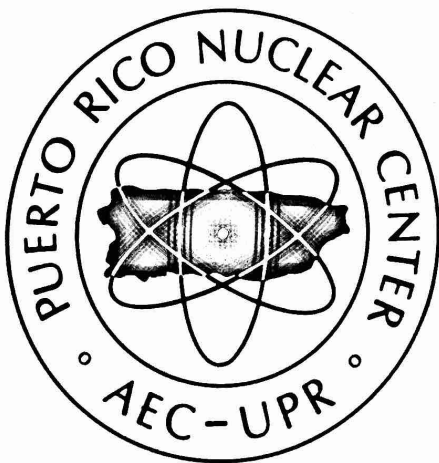
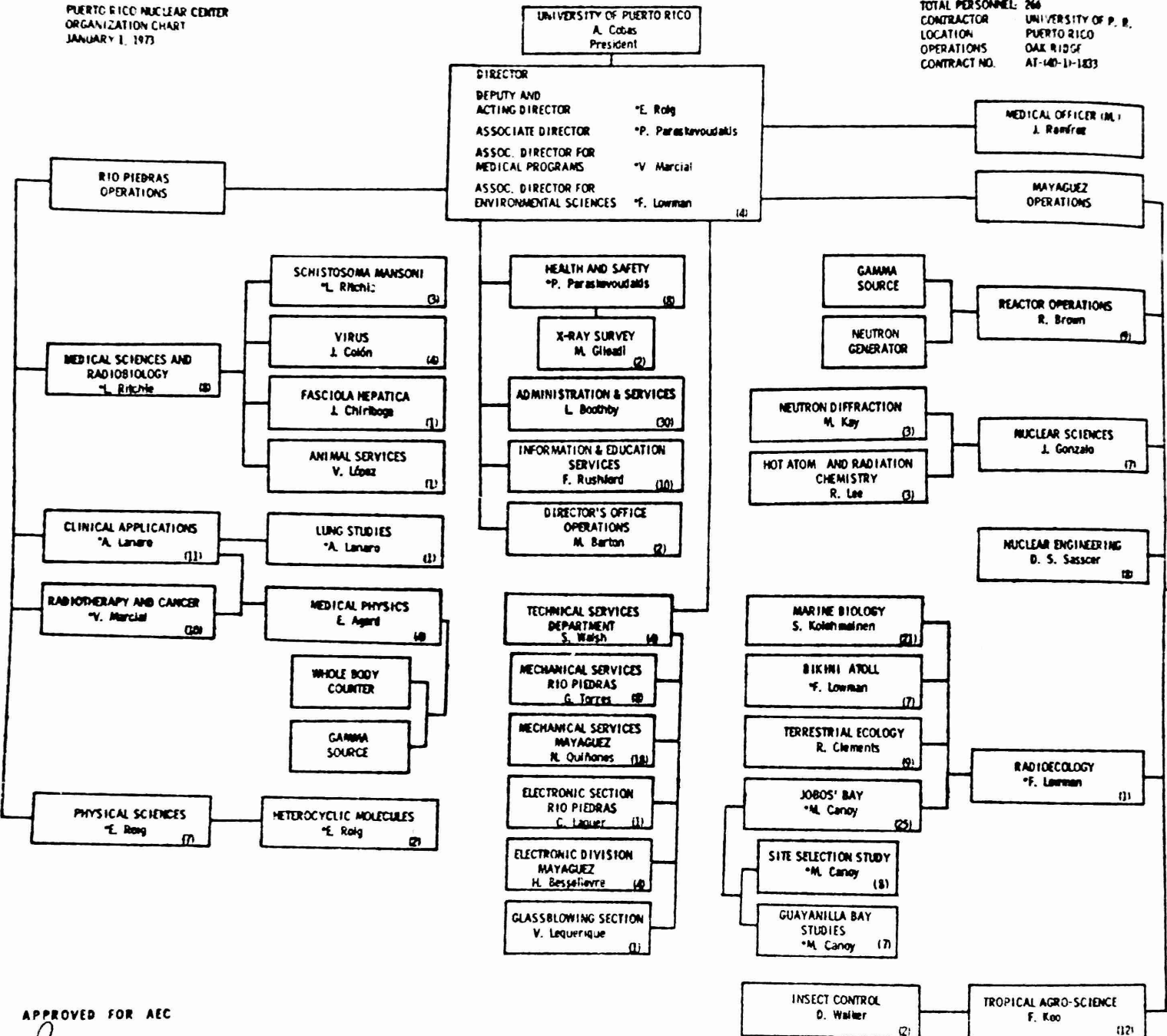


PUERTO RICO NUCLEAR CENTER

ANNUAL REPORT, 1972



OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT
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UPR President Amador Cobas (center) and Mrs. Cobas greeting Dr. Charles Dunham, Director of Medical Sciences at the National Research Council, and Mrs. Dunham at the San Juan airport. At right is Mr. Frederick E. Rushford, Head of the PRNC Information and Education Services Division. Dr. Dunham presented the Bugher Memorial Lecture in September.

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 opportunities for graduate students to do research and for faculty to teach specialized advanced courses. Research facilities are also made available to graduate students of Nuclear Engineering and Electrical Engineering, and to pre- and postdoctoral students from other universities interested in working at PRNC.

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

EDUCATIONAL ACTIVITIES

Graduate Courses. During 1972 four graduate courses were taught by PRNC personnel, with academic credit given by UPR:

Course	Professor	Enrollment
587 597- Introduction to Solid State Physics	Dr. J. A. Gonzalo	5
673- Chemical Kinetics	Dr. R. A. Lee	4
608- Radiation Chemistry	Dr. R. A. Lee	4

Thesis Research. The following students from Puerto Rico have completed thesis research under Nuclear Science Division staff supervision:

Student	Thesis Title	Advisor
Ramón E. Irizarry Lazzarini	Electroreflectance and thermo-reflectance in barium titanate	Dr. F. Vázquez
Aurelio Mercado	Static and dynamic critical behavior of triglycine fluoroberillate (TGFB) using Brillouin scattering	Dr. J. A. Gonzalo

The following students from Puerto Rico, Colombia, and Argentina are doing thesis research under Nuclear Science Division staff supervision:

Josefina Rodríguez	Electron impact studies	Dr. R. A. Lee
Moisés Camacho	Gamma-induced copolymerization	Dr. R. A. Lee
Roberto F. Amaris	Radiolysis of fluoroform	Dr. R. A. Lee
María B. Colón de Olmo	The effect of an applied electric field on copolymer formation	Dr. R. A. Lee
Aníbal J. Camnasio	Specific heat of second-order transition ferroelectrics in the critical region	Dr. J. A. Gonzalo
Prudencio Martínez	Thermoluminescence spectra from ferroelectric NaNO_2	Dr. J. A. Gonzalo

RESEARCH COMPLETED

Ferroelectric Behavior of Triglycine Fluoroberillate Near T_c — A. Mercado and Julio A. Gonzalo (UPR and PRNC Mayagüez). Dielectric constant and hysteresis loop measurements have been performed on single crystals of triglycine fluoroberillate (TGFB) in the vicinity of the critical point to characterize the second-order transition and to compare the results with previous data on its isomorph triglycine sulfate (TGS). The mean field critical exponents and the mean field equation of state are shown to give a good description of the ferroelectric behavior of TGFB as expected. The parameters entering in the statistical dipolar theory of ferroelectrics are derived, in some cases independently, from dielectric constant and hysteresis loop measurements, and this allows a distinction between dipolar and atomic (mainly ionic) polarization. The numerical values of parameters obtained in this way for TGFB, as well as for TGS, are discussed.

Construction of Brillouin Scattering Apparatus — A. Mercado and J. A. Gonzalo (UPR and PRNC Mayagüez). A system for the study of light scattering from acoustic modes in solids and liquids has been designed and built in our laboratory. The free spectral range of the apparatus can be changed from 15 cm to 0.1 cm. The essential features are those of the system developed by R. W. Gammon (Ph.D. thesis, Johns Hopkins University, 1966) but using piezoelectric scan. The layout of the system is as follows. A Spectra Physics 125 (6328-Å) laser produces a beam that passes through the crystalline sample, which is in a temperature-controlled oil bath in a holder consisting of a goniometer head installed in a precision x - y translation carriage. The scattered light coming from the sample passes

through a pinhole placed near it. The pinhole can be changed in size and can be moved in a horizontal or vertical direction. Behind a cardboard that stops unwanted light is a collecting lens followed by an iris diaphragm. From this the light passes through the Fabry-Perot interferometer, and then the scattered light passes through a lens and is focused into another variable-aperture pinhole with movement in all three space directions (x, y, z). From there the light goes to the photomultiplier tube, which is in a refrigerated housing. The whole system from the sample to the photomultiplier is in a wooden box painted flat black inside. The signal from the photomultiplier goes to an amplifier and then to a single-channel analyzer and printer or alternatively to a linear ratemeter and recorder.

Reflectivity of SbSI — F. Vázquez (UPR and PRNC Mayagüez). The reflectivity of SbSI around the transition temperature has been measured with perpendicular polarizations. The absorption edge shows a shift with temperature of 2.2×10^{-3} eV/°K below the transition temperature and 9×10^{-4} eV/°K above it. The same temperature dependence has been observed at the strongest transition of the reflectivity spectrum (2.24 eV). No discontinuity has been observed at the transition temperature. The reflectivity spectrum is rather narrow and shows some similarities with those of the III-V semiconductors. No band calculation has been made for this compound, and identification of the structure has not been possible. The reflectivity shows hysteresis effects at the transition temperature.

RESEARCH IN PROGRESS

Improvement of Adiabatic Calorimeter for Study of Solid Phase Transitions —

A. Camnasio and J. A. Gonzalo (UPR and PRNC Mayagüez). The calorimetric system has been improved in several ways. The vacuum is now 5×10^{-6} torr; thus conduction heat losses are minimized. The use of special microresistors (1000 Ω) and automatic timing has made the determination of the heat input to the sample much more accurate. A new apparatus that records the time variation of the sample temperature after heating makes it possible to measure specific heat of TGS single crystals (~ 6 g) at short temperature intervals ($\sim 0.06^\circ\text{C}$) from $\sim 100^\circ\text{K}$ to 400°K with an accuracy better than 5%. Since the thermocouple temperature indicators can not provide the desired accuracy in the vicinity of specific heat peaks from second-order ferroelectric transitions (such as TGS and isomorphous), a change is being made to thermistor indicators with provision for reading the temperature changes through a digital voltmeter (accuracy $1 \mu\text{V}$) and printer. The precision is expected to increase by a factor of ten. A lock-in amplifier will be used if necessary.

Acoustic Phonon Spectra of TGS and TGFB — A. Mercado and J. A. Gonzalo (UPR and PRNC Mayagüez). A Brillouin scattering system has been developed at our laboratory

which uses a He-Ne laser as the light source and a piezoelectrically scanned Fabry-Perot spectrometer. The Brillouin spectra for quasi-longitudinal and quasi-transverse phonons in the plane perpendicular to the b -axis (ferroelectric) were studied for TGS and TGFB. The results for TGS were in good agreement with those previously reported by R. W. Gammon. Those for its isomorph TGFB, studied for the first time, were similar, but the relative values of the elastic constants along the a and b axes were reversed (scattering angle 90°). The relative intensities and velocities were as follows (ϕ = angle between \bar{q} and \bar{c}^* -axis):

	ϕ	I_T/I_L	v_T/v_L
TGS:	45°	0.33	0.41
	-45°	0.20	0.46
TGFB:	-56°	0.31	0.39
	36°	0.31	0.48

Experimental Setup for Raman Scattering of TGS — R. S. Singh and J. A. Gonzalo (UPR and PRNC Mayagüez). For Raman scattering work, a Spex 1401 double monochromator has been aligned, and sample holders have been designed and fabricated in the machine shop. $F/1.0$ - 2.0 focusing and collecting optics have been designed, and the necessary components have been ordered. For the detection system, the photon counting system already in operation here will be used, and a photon multiplier tube and its cooling devices have been ordered.

Infrared Absorption of Complex Inorganic Crystals: Internal Modes of Oscillation — R. S. Singh and J. A. Gonzalo (UPR and PRNC Mayagüez). In general, complex crystals have internal modes of oscillation arising from the motion of the atoms in the structural group, and external or lattice modes of oscillation arising from the motion of the structural groups against each other. The former usually lie in the infrared region (4000 to 400 cm^{-1}) and the latter below 400 cm^{-1} . In order to study the internal modes of oscillation, room temperature IR absorption spectra (4000 to 350 cm^{-1}) of pressed pellets of KBr with TGS, TGSe, TGFB, Li-, Na-, K-, $\text{RbH}_3(\text{SeO}_3)_2$, Li-, and $\text{KC}_2\text{H}_3\text{O}_2$ have been recorded with a Perkin-Elmer-457 spectrophotometer. We plan to investigate these modes as a function of temperature and pressure. The external modes, since we have no far-IR experimental facilities, will be explored by Raman scattering.

Long-Wavelength Optical Phonons of Complex Inorganic Crystals, A Group Theoretical Study — R. S. Singh (UPR and PRNC Mayagüez). Theoretically, Brillouin zone center phonons of TGS, in both its ferroelectric and paraelectric phases, have been classified by

group theory. The same results apply to the isomorphous TGSe and TGFB. The crystal symmetry of TGS shows inversion symmetry in the paraelectric phase but not in the ferroelectric phase; therefore, all the lattice modes of the ferroelectric phase will be active in both infrared and Raman spectra — but these will be mutually exclusive in the paraelectric phase. Thus, both techniques are essential for investigating the lattice dynamics and phase transition of such materials. Work along these lines is in progress.

Reflectivity of BaTiO₃ — F. Vázquez (UPR and PRNC Mayagüez). Preliminary results of this work are included in Ramón E. Irizarry's M.S. thesis. The work will be extended to a study of the temperature dependence and structure around the ferroelectric transition. The results will be compared with theory in order to identify the electronic transition and its polarization dependence.

Brillouin Scattering Study of the Ferroelectric Transition in RbH₂PO₄ and RbD₂PO₄ — F. Vázquez and J. A. Gonzalo (UPR and PRNC Mayagüez). A cryostat with precise temperature control will be attached to the existing Brillouin scattering setup. The Brillouin spectra of RbH₂PO₄ and RbD₂PO₄ will be obtained around the transition temperatures (147° and 218°K respectively) with different crystal orientations. This will allow study of the order of the ferroelectric transition and related hysteresis effects, and determination of some of the elastic constants and electrooptic coefficients of these materials.

Electron Impact Study of Fluorotoluenes — R. A. Lee and J. Rodríguez (PRNC and UPR Mayagüez). The fragmentation patterns obtained by subjecting *o*-, *m*-, and *p*-fluorotoluene to 70-eV electrons in a Varian M.S. 600 mass spectrometer have been studied. Almost identical patterns were obtained, and the relative intensities of the various mass peaks were approximately the same. The most abundant ion found in all three cases is the (M⁺-H) peak. The (M⁺-X) peak (X=F) is negligible (<2%). This is in contrast to findings with the other halotoluenes, in which this peak is predominant, and it suggests that the (M⁺-H) ion is formed before fragmentation occurs. The probable explanation is that scrambling of the C and H atoms occurs and leads to ring expansion of the fluorotoluenes to give fluorocycloheptatrienes. If this takes place in all three cases prior to fragmentation, then it is easy to see why identical patterns are obtained. Ionization potentials were also measured for *o*-, *m*-, and *p*-fluorotoluene with CH₃I used as a standard and application of the semilogarithmic plot method of Lossing, Tickner and Bryce. The values obtained were 9.18, 9.11, and 9.13 eV respectively. The value reported for all three fluorotoluenes by the electron impact method is 9.3 eV and by the photoionization method, 8.91, 8.91, and 8.78 eV.

STAFF

Mr. Aníbal Camnasio, a graduate student in Physics from Argentina who was working on a part-time basis in this Division, was granted an OAS fellowship for research training at PRNC under Dr. Julio A. Gonzalo.

Mr. Braulio Mercado, who was working under Drs. F. Vázquez, J. A. Gonzalo, and M. I. Kay, obtained his M.S. degree in Electrical Engineering and left to work at the Boeing Company, Cape Kennedy, Florida.

Mr. Raúl Marco, who was working under Dr. R. A. Lee, obtained his M.S. degree in Chemistry and left to work at the Catholic University in Ponce.

Mr. Hernán Guido Vera Ruiz, an IAEA fellow from Bolivia, left PRNC on March 24 to enroll at the University of California at Irvine to work for a Ph.D. degree in Chemistry.

Dr. R. S. Singh was given a joint appointment by the Physics Department, UPR-Mayagüez, to work with Dr. J. A. Gonzalo on Raman scattering.

Meetings. Dr. Rupert A. Lee presented a paper at the Eleventh Latin American Congress of Chemistry in Santiago, Chile, January 5-11. On January 12-14 he visited Professor B. Zuluaga at the University of Antioquia in Medellín, Colombia, to discuss the possibility of cooperative research.

Dr. Julio A. Gonzalo and Dr. Florencio Vázquez attended the American Physical Society Meeting in Washington, D.C., on April 24-28 and each presented a paper.

Dr. Gonzalo spoke at the Annual Conference of the Science Teachers Association in San Juan on May 12.



Aerial view of PRNC Mayagüez.

Neutron Diffraction

The objective of the neutron diffraction program is to obtain structural information from crystals which will lead to an understanding of the geometry, mechanism, and physics of phase transitions, mainly ferroelectric. Neutron diffraction is uniquely effective in probing the positions of heavier atoms in the presence of light atoms (including hydrogen), since atomic scattering amplitudes do not rise directly with atomic number as do x-ray form factors. Further, the interaction of the magnetic moment of the neutron with any magnetic moment in the system can be used to determine the ordering and electron density of unpaired spin systems. Also, since the neutron-nuclide interaction is, unlike the x-ray interaction, independent of scattering angle, data from the two types of diffraction method may be combined to give electron density data. These types of data are being applied to problems of phase transitions in ferroelectrics, as defined in the sections below. This class of materials has current and potential electronic, optical, and electrical applications.

EDUCATION

The program has given support to the UPR-Mayagüez Physics Department by providing research facilities. A joint appointment on the project has been extended to Dr. Rastko Maglic. Mr. Jorge Gil-Anselmi, a physics student from Argentina, has been employed by the project and thus enabled to advance his education.

RESEARCH COMPLETED

During the current year, the tryglycine sulfate study outlined in PRNC 157 (p.12) was completed, and the nature of the hydrogen bonding in the ferroelectric phase was completely defined. Most of the electric polarization comes from the ammonium group on glycine I (see PRNC 157, p. 13). The short N_I-H_6 distance, previously reported, on further refinement changed to a normal (1.0 Å) distance. Both the geometry of the order-disorder transition and the large thermal amplitudes indicate a probable breakage of one or more hydrogen bonds connected to the ammonium group on glycine I.

RESEARCH IN PROGRESS

In June, AEC support for the project was terminated, but the National Science Foundation accepted a somewhat narrower proposal for work along the lines the program has been following.

Data collection has been completed on a $\text{Pb}_5\text{Ge}_3\text{O}_{11}$ crystal supplied by R. Newnham and R. W. Wolfe of Pennsylvania State University. Collection of data on the room-temperature phase of NaNO_2 has also been completed. These data will be combined with Los Alamos x-ray data in an attempt to define an electron density for the nitrate ion.

In October a pyrolytic graphite monochromator was substituted for the copper monochromator in the neutron single-crystal diffractometer. An increase in intensity by about a factor of 10 was noted. The factors involved are increased reflectivity due to a wavelength of 1.24 Å as opposed to 104 Å, a lower diffraction angle (Lorenz factor), and lower extinction. The increased intensity more than compensates for the loss in resolution due to the lower monochromator Bragg angle and increased monochromator mosaic.

STAFF

Dr. Rastko Maglic has joined the diffraction program. He has a joint appointment as Assistant Professor of Physics at UPR-Mayagüez and Scientist at PRNC. Dr. Maglic has a Ph.D. from MIT and has done postdoctoral work at Argonne National Laboratory on neutron diffraction and band theory calculations.

Meetings. Dr. M. I. Kay presented a paper at the American Crystallographic Association in Albuquerque, New Mexico, in April, and another at the Ninth International Congress of Crystallography in Kyoto, Japan, in August.

Dr. R. Maglic presented a paper at the Eighteenth Magnetism Conference in Denver, Colorado, in November.

Radiation and Hot-Atom Chemistry

In the past, this program has been concerned mainly with studies in the field of hot atom chemistry. A brief description of the last set of experiments carried out in this field is given below. The emphasis of the program has shifted almost completely to radiation chemistry.

The program provides in essence research topics for students working towards the M.S. degree, at present two students from Colombia and two from Puerto Rico.

WORK COMPLETED

Radiolysis of Fluoroform — R. A. Lee and R. Amaris. Fluoroform (CHF_3) has been irradiated with ^{60}Co gamma rays and the $G(\text{H}_2)$ value was determined to be 1.25 by two independent methods. The first method makes use of the well-known equation

$$G = M/N \times 100/W$$

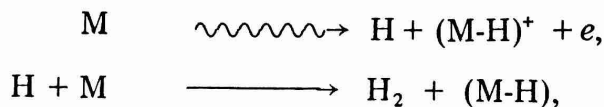
where M/N is the ion pair yield and W is the energy required to form an ion pair. This work was carried out by Mario Saca (now at the University of El Salvador) as part of his M.Sc. thesis in Physics. The second method, which is considered more conventional, involves a comparison of the energies absorbed in the CHF_3 and in some standard gas such as ethylene (C_2H_4). The formula

$$E_{\text{CHF}_3} = E_{\text{C}_2\text{H}_4} S_{\text{C}_2\text{H}_4}^{\text{CHF}_3}$$

is used, where E refers to absorbed energy and S to ratio of stopping powers. No pressure effect (200 to 760 torr) or dose effect (5-fold) is seen in the ranges investigated. Scavenger studies with sulfur hexafluoride (SF_6), an electron scavenger, revealed a 33% reduction in yield and with C_2H_4 , a hydrogen atom scavenger, showed a reduction to practically zero. A mechanism is being proposed that complies with these experimental results.

Radiolysis of *o*-, *m*-, and *p*-Fluorotoluenes — R. A. Lee and J. Rodríguez. The fluorotoluenes (*ortho*, *meta*, and *para*) have been irradiated with ^{60}Co gamma rays. The $G(\text{H}_2)$ values were measured as 0.13, 0.68, 0.11 by using the Fricke dosimeter and correcting for the difference in electron density. At the low conversions at which the experiments were carried out, it was not possible to identify any other products. An electron impact

study (see Nuclear Science) indicates that the molecules undergo ring expansion and then fragment giving off C_2H_2 . With this evidence one can suggest the following for the formation of hydrogen:



where M represents a fluorotoluene molecule.

Hot ^{18}F Reactions — R. A. Lee and Hernán Vera. Mr. Vera spent his first 3 months becoming acquainted with the setting up and operation of the neutron generator. During his second 3 months he studied the $^{19}F(n,2n)^{18}F$ reaction by submitting *o*-, *m*-, and *p*-fluorotoluenes to 14-MeV neutrons. Two methods were used to determine the percentage retention in the organic phase. The first consisted simply of extracting 3 ml of the irradiated substance with 0.01 M KF solution. The second method consisted of passing the irradiated substance through an Al_2O_3 column, and it gave in all three cases a higher retention in the organic phase. Analyses varied widely from experiment to experiment. The purpose of this exercise was mainly to teach Mr. Vera counting techniques, the use of the neutron generator, and the handling of radioisotopes.

WORK IN PROGRESS

Theoretical Studies — P. Delsanto and R. A. Lee (UPR and PRNC Mayagüez). The object of this investigation is to calculate the excitation and ionization yields, G_{exc} and G_{ion} , of a high energy radiation (1-MeV electrons) in a gas. Attempts at such a calculation for water vapor and simple molecules have been made by I. Santar and J. Bednar with the so-called optical approximation. Although their results were encouraging, many approximations found in their approach seem unnecessary. Therefore, as a first step, we have tried to develop more realistic formulas directly from the Bethe formula that gives, in the nonrelativistic first-order Born approximation, the differential cross sections for the inelastic collisions of fast electrons with the gas molecules and their subsequent excitations. The Bethe formula contains integrals such as

$$fn(\vec{K}) = \exp(-i\vec{K}\cdot\vec{r}/t\rho_n(\vec{r})d\vec{r}$$

where \vec{K} is the electron momentum transfer and $\rho_n(\vec{r})$ is the electron density; and

$$\rho_n(\vec{r}) = z \int \phi_n(\vec{r}, \vec{r}_1 \cdots \vec{r}_2) \quad \phi_i(\vec{r}, \vec{r}_1 \cdots \vec{r}_2) d\vec{r}_1 \cdots d\vec{r}_2$$

where ϕ_i and ϕ_n are the initial and final excited molecular wave functions. The computation of these integrals represents a serious difficulty in any quantitative treatment, if one wants to introduce realistic molecular wave functions; we are working on this problem. When this formalism is completed, it will be applied to the study of the interaction of radiation with the hydrogen halides.

