reactor Operator
Juan Carlos Alemañy, Reactor Operator
Sigfredo Torres, Reactor Operator
Juan Jesús Pérez Muñiz, Reactor Operator II

Health Physics Division

Peter Paraskevoudakis, Head (See Office of the Director)
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Heriberto Torres Castro, Scientific Associate II-Health Physics, M.S., U.P.R. (Health Physics)

X-Ray Survey Project

Michael Gileadi, Head (See Health Physics Division)

International Exhibits Project

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** Terminated before Dec. 31, 1969

PAPERS PRESENTED

Alemañy, A. - See Koo, F. K. S.

Arandia Patraca, A. - See Ritchie, L. S.

Armstrong, D. A. - See Lee, R. A.

Barnes, S. S. - See Lowman, F. G.

Bates, L.M. - See Villafaña, T.

Bosch, A. - See Lanaro, A. E.

Bosch, A. - See Marcial, V. A.

Brown, R.A. - See Chiriboga, J.

Bulla, I. - See Koo, F.K.S.

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2. Chiriboga, J., Ritchie, L.S., and Brown, R.A., Metabolic Utilization of Labeled ^{14}C Acetate, Pyruvate, and Glucose by Different Stages of *Schistosoma mansoni*, presented (by L. S. R.) at the Caribbean Com. Bilharzia Res., Maracay, Venezuela, Feb. 1969.

Chiriboga, J. - See Knight, W. B.

Chiriboga, J. - See Martínez-Silva, R.

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Cobas, A. - See Weisz, S. Z.

Cobas, A. - See Levinson, J.

Colón, J. I. - See Ritchie, L. S.

Colón, J. I. - See Rivera-Campos, C.

Cox, D. T. - See Kay, M. I.

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4. Gomberg, H. J., Isotopes and Radiation Uses in Latin America, presented at the Study Group Meeting on Isotope Production, Sao Paulo, Brazil, Oct. 1969.

5. Gomberg, H.J., Plowshare Studies at the Puerto Rico Nuclear Center, presented at the Symp. Educ. Peaceful Uses Nucl. Explosives, U. of Arizona, Tucson, Apr. 1969.

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6. Gonzalo, J. A. - See Tello, M. J.

7. Infante, G. A., Mechanism of the Radiolysis of Peptides (in Spanish) presented at 4th Jr. Tech. Mtg. Am. Chem. Soc., Rio Piedras, Aug. 1969.

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8. Jordan, C. F., Koranda, J. F., Kline, J. R., and Martin, J. R., Experimental Test of a Mathematical Model Predicting Tritium Movement Through A Tropical Rain Forest, presented (by C. F. J.) at the Am. Nucl. Soc. Mtg., San Juan, May 1969.

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9. Kay, M. I. and Gonzalo, J. A., Neutron Diffraction Studies of Sodium Nitrate Above and Below the Transition Temperature, presented (by J. A. G.) at the Intern. Ferroelectricity Mtg., Kyoto, Japan, Sept. 1969.

10. Kay, M. I., Okaya, Y., and Cox, D. T., Refinement of the Room-Temperature Phase of Phenanthrene, $C_{14}H_{10}$, A Molecule With Overcrowded Hydrogen Atoms, presented (by M. I. K.) at the Inter. Union Cryst., Stony Brook, N.Y., Aug. 1969.

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14. Koo, F. K. S., Ferrer-Monge, J., Muñiz de Otero, A., Bulla, I., and Alemañy, A., Effect of Fast Neutrons and Gamma Rays on Seedling Growth and Malate Dehydrogenase Isozyme Pattern in Soybeans, presented (by F.K.S.K.) at the IAEA Panel Mtg., Knoxville, Tennesse, Nov. 1969.

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15. Lanaro, A. E. and Bosch, A., Prolonged Blood Cell Survival in Patients With Hodgkin's Disease, presented (by A. E. L.) at the Integrated Cancer Congr., Sao Paulo, Brazil, Sept. 1969.

16. Lee, R. A. and Armstrong, D. A., Radiolysis of Gaseous HBr, presented (by R.A.L.) at the 5th Caribbean Chem. Conf., Barbados, Jan. 1969.

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17. Levinson, J., Marrero, J., Cobas, A., and Weisz, S. Z., Annealing of Singlet and Triplet Quenching Centers in Anthracene, presented (by J.L.) at the Intern. Conf. Luminescence, Newark, Delaware, Aug. 1969.

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19. Lomo, J. and Luis, A., Pectin Depolymerization Produced by Gamma Radiation, (in Spanish) presented at 10th Latin Am. Congr. Chem., San José, Costa Rica, Feb. 1969. (Paper generated at the Atoms in Action Exhibit).

20. López, M. E., Wheeler, O. H., and Solé, P., Kinetics of Isotopic Exchange Between Chloride Ion and Cycloalkyl Chlorides, (in Spanish) presented at 10th Latin Am. Congress Chem., San José, Costa Rica, Feb. 1969.
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21. Lowman, F. G., Martin, J. H., Barnes, S. S., and Ting, R. Y., The Effects of the Marine Biosphere, Hydrosphere, and Geosphere Upon the Specific Activity of Contaminant Radionuclides, presented (by F.G.L.) at the Symp. Public Health Aspects of Peaceful Uses of Nucl. Explosives, Las Vegas, Nevada, April 1969.

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22. Marcial, V. A., Comparison of Two Different Fractionation Schedules in the External Irradiation of Carcinoma of the Uterine Cervix - Influence on Curability (A Clinical Trial), presented at 12th Intern. Congr. Radiology, Tokyo, Japan, Oct. 1969.

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25. Martínez-Silva, R., López, V. A., and Chiriboga, J., Multiplication of *T. cruzi* in Irradiated Mice Measured by Tissue Culture Methods, presented (by R. M. S.) at 20th Ann. Mtg. Tissue Culture Assoc., Detroit, Michigan, June 1969.

26. Martínez-Silva, R., López, V. A., and Chiriboga, J., Titration With Tissue Culture on *Trypanosoma cruzi* in Organs of Acute and Chronically Infected Mice, presented (by R. M. S.) at 18th Ann. Mtg. Am. Soc. Tropical Med. Hyg., Washington, D.C., Nov. 1969.

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27. Muñoz-Ribadeneira, F., Leaching of Activated Chalcopyrite (in Spanish), presented (by O. H. Wheeler) at the Latin Am. Congr. Chem., San José, Costa Rica, Feb. 1969.

28. Muñoz-Ribadeneira, F., Roasting Chalcopyrite: Rate of Copper Sulfate Formation and Desulfurization, to be presented at 3rd Mtg. Pan-Am. Cong. of Mech., Elec., and Allied Eng. Branches, San Juan, Sept. 1969.

Okaya, Y. - See Kay, M. I.

29. Ritchie, L. S., Chiriboga, J., Liard, F., Colón, J. I., Martínez-Silva, R., and Arandia Patraca, A., The Effects of Whole-Body Radiation (^{60}Co) on the Host-Parasite Relationship Involving Mice Infected With *Schistosoma mansoni*, presented (by L. S. R.) at the Caribbean Com. for Bilharzia Res., Maracay, Venezuela, Feb. 1969.

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30. Rivera-Campos, C. and Colón, J. I., Enhancement of Interferon Production by Gamma Radiation in Chick Embryo, presented (by J. I. C.) at the Ann. Mtg., Am. Soc. Microbiol., Miami, May 1969.

31. Rivera-Oyola, L. and Lee, R. A., Radiolysis of HC1 in a Nuclear Reactor, presented (by R. A. L.) at the 5th Caribbean Chem. Conf., Barbados, Jan. 1969.

32. Saca, M. and Lee, R. A., W and G(H_2) Values for CH_3F and CHF_3, presented (by R. A. L.) at the 10th Latin Am. Conf., Costa Rica, Feb. 1969.

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34. Villafaña, T. and Bates, L. M., The Effect of A Finite Exposure Slit in Determining the MTF, presented by (T.V.) at 2nd Intern. Med. Phys. Conf., Boston, Mass., Aug. 1969; also presented at Puerto Rico Chapter of the Health Phys. Soc. Mtg., Mayagüez, P.R., Sept. 1969.

35. Weisz, S. Z., Levinson, J., and Cobas, A., Interaction of Triplet Excitons With Trapped Electrons in Anthracene Crystals, presented (by S.Z.W.) at 3rd Intern. Conf. Photoconductivity, Palo Alto, California, Aug. 1969.