Electron Impact Excitation Studies — F. Herrero and R. A. Lee (UPR and PRNC Mayagüez). A study will be made of the electron impact excitation processes of importance in the radiation chemistry of hydrogen halides. The experimental method involves the simultaneous use of an electron spectrometer with a photon spectrometer for the simultaneous measurement of electron energy loss spectra and photon emission spectra. The proposed experiments should provide information on excitation cross sections and on the electronic energy level structures of the hydrogen halides. Dr. Herrero has designed the electron spectrometer, and it is being constructed.

Radiolysis of Aqueous Methionine Solutions — R. A. Lee and María Lara (PRNC Mayagüez). Deaerated 0.1 M aqueous methionine solutions have been irradiated in 10-ml quantities with ^{60}Co gamma rays. The $G(\text{H}_2)$ value obtained is 0.34, which indicates that the high concentration of methionine is causing scavenging of H atoms within the spur. Two nonvolatile products are formed which have not yet been identified but are visible in the paper chromatography analysis. The ^{14}C -labeled compound was added, and the counts in the two positions for the unknown products gave G values of 0.14 and 0.24 respectively. Work on the identification of these compounds is being continued.

Radiolysis of Mixtures of Benzene with CH_3F and with CHF_3 — R. A. Lee and María Lara (PRNC Mayagüez). Mixtures of benzene and the organic fluoride are prepared in varying ratios from 10:1 to 1:1. After being degassed they are irradiated for different times (i.e., various doses). The products will be analyzed by mass spectrometry. It is hoped that the radicals CH_2F and CF_3 will become attached to the benzene molecule.

Radiolysis of Aqueous Solutions of $\text{cis-Co(en)}_2\text{F}_2^+$ Ion — R. A. Lee and María B. Colón (PRNC and UPR Mayagüez). This compound is being prepared. Solutions will be irradiated to determine whether the radiation causes isomerization or aquation. Photolytic results have shown isomerization to occur in preference to aquation, but pyrolytic experiments have shown the reverse. In the presence of water as solvent, the species H, OH, and e_{aq} would be present; therefore, even reducing and oxidizing reactions would be expected. Almost nothing has appeared in the literature on the radiation chemistry of coordination compounds.

STAFF

Mr. Hernan Vera, a Bolivian sponsored by IAEA, was here from November 1971 to March 1972 learning neutron generator and radioisotope techniques. He left to pursue studies towards the Ph.D. degree at the University of California, Irvine.

Dr. E. Bailey resigned from the program in June 1972. Dr. P. Delsanto took his place in August.

Mr. Raúl Marco passed his exam for the M.S. degree in Chemistry in April and is now teaching at the Catholic University in Ponce.

María García left in March without completing her thesis.

NUCLEAR ENGINEERING

The Nuclear Engineering Division is engaged in both teaching and research. Division staff members teach graduate courses at the University of Puerto Rico and direct the thesis work of nuclear engineering students. They conduct research on their own projects and also assist the staff of other PRNC divisions as the need arises.

EDUCATIONAL ACTIVITIES

Scientists on the staff of the Nuclear Engineering Division all hold joint appointments at PRNC and UPR. The faculty of the Nuclear Engineering Department of UPR is composed of such staff members. The Head of the PRNC Nuclear Engineering Division is also the Chairman of the UPR Nuclear Engineering Department. The Division provides the classrooms, offices, laboratories, and equipment and most of the administrative personnel required for the education and training of the graduate students at the UPR Nuclear Engineering Department.

Special Courses. Short courses covering a variety of topics related to nuclear engineering are offered from time to time for scientists, engineers, and technicians. During the summer a special 12-week intensive Reactor Training Program was conducted by the Nuclear Engineering Division in cooperation with the Reactor Division for engineers of the Puerto Rico Water Resources Authority. Twenty engineers (most of them recent UPR graduates) participated in this program in order to gain sufficient background in the various aspects of nuclear engineering to enable them eventually to become power reactor supervisors. The participants (all U.S. citizens) were Juan R. Alcaraz, José Alvarado, Teodoro Rodríguez, Eduardo Balsera Pérez, José R. Bas, Armando Carvajal, José E. Félix, Manuel O. Irizarry, Martides Lara, Edwin Miranda, Juan Noriega, Pascual Ortiz, Julio Purcell, Neftalí Rivera, Francis Rodríguez, Angel Raúl Vega, Vicente Vega, Héctor Alejandro, José A. Aramburu, and Eduardo R. Danger.

Master of Science Degree Program. UPR, in close cooperation with the PRNC Nuclear Engineering Division, offers a Master of Science degree in Nuclear Engineering. Students with a B.S. in engineering and a grade average above a prescribed minimum are eligible for the M.S. program. Requirements for the M.S. degree include 30 credit hours of graduate course work, a thesis, and a final oral examination.

Table 1
Students Enrolled in the M.S. Degree Program
in Nuclear Engineering

Name	Citizenship	Sponsor
Alcaraz, Juan R.	U.S.	GI Bill
Alvarado, José	U.S.	UPR
Arenas Rosillo, G.	Colombia	MMP
Benítez, Jaime	U.S.	AEC
Griffin, Luciano	Venezuela	IVIC
Lebrón Pitre, Daniel	U.S.	AEC
Lingappan, K.	India	Self
López Sullivan, Pedro	U.S.	UPR
Luongo, Albert	U.S.	UPR
Michelen Embarek, Jesús	Dominican Republic	UPR
Musalem, Abraham	Dominican Republic	UPR
Kuppusamy, N.	India	Self
Rodríguez, Teodoro	U.S.	UPR
Rosado Meléndez, M.	U.S.	AEC
Ufret, Rafael L.	U.S.	Self

Table 2
Student Thesis Research Projects

Name	Title of Thesis	Major Professor
Alcaraz, Juan R.	* Experimental Determination of Thermal Neutron Diffusion Length of Water as a Function of Temperature Using (n, γ) Reactions	H. Plaza
Alvarado Cruz, J.	* Determination of Total Cross Sections Using the UPR-RUM Texas Nuclear Model 9400 Neutron Generator	E. Ortiz
Benítez, Jaime	* Determination of Trace Elements in Some Foods in Puerto Rico Using Neutron Activation Analysis Techniques	K. Pedersen
Rodríguez, T.	* Determination of the Sedimentation Rate in the Mouth of the Guanajibo River by Activation Analysis	K. Pedersen
Kuppusamy, N.	* Computer Aided Decomposition of Gamma Spectra Emitted by Mixtures of Certain Radioactive Nuclides	A. Gileadi
Rosado, M.	Absolute Flux Determination Using Activity Ratio of Consecutively Produced Isotopes	D. Sasscer
Lebrón, D.	Natural Radiation Exposures in Puerto Rico	A. Gileadi
Arenas, G.	Gas Stopping Power Measurements for Alpha Particles	E. Ortiz
Musalem, A.	Determination of Uranium Content in Certain Ores Occurring in Puerto Rico by Delayed Neutron Counting	A. Gileadi
Ufret, R.	Determination of Prompt Neutron Decay Constant by Stochastic Methods	A. Gileadi
Griffin, L.	Experimental Determination of the Gamma Dose Absorbed in a Cylindrical Calorimeter	A. Gileadi

* Completed.

During 1972, fourteen students participated in the M.S. program (Table 1), of whom five completed the M.S. degree and the rest are working on their thesis projects and/or completing their course-work. Thesis research projects in progress or completed during the year under the supervision of the Division staff are shown in Table 2.

Graduate Courses. The staff of the Division taught ten graduate courses and one advanced undergraduate course for which academic credit was given by UPR (Table 3). Fifteen students besides those in the M.S. program participated (Table 4). Seven additional courses were taught as part of the Reactor Training Program (Table 3).

Table 3
Courses Taught by Division Staff

Course	Professor	Enrollment
Elements of Nuclear Engineering	D. Sasscer	4
Mathematics of Modern Science I	A. Gileadi	5
Reactor Theory	K. Pedersen	5
Nuclear Meas. & Instrumentation	H. Plaza	5
Advanced Reactor Theory	K. Pedersen	5
Mathematics of Modern Science II	A. Gileadi	5
Nuclear Reactor Technology II	H. Plaza	6
Reactor Laboratory	H. Plaza	6
Seminar	Staff	5
Introduction to Nuclear Engineering	D. Sasscer	15
Special Problems	H. Plaza	1
*Reactor Control & Instrumentation	H. Plaza, G. Arenas	20
*Reactor Physics	A. Gileadi, N. Kuppusamy	20
*Nuclear Physics	D. Sasscer, M. Rosado	20
*Power Reactor Technology	K. Pedersen, D. Lebrón	20
*Radiation Protection & Regulation	E. Rivera, R. Brown	20
*Reactor Operation & Experiments	A. Gileadi, D. Sasscer K. Pedersen, H. Plaza	20
*Reactor Safety & Licensing Regulations	R. Brown	20

* Special courses taught as part of the Reactor Training Program.

Table 4
Students Not in Degree Program Who Took Courses Offered by Nuclear Engineering Division
(U.S. Citizens Unless Otherwise Noted)

Campos Morales, José I.	Mireles Sahagun, José (Mexican)
Castro Cedeño, Mario H.	Pagán Feliciano, Luis M.
Ferrer Pi, Omar E.	Rivera Nieves, Neftalí
Huertas del Toro, Alfredo	Reyes Vega, Angel B.
Guzmán Colón, Héctor I.	Salichs Sotomayor, Luis G.
Martínez Figueras, Edmundo	Santana Castro, David A.
Lara Carrasquillo, A.	Soto Tur, Ramón
Michelen Embarek, Jesús (Dominican)	

RESEARCH PROJECTS

The research projects of the Division in progress or completed during the year are listed below.

Experimental Determination of Thermal Neutron Diffusion Length in Water as a Function of Temperature Using (n,γ) Reactions — H. Plaza and J. Alcaraz. The relationship between thermal neutron diffusion length in water and temperature has been established, as well as the number of emitted gamma rays resulting from the (n,γ) reactions of the neutrons with the hydrogen atoms of the water. (Completed.)

Thermal Flux Distribution in the PRNC TRIGA-FLIP Reactor — H. Plaza and A. Luongo. The relative thermal neutron flux distribution in the TRIGA-FLIP reactor core was measured with gold wires by the cadmium ratio technique. Absolute flux measurements at certain positions inside the reactor core with gold foils were made by β - γ coincidence counting techniques. (Completed.)

Measurement of the Total Cross Section of Various Metals at 4- and 14-MeV Neutron Energies — E. Ortiz and J. Alvarado. The total cross section of Al, Cu, Fe, and Pb was measured for two different neutron energies: at 4 MeV from the D-D reaction and at 14 MeV from the D-T reaction. A Texas Nuclear Model 9400 neutron generator was used as the source of neutrons, and a plastic scintillator was used to measure the transmitted beam. (Completed.)

Neutron Yield from D-D and D-T Reactions — E. Ortiz and J. Alemar. A study of the D-D and D-T reactions was made using a Texas Nuclear Model 9400 neutron generator. The D-D and D-T angular distributions were obtained by varying certain parameters of the generator such as accelerating voltage of the D's and beam current. A plastic scintillator was used as a detector. (Completed.)

Experimental Determination of the Gamma Dose Absorbed in a Cylindrical Calorimeter — A. E. Gileadi and Luciano Griffin. Lead cylinders of various dimensions are placed in a gamma field, and the resulting temperature changes are recorded by means of thermocouples fixed at given locations in the cylinders. The volumetric heat source created by the absorbed gammas is fitted to a mathematical model, and the computed results are compared with the measured ones. (In progress.)

Computer Aided Decomposition of Gamma Spectra — A. E. Gileadi and N. Kuppusamy. A computer code has been written that will compute the mixing factors of certain radioactive source mixtures, the input data being the gamma spectra of the source mixture and of its individual components. Applicability of the code was tested on specially prepared premeasured source mixtures. (Completed.)

Technological Studies on the Leaching of Copper from Chalcopyrite — F. J. Muñoz Ribadeneira. These studies have shown the feasibility of extracting copper from this insoluble copper iron sulfide ore if the ore particles have an average radius of 0.47 μ m and if chloride ion is used in addition to sulfuric acid in the leach solutions. Leaching rates depend on the specific surface of the particles and on the chloride ion concentration. Thermal activation of the ore can greatly accelerate the appearance of copper in the leach solutions. (Completed.)

Determination of the Prompt Neutron Decay Constant by Stochastic Methods — A. Gileadi and Rafael Ufret. A sophisticated high accuracy multichannel analyzer, equipped with a dual timer that allows count-rates to be taken for time intervals ranging from tens of microseconds up to arbitrarily long periods, is used to take neutron counts coming from a high sensitivity BF_3 counter located near the core of a critical or slightly sub-critical reactor. The variance to mean ratio is determined by Feynman's method and is then used to compute the prompt neutron decay constant. (In progress.)

Determination of the Uranium Content of Certain Samples by Delayed Neutron Counting — A. E. Gileadi and A. Musalem. Uranium-containing samples are being irradiated in the rabbit of the PRNC research reactor, and the delayed neutrons resulting from fission of the ^{235}U in the samples are counted in a multiscaler. Six BF_3 counters are used in an "almost" 4π configuration to detect the delayed neutrons. (In progress.)

Natural Radiation Exposures in Puerto Rico — A. E. Gileadi and D. Lebrón. The exposure of man to natural radiation sources in Puerto Rico is being calculated by means of a computer code developed for this purpose. The input data include geological characteristics, elevation, distribution of population, and other relevant factors. The results are expected to give a reasonable value of average per capita exposure to natural radiation in Puerto Rico. (In progress.)

Experimental Study of the $^{17}\text{O}(n,p)^{17}\text{N}$ and $^{18}\text{O}(n,d)^{17}\text{N}$ Reactions with High Energy Neutrons from the PRNC Neutron Generator — A. E. Gileadi and E. Ortiz. ^{17}N is a precursor emitting 4.17-sec delayed neutrons. These will be counted in a multichannel analyzer used in the multiscaling mode, subsequent to the creation of ^{17}N by irradiating ^{17}O and ^{18}O enriched water with high energy neutrons. (In progress.)

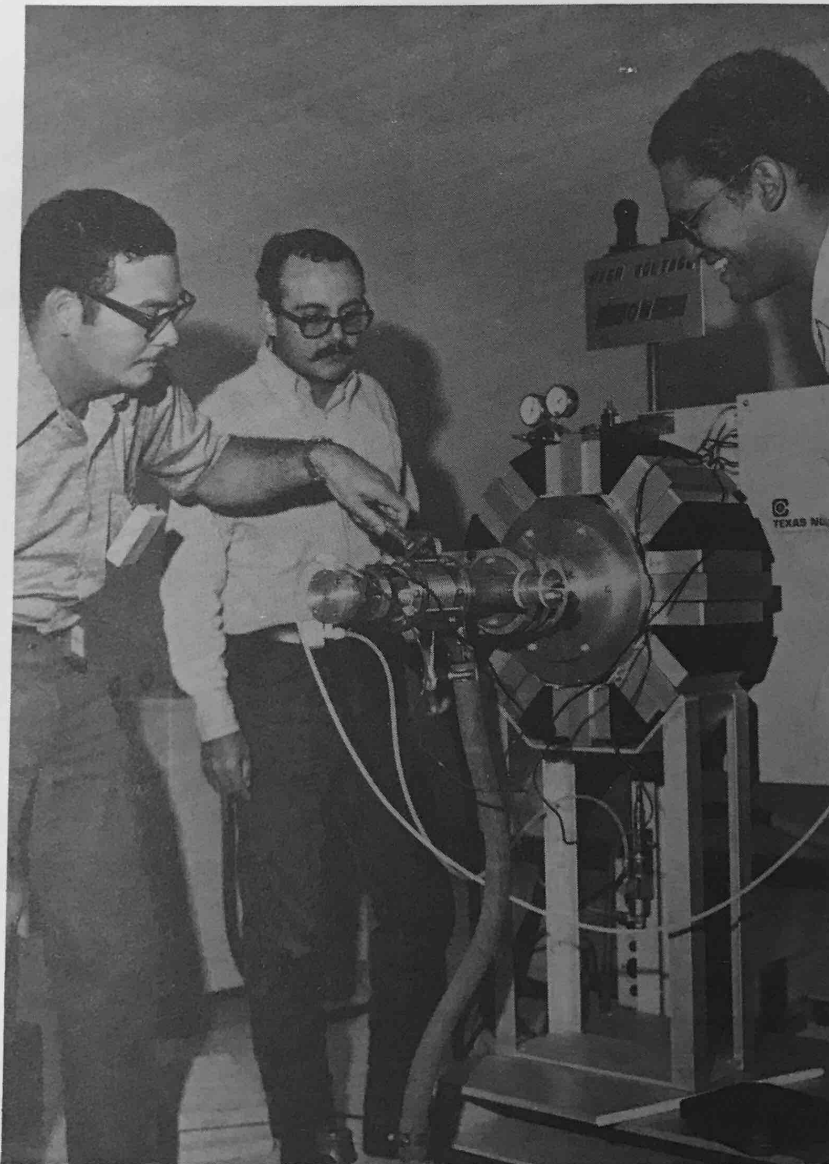
Determination of Trace Elements in Some Foods in Puerto Rico — K. B. Pedersen and J. Benitez. The contamination by selected elements in some foods considered to be staple items in the Puerto Rican diet was determined. Methods of direct nuclear instrumental analysis for some of these elements were investigated. (Completed.)

Flux Mapping of the PRNC TRIGA-FLIP II Reactor — K. B. Pedersen and T. Rodríguez. The thermal neutron fluxes along the length of the four irradiation positions in the reactor

have been measured by using bare cadmium-covered gold foils held in a rotating assembly at the face of the reactor. The absolute flux was measured at a point location and determined by coincidence counting. (Completed.)

Gas Stopping Power for Alpha Particles — E. Ortiz and G. Arenas Rosillo. A simple method will be developed to measure the stopping power of alpha particles from ^{241}Am in various gases by varying the gas pressure in a chamber. (In progress.)

Absolute Flux Determination Using Activity Ratio of Consecutively Produced Isotopes — D. S. Sasscer and M. Rosado. A new technique for the determination of neutron flux is being investigated, which is based on consecutive production of two radioisotopes from a stable nuclide. This technique minimizes corrections since use of the ratio of two activities cancels out some correction factors. (In progress.)



Nuclear Engineering graduate students at the 14-MeV neutron generator:
(from left) Juan R. Alcaraz, José Mireles Sahagún, and Teodoro Rodríguez Landrau.

PHYSICAL SCIENCES

A major objective of the Physical Sciences Division is to provide advanced training for Puerto Rican and Latin American trainees, primarily through participation in research with high energy radiation and radioisotopes. This program is geared to regional needs, and it includes an introductory training course in the use of radioisotopes. Participation of the scientific personnel in the academic activities of the natural sciences departments of the University of Puerto Rico, Río Piedras, is encouraged through joint appointments.

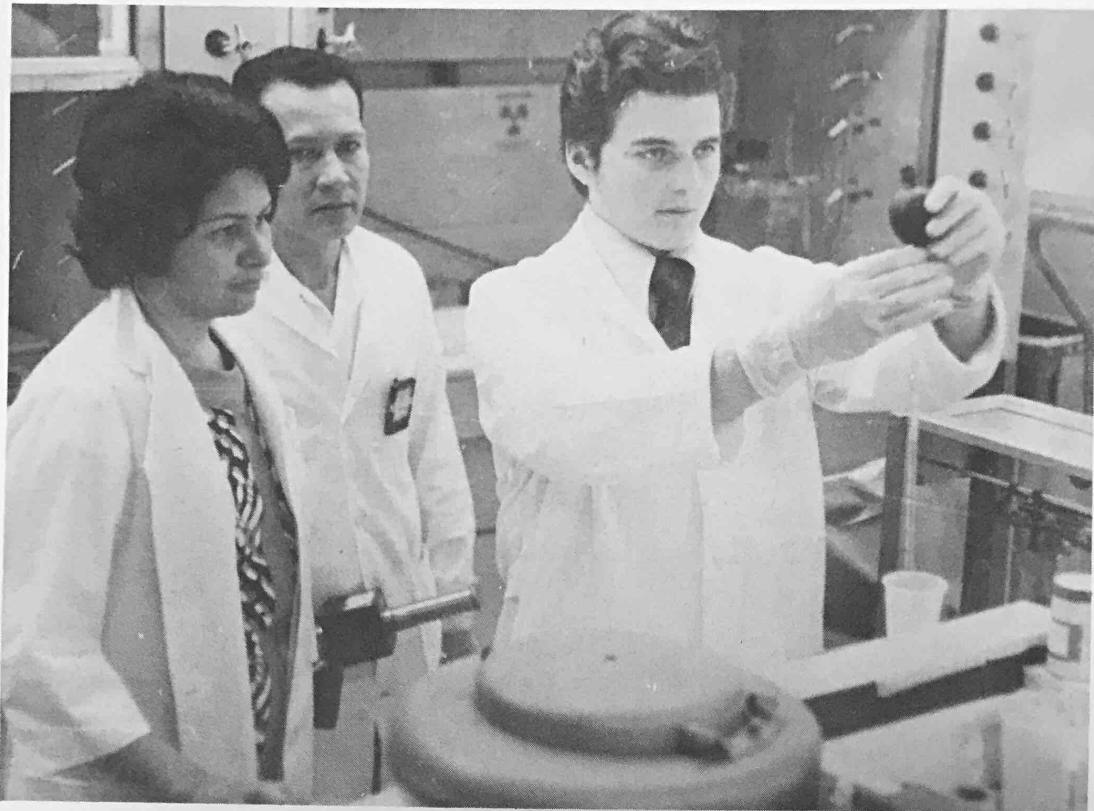
EDUCATIONAL ACTIVITIES

The educational activities of the Division range from a four-week noncredit training course in the techniques of radioisotope applications to research training in the laboratories of the Center. The four-week course was offered twice during 1972. The distribution of the 17 trainees by geographical origin is shown in Table 1.

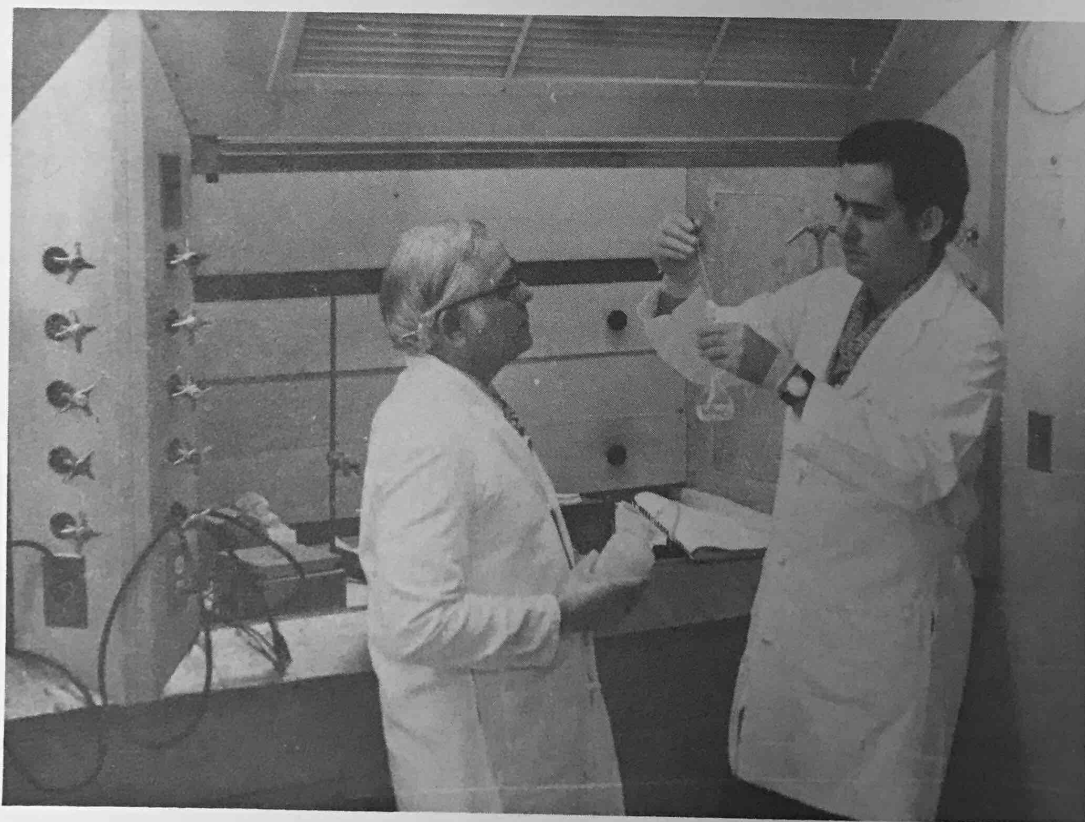
Table 1
Participants in Basic Course in Radioisotope Techniques, 1972

Name	Country	Field of Interest
Arozena Gorostegui, Xabier	Venezuela	Radioisotopes
Conde de Miraldi, Mirva	Puerto Rico	Radioisotopes
* Dreyfous Jiménez, Ana R.	Santo Domingo	Radioisotopes
Pagán Suárez, Nilsa	Puerto Rico	Radioisotopes
Tamayo Londoño, Jorge	Colombia	Radioisotopes
Acevedo Meléndez, José A.	Puerto Rico	Microbiology
Bonilla Torres, Angélica	Puerto Rico	Nuclear medicine
Bontá Dávila, Carmen Y.	Puerto Rico	Endocrinology
**Caputto Escudero, Jorge D.	Argentina	Endocrinology
† González Bolaños, Armando	Cuba (U.S. Citizen)	Chemistry
Natal Pomales, Annie	Puerto Rico	Microbiology
Martínez Lanausse, Ivelysse	Puerto Rico	Nuclear medicine
**Decillis Caló, Ricardo C.	Argentina	Neurology
Toro de Berrios, Luz	Puerto Rico	Radiotherapy
Saavedra Sanquirico, Sonia	Puerto Rico	Microbiology
Rodríguez del Valle, Nuri	Puerto Rico	Microbiology
**Naranjo Williams, Percy	Peru	Pathology

Financial sponsors: *Picker Co. ; **PRNC Economic Aid Program; † Colegio San Ignacio.
Other participants were self-sponsored.



Students of the Radioisotope Techniques Course working in the radiochemistry laboratory: Professor Rosa Santana de Tirado (Puerto Rico), Mr. Obdulio E. Maldonado (San Salvador), and Mr. Alejandro Trigo Chaves (Bolivia).



Students of the Radioisotope Techniques Course performing dilution procedures: Dr. Jafeth Ramírez Ledesma (Puerto Rico), left, and Mr. Gustavo José Fernández (Santo Domingo).

The following University courses were given:

1. Advanced Quantum Chemistry (Chem. 564, three credits). A one-semester graduate course. Dr. Alec Grimison.
2. Natural Sciences 101 (12 credits). First half of a two-semester undergraduate interdisciplinary course in Chemistry, Physics, and Biology. Dr. Alec Grimison.
3. Physical Chemistry (Chem. 363 and 364, three credits each). A two-semester undergraduate course. Dr. Rafael Arce Quintero.
4. Physical Chemistry Laboratory (Chem. 365, two credits). A one-semester undergraduate course. Dr. Rafael Arce Quintero.
5. General Chemistry (Chem. 102, three credits). A one-semester undergraduate introductory course. Dr. Rafael Arce Quintero.
6. Radiation Chemistry (PRNC 505, two credits). A one-semester graduate course for the School of Public Health. Dr. Manfred K. Eberhardt.
7. Undergraduate Research Training. Four undergraduate science students took advantage of training opportunities in this Division during 1972: Luis Matos, supervised by Dr. M. K. Eberhardt; Lorna Ramírez, supervised by Dr. Rafael Arce; Betzaida Castilla, supervised by Dr. G. A. Simpson; and Félix Santos, supervised by Dr. A. McB. Block.

Thesis Research. The following M.S. thesis research was sponsored by the Division during 1972 (see also Radiation Chemistry):

1. Influence of Chemical Structure on Quenching — Elsa Gómez (Puerto Rico). Experimental work completed in 1972 under Dr. José Castrillón.
2. Aromatic Nitriles as Scintillation Solutes — Carmen Velázquez (Puerto Rico). Experimental work completed in 1972 under Dr. José Castrillón.
3. Adducts of Cadmium and Mercury Halides with Some Mesoheteroanthracenes — Sonia Vázquez (Puerto Rico). Experimental work completed in 1972 under Dr. José Castrillón.

RESEARCH

The research activities of the Physical Sciences Division include studies on radiation effects and radioisotopes, and work supporting these studies. The projects are described briefly below.

Radiation Effects. The effects of high-energy deposition in chemical systems are studied in order to clarify the mechanisms of radiation-induced changes. In some systems the emphasis is on the initial, or primary, products of radiations; in others, on the final products produced by secondary chemical reactions.

1. Matrix Isolation Studies of the Gamma Radiolysis of Heterocyclic Molecules — A. Grimison and G. Simpson. This project receives support from the AEC Division of Biology and Medicine and is described elsewhere in this *Annual Report*.

2. Radiation-Induced Aromatic Substitution — M. K. Eberhardt. Work on homolytic hydroxylation of aromatic compounds is being continued.

Radioisotopic Studies. Liquid Scintillation Counting — J.P.A. Castrillón. Means are being sought for improving present techniques by the use of better solvents and solutes and control of quenching.

a. The Influence of Chemical Structure on Quenching. Studies are continuing on the effects of a series of substituted benzophenones and of a series of substituted diphenyl sulfoxides on the β -spectrum of ^{14}C . The contribution of color quenching has been measured. Graduate student trainee: Elsa Gómez.

b. New Solvents and Solutes. Attempts are being made to improve known liquid scintillators, in particular those used for aqueous and polar samples. Simple aromatic nitriles have been found to behave as efficient scintillation solvents, and a U.S. patent has been obtained. Selected organic structures with cyano substituents have been synthesized and used as efficient scintillation solutes. Graduate student trainee: Carmen Velázquez.

Supporting Research. One of the essential functions of the Physical Sciences Division is to provide technical assistance to other divisions or programs needing its particular expertise or facilities. The projects described below may not directly involve the use of radiation or radioisotopes but they provide supporting information needed for the projects listed above, or for similar projects in other divisions.

1. Light Scattering by Stream Water — A. McB. Block and F. Santos. A commercially available laser source has been adapted to a Brice Phoenix BP-2000 light-scattering photometer to give measurement capability with light of wavelength 6328 Å. The laser must be acoustically isolated, and a Wratten filter to eliminate the blue corona from the beam is also necessary. Current stabilization and a steady dc source for the laser filaments are absolutely necessary for a stable scattering output. The scattered light from model systems has been measured by this technique. Scattered light from natural sources such as stream water may be correlated with the spore count of the water; this possibility is under investigation.

2. Adsorption Complexes of Silica and Protein — A. Grimison and A. McB. Block. In 1971, the width of the trypsin layer adsorbed to colloid silica was estimated at $55 \text{ \AA} \pm 10\%$ by measuring τ , the turbidity of the freshly formed adsorption complex. Since $\tau = N\pi b^2 Q$ (with N = number concentration of silica particles, b = radius of silica + protein layer, and Q = extinction efficiency), then $b^2 Q = \tau / N\pi$. The quantity $b^2 Q$ is calculated from the theory of Aden and Kerker by CONSF 2, a computer routine developed by Block and Grimison to solve Maxwell's equations for a concentrically spherical model system. The values of $b^2 Q$ are plotted versus the protein thickness, and measurements of τ/π vs N give a straight line of slope $b^2 Q$. Reference to the theoretical graph gives a fair value of the protein thickness. In 1972, a closer estimate of trypsin thickness was begun. In the

new approximation, the variation of silica particle diameter in a typical solution is taken into account. Electron microscopy is used to estimate the distribution in diameter of the silica particles.

3. Electronic Structure of Synthetic Plant Hormones — A. McB. Block, M. Eberhardt, and R. C. Clements. Synthetic plant hormones of the phenoxyacetic acid type — 2,4-dichlorophenoxyacetic acid (2,4-D), *para*-chlorophenoxyacetic acid (PCAC), and phenoxyacetic acid — are active as auxins in plant metabolism. 2,6-Dichlorophenoxyacetic acid (2,6-D) has a very much weaker auxin activity. Closed-shell calculations of the electronic structures of the four compounds using the CNDO (complete neglect of differential overlap) approximation have been completed, and others are in progress, to determine the electronic basis for their relative auxin activities. Similar calculations are in progress to determine electronically why the *cis*-isomer of cinnamic acid has weak auxin activity although the *trans*-isomer is a plant growth inhibitor. This project is a cooperative effort with the Physical Sciences Division and the Terrestrial Ecology Project.

4. Organic Complexes of Heavy Metals in Stream Water — A. McB. Block and R. C. Clements. Humic and fulvic acid complexes of heavy metal ions in stream water have been removed by adsorption to Rohm and Haas X-AD-2 resin, which is composed of neutral noncharged “macroreticular” particles of polystyrene bonded together and has a relatively hydrophilic surface and excellent holdup properties. The concentration of free metal ions in stream water is under investigation as part of the parametrization of the watershed draining the El Verde experimental forest. This project is a cooperative effort with the Physical Sciences Division and the Terrestrial Ecology Project.

5. Electrophilic Aromatic Triphenylmethylation — M. K. Eberhardt. This joint research project with IVIC (Instituto Venezolano de Investigaciones Científicas) has continued, and results have been published on aniline and phenol compounds.

6. Aminomethylation of Lactam-Lactim Tautomers — M. K. Eberhardt. SCF-MO (CNDO, INDO, MINDO) calculations are being carried out to correlate electronic properties of a series of tautomers with their reactivity in the aminomethylation reaction.

7. Electronic Structure of Aromatic Boronic Acids — M. K. Eberhardt. A large number of aromatic boronic acids have been tested by others in neutron irradiation therapy of brain tumors. A desirable feature is a high tumor/normal-brain ratio. SCF-MO calculations have been carried out to see what electronic properties might be responsible for a high ratio.

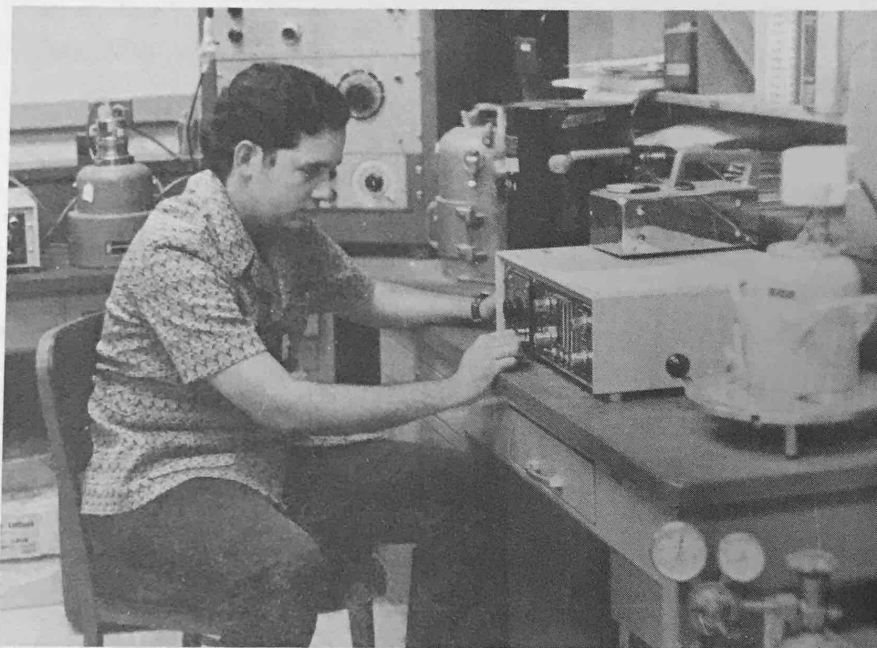
8. Thioxanthone and Related Compounds — J. P. A. Castrillón. Studies on the determination of the ultraviolet and infrared spectra of this family of metallic complexes were completed. It was shown that complex formation in the case of sulfoxides allows easy identification of the sulfoxide stretching band, indicates whether coordination takes place on the sulfur or the oxygen atom, and also provides a clear distinction between equatorial and axial bonds. Deformations of the S-O bond with diagnostic value were identified. Graduate student trainee: Sonia Vázquez.

STAFF

Dr. Martin Pope, who was collaborating with this Division, concluded his sabbatical year at the UPR Physics Department on January 31, 1972, and returned to New York University. He continues as a consultant to this Division.

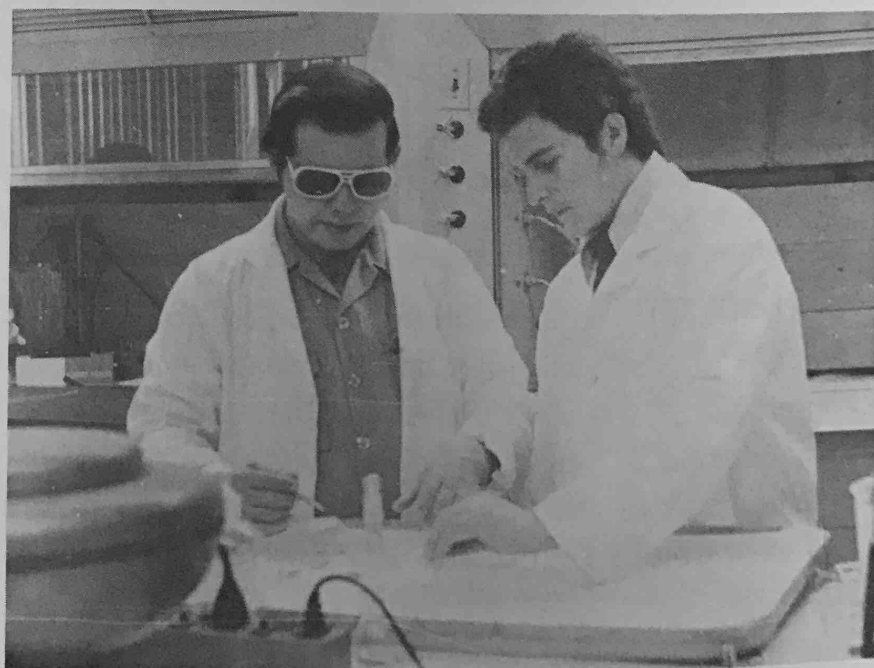
Dr. José Castrillón returned in August 1972 from a year's leave of absence at the Institute of Sciences, Asunción National University, Paraguay, sponsored by the Organization of American States.

Dr. Alec Grimison, who was Acting Head of the Division, left PRNC on December 1, 1972, to become Associate Director of the Office of Information Systems, Central Administration, University of Puerto Rico.



Student Gustavo José Fernández (Santo Domingo) counting radioactive samples in the gas flow proportional counter.

Students Dr. Francisco A. Torres (Puerto Rico) and Mr. Alejandro Trigo Chavez (Bolivia) performing decontamination tests in the radiochemistry laboratory.



Radiation Chemistry

GAMMA RADIOLYSIS OF HETEROCYCLIC MOLECULES

The object of these studies is the identification of the species formed by gamma radiolysis of heterocyclic molecules of possible biological importance; therefore, emphasis is on direct observation of the normally labile intermediates formed after the absorption of high energy radiation. This is done by the matrix isolation technique, in which the molecule is irradiated in a rigid matrix at low temperature so that radicals and radical ions are stabilized for extended periods and can be characterized by spectroscopic techniques. The results of quantum mechanical calculation of electronic properties of heterocyclic radicals and ions are used in conjunction with experimentally measured properties to identify unknown intermediates.

THESIS RESEARCH

Use of Single-Center Expansions in Photoionization Cross Section Calculations — Gladys Rodríguez (Puerto Rico) for the Ph.D. degree, to be completed in 1973; under Dr. A. Grimison.

Flash Photolysis of Heterocyclic Compounds — José Revuelta (Cuba) for the M.S. degree, to be completed in 1973; under Dr. G. Simpson.

Electron Spin Resonance Studies of Intermediates Stabilized at Low Temperatures — Lorna Ramírez (Puerto Rico) for the Ph.D. degree, to be completed in 1975; under Dr. R. Arce Quintana.

UNDERGRADUATE RESEARCH

Phosphorescence Yield Studies of Some Nitrogen Heterocyclics at 77°K — Betzaida Castilla (Puerto Rico), UPR; under Dr. G. Simpson.

CURRENT RESEARCH

Theoretical Calculation of Radical Spectra — A. Grimison and M. K. Eberhardt. Theoretical calculations involving all valence electron SCF-MO (INDO approximation) calculations on the electron densities, and Parisier-Parr-Pople calculations which included configuration interaction on the electronic transition energies, have been made for the

simple anions, the radical anions, and the suspected protonated species which may be produced from these anions of cytosine and uracil. The results of the calculations are consistent with the experimental observations of the intermediates formed during pulse radiolysis of aqueous solutions of these compounds. However, rather than the attachment of a solvated electron at the C₂ and C₄ carbonyls, as had been proposed, the calculations suggest that the solvated electrons react with uracil and cytosine by attachment to the C₅-C₆ double bond. The resultant species may then protonate in the appropriate pH range to form the C₄ ketyl radical in the case of uracil and the C₂ ketyl radical in the case of cytosine.

Flash Photolysis of Heterocyclics in Solution — José Revuelta. Transients produced by the flash photolysis of several nitrogen heterocyclics have been observed in several solvents by the techniques of flash spectroscopy and kinetic spectrophotometry. For indole, quinoline, and isoquinoline previously reported transients have been observed to display striking solvent effects, which clearly suggest that the occurrence of either proton transfer or hydrogen bonding processes is important in the production of triplet related processes. Transients associated with benzimidazole and purine are assigned as cationic intermediates on the basis of low temperature glass-matrix studies. A detailed kinetic analysis of the decay of indole transients in water is consistent with the production of indolyl radicals as a result of initial photoionization processes of a hydrogen-bonded indole species.

Photoionization of Nitrogen Heterocyclics — G. Simpson, F. Bernasconi, and B. Castilla. Studies of the luminescence effects associated with the process of biphotonic photoionization of several nitrogen heterocyclics in rigid glasses at 77°K (reported in PRNC-128) have been extended by measurements of the absolute phosphorescence quantum yields of these compounds. These measurements, along with the previously reported relative luminescence yields, provide a measure of the photoionization efficiency. The values of the phosphorescence yields and decay constants agree with the values determined by electron paramagnetic resonance studies carried out concurrently.

Electron Paramagnetic Resonance Studies of Intermediates at 77°K — R. Arce and Lorna Ramírez. Studies have been completed on the paramagnetic species produced from several nitrogen heterocyclics in glassy solvents on exposure to ultraviolet radiation at 77°K. The zero-field parameters and the decay constants defining the lowest triplet states of indole, purine, and indazole have been obtained as well as absolute measurements of the yields of these triplet states (the intersystem crossing efficiencies) and the yields of free radicals produced by energy transfer from an excited triplet state to the solvent matrix. The results indicate that energy transfer to the solvent from excited triplet states competes with the processes of photoionization and internal conversion in these compounds.

Thermoluminescence Associated with Gamma Irradiation of Glassy Solutions Containing Purines and Pyrimidines — A. McB. Block. Previous studies of thermoluminescence

associated with matrix-isolated intermediates of biologically important compounds have been limited to the use of matrices which were non-"cell"-like or in which these compounds had very limited solubilities. Preliminary investigations of an ethylene glycol:H₂O matrix showed these limitations to be circumvented. Thermoluminescence yields associated with gamma irradiation of this matrix with adenine, cytosine, thymine, adenine monophosphate, thymine ribonucleoside, or DNA were in excess of the matrix value, and specific glow peaks were observed in the case of cytosine and DNA.

SUPPORTING RESEARCH

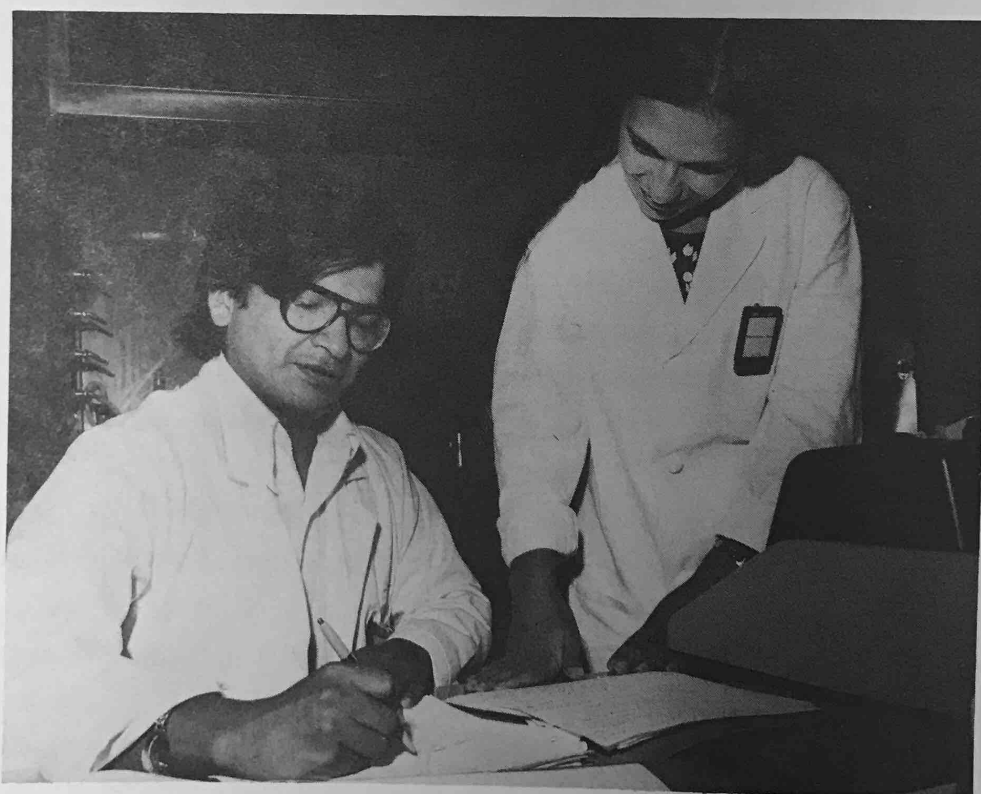
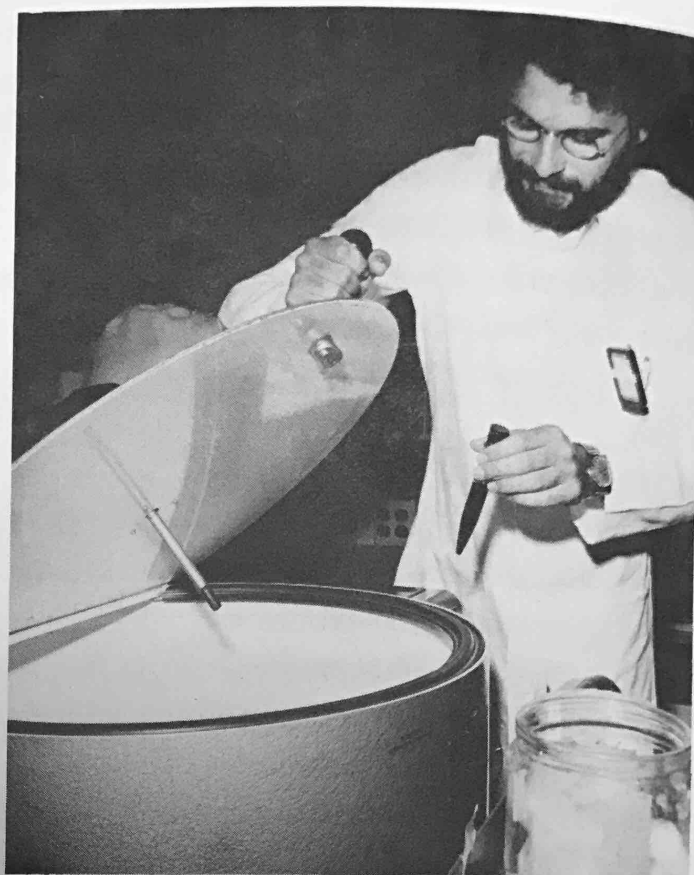
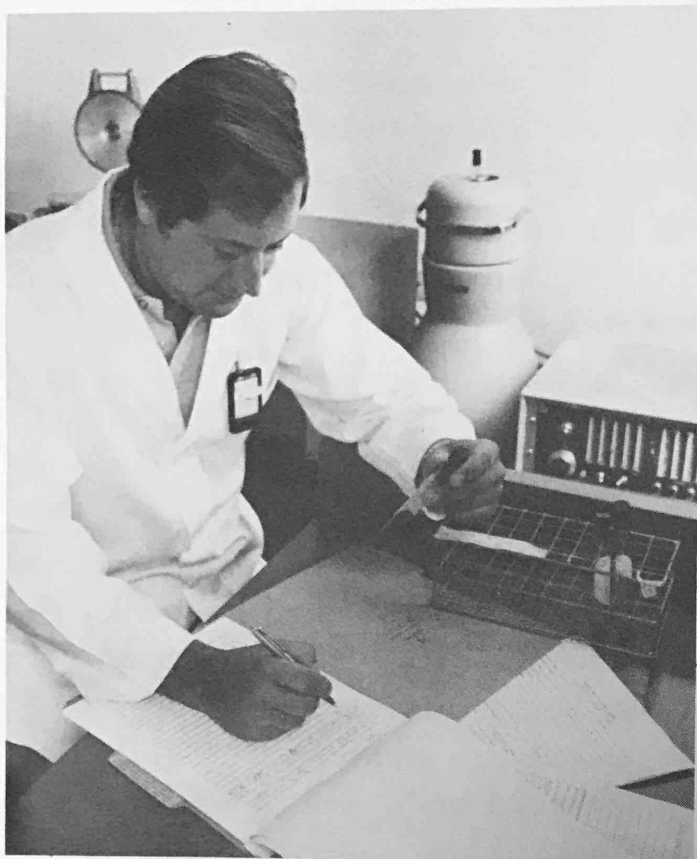
Chemiluminescence of Cyclic Peroxides — W. Adam and G. Simpson. Collaboration has been extended to the laboratory of Dr. W. Adam (UPR) for the purpose of determining the absolute chemiluminescence yields of a class of energy rich, but relatively stable, cyclic peroxides. These compounds, *α*-peroxylactones, long suspected to be the light precursors in some bioluminescence reactions, and of possible importance in some radiation chemical systems, can now be synthesized. The experimental work in progress has shown that the luminescence yields of the peroxylactones alone is of the order of 10⁻⁷ photon per molecule, indicating relatively few excited singlet states produced during the decomposition of these compounds, but that in the presence of appropriate energy acceptors emission yields of the order of 10⁻² photon per molecule result — this is attributed to efficient triplet state production.