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2. *Puerto Rico Nuclear Center Education and Training Bulletin*, PRNC-124 (1969).
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4. Adam, W., Grimison, A., and Hoffman, R., Hetaryne Intermediates, *J. Am. Chem. Soc.* 91, 2590 (1969).
5. Eberhardt, M. K., Steric Effect in the Radiolysis of cis-and trans-1,2-Dimethylcyclohexane, *J. Phys. Chem.* 72, 4509-11 (1968).
6. Wheeler, O. H., Santos, M., Ribot, R.A., and Ramos, M., Radiation Protection of Glycine and Glycylglycine, *Radiation Res.* 36, 601-9 (1968).
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8. Adam, W., Grimison, A., and Rodríguez, G., The Average Excitation Energy Approximation in the Calculation of Carbon-13 Chemical Shifts of Nitrogen Heterocyclics, *J. Chem. Phys.* 50, 645 (1969).
9. Aristizabal, S. A., Bosch, A., Frías, Z., and Marcial, V. A., Cancer of the Urinary Bladder: Experience at the I. González Martínez Hospital (in Spanish), *Bol. Asoc. Med. Puerto Rico* 61, 83-9 (1969).

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10. Berríos-Durán, L. A. and Ritchie, L. S., Molluscicidal Activity of Bis (tri-n-butyltin) Oxide Formulated in Rubber, *Bull. World Health Organ.* 39, 310-2, (1968).

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12. Castrillón, J. P. A., Chemical Effects of Nuclear Transformations (in Spanish), *Revista Colegio de Químicos de Puerto Rico* 28, 6-8 (1969).

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13. Clark, W. D., Ratner Lynn, H., Martínez, R., and Colón, I, Epidemic Erythema Infeciosum in Adjuntas, Puerto Rico, *Bol. Asoc. Med. Puerto Rico*, 61, 286 (1969).

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    Drewry, G. E. - See Jordan, C. F.

Facetti, J. F. - See Wheeler, O. H.

Fox, I. - See Ritchie, L. S.

Frias, Zenaida - See Aristizabal, Silvia A.

Frías, Z. - See Bosch, A.

14. Gileadi, A. and Talley, W. K., Nuclear Excavation of an Elat-Dead Sea Waterway, *J. Waterways Harbors Div.*, 329-35 (1969).

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17. Gomberg, H. J., Plowshare Studies at PRNC, *in Proceedings on Symp. Educ. Peaceful Uses Nucl. Explosives*, 273-9 (1969).

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Gonzalez, C. L. - See Wheeler, O. H.

Gonzalo, J. A. - See Nazario, I.

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20. Jordan, C. F. and Drewry, G. E., *The Rain Forest Project, Annual Report, June 1969*, PRNC-129.

21. Kay, M. I. and Kleinberg, R., *Neutron Diffraction Program, Progress Summary Report No. 7*, PRNC-127, April 1969.

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López-Alonso, H. - See Wheeler, O.H.

López, V. A. - See Martínez-Silva, R.

25. Lowman, F. G., The Effects of the Marine Biosphere and Hydrosphere Upon the Specific Activity of Contaminant Radionuclides, in *Proceedings for the Symp. Public Health Aspects of Peaceful Uses of Nuclear Explosives*, 436-59 (1969).

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35. Phelps, D. K., Santiago, R. J., Luciano, D., and Irizarry, N. Trace Element Composition of Inshore and Offshore Benthic Populations, *Proc. National Symp. Radioecology*, 509-26, CONF-670503 (1969).

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37. Ritchie, L. S. and Berríos-Durán, L. A., Chemical Stability of Molluscicidal Compounds in Water, *Bull. World Health Organ.* 40, 471-3 (1969).

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58. Wheeler, O. H. and Reyes-Zamora, C., Steroid Derivatives of Cysteamine and Cysteine, *Can. J. Chem.* 47, 160 (1969).

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60. Wheeler, O. H. Román, F., and Rosado, O., The Intramolecular Nature of the Rearrangement of Benzimidates, *J. Org. Chem.* 34, 966-8 (1969).

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WEEKLY SEMINARS - RIO PIEDRAS

1. Dr. Conrado F. Asenjo, Associate Dean of UPR School of Medicine, "Facilities and Plans for the Basic Sciences Building of the UPR School of Medicine" - January 17.