STAFF

Dr. George A. Simpson, who participated in the matrix isolation program from 1966 until 1969, was made the principal investigator of the program in July 1972 under a joint appointment with PRNC and UPR, where he is a senior postdoctoral appointee to the Department of Chemistry.

Dr. A. Grimison resigned his position at PRNC in December 1972 to assume responsibility for computer research programs on the UPR campuses. He will continue research on heterocyclic intermediates on an *ad honorem* basis.

Dr. A. McB. Block is collaborating with the matrix isolation program and the Physical Sciences Division on an *ad honorem* basis.



Basic Clinical Radioisotope Applications Course: (top left) Dr. Jorge Caputto (Argentina) doing laboratory work; (top right) Dr. Ricardo Decillis (Argentina) working with ^{51}Cr -labeled blood cells; (bottom) Dr. Percy Naranjo Williams (Peru) and Dr. Nelida E. Pérez (Argentina) working with data from hematology tests.

CLINICAL RADIOISOTOPE APPLICATIONS

The major function of the Clinical Radioisotope Applications Division is to train physicians and technicians in the medical uses of radioisotopes. Most of the trainees are from Puerto Rico and various Latin American nations. The Division also disseminates data on the clinical applications of radioisotopes and develops clinical research plans for incorporation into its training courses. The Division's service to community hospitals lacking radioisotope facilities assures the availability of patients necessary for the development of courses and research plans.

EDUCATIONAL ACTIVITIES

Basic Clinical Radioisotope Applications Course. This course was described in detail in the 1970 *Annual Report*. This year thirteen students took the course (country of origin and sponsor, if any, follow each name):

February 7—March 31, 1972

Ana Rosa Dreyfous, Dominican Republic, Picker del Caribe, Inc.

Jorge Tamayo, Colombia

Mirva Conde, Puerto Rico

Xabier Arozena, Venezuela

Manfred Eberhardt, Puerto Rico, PRNC (observer)

July 3—August 25, 1972

Ingrid Erdelyi, Brazil, Amer. Assoc. Univ. Women Educ. Found.

Luisa Nélide E. Pérez, Argentina, PRNC

Jorge Caputto, M.D., Argentina, PRNC

Joao Soares de Almeida, M.D., Brazil, PRNC and Liga Bahiana Contra el Cancer

Ricardo C. Decillis, M.D., Argentina, PRNC

Percy Naranjo Williams, M.D., Peru, PRNC

Lucy Toro de Berríos, M.D., Puerto Rico (observer)

Angelica Bonilla, Puerto Rico, Bayamón Nucl. Med. Lab. (observer)

Radioimmunoassay Course. On September 5-25, a special course on radioimmunoassay was offered in collaboration with Dr. Francisco Aguiló, Department of Medicine, University Hospital, UPR School of Medicine, which included principles and history of radioimmunoassay, radioiodine labeling, and methods for determining insulin and growth hormones. The participants in the course were Luisa Nélide E. Pérez, Argentina, PRNC; Jorge Caputto, M.D., Argentina, PRNC; and Ricardo C. Decillis, M.D., Argentina, PRNC.

Informal Training. Practical training is offered to students wishing to obtain clinical and laboratory experience under the guidance of Division staff members. The following students took such training:

Miss Angelica Bonilla (Puerto Rico) — general application of radioisotopes; March to June.

Miss Nilsa I. Pagán (Puerto Rico) — general application of radioisotopes; March to September (part time).

Dr. Xabier Arozena (Venezuela) — general application of radioisotopes; April 10-28.

Miss Nayda R. Figueroa Vallés (Puerto Rico, candidate for the M.S. degree in Radiological Health) — diagnostic tests; June 5-16.

Dr. Marco A. Luján (Colombia) — diagnostic procedures, especially with the Anger camera; June 8-15.

Miss Cecilia Salazar (Venezuela) — use of the Anger camera; June 26-30.

Educational Activities Outside the Division. An orientation course in the Clinical Application of Radioisotopes, January 18-29, was offered to 48 students enrolled in the Medical Technologists course at the UPR School of Medicine. All the students were from Puerto Rico:

José Luis Alcalá Collazo
Bethzaida Alvarez Martínez
Evelyn Asencio Orlang
Zarahi M. Belén Rivera
María T. Berríos Ramos
Carlota Blanco Ramos
Isabel Candelario Anguita
Alma R. Cañuelas León
María E. Ojeda Rentas
Cándida Pagán Reyes
Noelia Pérez Arriaga
Carmen Pescador Vélez
Ana María Pietri Padilla
Ana Lydia Prieto de Jesús
Evelyn Reyes García
Miriam Ríos Serrano
Julia Carrero Rivera
Maritza Cartagena Palmer
Agnes Cintrón Santiago
María de los A. Colón
Aurea E. Correa Maldonado
Margarita Crespo Rosa
Elizabeth Cruz Danoy
Lourdes D'Acosta Nazario

Migda M. Dieppa Mendoza
Ida González Ortega
Nydia Irizarry Martínez
Ada Irizarry Montalvo
Sandra Lynne Likus
Evelyn Meléndez Ramos
Marisol Méndez Rosa
Juan R. Miranda Reverón
María C. Rivera Luna
Carmen Rivera Marcano
Jaime Rodríguez Colón
María T. Rodríguez Malavé
Magda S. Rodríguez Morales
Ivelisse Rodríguez Ortiz
Juan A. Serrano Torres
Zoraida Sánchez Otero
Francisca Santiago Medina
Pablo D. Soto Soto
María T. Vázquez Berio
Luis Vázquez Román
Agnes Vélez Pancorbo
Miriam Vélez Toro
Ana Nilda Vila Pérez
Magda Visbal Avilés

This course was repeated, November 13-28, for another 49 students:

Aida Alejandro Martínez	Edia López López
Rosalía Alonso Castro	María T. Martínez Vela
Tomasita Arroyo Maldonado	Ileana Matos Doval
Aida Avila Hernández	Sarah Matos Pacheco
Liliana Belvis Tavard	Carmen O. Meléndez Torres
Marta Cabrera Amador	María Mercado Cruz
María Casasnovas González	Cándida Monroig Rodríguez
Coralys Colón Cardona	Crimilda Nogueras Salinas
Myriam Corazón Robles	Ada Noy Anchia
Maria Cortes Alemán	Zydnia Pomales Torregrosa
Haydee Cuevas Carrasquillo	Mirna Quetell Hernández
Ruth J. Dávila Matos	Víctor Quiroz Naranjo
Milagros de Jesús Santiago	Ivette Ramos González
Iris González Cognet	Jeannette Rivera D'Ambrosio
Ivonne González Otero	Ivette Rivera Cabrera
Isabel González Soto	Luz M. Rivera Figueroa
Lisette Huertas Solá	Ivonne Rivera Maldonado
Carmen Javier Camacho	Marlyn Rodríguez Ginorio
Denisse Javier Castrillo	Evelyn Rodríguez Sanchez
Matilde Landrón Montalvo	Maria Rodríguez Walker
Enid Lang Montilla	Maria Roura Gil de Lamadrid
Maria Laracuenta Cortés	Enid Santi Meléndez
Brisette Lebrón Rivera	Maria Suárez Alonso
Margarita Lloréns Vega	Luis Torres Bauzá

Carmen C. Vivero Maldonado

As part of a Pathologic Anatomy and Physiology course offered by the UPR School of Medicine to second-year students, a conference and demonstration were given on January 17 on the clinical application of radioisotopes.

As part of the School of Medicine course in Biochemistry and Nutrition, a series of short lectures and demonstrations on the application of radioisotopes to clinical problems and a tour of Division facilities were offered on March 20 and 23 to 100 first-year students.

A special one-week program in Nuclear Medicine was offered to the students enrolled in the M.S. degree program in Radiological Health offered jointly by PRNC and the UPR School of Public Health. The course included two lectures on general applications of radioisotopes and four practical demonstrations and films. The ten students were María Amaro Martínez, Efraín Santiago Bonilla, Ingrid Erdelyi, Nayda Figueroa Vallés, José L. González Rivera, Alvaro J. Jordán Medrano, Eleuterio Molina Villasanti, Etienne Rodríguez Rodríguez, David Saldaña Cruz, and Porfirio Toledo Charneco.

On May 3, a lecture was presented to 15 students taking the course in Comprehensive Nursing Care at the Nursing Section of the UPR School of Medicine. The students were also shown the nuclear medicine facilities of the Division.

The Radiology Section of the UPR School of Medicine offered a course in Nuclear Medicine to Radiology residents during the period November 10, 1971, to April 26, 1972. Dr. Lanaro serves as a member of this Section.

Procedure	Clinical teaching	Teaching	Service
Thyroid studies	461	497	1434
Gastrointestinal	3	23	244
Hematology	-	49	8
Liver studies	5	39	8
Circulation studies	5	40	33
Renal studies	31	68	105
Organ and tumor localization	183	141	769
Water and electrolytes	2	6	-
Anger chamber Static studies	107	114	580
Dynamic studies	28	31	143
Total	825	1008	3324

RESEARCH ACTIVITIES

Red Blood Cell Survival in the Normal Population in Puerto Rico. This work, described in the 1970 and 1971 *Annual Reports*, was prepared for publication.

Daily Ingestion of Iodine with Natural Diet of Inhabitants of Puerto Rico. A preliminary evaluation of the data obtained so far showed the tested group to have a great prevalence of females and persons living along the coasts of Puerto Rico. Data collection was continued on males living in Puerto Rico. A total of about 296 urine samples were collected. Urine creatinine levels were measured in 265 samples, and 40 were sent to the Biochemical Procedures Laboratory for determinations of total iodine eliminated in 24 hours. The results obtained are being analyzed. (In collaboration with Dr. L. Haddock.)

Renal Plasma Flow. This study (see 1971 *Annual Report*) has been delayed by a lack of special material for the glomerular filtration test and by budget problems. The test was made on 6 patients, and we plan to continue the study as soon as possible.

Follow-up of Hyperthyroid Patients Treated with ¹³¹I. Once again (see 1970 and 1971 *Annual Reports*) hyperthyroid patients treated with ¹³¹I in this Division were asked to come for an annual checkup. Clinical examinations and thyroid uptake tests were made on 93 patients. The condition of these patients at present is as follows: hypothyroid, 21; hyperthyroid, 11; euthyroid, 61.

Lung Scanning in Children with Congenital Cardiac Malformations. This study, begun in 1970, was continued with the collaboration of Dr. A. Martínez Picó (Pediatrics Department, UPR School of Medicine) and Dr. René Dietrich. Very satisfactory results were obtained. This year, 34 tests were performed on 28 patients. The diagnoses were as follows:

	<u>Tests</u>
Fallot's tetralogy	22
Interventricular defect	3
Mitral insufficiency	3
Transposition of large blood vessels	1
Ebstein abnormality	2
Tricuspid atresia	2
Arterial trunk	1
Total	34

In all, 58 tests have been done on 49 patients, and the results have been presented at several meetings.

Determination of Splenic Function in Tropical Sprue. This study was begun in 1970, to investigate whether patients with acute tropical sprue had the same alterations in splenic function as patients with nontropical sprue. This year, tests performed on 4 patients did not show the low function reported in the other groups. (In collaboration with Dr. J. J. Corcino, Medicine Department, UPR School of Medicine.)

Measurement with the Whole-Body Counter of Vitamin B₁₂ Absorption in Patients with Intestinal Malabsorption. The collection of data was continued (see 1970 and 1971 *Annual Reports*); 128 tests were performed on 87 patients:

	Tests	Patients
Tropical sprue (before treatment)	65	40
Tropical sprue (treated)	9	9
Pernicious anemia	19	11
Hodgkin's disease	12	4
Controls (volunteers)	23	23
Total	128	87

Two papers have been presented, and work is continuing. (In collaboration with Dr. J. J. Corcino, Medicine Department, UPR School of Medicine.)

Measurement with the Whole-Body Counter of ^{57}Co -Labeled Vitamin B 12 Absorption in Children with Intestinal Diseases. This work is being done in collaboration with Drs. Pedro Juan Santiago and Irma Ramírez (Pediatrics Department, UPR School of Medicine) and Dr. René Dietrich. The intestinal absorption in children with different kinds of intestinal pathology is being studied by the same procedure as that used for tropical sprue. During 1972, 36 tests were performed on 34 patients. Work is continuing.

Isotopic Angiocardiology in Congenital Cardiovascular Diseases. This work (see 1971 *Annual Report*) has had very encouraging results, and the pediatric cardiologists are enthusiastic about the procedure. In 1972 a total of 15 patients with the following abnormalities were tested: Fallot's tetralogy, 6; atrial tumors, 3; interventricular defect, 2; mitral insufficiency, 2; transposition of large blood vessels, 1; tricuspid atresia, 1. Work is continuing. (In collaboration with Drs. J. Sánchez, A. Muñoz, and A. Martínez Picó, Pediatrics Department, UPR School of Medicine.)

Measurement with the Whole-Body Counter of Vitamin B $_{12}$ Absorption in Thyroid Dysfunction. This work was started (see 1971 *Annual Report*) with the objective of determining whether thyroid malfunction influences intestinal absorption of vitamin B $_{12}$, and with the knowledge that the anemia present in some cases of hyperthyroidism may be related to malabsorption of vitamin B $_{12}$. In a group of patients with proved hypothyroidism or hyperthyroidism, absorption of the vitamin before and after treatment is measured by the same procedure as that used in the work on intestinal malabsorption. During 1972, 40 tests were done on 33 patients, 12 hyperthyroid and 21 hypothyroid.

Measurement with the Whole-Body Counter of Iron Absorption. A procedure is being set up to measure iron absorption with the whole-body counter so that studies can be made on patients with some tropical diseases. Tests have been performed on 11 normal volunteers, and work is continuing. (In collaboration with Dr. J. J. Corcino, Medicine Department, UPR School of Medicine.)

STAFF

On January 24, Mrs. Olga Aponte was appointed Research Assistant I in Nursing Services. Dr. Aldo E. Lanaro passed the certifying examination in Nuclear Medicine offered by the American Board of Nuclear Medicine, Inc., on March 25, and was certified as a specialist in all aspects of the diagnostic, therapeutic, and medical research uses of radioactive materials.

On July 1, Dr. René Dietrich was appointed Scientist I to work in the Division.

On September 5, Miss Nydza Bajandas was appointed Research Associate I and Miss Irma Rodríguez was appointed Laboratory Technician (by the UPR School of Medicine).

On September 5, Mrs. Myrta C. de Pagán was given a joint appointment between the UPR School of Medicine and the Clinical Radioisotope Applications Division.

On September 29, Mrs. Leila C. García, Scientific Associate I, was granted leave without pay for one year.

On November 9, Mrs. Adriana R. de Calderón resigned her appointment as Scientific Associate I.

Dr. Ramón Figueroa, Veterans Administration Hospital, San Juan; Drs. J. Vázquez Plard and Francisco Aguiló, UPR School of Medicine; Dr. Jorge Chiriboga, Medical Sciences Division; Mr. Heriberto Torres, Health Physics Division; and Dr. Antonio Bosch, Radiotherapy and Cancer Division, participated in the two Basic Clinical Radioisotope Applications Courses, giving conferences.

The following *ad honorem* appointments were continued for FY 1972-73: For participation in conferences and demonstrations in the Clinical Radioisotope Applications Courses - Drs. Pedro Juan Santiago, J. J. Corcino (who are also taking part in research projects), Mario E. Rosa-García, Julio V. Rivera, and Francisco Aguiló (who participated also in the Radioimmunoassay Course). For participation in research projects - Dr. A. Rodríguez Olleros.

Dr. Aldo E. Lanaro was appointed a member of the Radioisotopes Committee of the University District Hospital for FY 1973 by Dr. Lloyd A. Le Zotte, President of the hospital's Medical Faculty.

Visitors. March 1-7: Dr. Michael Davis (Director, Radiopharmacy, Children's Hospital Medical Center, Boston) served as consultant to PRNC concerning radiopharmaceuticals.

April 12: Dr. Henry Wellman (Medical Center, Indiana University) gave a seminar on radionuclides in medicine.

May 8-10: Dr. Modesto Rivera (Hospital Universitario, Caracas) observed the Anger camera.

May 8-10: Dr. Paul Kramer (School of Nuclear Medicine, St. Joseph's Hospital, Paterson, N.J.) observed our training facilities for nuclear medicine.

May 30: Dr. Juan Ramón Zaragoza (Physical Therapy Department, School of Medicine, Seville) investigated our relationship with the School of Medicine in the teaching of Nuclear Medicine.

May 30: Dr. Rafael E. Siguenza Vielman (Radioisotopes Department, Roosevelt Hospital, Guatemala City) investigated our facilities with regard to sending people here for training.

July 12: Dr. Italo Zanzi (Hospital José Joaquín Aguirre, Santiago) observed the whole-body counter. He was trained in this Division in 1960.

October 20: Dr. Helmut C. Heinrich (Director, Institute of Physiologic Chemistry, University of Hamburg) gave a seminar on ^{59}Fe turnover.

Meetings. Dr. Aldo E. Lanaro spent March 12-25 in Miami, Florida, where he attended the Fourth Annual Nuclear Medicine Seminar and visited the Mount Sinai Hospital Department of Nuclear Medicine. Dr. Lanaro attended the Nineteenth Convention of the Society

of Nuclear Medicine in Boston, Massachusetts, on July 9-15. He also visited Dr. Michael Davis at the Radiopharmaceutical Laboratory of Harvard Medical School.

Mrs. Carmen C. Villodas attended the Second Catholic Congress of Nurses from Central America, the Caribbean and Mexico (Cencamex 72) in San Juan, Sept. 11-15.

Drs. Aldo E. Lanaro and René C. Dietrich attended the Twelfth Annual Meeting of the Heart Association (affiliated with the American Heart Association) in San Juan, September 30 - October 1, and Dr. Lanaro presented a paper.

Dr. Lanaro attended the Fourth Latin American Congress of the Association of the Societies of Nuclear Biology and Medicine in Santiago, Chile, October 24-27, and presented two papers. In Buenos Aires, he visited the National Atomic Energy Commission; Mr. Myron Kratzer, Scientific Representative, U. S. State Department; and former trainees and physicians. He also attended the Joint Congresses of Pediatrics in Cordoba, Argentina, November 5-10, and presented a paper. On December 1, he gave a talk at the Medical Center, Mar del Plata, Argentina, at the invitation of Dr. Carlos Roldán, a former PRNC trainee.



IV Congreso de la Asociación Latinoamericana de Sociedades de Biología y Medicina Nuclear

SANTIAGO DE CHILE 24 AL 27 DE OCTUBRE DE 1972

FOTO ZENITH

RADIOTHERAPY AND CANCER

The Radiotherapy and Cancer Division conducts a program of education and research based on an advanced cancer therapy service. This Division functions as the Radiotherapy Department of the University Hospital and is responsible for the radiation therapy program of the University of Puerto Rico School of Medicine. It collaborates with other institutions of the Puerto Rico Medical Center as they require support to carry on advanced radiation therapy and cancer activities. The program utilizes equipment and space, operating rooms, hospital beds, out-patient facilities, clinical laboratories, and other medical services for the care of cancer patients in hospitals at the Medical Center.

The Division also collaborates with the UPR School of Dentistry and with the Puerto Rico Regional Medical Program. It provides radiological physics and radiotherapy consultation services to the Veterans Administration Hospital and to the Ponce Oncologic Hospital. Partial support for the program is obtained from the UPR School of Medicine and from the National Cancer Institute through grants for education and research to the School of Medicine.

EDUCATION PROGRAM

The educational program includes the radiotherapy residency program (long-term training); the short-term radiotherapy training program; in-service training for medical students on cancer and radiation therapy (summer fellowships); in-service training for radiological physicists and radiotherapy technicians; and a lecture course in radiotherapy and cancer for third-year medical students and fourth-year dental students. It also provides lectures for the Basic Radioisotope Course. Personnel from this Division participate actively in multidisciplinary teaching of cancer management at the University Hospital, the I. González Martínez Oncologic Hospital, and the V. A. Hospital as part of the Medical School Program.

The radiotherapy residency program is approved by the American Board of Radiology for therapeutic radiology training.

The short-term radiotherapy training course (one-month minimum) for persons with previous radiotherapy experience is adjusted to individual needs and may include participation in research and in Division training activities but not responsibility for patients unless the candidate obtains a license to practice medicine in Puerto Rico.

The in-service training on cancer for medical students (one-month minimum) acquaints them with clinical problems and current research in cancer and radiation therapy. In-service training for radiological physicists and radiotherapy technicians is provided as called for and includes supervised practice in the Division's facilities.

The lecture course (12 hours per year) for third-year medical students is part of the curriculum of the UPR School of Medicine and highlights epidemiology of cancer, radiological physics, radiobiology, instrumentation, clinical radiotherapy, and radioisotopes in therapy. Two one-hour lectures are given each year to fourth-year students at the UPR School of Dentistry, and demonstration exercises are organized in the Division.

This year formal programs and courses were offered to physicians and medical students (see Table 1); these included lectures, seminars, multidisciplinary cancer management demonstrations, treatment planning exercises, and patient care under supervision with rotation through various services (PRNC and Oncologic Hospital treatment areas, follow-up clinics, hospital wards, brachytherapy planning and insertion, and radiological physics). Resident physicians in the program also rotated through the Pathology Department of the School of Medicine, the Medical Physics Program of PRNC, the PRNC radioisotope courses, and the PRNC Medical Sciences and Radiobiology Division for radiobiology training and laboratory experience. Thirteen persons received in-service training in radiotherapy dosimetry.

Table 1
Trainees, 1972

Name	Country	Date	Present position
<u>Short-term Radiotherapy Training</u>			
Dr. William H. Yeh	China	January	Bronx V. A. Hospital
Dr. Soe K. Tjia	Indonesia	Feb.-Mar.	" " "
Dr. Steven Lunzer	USA	April	" " "
Dr. Assad Sabag	Mexico	August	PRNC
<u>Training Course for Medical Students</u>			
Hipólito Poussin	P.R.	June-July	UPR School of Medicine
Lizardo Cerezo	P.R.	" "	" " "
Francisco Capó	P.R.	" "	" " "
<u>Long-term Radiotherapy Training</u>			
Dr. Luz Toro de Berríos	P.R.	January 70-	4th Year Resident
Dr. Omar M. Salazar	P.R.	July 70-	3rd Year Resident
Dr. Niní M. Bermúdez	P.R.	July 72-	1st Year Resident

Table 2
Case Load of Radiotherapy and Cancer Division, 1972

Site	No. of cases	
A. New Cases Treated		605
Oral Cavity	37	
Anterior 2/3 of tongue	9	
Floor of mouth	10	
Oral mucosa	1	
Other	17	
Oropharynx	61	
Base of tongue	24	
Tonsil	21	
Faucial arch	13	
Other	3	
Hypopharynx	26	
Pyriform sinus	13	
Other	13	
Nasopharynx	6	
Respiratory system	64	
Bronchus and lung	28	
Larynx	29	
Paranasal sinuses	6	
Other	1	
Digestive system	62	
Esophagus	50	
Other	12	
Breast	72	
Female genital organs	87	
Cervix uteri	62	
Endometrium	11	
Ovary	9	
Other	5	
Male genital organs	11	
Urinary organs	13	
Bladder	9	
Kidney	4	
Skin	44	
Brain and nervous tissue	23	
Bone and connective system	12	
Lymphatic and hematopoietic system	59	
Hodgkin's disease	15	
Other	44	
Histiocytosis X	1	
Other	27	
B. Teletherapy Applications (⁶⁰ Co, x rays, ¹³⁷ Cs)		21,003
C. Intracavitary and Interstitial Therapy		107
D. Follow-up		4,030

RESEARCH PROGRAM

Research by Residents

1. Neuroblastoma, Review of the Experience at the I. González-Martínez Oncologic Hospital — Dr. Luz Toro. A review of the data is in progress.
2. Acute Leukemia Study — Dr. Omar Zalazar. The experience with this disease at the University Hospital is being reviewed with emphasis on recent therapeutic advances.

Research by Medical Students

1. Mechanisms of Metastases — Hipólito Poussin.
2. Multiple Myeloma — Hipólito Poussin.
3. Paget's Disease of Breast — Lizardo Cerezo.
4. Mycosis Fungoides — Lizardo Cerezo.
5. Kaposi Sarcoma — Francisco Capó.

Research in Progress

1. Floor of the Mouth. In this study (see last year's *Annual Report*, p.53), follow-ups are being obtained and new cases are being incorporated in the review of clinical material from the University Hospital and the I. González Martínez Oncologic Hospital.
2. Effect of Therapeutic Irradiation on the Lung as Studied by Pulmonary Function and Lung Scan. This is a collaborative project between the Radiotherapy and Cancer Division and the Clinical Radioisotope Applications Division.

National Collaborative Research Projects. This Division continued its active participation in the Radiation Therapy Oncology Group (RTOG), which is a group of academic institutions involved in collaborative clinical trials on radiation therapy of cancer (see 1972 *Annual Report*). This Division participated in the following projects:

1. *Split-Course Project.* The staff of this Division began assessing patients for the national split-course protocols in February 1972. The following 25 cases were incorporated: nasopharynx, 4; tonsillar fossa, 6; base of tongue, 12; urinary bladder, 3. All these cases are candidates for curative radiotherapy. Dr. Víctor A. Marcial acted as Project Director and Chairman of the Steering Committee for the split-course national study. The RTOG met in Philadelphia in June to discuss the initial experiences with the various studies. Some of the members presented some observations regarding the normal tissue reactions to continuous irradiation for head and neck cancer delivered with fractions of 220 rads, 5 times per week, for a total of 6600 rads. The group decided to accept continuous irradiation with 200-rad fractions up to 1000 rads per week for total doses of 6600 to 7000 rads. The participants in the study will have two options for uninterrupted irradiation. A preliminary

analysis on the cases registered with sufficient data, prepared by the Statistical Office of the RTOG, showed, as of December 1972, no difference in normal tissue reactions between cases treated with split-course and those treated with continuous irradiation.

2. *Carbogen Study.* The purpose of this RTOG project is to compare, for selected cancer sites, the degree of tumor control achieved by radiation therapy combined with the breathing of a normobaric oxygen—5% CO₂ mixture with that achieved by radiotherapy alone. Breathing this mixture should result in greater oxygenation, and therefore increased radiosensitivity, of the tumor cells. Because of delays in acquiring the equipment (oxygen tanks, breathing masks, gages, etc.) the study did not start until November. Only one case has been acquired for the project because, of the six patients considered, the rest did not tolerate breathing the gas mixture.

3. *Brain Metastasis Study.* The objective of this RTOG study is to determine the optimal radiotherapy technique for brain metastasis from a variety of cancer sites. The options are two weeks of treatment with 10 fractions for a total of 3000 rads, three weeks of treatment with 15 fractions for a total of 3000 rads, three weeks of treatment with 15 fractions for a total of 4000 rads, and four weeks of treatment with 20 fractions for a total of 4000 rads. Some institutions have agreed to treat their cases with a single dose of 1000 rads. Our Division began assessing cases in December, and one case was incorporated in the study.

4. *Other RTOG Studies.* Protocols have been circulated for future discussion of the following: preoperative irradiation in rectal cancer, surgery versus irradiation in bladder cancer, and irradiation of inoperable lung carcinoma.

Arrangements for contributing patients for these studies have been made with the San Juan V. A. Hospital, San Juan Municipal Hospital, and Radiotherapy Institute of the Metropolitan Hospital, and are under way with the Ponce Oncologic Hospital.

Plans for a Cancer Research Center at the UPR School of Medicine. This project (see 1971 *Annual Report*, p.53) is continuing. The planning firm, Enviro-med, circulated questionnaires, interviewed interested persons in Puerto Rico, and met with the Project Director, Dr. Víctor A. Marcial, in November at La Jolla, California, to finish the first phase of the project, which is the presentation of three alternatives for the development of a cancer research center. Representatives of Enviro-med will visit Puerto Rico during January 1973 to report on the first phase. The second phase of the planning process will be the preparation of detailed proposals to implement the ideas developed in phase 1.

The core staff for the planning project includes Dr. Víctor A. Marcial, Dr. Antonio Bosch, and Miss Zenaida Frías from this Division. Persons from other PRNC programs have been invited to participate in some of the sessions. Since August the Dean of the School of Medicine has been meeting with the core staff and with representatives of other community institutions that deal with cancer, including the I. González-Martínez Oncologic Hospital, the V. A. Hospital, the Mayagüez Medical Center, and the Ponce Oncologic Hospital. PRNC is expected to have a continuing role in the cancer research program developed under this project.

STAFF

Dr. Antonio Bosch (UPR School of Medicine) has continued doing his work at PRNC on an *ad honorem* basis.

Since March 1, Miss Zenaida Friás, M.S., has had a joint appointment at PRNC and the School of Medicine, but all her work is done in this Division.

Mrs. Ana H. O'Neill, R.N., chief radiotherapy technician, worked under a joint appointment between PRNC and the School of Medicine from March to July, when she resigned.

Miss Elsa Colón (UPR School of Medicine) began working in this Division as a radiotherapy technician in May.

Dr. José M. Tomé resigned his position as Chief Scientist I under a joint appointment with the School of Medicine in December but is continuing part-time work here on an *ad honorem* basis.

Dr. Jeanne Ubiñas resigned her position as Chief Scientist I to accept the position of Chief of Radiotherapy at the V. A. Hospital, but she is continuing some work here on an *ad honorem* basis.

Miss Teresa Vázquez and Miss Angelina Caraballo, radiotherapy technicians, began work with the UPR School of Medicine radiation therapy program in July and were assigned to PRNC.

Visitors. The following scientists acted as visiting professor in the Division: Dr. Seymour H. Levitt, Chairman, Radiotherapy Department, University of Minnesota School of Medicine, in May; Dr. Giulio D'Angio, Chief of Radiation Therapy, Memorial Hospital for Cancer and Allied Diseases, New York, in August; and Dr. Ralph E. Johnson, Chief of Radiation Therapy, Clinical Center, National Cancer Institute, in December.

Dr. Modesto Rivero, from the School of Medicine of Caracas, a former trainee of this Division, visited in May.

Meetings

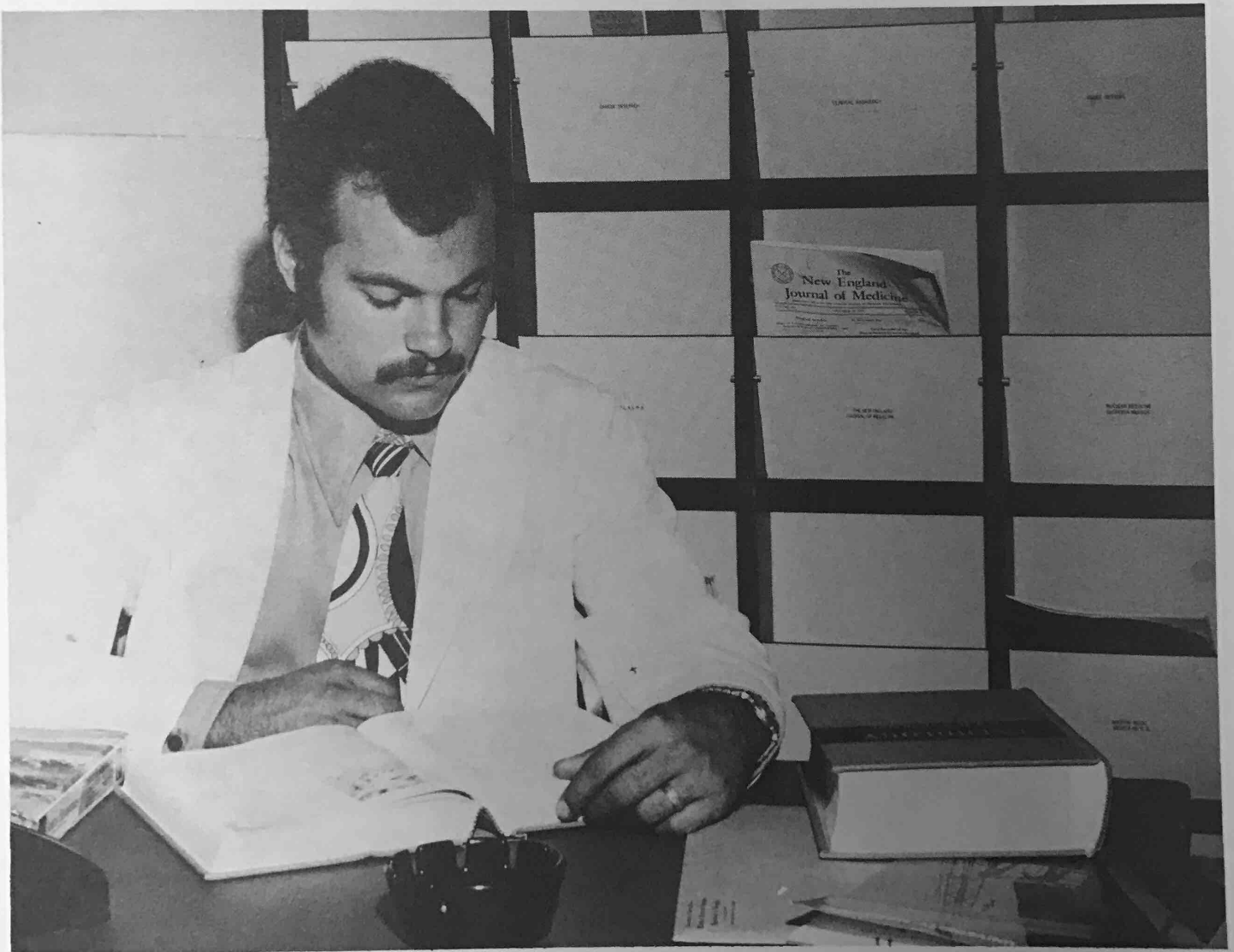
Dr. Víctor A. Marcial: American College of Radiology Committee for Cancer Management, Atlanta, January 7; Radiation Therapy Oncology Group, Philadelphia, May 6; American Radium Society (Executive Committee meetings), Boca Raton, Florida, May 14-19; Radiotherapy Department, Walter Reed Hospital, May 30-31; Radiation Therapy Oncology Group, Philadelphia, June 14-17; Site-Visit Committee for Clinical Cancer Training Committee of National Cancer Institute, Georgia Medical College, Augusta, July 26-27; Clinical Cancer Training Committee of National Cancer Institute, Bethesda, Sept. 23-24; Seventh National Cancer Conference (Invited Lecturer), Los Angeles, Sept. 25-28; visiting professor at Memorial Hospital for Cancer and Allied Diseases, Mount Sinai Medical School, and Downstate Medical College, New York, Oct. 25-27; American Society of Therapeutic Radiologists, Phoenix, Nov. 1-5; Enviro-med staff, La Jolla, Nov. 20-22;

Site-Visit Committee for Clinical Cancer Training Committee of National Cancer Institute, Washington University, St. Louis, Nov. 27-Dec. 1.

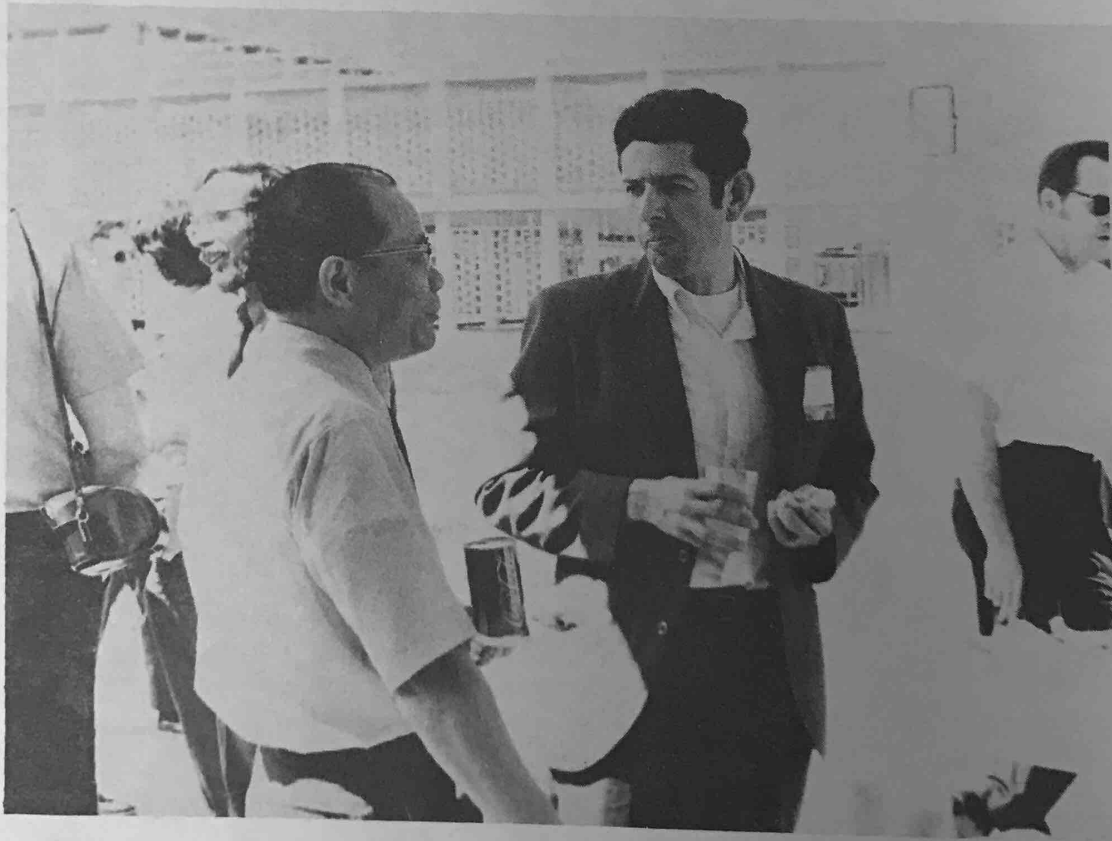
Dr. Antonio Bosch: American Radium Society, James Ewing Society, Society of Head and Neck Surgeons, Annual Meeting, Boca Raton, Florida, May 14-19; Seminar on Medical Planning and Care in Radiation Accidents, Oak Ridge, May 14-21.

Mis Zenaida Frías: Annual Meeting of the Society for Epidemiological Research, Houston, May 4-6; meeting regarding plans for cancer center, M.D. Anderson Hospital and Tumor Institute, Houston, May 8-12.

Dr. Omar M. Salazar and Dr. Niní M. Bermúdez: Annual Meeting of Radiological Society of North America, Chicago, Nov. 26-Dec. 4.



Francisco J. Capó, student from UPR School of Medicine, enrolled in short-term radiotherapy course.



AEC Bio-Medical Program Director's Meeting: (top) Dr. F.K.S. Koo chats with a visitor; (bottom) lunch break in courtyard of PRNC Bio-Medical Building.

TROPICAL AGRO - SCIENCES

The purpose of the Tropical Agro-Sciences Division remains twofold: (1) to train students in agricultural and biological research with emphasis on the applications of nuclear science, and (2) to conduct basic research, particularly on problems in tropical agriculture that can uniquely be studied by nuclear techniques.

EDUCATIONAL AND TRAINING ACTIVITIES

During 1972, the emphasis on education and training continued to be directed toward the graduate and postgraduate level. The activities were frequently related to the Division's basic research programs.

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

Agro	415	Special Problems in Agronomy — Dr. F.K.S. Koo and Mr. J. Cuevas-Ruiz
"	556	Nuclear Techniques in Agriculture — Dr. S.N. Deshpande, Mr. J. Cuevas-Ruiz, and Dr. J.A. Ferrer-Monge.
Hort	426	Special Problems in Horticulture — Mr. J. Cuevas-Ruiz
"	605	Nuclear Techniques in Agricultural Research — Dr. S.N. Deshpande, Mr. J. Cuevas-Ruiz, and Dr. J.A. Ferrer-Monge
"	699	Research (Thesis) — Mr. J. Cuevas-Ruiz
Biol	614	Nuclear Techniques in Biological Research — Dr. S.N. Deshpande, Dr. J.A. Ferrer-Monge, and Mr. J. Cuevas-Ruiz
"	618	Cytogenetics — Dr. J. A. Ferrer-Monge
"	480	Thesis Research — Dr. F.K.S. Koo (Río Piedras Campus)
"	699	Research (Thesis) — Dr. J.A. Ferrer-Monge and Dr. F.K.S. Koo
Chem	566	Food Chemistry — Dr. S.N. Deshpande
"	571	Nuclear Chemistry — Dr. S.N. Deshpande
"	601	Radiochemistry — Dr. S.N. Deshpande
"	699	Chemistry Research (Thesis) — Dr. S.N. Deshpande

Graduate Research. During 1972, eleven graduate students were active in thesis research leading toward the M.S. degree in biology, chemistry, or agriculture under the supervision of Division staff members. Five students completed their thesis research. Research topics reflected the broad interests of the Division:

1. Electrophoretic studies of cytoplasmic and mitochondrial malate dehydrogenase isozymes in soybean seedlings (completed) — Isabel Bulla Dueñas (Colombia) under Dr. F.K.S. Koo.

2. Complementary effects of ionizing radiation and lipoxidase activity on the fatty acids of soybeans (completed) — Oscar V. Aragon (Nicaragua) under Dr. S.N. Deshpande.
3. Microanalysis of sulfur-containing amino acids by isotopic dilution and neutron activation (completed) — Carmen A. Vega (Puerto Rico) under Dr. S.N. Deshpande.
4. Studies to determine the presence of growth inhibitors in the seminal structures of *Carica papaya* and to improve germination (completed) — Nihlson Reyes (El Salvador) under Dr. A. Pérez and Mr. J. Cuevas-Ruiz.
5. Effect of Ethrel (2-chloro-ethanephosphonic acid) on the expression of sex in the squash (*Cucurbita moschata* Poir (completed) — Carlos Agiare-Castillo (Guatemala) under Dr. M. Rico-Ballester and Mr. J. Cuevas-Ruiz.
6. Mutagenic effect of N-methyl-N'-nitro-N-nitrosoguanidine on histidine operon of *Escherichia coli* strain C — Carmen Baerga Santini (Puerto Rico) under Dr. F.K.S. Koo.
7. Electrophoretic analyses of several seed protein fractions in *Glycine max* (L.) Merrill — Ileana Rivera (Puerto Rico) under Dr. J.A. Ferrer-Monge.
8. Effect of low doses of gamma radiation on higher plants — Eblis Alvarez (Colombia) under Dr. J.A. Ferrer-Monge.
9. Characterization of some flavoring compounds of Puerto Rican coffee by gas-liquid chromatography and mass spectrometry — Angel A. Aguilar (Ecuador) under Dr. S.N. Deshpande.
10. Effect of ionizing radiations on the Krebs cycle and the kinetics of the activity of the pectic enzymes in pineapple — José M. Ortiz (Guatemala) under Dr. S.N. Deshpande.
11. The effect of applying nutrients and phytohormones on root formation in hibiscus variety Ruth Wilcox — Francisco Vázquez Ayala (Puerto Rico) under Dr. F. Jordán Molero and Mr. J. Cuevas-Ruiz.

Special Training. The Division has been active in technical and scientific training programs. Mr. Santiago Gómez, Professor of Physics at Universidad Industrial de Santander, Colombia, received six months of training in the application of nuclear techniques to agriculture, especially in the area of food preservation, under the sponsorship of the Organization of American States.

RESEARCH ACTIVITIES

Crop Improvement. In the soybean mutation breeding program, photoperiod-insensitive mutants selected from those developed in previous seasons were entered in the preliminary yield test during the summer. Fourteen lines from the Lee variety and nine from the Hill variety were grown in replicated three-row plots in Isabela. Since unfavorable field conditions resulted in the majority of the plots having extremely poor stands and growth, the yields were not measured. In the same planting, selections from the high protein crosses were also abandoned for the same reason. Similar plantings were made in the winter. The primary aim of these tests was to select the most promising lines for further trials in Latin America and the Caribbean.

Although the yam is an important starchy food crop in the tropics, it has not received enough attention for its much-needed improvement. Virtually no work has been done on hybridization breeding, presumably because of several genetic recombination barriers inherent in the common cultivars. To circumvent such difficulties, one may resort to mutation breeding. The most promising technique appears to be to use the vegetative parts that are capable of regenerating adventitious buds from single cells following mutagenic treatment. The mutant so derived is often a solid mutant, i.e., one obtains a whole plant that is a mutant of a single type rather than a sectorial or periclinal mutant. In the exploratory investigation, some 700 aerial tubers of *Dioscorea alata* varieties Cuello Largo, Purple Lisbon, Hawaii Branched, Brazo Fuerte, Farm Lisbon, and Irene were each cut into two parts. The crown parts served as control and the lower parts were treated with 2000 rads of gamma rays. The material was grown in soil benches in the greenhouse. The first shoots of the irradiated material at the 3 to 4-leaf stage were studied for new variations by comparison with the corresponding controls. Crinkled and deformed leaves were observed more often than leaves with sectorial color changes. The shoots were then cut back above the ground to force new shoots to develop for further observation. Two dozen solid mutants were recovered among the new shoots following one to several cut-backs. The light green type was most frequent. Some of the variants classified as light green mutants might be caused by root rot infection. Also recovered but in very low frequency were pale green and small leaf types. These solid mutants originated from either the tubers or the leaf axils of the pruned shoots. Some varieties, such as Cuello Largo, were more amenable to mutation induction than the others. These findings suggest that a number of new shoots in yam aerial tubers or leaf axils were derived from single cells after the earlier shoots had been pruned. Such capacity to regenerate new shoots from single cells in the tubers or in the leaf axils following pruning at an early stage is of great importance to yam mutation breeding programs.

Methionine Determination. Work continued on improving methods for methionine determination. The improvement over last year's work on isotopic dilution consisted of determining the specific activity by measuring the intensity of the isolated spot containing amino acids by reflectance densitometry to determine the concentration, and assay of the dilution factor by scintillation counting.

The isotopic dilution technique has proven to be sensitive and rapid in that the sample size can be reduced from 1 g to 50 mg, and the hydrolysis time can be reduced from 24 hr of refluxing to 4 hr of autoclaving. In order to increase the sensitivity even further and to increase the number of analyses, neutron activation of the mercuric derivatives of the amino acids was attempted. The methyl group of methionine was eliminated by periodate oxidation at 4°C. The methyl iodide liberated in the process was determined by gas-liquid chromatography. The optimum conditions for this reaction were further ascertained by spotting distillate containing methyl iodide and determining the activity of ¹⁴C-labeled methyl iodide by scintillation counting. The sulfhydryl group produced in place of the

methyl group was further reacted with mersalyl acid to yield the mercuric derivative. In the same manner, the sulfhydryl group of cysteine reacted with mersalyl acid to yield the mercuric derivative, and the disulfide linkage of cystine was broken by acid hydrolysis to yield two cystine residues and the same mercuric derivatives were made with mersalyl acid. This mercuric complex after further processing was subjected to neutron bombardment with a flux of 3×10^{12} n/sec/cm². The radioactivity of the mercuric complex was determined by gamma-ray spectrometry. ¹⁹⁷Hg and ¹⁹⁹Hg were found to be particularly useful in relating the radioactivity to concentration. Recovery of methionine was 100% and that of cystine 79.8%. Further studies are in progress to apply these techniques to various types of protein hydrolyzates, and then to combine the two techniques of isotopic dilution and neutron activation. The combined technique is expected to be sensitive enough to detect 10⁻⁹ g of the sulfur-containing amino acids and also to reduce the time needed for analysis.

Food Science. The acid component is one of the important attributes of the flavor of coffee. The acidity varies with varieties of coffee beans and roasting conditions. It has been reported that irradiation of coffee enhances its flavor; perhaps this is due to an influence on acidity. Since caffeoylquinic acids are the major acid components, determination of these acids should serve as an index of characterization and perhaps offer a clue to the chemical changes due to roasting and irradiation. Four varieties of Puerto Rican coffee, *Coffea arabica* varieties Caturra, Borbon, and a special "Puerto Rico" selection and *Coffea canephora* variety Robusta were selected for study. The coffee beans after roasting were percolated with deionized water, and the decoction was passed over Dowex-50 cation exchange resin to remove the sugars. The eluant was passed over anion exchange columns to adsorb the nonvolatile acids, and these in turn were eluted with formic acid. The formic acid was evaporated in a rotary evaporator under vacuum. A second aliquot of the decoction was subjected to lyophilization, and the freeze-dried material was ground and subjected to silylation to make volatile silyl derivatives of the caffeoylquinic acid. The trimethylsilyl derivatives of 3-caffeoylquinic acid, 3,5-dicaffeoylquinic acid, and chlorogenic acid were made with hexamethyldisilazane and N-O-bis(trimethyl)acetamide. These derivatives were further subjected to gas chromatographic analysis. So far only the special "Puerto Rico" selection has been analyzed, and it was shown to contain caffeoylquinic acids by comparison of the retention times of the pure derivatives with those of the derivatives made from the lyophilized material. Mass spectrometric analyses are in progress.