2. Dr. Peter Avakian, E.I. Du Pont de Nemours Company, "Triplet Excitons in Anthracene Crystals"-January 21.

3. Dr. Amador Cobas, Deputy Director-PRNC, "Present Activities and Future Plans for the Division of Physical Sciences" - February 7.

4. Dr. G. J. Dienes, Brookhaven National Laboratory, "Enhanced Diffusion in Alloys" and "Radiation Damage in Lithium Hydride" - February 17-19.

5. Dr. Jacob Levinson, "Photo-Enhanced Emission Currents From Alkali Metals Contacts into Anthracene" - February 21.

6. Dr. G. Hoyt Whipple, U. of Michigan, "Environmental Studies of Radioactive Waste"-March 14.
7. Dr. Oscar García-Ramirez, Puerto Rico Health Department, and Dr. Jeanne Ubiñas, "Our Experience in Puerto Rico With the Pap Test" - March 21.

8. Dr. Bland Houston, U.S. Naval Ordance Laboratory, "Chemical Physics of Non-stoichiometric Binary Compounds" - March 3.

9. Dr. Bland Houston, "Crystal Growth and Evaluation" - March 4.

10. Professor Jan Kommandeur, U. of Gromingen, Netherlands "Electron Spin Resonance of Defects in Molecular Crystals" - March 6.

11. Prof. Jan Kommandeur, "Ionic Conductivity of Iodine", March 7.

12. Dr. R. G. Kepler, Sandia Laboratory, New Mexico, "Photoconductivity in Anthracene I" - March 20 .

13. Dr. R. G. Kepler, "Photoconductivity in Anthracene II" - March 21.

14. Prof. Abraham Many, The Hebrew University of Jerusalem, Israel, "Semiconductor Surfaces" - March 25.

15. Prof. Abraham Many, "Semiconductor Surfaces" March 27.

16. Prof. Abraham Many, "Semiconductor Surfaces, III and IV" - April 1, 2.

17. Dr. George E. Drewry, "The Development of Biological Diversity" - April 18.

19. Dr. Eduardo Touya, Universidad de Montevideo, Uruguay, "La Serio-Centelleografia Renal" (Serial Renal Scanning) and "La Centelleografía del Encéfalo y del Espacio Sub-Aracnoideo" (Scanning of the Encephalus and Sub-Arachnoidal Space" - May 6.

20. Dr. Louis J. Olivier, Pan. Am. Health Organization, Wash., D.C., "The Programs of the Pan American Health Organization" - May 9.

21. Dr. Raymond A. Brown, "Current State of the Art in Preparative Analytical Ultracentrifugation" - May 9.

22. Dr. Peter Paraskevoudakis, "The Role of Film Badges as Personnel Monitoring Devices" - May 23.

23. Dr. Howard L. Andrews, U. of Rochester, "Health Physics as a Career for Physics Majors" and "The Physics of Whole Body Counters" - June 27.

24. Dr. Francis K. S. Koo, "Research Activities of the Agricultural Bio-Sciences Division" August 22.

25. Dr. Michel A. Pothier, U. of Lyon, France, "New Fluorescent Methods in the Diagnosis of Parasitic Diseases" - August 27.

26. Dr. Walmor de Mello, UPR School of Medicine, "The Effect of Stimulation on Myocardial Healing Over" - August 28.

27. Dr. Franklin W. Martin, Federal Experiment Station, Mayagüez, P.R., "The Sterility Incompatibility Complex of *Ipomoea batatas*" - September 5.

28. Dr. George A. Simpson, "Radiation Induced Intermediates of Nitrogen Heterocyclic Compounds" - September 11.

29. Dr. Sergio Irizarry, "Pulmonary Embolism Problems" - September 19.

30. Dr. Hermann Niemeyer, UPR School of Medicine, "Glucokinase Induction in Rat Liver" - September 25.

31. Dr. Sergio Irizarry, "Tratamiento del Cancer de Tiroides con ^{131}I" (Treatment of Cancer of the Thyroid with ^{131}I) - October 10.