Studies (in cooperation with the UPR Agricultural Experiment Station) on radiation preservation of yam variety Florido showed that gamma irradiation at the 10-krad level inhibited sprouting to a much greater extent and for a much longer period than did the chemical inhibitor isopropyl N-(3-chlorophenyl)carbamate. Further irradiation treatments were made at 5, 7.5, and 10 krads to determine the optimum dose below the 10-krad level to reduce the weight loss in yams during post-irradiation storage.

Studies of Proteins and Isozymes. The effect of gamma radiation on the consumption of three protein fractions in soybean cotyledons during seedling growth was investigated. Seeds of variety Hill were exposed to 5, 15, and 25 krads. Seedlings were grown for 12 days, and the cotyledons were analyzed for globulin, albumin, and basic protein fractions by the Lowry method. The preliminary results were as follows: (a) dry seeds contained 642 mg globulin, 258 mg albumin, and 100 mg basic protein per gram of extractable protein, (b) the three protein fractions were reduced in both the control and irradiated series with seedling development, (c) the consumption rate was highest for globulin, lowest for basic protein, and intermediate for albumin, (d) consumption of globulin and albumin was slower in material irradiated with 25 krads than in material given lower doses or in the control, and (e) consumption of the basic protein fraction was slower in material irradiated with 15 krads than in that given 5 or 25 krads.

Additional study of esterase isozymes in soybeans revealed two different esterases, E1 and E2. The E1 system apparently has as substrates both α - and β -naphthyl acetate plus coupling dyes, but the E2 system has α -naphthyl acetate only. Further study of soybean malate dehydrogenase isozymes showed only one isozyme band in the mitochondrial fraction in contrast to four bands in the cytoplasmic fraction.

STAFF

Dr. S.N. Deshpande attended the Eleventh Latin American Congress of Chemistry in Santiago, Chile, January 5-11, and presented three papers.

Dr. F.K.S. Koo and Dr. J. Ferrer-Monge participated in the Mutation Breeding Workshop at the University of Tennessee in Knoxville on January 17-18.

Dr. Koo, Dr. Deshpande, Dr. D.W. Walker, Mr. J. Cuevas-Ruiz, Miss Carmen Asencio, and Miss Carmen A. Vega attended the Tenth Annual Meeting of the Caribbean Food Crops Society held June 11-17 at UPR-Mayagüez, and Dr. Koo and Dr. Walker presented papers.

Dr. Koo attended the Twelfth International Congress on Basic Biology at Cali, Colombia, November 27-December 1, and presented an invited paper. He also visited agricultural research institutions in Colombia including the International Center of Tropical Agriculture and the Instituto Colombiano Agropecuario.

Dr. E.R. Graham, Professor of Soil Sciences, University of Missouri, arrived on November 27 as Visiting Scientist in the Division to perform a short-term study on the labile pool and the selective distribution of micronutrient elements in tropical soils and the relationship of these parameters to plant nutrition.



Enclosure for insect sterility studies.

Induced Sterility in Insects

After accomplishing the original objective of the program we have continued our efforts in the area of inherited partial sterility (IPS), using organisms with holokinetic chromosomes. It has been observed that these organisms have the capacity to withstand high dosages of ionizing radiation with a relatively small dominant lethal effect, but that the lethality, suppressed in the first generation, becomes progressively more damaging in the F_2 and subsequent generations. The precise cause of this phenomenon is not known. Its utility in pest control is mainly in providing the opportunity to introduce a genetic load into a natural population and to have the genetic load disseminated fairly widely within a natural population before the deleterious effects become operable. The situation is somewhat analogous to a time delay bomb. In brief we are attempting to introduce a biological insult into a natural population and to have the effectiveness magnified to a sufficient extent to cause population collapse.

IPS FIELD TEST

Program activities in 1972 were concentrated on a field testing program, begun at the request of the US AEC Division of Biology and Medicine, to confirm our laboratory data under field conditions. Work is being continued with the sugarcane borer, *Diatraea saccharalis* (Fab.), with emphasis on evaluating the practical use of IPS as a control method under field conditions. A series of tests using eight field cages were planned and put into operation. Environmental problems (background light at night, control of insecticide drift, and irrigation problems) made it necessary to move the field cage to a new location. Fortunately we were able to obtain a satisfactory site at the Federal Experiment Station (USDA) near our laboratory. The cage was dismantled and moved in July, the framework was reassembled in August, and a new Saran cover was installed in October.

Corn plants are used as host material in the cage tests. Corn is planted and grown in individual containers, and each plant is irrigated and fertilized individually. In order to reduce ant predation of the larvae in the corn stalks and to prevent weed growth in the cages, the floor of each cage has been covered with polyethylene sheet.

In the initial series each test is set up in a pair of cages, one containing corn plants on which irradiated males, normal males, and normal females have been released and the second containing plants on which only normal males and females have been released:

	Irradiated males	Normal males	Normal females
Test cage	210	15	15
Control cage	0	15	15

The ratio of irradiated males to normal males is 14 to 1. The experimental design of this series of tests is based on the hypothetical model of population collapse proposed by Walker and Pedersen. The two major factors contributing to the success of the method are (1) high reproductive and survival rates in the P to F₁ generation in outbred lines (the increase was 4.1-fold in laboratory experiments compared with an estimated 5-fold increase in normal lines in nature), and (2) a drastic reduction in the chances of normal-to-normal matings in the P, F₁, F₂, F₃, and F₄ generations (estimated at 15, 6.7, 2.2, 4.2, and 7.6 per generation respectively). These theoretical values are based on yields obtained in laboratory tests.

The tests under way are designed to evaluate the effectiveness of only a single release. Under operating conditions in an area program having the capacity to rear enormous numbers of insects, releases would be made over more than one generation. However, if the eradication occurs in the test where only a single release is made then multiple releases would be even superior in reducing population since repeated releases would further increase the sterile-to-normal ratio and thus hasten the collapse of the population.

In the control cages, with only normal adults, the theoretical population increase, based on field data, is expected to be fivefold at each generation.

A number of serious problems have beset the program in the earlier phases. The most serious has been a persistent virus disease that has reduced larval survival in the laboratory colony to such an extent that we have had great difficulty in collecting sufficient adults for release without seriously depleting the rearing colony. Larvae succumb early in development in the L₁ and L₂ stages. Losses during winter months have been > 50%. The corn plants have required frequent watering during the dry season; since each plant must be watered individually by watering can, this has required more labor than originally anticipated. Under adequate watering and fertilizing schedules the plants have developed well in the shade of the screen. The new cage site is surrounded by bamboo, which provides excellent shielding from background light at night and from wind. The sugarcane borer prefers to mate in the dark in still air.

WAX MOTH STUDIES

Dr. Harpal Singh, ORAU summer participant from Knoxville College, worked here for three months during the summer. He developed methods and made preliminary observations on gamma radiation dose and sterility induced in the greater wax moth, *Galleria mellonella* (L), Pyralididae, Lepidoptera. He also made preliminary observations on the effectiveness of fractionated versus single doses with adults. We had found no apparent

difference in earlier trials with the sugarcane borer, but there is an apparent difference in the wax moth. Confirmatory tests are in progress.

LABORATORY REARING METHODS

A higher sucrose level and addition of molasses and corn syrup to the modified bean diet have resulted in longer-lived and more vigorous adults. In addition, feeding has been enhanced by adding powdered cellulose to the diet.

New larvae are now placed on small cylinders of food (extruded from drinking straws) in plastic cups. This has reduced mold growth in the colony and also has allowed crowding of young larvae in cups (up to 20 per one-ounce cup) with a consequent saving in labor in the larval transfer operation and in shelf space in the rearing room.

The rearing procedure continues to be the limiting factor in the operation. An increase in staff and upgrading of facilities would greatly help in overcoming this. We have great difficulty in keeping the environment sufficiently sterile to prevent mold contamination in the colonies.

HEMIPTERA

Mr. Ruben Restrepo, a graduate student in Biology and summer participant sponsored by the PRNC Student Economic Aid Program, has continued his work with the southern green stinkbug, *Nezara viridula* (Pentatomidae). He is confirming data from some of the earlier tests and developing better rearing methods.

STAFF

Mrs. Alba Rivera is continuing her work on the characterization of the hemolymph proteins of sugarcane borer larvae for her M.S. thesis research.

Dr. Nader Vakili and Dr. Walker presented three papers at the Symposium on Tropical Agriculture in June in Mayagüez, and Dr. Walker also presented seminars at UPR-Mayagüez.



Dr. Raymond A. Brown using the scintillation counter to measure binding of ^{131}I -labeled *S. mansoni* antigen.

MEDICAL SCIENCES AND RADIOBIOLOGY

The Medical Sciences and Radiobiology Division is primarily concerned with tropical diseases, particularly parasitic and virus infections. Its research program also provides training opportunities in the use of nuclear energy at the molecular, cellular, and organism levels. The four projects sponsored by the AEC Division of Biology and Medicine include those on schistosomiasis, trypanosomiasis, virus infections, and fascioliasis (supported also by the Puerto Rico Department of Agriculture and the UPR Agricultural Experiment Station). Supportive disciplines provided by the Division are biochemistry, immunology, and radiobiology. The major facilities include a tissue culture unit, an electron microscope, a ^{60}Co radiation source, a mouse colony, and snail colonies.

EDUCATIONAL ACTIVITIES

M.S. Thesis Research.

1. Search for plants toxic to snails — Freddy Medina (Dominican Republic), UPR Department of Biology.
2. The effect of gamma irradiation on rats actively immunized with Sindbis, wild strain: Reactivation of the latent virus by radiation — Gualberto Borrero (Puerto Rico), UPR Medical Sciences Campus.
3. The effect of radiation on infectious nucleic acid and latent viral infections — Ann S. Mercer (U.S.), UPR School of Medicine.

Ph.D. Thesis Research. Genetic analysis of the *Microsporium gypseum* complex at the molecular level — José A. Carrasco (Puerto Rico), UPR School of Medicine.

Formal Courses for Academic Credit.

PRNC 515, Radiation Effects on Mammals and Humans, was taken by the following students: Efraín Bonilla, José L. González, David Saldaña, Nayda R. Figueroa, María de los Angeles Amaro, Porfirio A. Toledo, and Etienne Rodríguez, from Puerto Rico; Alvaro Jordán, Bolivia; Ingrid Erdelyi, Brazil; and Eleuterio Molinas, Paraguay.

PRNC 510, Radiation Biology, was taken by the following students: Hilda M. Colón Plumey, Nimia E. Irizarry Cancel, Asterio Santos Portalatín, and Víctor M. Velázquez, from Puerto Rico; Clovis Abrahao Hazin, Brazil; and Santiago Gómez Figueroa, Colombia.

Special Training

1. Virology for graduate students from the UPR Medical Sciences Campus — Ann S. Mercer (U.S.), Aida D. Jackson (P.R.), José A. Acevedo (P.R.), Yolanda Bontá (P.R.), Sonia Saavedra (P.R.), Josefina Betancourt (P.R.), Robert Saylor (U.S.), Plinio C. Gomes (Brazil) (auditor), and Alfredo Velarde (Peru) (auditor).

2. *Fasciola hepatica* — Dr. Plinio Gomes (Brazil) and Dr. Alfredo Velarde (Peru) finished their training under fellowships sponsored by the Pan American Health Organization, and Dr. Danilo Parra (Colombia) started training this year. Enid Acosta Caballero (P.R.) studied egg laying in *Physa cubensis*; Norma I. Ortiz (P.R.) studied preliminary screening of plants toxic to *Physa cubensis*; Rosa E. Real Cuadrado (P.R.) studied the life cycle of *Fasciola hepatica*; Johanna Deloris Quiara (P.R.) studied the reproductive capacity of *Lymnaea cubensis*; Irma M. Llavona, M.V.D. (P.R.) took special training in *Fasciola hepatica*; Virginia Rodríguez, Amaury López, and Luis Colón (all P.R.) took a special course including snail biology, epidemiology, and biochemistry; and Ricardo Pontón, from the Santa María Catholic University in Ponce, was trained in the care of animals.

3. Schistosomiasis — The trainees were all from Puerto Rico. María M. Ortiz studied the effect of cortisone on *Strongyloides* infections in mice; Gloria Rosado and Nilda Cruz studied the acute radiation syndrome; Migdalia Santiago worked on definite screening of a candidate molluscicide; José M. Frago studied the effect of plants toxic to *Physa cubensis*; Yolanda Mendoza did a comparative study of the amino acids in the mucus substance of *Biomphalaria glabrata* and *Physa cubensis*; and Luis Oscar Nieves took special training in schistosomiasis.

COOPERATIVE TRAINING AND RESEARCH

Collaborative interests and needs of investigators in other PRNC divisions and also outside the Center are supported by exchange of information and cooperation between staff members. Fourteen *ad honorem* appointments in this Division are held by people from the UPR School of Medicine, U. S. Public Health Service Laboratory, Puerto Rico Department of Health, Puerto Rico Department of Agriculture, Ponce Oncological Hospital, and UPR Agricultural Experiment Station. Members of this Division holding *ad honorem* appointments at the School of Medicine and the UPR Department of Biology are Doctors Raymond A. Brown, Jorge Chiriboga, and Lawrence S. Ritchie. Services to other PRNC divisions include teaching activities in the Physical Sciences, Health and Safety, and Clinical Radioisotope Applications Divisions. Some examples of cooperative activities with outside institutions are listed below:

UPR School of Medicine - Dr. Julio Colón of the Microbiology Department continues to direct the research on viruses and participates in the training program of the Division. A monthly seminar on parasitology has been jointly promoted by the Department of Zoology of the School of Medicine and this Division.

UPR Agricultural Experiment Station - Dr. Delfín D. de León, a veterinarian and parasitologist, continues to work full time on the fascioliasis program through an agreement with the Experiment Station.

U. S. Public Health Service - Close liaison is maintained with the schistosomiasis program, with frequent exchanges of information and materials.

Puerto Rican Committee for Bilharzia Control - Dr. L. S. Ritchie is a member of this Committee and chairman of a special group whose task is to evaluate the risk of bilharzia infections in the freshwater lakes in Puerto Rico. The Tourist Department would like to open these lakes for recreational and tourist use.

Caribbean Committee for Bilharzia Research - An annual meeting provides the opportunity for representatives of countries where bilharzia is endemic to share research findings and review new developments.

Puerto Rico Department of Agriculture - The Department continued to collaborate in the Division's research on *Fasciola hepatica* and provided one veterinarian and two field workers.

Pan American Health Organization - The cooperation for research and training includes support of trainees by the Organization. This year one from Brazil and one from Peru completed a year's training on fascioliasis in the Division, and another from Colombia started.

National Institutes of Health - Dr. Ramiro Martínez-Silva has spent the past year and a half working on biochemical problems of *Trypanosoma cruzi* at the National Institutes of Health in Baltimore. In November 1973 he will be transferred to the American Health Organization in Caracas for a two-year period to work on Chagas' disease.

Academic Institutions - Division staff members provide demonstrations for classes in biology and parasitology at UPR (Department of Biology and School of Medicine), Inter-American University, and Puerto Rico Junior College. They also provide orientation to public school students in preparing experiments to be presented at the Annual Science Fair.

Committee to review possible hazards at PRNC due to experimental organisms — This committee is composed of representatives of the Environmental Health Department of the University Hospital, the Puerto Rico Department of Health, the Puerto Rico Agricultural Experiment Station, and the US PHS Tropical Disease Laboratories. Several meetings were held during the year, and recommendations were made to improve the animal facilities.

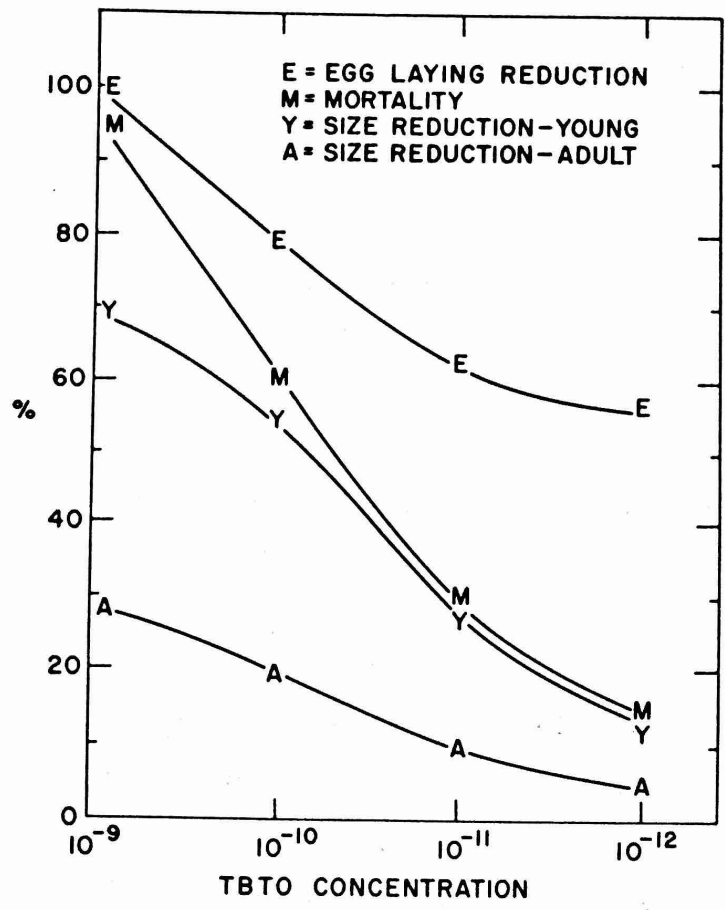


Figure 1. Development of 1-day-old *B. glabrata* continuously exposed to TBTO.

Schistosomiasis

Despite the dedicated work of a large number of specialists, the *Schistosoma mansoni* parasite remains a worldwide health problem. The group at PRNC is looking for new control methods using several widely different experimental approaches. The availability of a slow-release formulation of a toxicant lethal to both the parasite and the snail opens new possibilities for control of the disease. Irradiation of the infective stage of parasites has in several instances produced successful vaccines. Although irradiation of the cercariae of *S. mansoni* produces only a marginally effective vaccine, evidence has been obtained in that irradiation of the parasite does shift the immunological balance in favor of the host. Progress has been made in purifying a secretory antigen of *S. mansoni*. It is hoped that this antigen will be useful for epidemiological screening. Irradiation of *S. mansoni* cercariae results in stunted adult worms. To clarify this phenomenon the development of the worm *in vitro* is being studied by ultrastructural and immunological techniques.

TOXICANTS

Effect of Continuous Application of TBTO on the *Biomphalaria glabrata* Snail, Cercariae, and Miracidia. The slow release into the environment of a potent toxicant, bis(tri-*n*-butyltin) oxide (TBTO), from a synthetic rubber formulation makes feasible the continuous treatment of water bodies for the control of schistosomiasis. With slow continuous release of a toxicant, the snail-parasite cycle can be interrupted at points not previously accessible with single or multiple discrete applications.

Cercariae treated for 5 min with a concentration of 10^{-8} (10 ppb) TBTO, although still motile, lost 72 to 100% of their infectivity for mice. Miracidia treated for 40 min with 10^{-8} were not infective. Egg laying was completely arrested by continuous exposure to 10^{-8} , and all the snails died within 5 days in this concentration. At 10^{-9} (1 ppb) the number of clutches was reduced by 80% and the eggs per clutch by 70%, and embryonic development was arrested in 97% of the eggs. Oviposition returned to almost normal levels after removal from a 24-hour exposure to 10^{-8} and 10^{-9} . Development of the embryo was resumed after removal from a 34-day exposure to 10^{-9} , but only 35% of the eggs hatched after a prolonged incubation period.

Continuous exposure of newly hatched snails (less than 1 day old) resulted in 100% lethality at 10^{-9} and 90% at 10^{-10} (Figure 1). The surviving snail at 10^{-10} did not lay eggs up to 85 days of age, although it grew to almost normal diameter. Newly hatched snails, exposed continuously to 10^{-11} and 10^{-12} TBTO until mature, laid only about one-third as many eggs as normal controls.

Bioassay for TBTO. No adequate chemical test is available for determination of low concentrations of TBTO. A bioassay has been used to compare the amount of TBTO released from rubber with the amounts in standardized solutions. These comparisons showed that 1 gram of the rubber formulation with a 6.0-cm² surface, when kept in 100 ml of water which was changed daily, produced a concentration of 2 to 8 × 10⁻⁸. At equilibrium the concentration was 2 × 10⁻⁷.

Continuous Application of Frescon. Work similar to that with TBTO has also been done with Frescon (*n*-tritylmorpholine). With a 5-min exposure, cercariae were completely immobilized by 0.7 ppm of Frescon and partially immobilized by 0.07 ppm. A 10-min exposure to 0.07 ppm completely suppressed infectivity. Exposure of newly hatched snails to 0.01 ppm produced 30% mortality and to 0.1 ppm, 100% mortality.

DELAYED EFFECTS OF IRRADIATION ON THE *S. MANSONI* WORM

It was reported in the last *Annual Report* that the stunting of *S. mansoni* adult worms resulting from the irradiation of cercariae could be partially reversed by irradiating the mice to be infected by the irradiated cercariae. A reasonable explanation for the data was that the stunting of the worms was the result of an immune response by the mouse and that this response could be suppressed by irradiation.

Another immunosuppressive agent, antilymphocyte serum (ALS), has been used to study the interaction of the host and the parasite. Table 1 shows the results of several experiments. The ALS does not reverse the stunting of the worm, but further enhances it, as shown by two statistically significant results. The opposite effects of the two immunosuppressive agents may be a reflection of the fact that irradiation primarily affects the system of humoral immunity and ALS, that of cellular immunity. This would suggest that humoral immunity is the effective system in mice infected with *S. mansoni*. When adequate technology is developed, the effect of irradiation on secretion of antigens by the worm will be measured.

	Irradiation to cercariae, rads	Treatment with anti-lymphocyte serum, ml	Average length of worms, mm	<i>p</i>
Exp I	2000	-	3.9 ± 0.33	
	2000	0.25	3.1 ± 0.51	0.10
Exp II	2000	-	5.1 ± 0.32	
	2000	0.25	4.1 ± 0.47	0.02
Exp III	2000	-	6.4 ± 0.37	
	2000	3×0.25	5.2 ± 0.35	0.002

Normal and irradiated (2000 R) cercariae were transformed into schistosomules by mouse skin artificial penetration. Four skins were used, two for normal and two for irradiated cercariae. There was no significant difference in the number of larvae penetrating the skins after 3-hr exposure. Each group of schistosomules was cultured in media containing human serum and human erythrocytes. Mice inoculated intraperitoneally and intravenously with equal numbers of flukes from each group on the 4th and 7th culture days yielded comparable numbers of adults 5 weeks after inoculation. When cercariae were put directly into mice, however, the survival of the irradiated ones was inferior to that of the normal ones. This implies that a period of one week *in vitro* is sufficient to repair the irradiation damage to the cercariae.

AN EXOANTIGEN OF *S. MANSONI*.

Partial success has been achieved in purifying an antigen secreted by cercariae. Radioimmune assays with ^{131}I -labeled purified antigen have demonstrated that in some fractions 30% of the material is specifically bound to globulins of sera from infected animals.

Several factors complicate work with the exoantigen. Many sera of infected animals appear to contain not only antibody but also a competitive inhibitor to the labeled antigen. The sera of mice cured of infection by chemotherapy contain less inhibitor, which implies that the inhibitor is an antigen secreted by the worm.

The antigen interacts strongly with impurities present in the secretions; therefore, its properties depend on its degree of purity. Figure 2 shows the distribution, after molecular sieve

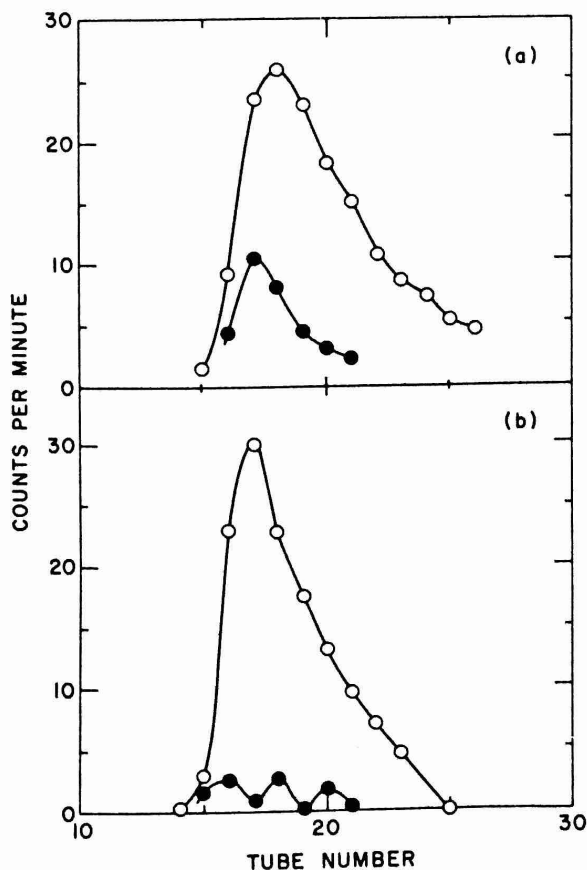


Figure 2. Distribution of two preparations of specifically bound antigen after molecular sieve chromatography. Preparation *b* is more highly purified. \circ , Total counts; \bullet , counts specifically bound.