32. Dr. Efraín Toro-Goyco, UPR School of Medicine, "Kinetic Studies on Pinguinain, a Plant Protease" - October 23.

33. Mr. Peter Willmann, "Computing at PRNC" - October 30.

34. Dr. M. Alexander, Cornell University, "Biochemistry, Ecology, and Natural Selection of Microorganisms" - October 30.

35. Dr. Fermín Sagardía, UPR School of Medicine, "Comparative Studies in Phosphorylase" - November 6.

36. Colonel Alvin M. Burner, M.D., U.S. Air Force, "Biological Hazards of Microwaves : A Comparison with Ionizing Radiation Hazards" - November 14.

37. Dr. Jesús Santos Martínez, Professor, UPR School of Medicine , "Renal Lymph and its Relationship to the Counter Current System of the Kidney" - November 2.

38. Dr. Theodore Villafaña, "The Problem of Evaluating Radiologic Systems: The MTF of Scanning Apertures" - November 21.

39. Dr. Ramiro Martínez-Silva, "Problems of Virulence in *Trypanosoma cruzi*" - Dec. 4.

40. Dr. Peter Paraskevoudakis, "Dosimetry by Photographic Emulsions and Film Badges" - December 5.

WEEKLY SEMINARS - MAYAGUEZ

1. Dr. Melvin M. Levine, Brookhaven National Laboratory, "The Use of Computers in Reactor Studies" - January 20.

2. Dr. G. J. Dienes, Brookhaven National Laboratory, "Enhanced Diffusion in Alloys" - February 21.

3. Mr. T. A. Lawand, McGill University, "Solar Energy Applications in the Caribbean" - February 28.

4. Dr. Jack Chermick, Brookhaven National Laboratory, "Nuclear Engineering Work at Brookhaven" - March 3.

5. Mr. Leslie S. Ayres, U.S. Arms Control and Disarmament Agency, Washington, D.C., "Current Problems in Nuclear Arms Control" - March 12.

6. Dr. Herman Sulsona, UPR Mayagüez, "Stress Corrosion Cracks in Uranium Molybdenum Alloys for Fast Burst Reactors" - March 17.

7. Dr. George A. Ferguson, Howard University, "Neutron Diffraction From Glasses" - June 9.

8. Dr. Mortimer Kay, "Crystal Structure of Phenanthrene" - August 12

9. Mr. Fausto Muñoz-Ribadeneira, "Estudio de Algunas Reacciones Quĩmicas Producidas en la Tostación de Calcopirita" (Study of Some Chemical Reactions Produced by the Roasting of Chalcopyrite) - August 28.

10. Mr. Peter A. Willman, "Computing at the Nuclear Center" - September 22.

11. Mr. Octave J. DuTemple, Exec. Secretary-American Nuclear Society, "Project Rulison" - October 3.

TABLE SHOWING PRNC STUDENTS BY COUNTRY*
From FY-1958 through FY-1969

	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	TOTAL
Argentina	1	-	2	1	4	1	2	-	4	1	1	3	20
Bolivia	1	-	-	-	1	4	1	-	-	1	1	-	9
Brazil	-	-	-	-	-	-	-	-	-	1	1	1	3
Chile	1	1	2	2	-	-	1	1	2	4	4	3	21
Colombia	1	5	3	6	3	6	7	4	4	5	4	8	56
Costa Rica	-	2	-	-	-	-	1	-	-	2	1	1	7
Cuba	-	1	3	-	-	-	3	1	1	-	-	2	11
Dominican Republic	-	-	1	-	-	14	1	1	2	2	5	6	32
Ecuador	3	-	1	1	-	-	1	1	1	2	1	3	14
El Salvador	-	-	1	-	1	1	2	-	1	2	1	-	9
Formosa	-	-	-	-	-	-	-	1	3	2	6	-	12
Germany	-	-	-	-	-	-	-	-	1	1	-	-	2
Great Britain	-	-	-	-	1	-	1	-	1	1	1	-	5
Guatemala	-	-	-	1	-	1	2	-	-	-	2	2	8
Haiti	-	-	1	-	-	-	-	-	-	-	-	-	1
Hungary	-	-	-	-	-	-	-	-	-	-	1	-	1
India	1	-	-	-	1	-	-	-	-	3	4	-	9
Israel	-	-	-	-	-	-	-	-	-	-	1	1	2
Japan	-	-	-	-	-	-	1	-	-	-	-	-	1
Korea	-	-	-	-	-	-	-	-	-	-	-	2	2
Lebanon	-	-	-	-	-	-	-	-	-	1	1	-	2
Liberia	-	-	-	-	-	-	-	-	-	1	1	1	3
Mexico	-	5	1	1	2	1	3	2	-	1	2	1	19
Nicaragua	-	-	1	1	-	-	-	-	-	1	2	2	7
Panama	-	-	-	-	-	1	1	-	-	-	-	1	3
Paraguay	-	-	-	-	1	3	2	-	-	-	-	3	9
Peru	-	1	3	1	1	1	5	-	1	-	3	2	18
Philippine Islands	1	-	-	-	-	-	-	-	2	1	1	1	6
South Africa	-	-	-	-	1	-	-	-	-	-	-	-	1
Spain	-	1	3	3	3	2	1	-	2	-	2	2	19
Thailand	-	-	-	-	-	-	-	-	-	-	-	2	2
Turkey	-	-	-	-	-	-	-	-	-	-	1	-	1
United Arab Republic	-	-	-	-	-	-	-	-	1	-	-	-	1
Uruguay	-	1	1	1	-	1	-	1	1	1	-	1	8
Venezuela	-	3	4	3	2	-	-	1	2	3	3	2	23
TOTAL NON-U.S. CITIZENS	9	20	27	21	21	36	35	13	32	37	46	50	347
TOTAL U. S. CITIZENS	50	52	71	74	101	161	176	198	141	199	167	149	1,539
TOTAL STUDENTS	59	72	98	95	122	197	211	211	173	236	213	199	1,886

* A student is counted once each Fiscal Year he is in training.

Tabulated: August 15, 1969, by Office of the Technical Assistant to the Director

Student Enrollment at PRNC During Fiscal Years 1968 and 1969 *

Programs and Courses	Months	FY-1968 Students	FY-1968 Students Months	FY-1969 Students	FY-1969 Students Months
Radioisotope Techniques Course	1	21	21	25	25
Chemistry - Thesis Research	12	14	168	12	144
Chem 465 - Radiochemistry	4	1	4		
Clinical Applications of Radioisotopes	2	9	18	10	20
Special Training in Tumor Localization and Organ Visualization	1	-	-	1	1
Orientation Course on the Clinical Uses of Radioisotopes	1	-	-	45	45
Radiotherapy and Cancer - Residency	6-12	2	18	4	48
Short Term Radiotherapy Training	1	8	8	10	10
One Month Cancer Course	1	10	10	14	14
Radiological Physics Conferences	3	-	-	8	24
Tissue Culture and Radioisotopic Techniques at Cell and Subcellular Level	1-5	13	19	-	-
Special Training in Medical Sciences and Radiobiology	.05-12	8	26	13	15.50
Physics - Thesis Research	12	-	-	2	24
Biochemistry 414 - Instrumental Techniques in Biological Research	4	6	24	-	-
Biochemistry - Thesis Research	12	-	-	1	12
Microbiology - Thesis Research	12	-	-	1	12
Biol 335 - Cytogenetics	4	9	36	-	-
Biology - Thesis Research	1-12	-	-	3	19
Radiation Chemistry of Food Irradiation	3-5	1	5	-	-
PRNC-ICAITI Technical Assistance Program in Food Preservation by Radiation	.50	-	-	2	1
M. S. Degree Program in Radiological Health	4-8	-	-	5	36
PMPH 231 - Fundamentals of Radiological Hygiene	4	10	40	-	-
Individual Courses, PRNC	4	9	36	-	-
Rio Piedras TOTALS		125	481	156	450.50
Nuclear Engineering	8-12	10	120	7	84
Nuclear Sciences	8-12	8	96	14	168
Agriculture and Biology - Thesis Research	8-12	7	84	2	24
Health Physics	12	1	12	1	12
Special Training in Health Physics	3	1	3	-	-
" " Glassblowing	5	1	5	-	-
" " Food Irradiation Preservation	12	-	-	1	12
" " Radiopharmaceuticals	8	-	-	1	8
" " Neutron Activation Analysis	3	-	-	1	3
Individual Courses, PRNC	1-12	57	221	13	52
Mayagüez TOTALS		85	541	40	363
Oak Ridge Research Participation Program	1-12	4	12	3	9
Oak Ridge Graduate Fellowship Program	-	-	-	-	-
ORAU TOTALS		4	12	3	9
GRAND TOTALS		214	1034	199	417.50

* Tabulated: August 20, 1969