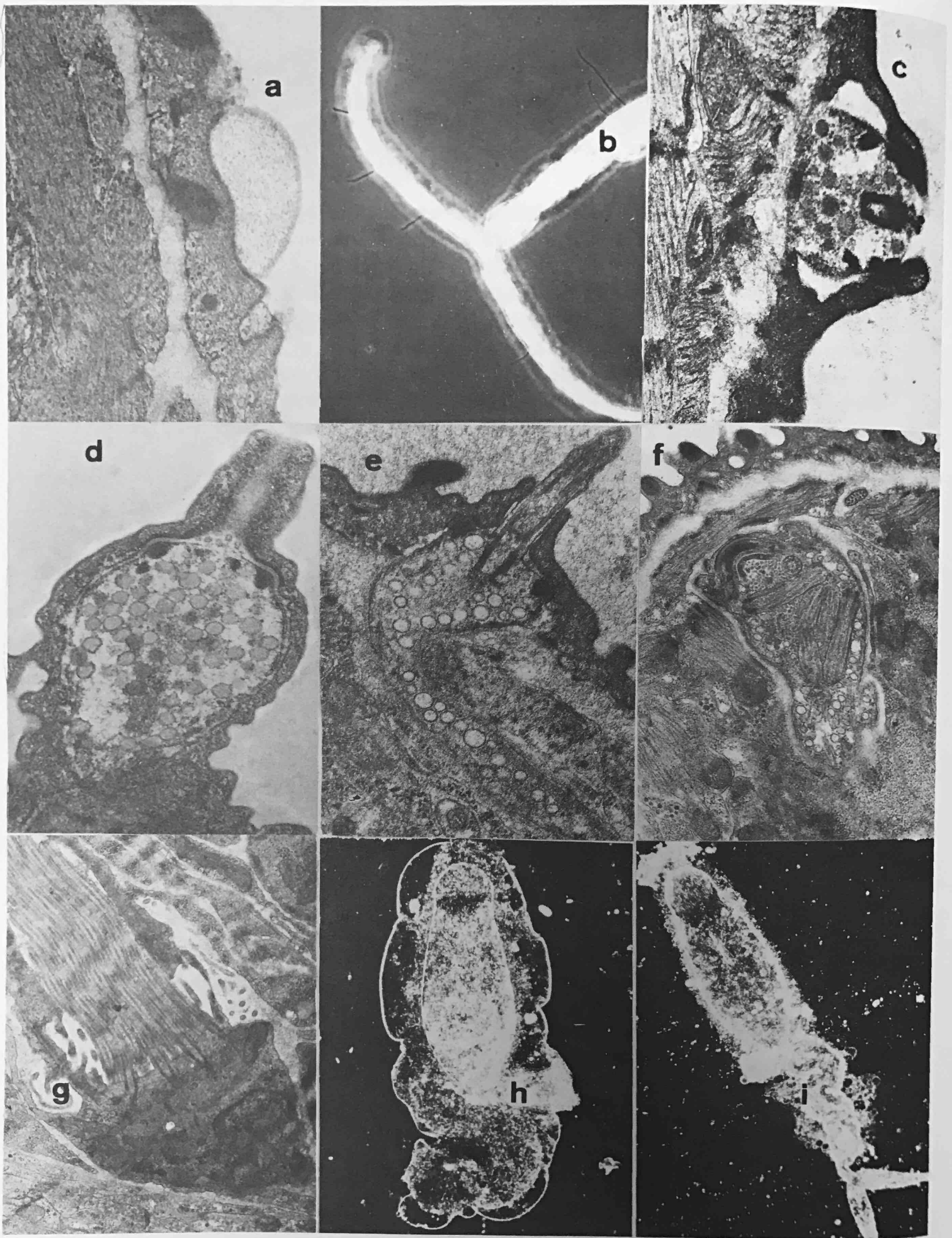


Figure 3. (See text.)

chromatography with P-6 acrylamide gel, of specifically bound antigen in two preparations. The more highly purified antigen (preparation *b*) contains components which penetrate the gel and therefore would not be larger than 6000 Daltons. Since the smaller molecules are competitive inhibitors of the larger molecules, all components must be very similar chemically. Preliminary data suggest that these small molecules are polysaccharides which are poorly labeled by standard iodination procedures.

The antigen interacts strongly with impurities present in the secretions; therefore, its properties depend on its degree of purity. Figure 2 shows the distribution, after molecular sieve chromatography with P-6 acrylamide gel, of specifically bound antigen in two preparations. The more highly purified antigen (preparation *b*) contains components which penetrate the gel and therefore would not be larger than 6000 Daltons. Since the smaller molecules are competitive inhibitors of the larger molecules, all components must be very similar chemically. Preliminary data suggest that these small molecules are polysaccharides which are poorly labeled by standard iodination procedures.

Work is in progress to improve labeling efficiencies and purification. The availability of pure labeled antigen will make possible investigations in epidemiology, the biological role of secretory antigens, and the effect of radiation on the secretory activity of the worm. Preliminary data suggest that the exoantigen active in the radioimmune assay is secreted by cercaria, adult worms, and eggs. Hence it may play an important role in the biology of the parasite.

ULTRASTRUCTURAL STUDIES

The fact that cercariae, free living organisms, can be induced to penetrate mouse skin *in vitro* with consequent rapid transformation into schistosomules, which are capable of survival only in the host, makes this whole process of differentiation accessible to study, particularly with electron and light microscopes.

Previous biochemical studies done in our laboratory have indicated marked differences between the metabolic capacities of the cercariae and of the very young schistosomules of *S. mansoni* recovered *in vitro*. Ultrastructural studies have been undertaken to demonstrate differentiation changes that can be correlated with the biochemical findings, with special attention to the integument and its related structures. Remarkable changes have been observed in the integument of schistosomules only 3 hr old, including an increase in the width of the integument, the presence of more mitochondria, and an apparent increase in metabolic activity demonstrated by the presence of a large number of vesicles not observed in the integument of the cercariae. Large globules related to these vesicles are also observed on the surface of the integument (Figure 3a, $\times 34,500$). Their nature is not yet known, but experiments with radioisotopes and E. M. radioautography are being planned to demonstrate whether they are substrates being ingested from the culture medium or metabolic secretions. These changes seem to be closely related to the glycocalyx that surrounds the integument of the cercariae and is lost after they pass through a skin.

Ultrastructural studies are also being done on some ciliary structures related to the integument, illustrated in Figure 3b (phase microscope) and 3c to 3f (electron micrographs). Figure 3b ($\times 500$) shows some of the cilia of the tail. Figure 3c ($\times 25,000$) shows the basal body in the sensory bulb of one of the tail cilia. A sensory bulb of one of the cilia at the proximal end of the head can be seen in Figure 3d ($\times 34,000$). A cilium at the lateral side of the head with its basal body and sensory bulb is shown in Figure 3e ($\times 25,000$). In Figure 3f ($\times 13,200$), a different ciliary structure is demonstrated, which consists of several cilia and is embedded in the parenchima, at the lateral side of the head.

The function of these structures is not clear. Some authors claim that they are just flagellae, but the vesicles observed in the bulbs suggest a sensory function. Histochemical studies are planned on these vesicles and the effect of irradiation upon them. The cilia on the proximal end of the head are presumed to have an important role in the discharge of the acetabular glands and the penetration of the cercarial head into the host. Figure 3g ($\times 12,100$) is an electron micrograph of a flame cell at the head of a cercaria. The cilia in this structure are characteristic flagellae, at the base of which, instead of a bulb with vesicles, there is a well organized cell with nucleus and mitochondria.

NONSPECIFIC "CERKARIENHULLEN-REAKTION" (CHR)

The CHR is a specific reaction in which the glycocalyx of the cercaria increases in size so that the cercariae are immobilized and trapped when they are placed in homologous antiserum. The reaction starts with the discharge of the acetabular glands, and within an hour well delimited sheaths are formed around the cercariae (Figure 3h, $\times 260$). We have observed that placement of cercariae in sera in which an antigen-antibody reaction has taken place (Mouse Anti Rat RBC sera plus Rat RBC) results in a CHR-like discharge of their acetabular glands but no sheath formation (Figure 3i, $\times 200$). This suggests that the discharge of the acetabular glands responds to the sequelae of an Ab-Ab reaction.

Published work on the electron microscopy of the CHR has shown an increase in the glycocalices surrounding the cercariae, but not the well delineated sheath that apparently is formed when a highly potent homologous antiserum is used. Ultrastructural studies are planned on the sheath and changes in the integument and sensory organs of cercariae subjected to the CHR.

Fascioliasis

Fasciola hepatica, the common liver fluke of cattle, is a problem to human and animal populations throughout the world. In 1970 a program to study *F. hepatica* was established at the Puerto Rico Nuclear Center in cooperation with the UPR Agricultural Experiment Station and the Puerto Rico Department of Agriculture. In 1971 the Pan American Health Organization started sending agricultural and health workers from Latin America for observation and training in the program.

The program is designed to find better control methods for fascioliasis in Puerto Rico and to transmit the findings to workers in other countries through publication and in-service training. Means are being sought to control the snail intermediate hosts by the use of molluscicides and biological control organisms, and to control the liver fluke itself by the use of irradiated metacercariae as a vaccine, which is being tested in laboratory animals for eventual use in cattle.

EPIDEMIOLOGICAL STUDIES

In Puerto Rico the epidemiological situation varies in the different areas where fascioliasis is endemic.

Man-made Environmental Factors. On a farm with more than 400 cows located near the ocean in the Dorado area, a snail habitat and consequently a heavy *F. hepatica* infection has been created by poor management of the drinking troughs. Overflowing water creates mud in which algae grow luxuriantly, and the snail intermediate host, *Lymnaea cubensis*, is found throughout the year. In a survey made in November 1972, of the 268 snails collected around the 6 drinking troughs, 44 were positive for rediae and cercariae. The average total infection rate of fascioliasis on this farm is 86%, the older cows having a higher rate (95.4%) than the younger ones. The number of eggs per gram of feces varied from 6 to 8 in 40 cows of the 55-to-66-month-old group to 14.4 in 22 cows of the 103-month-old or older group. The monthly rate of infection on this farm is shown in Figure 1. Many cases of fascioliasis result from poor management; it is in such situations that our control program may be most effective.

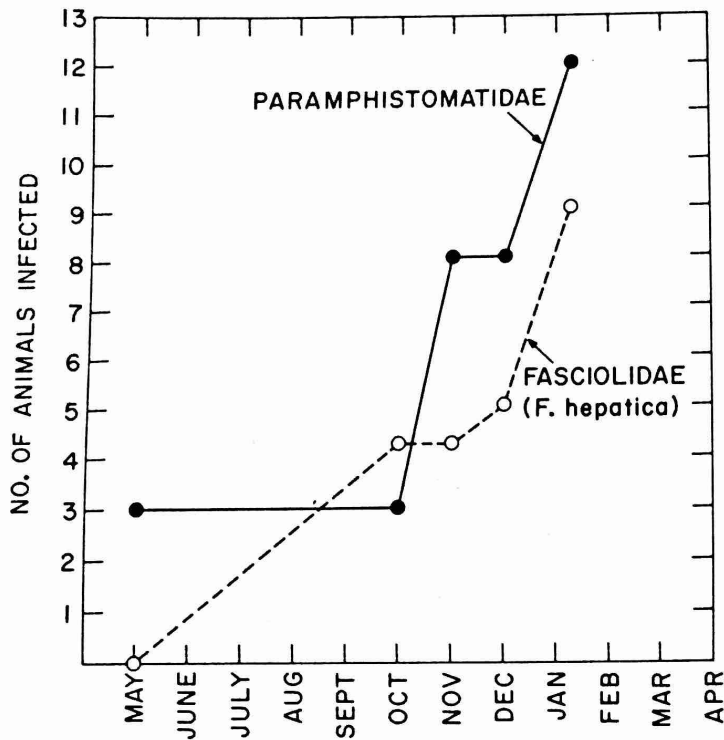


Figure 1. Monthly cumulative infection of cows on a Dorado farm.

Low Land. In Vega Baja, adjacent to Dorado, we examined a farm with ~500 cows, which differs in both management and environment from the Dorado farm. On the Vega Baja farm, *L. cubensis* is the only snail intermediate host present; this snail has been observed on a well drained hill in some months of the year. The average infection rate on this farm is 50%; it is 46.8% for 31-to-42-month-old cows and 80% for 103-month-old or older cows. The average number of eggs per gram of feces varied from 3.2 in the 31-to-42-month-old group to 9.5 in the oldest group; this is lower than the average at the Dorado farm.

Fascioliasis in low land areas is much more difficult to control.

High Altitude. In searching for an isolated farm suitable for testing biological control of fascioliasis by snail-killing flies, we went to Jayuya, in the central mountainous part of Puerto Rico. We found a farm in an isolated valley having environmental conditions very different from those of the other areas mentioned. In this valley it rains almost every day, usually in the afternoon, and the humidity is high. Records as to age, diseases, etc., are not kept. Meat dealers in the area said that the livers of most old cows sent to the slaughterhouse were condemned because of *F. hepatica*. The two known snail intermediate hosts, *L. cubensis* and *L. columella*, occur on this farm. *L. columella* is usually found in slow flowing rivers, creeks, and drainage canals, but on this farm it is found in close association with *L. cubensis* in muddy pasture. Of the 173 *L. columella* examined for rediae and cercariae of *F. hepatica*, 49.7% were infected and of the 17 *L. cubensis* examined, 100%. The average infection rate of cows on this farm was 56%. In a small creek traversing the

pasture, *Biomphalaria glabrata*, the snail vector of schistosomiasis, had been collected by public health workers, and, although the creek and pasture had been sprayed by them with molluscicide, *L. cubensis* and *L. columella* were seen in large numbers.

Seasonal Effects. The seasonal dependence of fascioliasis infection in Puerto Rico is in general not known. Figure 1 shows that the cumulative number of fascioliasis infections on the Dorado farm increases linearly with time and therefore is nonseasonal. However, the infection there is the result of a constant man-made snail habitat. Fluctuations in snail populations and infection rates would be expected in natural habitats subjected to dry and wet seasons.

IMMUNITY AND CIRCULATING ANTIBODIES IN RATS

As reported last year, rats were fully protected against fascioliasis by vaccination with 3 oral doses, at 2-week intervals, of metacercariae that had been irradiated with 2500 rads.

Circulating Antibodies. Although circulating antibodies were present in rats infected with normal metacercariae, they did not protect the rats against liver fluke. In rats previously infected with irradiated metacercaria, normal metacercariae administered as a challenge gave rise to very few circulating antibodies in the sera, and none developed into adults in the liver. It seems that immunity against *F. hepatica* is cellular rather than humoral.

Mass Production of Miracidia. The production of large quantities of metacercariae is necessary for our immunological studies in fascioliasis. This will require not only an improved technique of raising snails but also an efficient method of mass production of miracidia. We reported a mass production method last year, but it requires shaking and changing of the water in the flask every day. To avoid this step, addition of antibiotics and antifungus compound was recommended. The miracidia emerging from eggs cultivated with the recommended drugs penetrated the snail host as usual.

Relationship of Age to Immunity Against *F. hepatica* in Cattle. The ultimate goal of our immunological studies is to find a vaccine or other biological means to protect cattle and sheep against *F. hepatica*. The favorable result of the rat experiment perhaps may serve as a guide for immunological experiments in other animals.

The infection rates of fascioliasis clearly show that natural infection in endemic areas does not decrease with age; that is, no immunity develops in the cows.

Biochemical Studies in Cattle. *Fasciola hepatica* produces liver lesions; and recently an increase in transaminase has been shown in the serum of mice infected with it. In order to explore the utility of biochemical tests for detecting physiological changes in infected cattle,

tests were made on the blood of 7 positive and 8 negative cows. The negative cows had no eggs in their feces on the day of blood sampling and for one month before and after. As shown in Table 1, no significant differences were found between the two groups in the blood levels of the various parameters tested.

		Positive (7 cows)	Negative (8 cows)
Ca ⁺⁺ ,	mg %	8.88± 0.12	8.74± 0.35
Inorganic phosphate,	mg %	5.67± 0.43	6.53± 0.78
Glucose,	mg %	26.55± 2.85	30.04± 4.82
Blood urea nitrogen,	mg %	18.03± 1.69	20.11± 2.13
Uric acid,	mg %	1.72± 0.20	1.93± 0.29
Cholesterol,	mg %	118.13± 3.08	142.14± 18.93
Total proteins,	g %	8.25± 0.17	9.63± 1.38
Total bilirubin,	mg %	0.35± 0.21	0.60± 0.28
Alkaline phosphatase,	mV/ml	57.07± 8.85	72.53± 24.49
Lactic dehydrogenase,	mV/ml	768.45± 72.80	804.09± 145.29
Serum glutamic oxalacetic transaminase,	mV/ml	127.41± 11.54	143.42± 27.19

BIOLOGICAL CONTROL OF *F. HEPATICA*

The development of resistance by disease vectors against some pesticides and chemotherapeutic agents plus the continuing public protests against the widespread use of agricultural chemicals make biological methods of disease control highly desirable.

Paramphistomes (Cotylophoron cotylophorum). During our snail surveillance in the Dorado area, we observed a large number of *L. cubensis* infected with *F. hepatica* and a few with *C. cotylophorum* rediae and cercariae but no mixed infection. A study is in progress to determine whether there is antagonism between *F. hepatica* and *C. cotylophorum*. If we find that the presence of *C. cotylophorum* in the snail controls the growth of *F. hepatica* or prevents its penetration, then we may introduce miracidia of *C. cotylophorum* into a snail habitat to see whether we can break the life cycle of *F. hepatica* on a particular farm.

The life cycle of *C. cotylophorum* is being studied with *L. cubensis* as host.

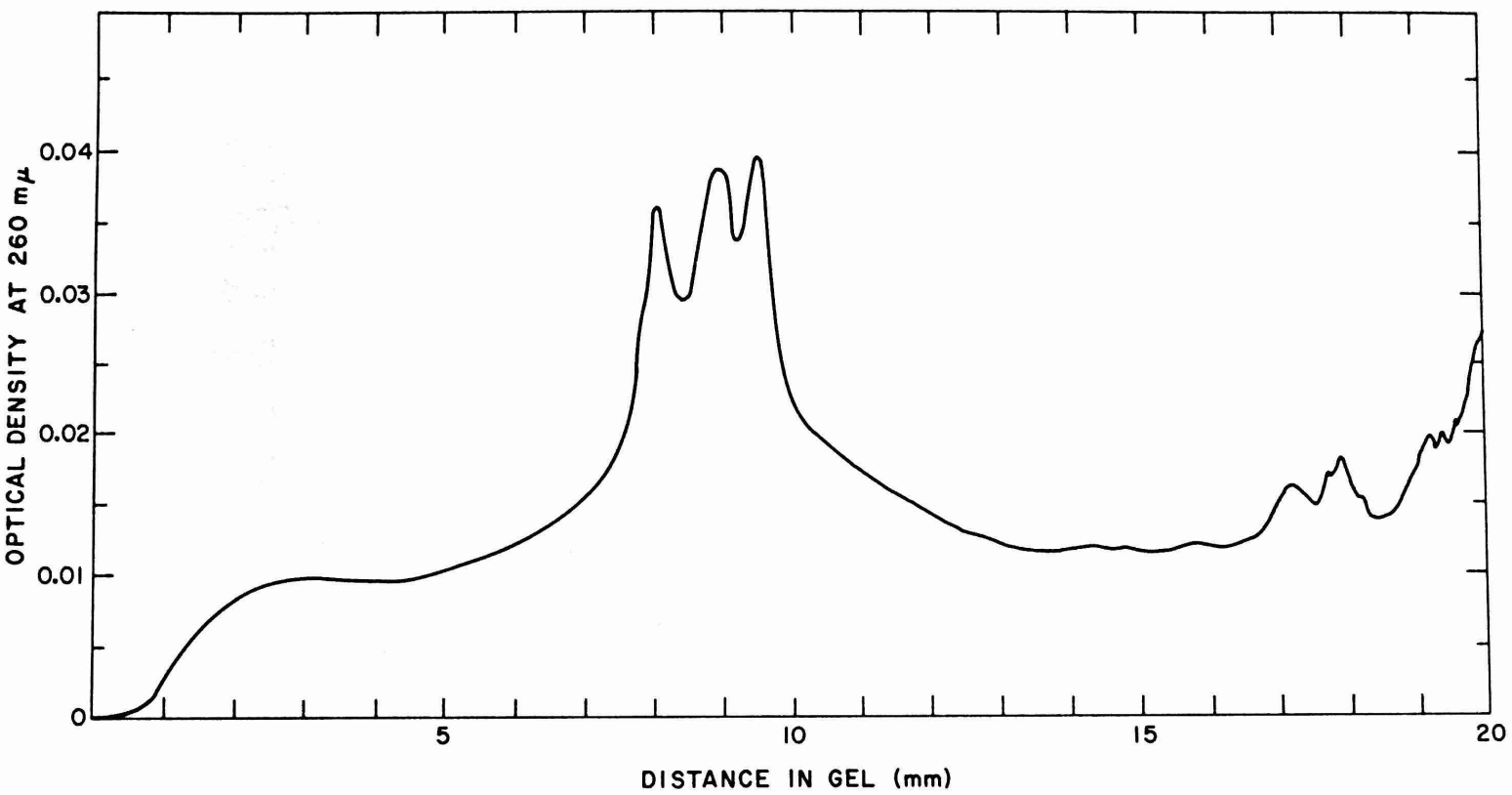
Snail-Killing Flies (*Sepedon* spp.). Flies of the genus *Sepedon* are snail killers. Of the 200 known species, five have been reported and described in Puerto Rico. In December 1972, Drs. Knutson and Jenkins, from the Ecology Branch of the Smithsonian Institute, collected two species in Jayuya, where we intend to study the feasibility of using *Sepedon* spp. for biological control of *L. cubensis* and *L. columella*. We have applied for a permit to introduce different species of *Sepedon* into Puerto Rico for the studies in Jayuya.

To evaluate the effectiveness of biological control of fascioliasis with *Sepedon* spp., we plan to introduce "clean" cows into the endemic area and then to do monthly examinations of feces for eggs and of serum for transaminase levels.

MOLLUSCICIDES

Organotin (TBTO). Organotins are effective against many freshwater snails. Their effectiveness against *L. cubensis*, which lives in muddy and swampy water, is not known. In a preliminary experiment in July, mud from Dorado was placed at the bottom of each of 10 plastic boxes and a liter of TBTO solution with a different concentration was poured into each. Then 10 *L. cubensis* were introduced into each box. TBTO at a concentration of 10^{-4} did not kill the snails in 5, 12, or 24 hr. It is not known why *L. cubensis* is less sensitive to TBTO than *B. glabrata*.

Field Tests. Pilot experiments with molluscicides in the field are being started. Two sites have been selected for experiments with "slow release" molluscicides, and a third site will be chosen to serve as a control.



Trypanosomiasis

Chagas' disease, or American trypanosomiasis, is a zoonosis caused by *Trypanosoma cruzi*; it spreads from the 42nd parallel in Argentina and Chile to the 41st parallel in Maryland. In the northern areas the infection is maintained practically only in animal reservoirs, but in the southern areas, in the vast "Chagas belt," some 25 million people are exposed to the parasite and an estimated 9 million people are infected. The chronic phase of the disease is characterized by serious and irreversible heart manifestations. This is the most important parasitic disease in the Western Hemisphere, and it tends to spread to new areas with the development of agriculture and cattle raising. Control campaigns are difficult to carry out, and no effective therapeutic agent is known.

Studies on the effects of radiation on the host-parasite interactions at the cell and animal levels were started at PRNC in 1966. Later, official support from the US AEC Division of Biology and Medicine permitted expansion of the program and led to development of new methods which have helped clarify the factors affecting the host-parasite relationship. This work also led to the possibility of applying these techniques to diagnosis of the disease in the field.

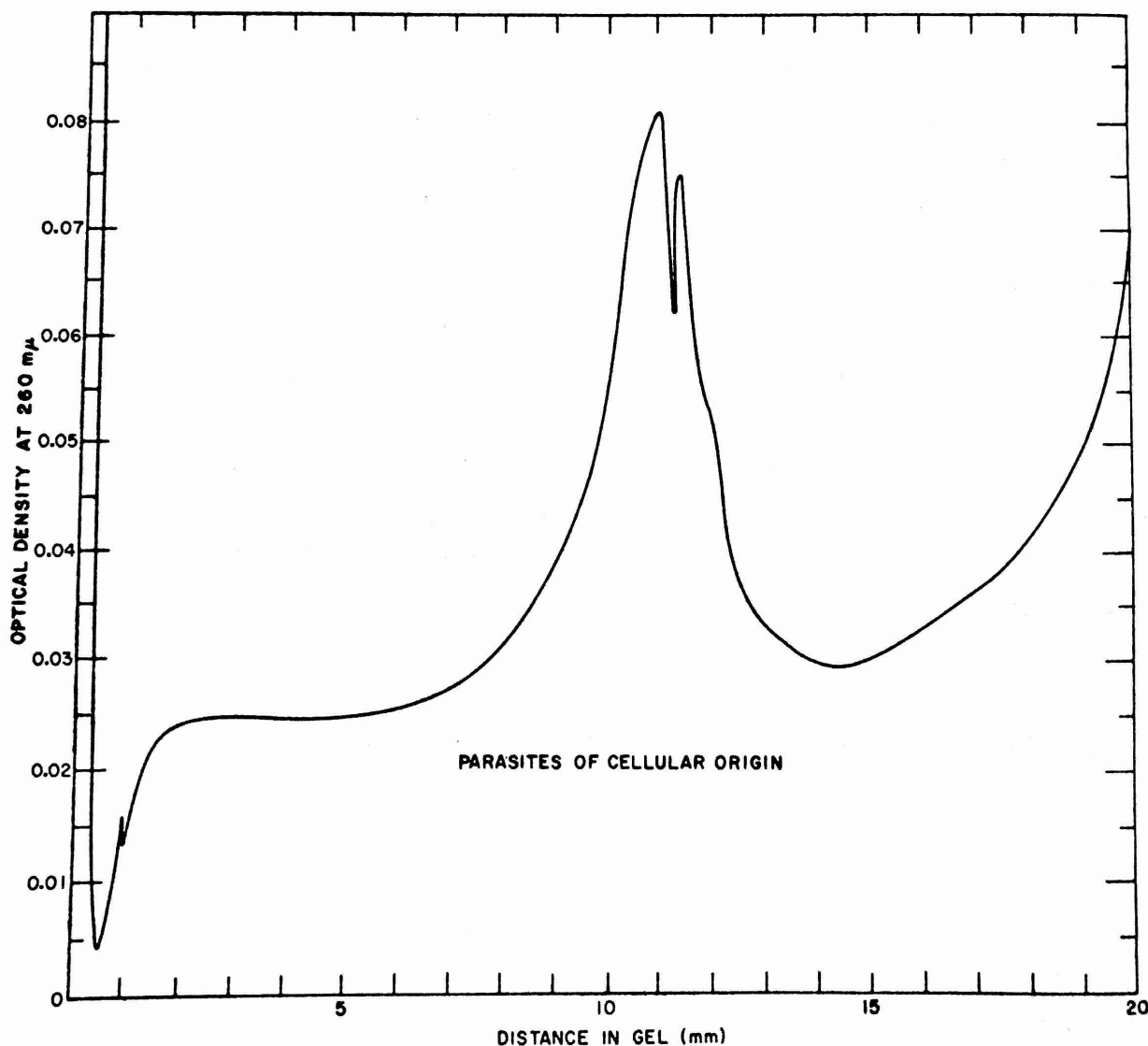
The molecular aspects of the host-parasite relationship are important in developing a rational way to attack the intracellular parasite with new therapeutic agents. As reported in the 1970 *Annual Report*, the administration of substances inhibiting DNA and RNA synthesis, such as actinomycin D, FUdR, etc., suppresses multiplication of the parasites inside the cells. This finding suggested studies on the synthesis of macromolecules by infected cells in tissue culture to determine the difference between normal and parasitized cells, which might enable us to approach the problem in a more rational way.

HOST-PARASITE INTERACTIONS AT THE MOLECULAR LEVEL

In the 1971 *Annual Report* we reported that cells infected with *T. cruzi* showed a new species of ribonucleic acid (RNA) due to the presence of the parasite in the cytoplasm of the cell. Studies with ³H-uridine showed that this new species of RNA appeared in the region between the 28S and 18S host ribosomal RNA. Resolution of this species was possible by increasing the concentration of acrilamide gel to 3% and changing the electrophoresis time from 1 hr 45 min to 3 hr 30 min (Figure 1).

Characterization of *T. cruzi* Ribosomal RNA. The RNA's from intracellular parasites, parasites grown *in vitro*, and virulent and avirulent parasites were compared after extraction with phenol. The RNA's from all these sources were similar, with three different peaks corresponding to sedimentation constants of 24S, 20S, and 10S (Figure 2). These values are different from those of mammalian cell RNA and explain the observed extra peak seen in infected cells.

Immunization Produced by Injection of Ribosomal RNA. The observed differences between cellular and parasite ribosomal RNA suggest a uniqueness of the parasite ribosomes that it might be possible to exploit immunologically. Mice were injected with 100 μ g of ribosomes in 0.5 ml balanced salt solution (group 1), 100 μ g of ribosomes plus 50 mg of poly-IC (a potent potentiator of the immune response) (group 2), and salt solution alone (control group). When challenged with 1×10^5 trypanosomes of the Tulahuen strain, two out of five mice died in group 1 and also in group 2, but five out of six died in the control group; this suggests a small protective effect. Further experiments are being done.



Radiation Activation of Latent Viruses

The purpose of this project is to study the impact of gamma irradiation on virus infections in wild arthropods and vertebrates. The isolation of Coxsackie type A10 virus from the blood of sick wild rats found in a small irradiated portion of the rain forest and from some organs of a dead one led to studies of the changes induced by radiation in the virus-host relationship in order to answer some fundamental questions in virology and immunology, especially those related to viral latency, viral long-lasting immunity, and the synthesis of neutralizing antibodies and interferon.

Latency (i.e., infection of an organisms by a virus with no apparent ill effect) is a commonly seen but interesting phenomenon. Gamma radiation is being used to elucidate the mechanisms by which latent infections are established and activated.

EFFECT OF RADIATION ON VIRAL INFECTIONS

Gamma radiation activated Coxsackie virus in immune mice which, at the time of irradiation, had no active virus in the blood, feces, or several organs tested. In similar experiments on rats with Sindbis virus, no active virus could be recovered from the animals after lethal or sublethal doses of gamma radiation. Some arboviruses are very difficult to isolate from the blood because of the presence of antibodies. We reported last year that in immune rats the circulating neutralizing antibody disappeared 6 to 8 hr after irradiation and reappeared after another 4 to 6 hr. No direct evidence has been obtained to demonstrate the presence of active virus, but, as previously stated, recovery of the antibody titer could be due to the presence of the virus causing an amnestic response. Taliaferro and Taliaferro (1970) in a similar experiment, in which they used RBC as antigen and followed the hemolysin titer, found that x irradiation accelerated the fall of the titer, but that the titer did not rise again unless new antigen was inoculated. We repeated their experiment in rats with RBC as antigen and hemagglutinin titers. The titer was slightly affected by gamma radiation, with a small decrease 24 to 48 hr after irradiation, and the drop did not recover.

If the effect of the gamma radiation was purely on the immune apparatus itself (immunocompetent cells), one would expect the antibody titer in animals immunized with replicating antigen (virus) and with nonreplicating antigen (red blood cells) to be affected in the same way by radiation. However, this is not so: the data suggest that the virus remains active in the immune animals and multiplies in such a way as to stimulate the formation of antibodies. The antibody titer remains constant as long as there is active virus in the tissue of the animal; and when the virus disappears the antibody also disappears.

Table 1

Effect of Radiation on Passively Transferred Antibodies

Coxsackie virus immune serum (0.2 ml; 1:64) was inoculated in the tail vein of 8-week-old mice. The mice were irradiated and bled at the indicated times, and the serum was tested for the presence of antibodies by the neutralization test in suckling mice.

Group No.	Radiation treatment	% Suckling mice protection	
		6 hr	24 hr
1	No radiation	100	87.5
2	400 rads before serum	100	37.5
3	400 rads after serum	87.5	50.0
4	800 rads before serum	87.5	28.6
5	800 rads after serum	87.5	0.0

Table 2

Effect of Radiation on Passively Transferred Antibodies

Coxsackie virus immune serum (0.2 ml; 1:200) was inoculated in the tail vein of 8-week-old mice. The mice were irradiated and bled at the indicated times, and the serum was tested for the presence of antibodies by the neutralization test in suckling mice.

Group No.	Radiation treatment	% Suckling mice protection				
		0 hr	2 hr	4 hr	6 hr	24 hr
1	No radiation	100	100	88	100	100
2	400 rads before serum	100	100	100	67	100
3	400 rads after serum	100	100	100	100	100
4	800 rads before serum	100	100	100	100	100
5	800 rads after serum	100	100	100	100	50

Table 3

Reactivation of Coxsackie Virus from Immune Animals by Radiation

Active immunity: Eight-week-old mice were immunized with 3 intraperitoneal injections of 10^5 LD₁₀ of Coxsackie virus. One week after the last inoculation the animals were irradiated and sacrificed, and the organs were tested for active virus.

Passive immunity: Coxsackie virus immune serum (0.2 ml; 1:200) was inoculated in the tail vein of 8-week-old mice. One hour after infection the mice were irradiated and sacrificed, and the organs were tested for active virus.

	Rads	Heart	Liver	Pancreas	Spleen
Immune mice (active)	400	-	-	+	-
	800	-	-	+	-
Immune mice (passive)	400	-	-	-	-
	800	-	-	-	-

EFFECT OF WHOLE-BODY GAMMA IRRADIATION ON PASSIVELY IMMUNIZED MICE AND ON ACTIVELY IMMUNIZED MICE

Adult (8-week-old) Bagg Swiss mice were passively immunized by inoculation with 0.2 ml of anti-Coxsackie A10 serum (titer 1:64) via the tail vein. The animals were divided into 5 groups. Neutralization tests were performed on the serum to determine the effect of the radiation on serum antibody titers at 6 and 24 hr. The results are summarized in Table 1. The serum from group 1 mice (control, no radiation) had enough antibodies to protect 100% at 6 hr and 88% at 24 hr. The serum from mice in the other groups (irradiated before or after receiving serum) had high antibody titers at 6 hr but at 24 hr the titers had decreased significantly. The results indicate that the passively transferred antibodies disappear faster in irradiated animals than in unirradiated controls.

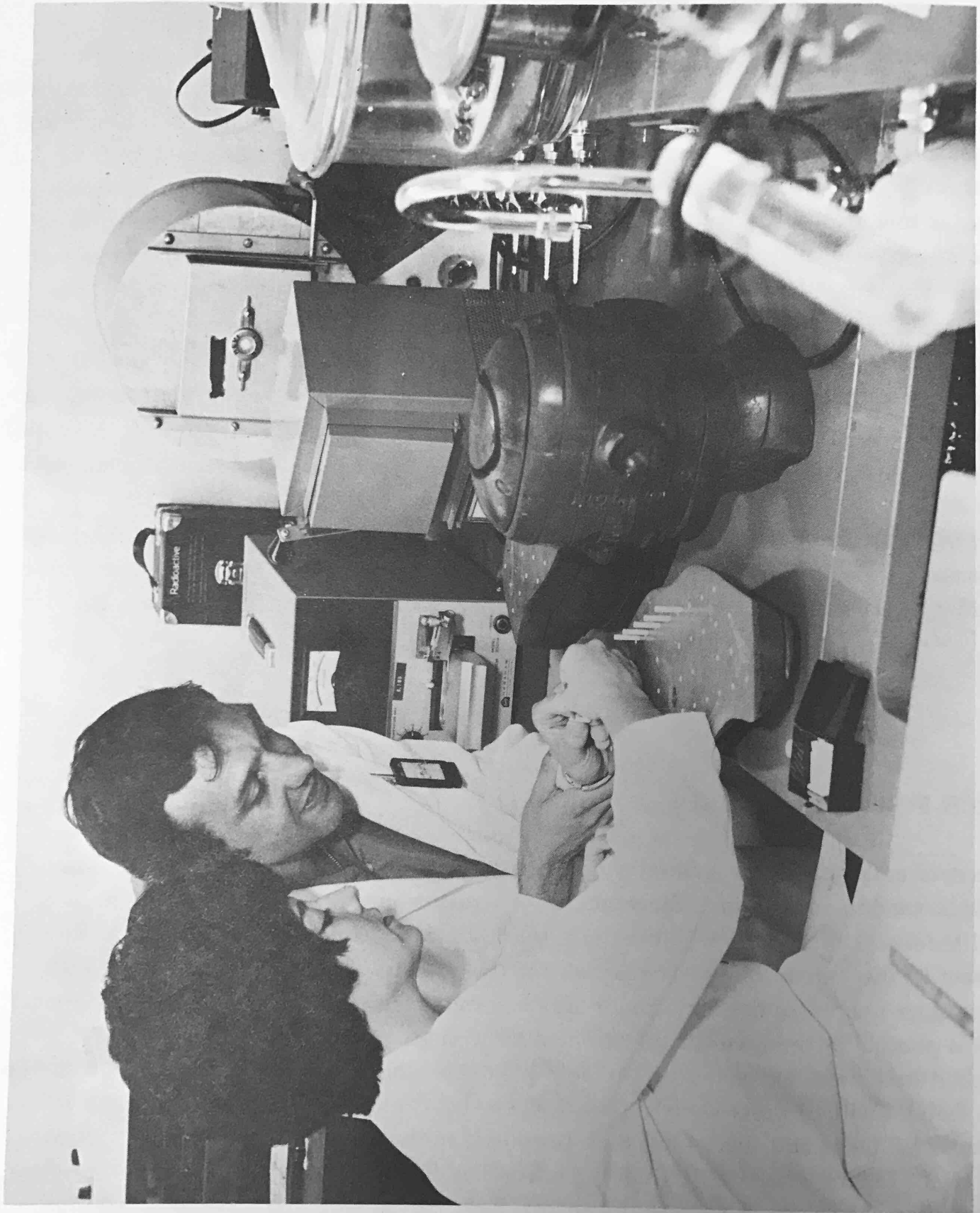
A similar experiment was done with a serum of titer 1:200. The mice were bled at 2, 4, 6, and 24 hr after irradiation. The results (Table 2) again show that in irradiated animals the passively transferred antibodies disappear faster than in unirradiated controls. No active virus was isolated at the indicated time in the animals that had been passively immunized (Table 3).

Previous work has shown that radiation activates virus in mice actively immunized with live Coxsackie virus. A comparative study of actively and passively immunized mice after irradiation (Table 3) showed that virus is found only in the actively immunized mice.

SEARCH FOR LATENT VIRUS

The data collected in the laboratory during the past years indicate that active virus persists in the immune animal. Since no active virus has been isolated from an immune animal before irradiation, it would be interesting to demonstrate in what form the virus is present in the immune host. The search for this "latent" virus has been started with electron microscope studies and immunofluorescence techniques. It is also possible that the virus persists in the form of infectious nucleic acids.

Nucleic acids were extracted by the cold phenol method and then titered on chick fibroblasts. Reproducible results were obtained when the virus was diluted in a 1 M NaCl nucleic acid diluent and the 24-hr chick fibroblast monolayers were washed with 2 ml 0.5 M NaCl before the viral RNA was plated. The RNA was allowed to adsorb for 20 min and then the excess RNA was drawn off. Eggs harvested at 10 hr showed 10^3 infectious RNA units/egg.



Miss Cecilia Ramírez giving instruction on phantom dosimetry to Dr. Alvaro Luongo from Uruguay.

MEDICAL PHYSICS

The major functions of the Medical Physics Division are to provide radiation dosimetry and treatment planning services to the Radiotherapy and Cancer Division, to conduct scientific programs, to supervise operations at the whole-body counter facility and at the ^{60}Co irradiator facility (gamma source), and to conduct an educational program in the area of radiological physics for residents training in Radiotherapy, Latin American students in Medical Physics, and other participants in graduate degree programs. The Division also provides consultation services to local hospitals.

EDUCATIONAL ACTIVITIES

On-the-job training courses were taken by the following five students (country of origin, sponsor, and dates follow each name):

- Dr. Omar Salazar — U.S.A., Radiotherapy Resident,
- Dr. Alvaro Luongo — Uruguay, IAEA, July-September
- Mr. Daniel Torres — P.R., Department of Health, July-September
- Mrs. Ingrid Erdelyi — Brazil, Women's Association, August-December
- Dr. Niní Bermudez — U.S.A., Radiotherapy Resident, October-November

M.S. in Radiological Health summer training in Medical Physics was taken (June 19-23) by the following ten students:

- Mr. Etienne Rodríguez — P.R., Public Health School
- Mr. Efraín Bonilla Santiago — P.R., Public Health School
- Mrs. Ingrid Erdelyi — Brazil, Women's Association
- Mr. Porfirio Toledo Charneco — P.R., Public Health School
- Mr. Eleuterio Molinas Villasanti — Paraguay, O.A.S.
- Miss Nayda Figueroa Vallés — P.R., Public Health School
- Miss María de los A. Amaro — P.R., Public Health School
- Mr. José González — P.R., Public Health School
- Mr. David Saldaña — P. R., Department of Health
- Mr. Alvaro Jordán Medrano — Bolivia, O.M.S.

STAFF

In July 1972, Dr. E. T. Agard was appointed Medical Physics Program Director.

On September 18, Miss María de los A. Amaro was appointed Technical Associate I to work part-time with the whole-body counter.

On July 3-21, Mr. José Pacheco attended two courses on dosimetry at the M.D. Anderson Hospital and Tumor Institute, Houston, Texas.

On December 11-14, Dr. Agard and Mr. Pacheco attended the Health Physics Society Seventh Midyear Topical Symposium in San Juan, for which PRNC was one of the sponsors. Dr. Agard presented a paper, and Mr. Pacheco served as chairmen of the scientific and commercial exhibits committee.

REACTOR

The Reactor Division provides neutron and gamma irradiation services to other PRNC divisions as well as training and education in reactor operations and related subjects. The Division operates and maintains (1) a 2-MW pool-type research reactor with 2000-MWt pulsing capability; (2) a 10-W aqueous homogeneous L-77 reactor; (3) a cobalt-60 gamma irradiation pool; (4) a cobalt-60 reactor pool gamma irradiation facility; (5) a 150-kV particle accelerator for the production of 14-MeV neutrons; and (6) two high level hot cells.

Irradiation services rendered during this year are summarized below:

1. 1250 megawatt-hours of operation at a nominal power level of 1.2 MW (routine reactor operations started March 28, 1972).
2. 98 side-of-core irradiations accumulating a total of 579 hours of irradiation time.
3. 90 side-of-core rabbit irradiations accumulating 3 hours, 8 minutes.
4. 64 in-core rabbit irradiations accumulating 2 hours, 40 minutes.
5. 225 samples irradiated in the gamma pool facility accumulating 2894 hours.

During the year the L-77 reactor was operated for a total of 21.9 watt-hours for the thesis work of nuclear engineering students, for one neutron irradiation, and for test purposes.

In addition the neutron generator was operated a total of 62 hours for student thesis work and test purposes. A total of 21 irradiations accumulating 2 hours, 5 minutes of irradiation time were also performed.

TRIGA REACTOR START-UP AND INITIAL OPERATION

On January 19, the 2-MW TRIGA reactor, whose installation began in April 1971, was made critical for the first time. Its core consists of 94 cylindrical stainless-steel-clad fuel pins containing a mixture of uranium (70% enriched), erbium, and zirconium hydride. Initial criticality was achieved with 7662 grams of uranium-235. The operating core contains 11,622 grams.

During the initial reactor tests to determine core behavior and operating parameters it was found that power fluctuations starting at ~ 1.4 MW prevent the reactor from being satisfactorily operated at 2.0 MW. For this reason 1.2 MW was selected as a temporary operating level until the reactor contractor-manufacturer corrects the condition causing the power fluctuations. To find the cause of the fluctuations, two experiments were

conducted during August and December. During the first, a shroud was placed around the reactor to determine the effect on its behavior of enhanced water circulation. During the second, the effect of flux-flattening devices was studied, and this will be further tested in January 1973. Final correction is expected in 1973.

Except for the dates during which test runs were scheduled, the reactor operated routinely at a power level of 1.2 MW.

EDUCATIONAL ACTIVITIES

As part of the M.S. program in Radiological Health, the Reactor Division offered the course PRNC 555, Safety in Reactor Operations, during the spring of 1972.

Also during the first semester of 1972 the Division trained three reactor operators. Of these, two are part-time engineering students at UPR-Mayagüez and have become part-time Division staff members. The third, Mr. Ariel Alonso, is an Uruguayan student with an OAS scholarship who will take supervisory responsibility for a research and training reactor now under construction upon his return to Uruguay. All students successfully passed an AEC-sponsored reactor operator qualification test.

During the summer the Reactor Division, in cooperation with the Nuclear Engineering Division, conducted a 12-week Reactor Supervisor Training Course for 20 employees of the Puerto Rico Water Resources Authority. The Reactor Division portion consisted of 40 lectures on Reactor Operations, Reactor Safety, and Licencing Regulations and 140 hours of reactor experiments and practical operation of the reactor by all students.

The Reactor Division is sponsoring work by Mr. Efigenio Rivera from the Health and Safety Division to determine gas evolution (radiolytic dissociation) and radioactive argon production by the TRIGA reactor. This work also includes standardization of a Kanne chamber (monitor) for effluent gas monitoring and calculation of total activity released to the environment.

HEALTH AND SAFETY

The Health and Safety Division, which deals with all health and safety related problems, operates at both Río Piedras and Mayagüez providing the services needed for the safe operation of the Puerto Rico Nuclear Center and implementing the radiation, industrial, and fire safety regulations (State and Federal). It also contributes to PRNC's educational and research programs in the fields of Radiological Health and Medical Physics.

The services, which include consultation and supervision in all matters concerning safety, especially radiation safety, are as follows: personnel and area monitoring and calibration of monitoring equipment; radioactive material handling; environmental surveillance; dosimetry; decontamination and waste disposal; industrial hygiene; general laboratory safety, industrial safety, and fire safety; indoctrination of staff members in health physics, industrial hygiene, industrial safety, and fire prevention. The Division maintains regular inspections and monitoring and cooperates with safety committees within each Division. Indoctrination on safety, especially radiation protection, is offered to PRNC personnel through special courses, lectures, leaflets, and films and through the Safety Coordinating Committee which meets monthly. A constant effort is made to improve the safety consciousness of personnel and to raise safety standards, with special emphasis on emergency planning within and outside PRNC.

The Division also participates in teaching and training special students in radiation protection and all phases of safety through academic and informal courses, seminars, and thesis research. The education and research program includes:

1. An M.S. degree program in Health Physics at UPR Mayagüez.
2. An M.S. degree program in Radiological Health at UPR San Juan.
3. Courses at UPR Mayagüez and UPR San Juan in basic Radiation Protection at the graduate level for students not specializing in the field.
4. Special training in Applied Health Physics to fit the needs of students, particularly from Latin America.
5. Basic research as permitted by budget and time limitations.

SERVICES

Service functions are updated in accordance with needs. Two committees with members in Mayagüez and Río Piedras deal with all safety problems. (1) The Safety Advisory Committee, consisting of all division heads and one member from the Director's Office, reviews and approves general safety policy matters and regulations. (2) The Safety Co-

Table 1
Health and Safety Services, 1972

1. Film service:	Neutron	Beta, Gamma
PRNC	643	3342
Oncologic Hospital		1753
University Hospital		252
Instituto Nacional de Energía Nuclear, Guatemala		1925
Military and Rosales Hospital, El Salvador		597
Medical Center, Mayagüez		512
Local Civil Defense		54
Experimental Station, Lajas		72
Metropolitan Hospital		44
Fomento		48
	Total 643	8599
2. Radiation survey meters calibrated:		
Gamma		190
Neutron		35
	Total	225
3. Area monitoring samples analyzed:		
Smears		300
Water		24
Air		3
	Total	327
4. Review of questionnaires for reactor experiments:		126
5. Review of requests for use of irradiation facilities other than reactor:		6
6. Review of requests for radioisotopes procurement:		27
7. Medical Dispensary cases seen:		
Minor accidents		59
Physical exams		40
Vaccinations (tetanus toxoid)		40
	Total	139

ordinating Committee, which has members from each division, implements safety regulation and deals with problems as they arise.

Personnel Exposure. The reporting of personnel exposure has been further improved with the purchase of another densitometer with digital voltmeter display to facilitate and expedite film readings and reporting in conjunction with the already established computer program. The personnel exposure dosage continued to be < 1 rem during 1972. The film badge laboratory at Cornelia Hill provides services also for programs in San Salvador and Guatemala.

Environmental Surveillance. The environmental surveillance program was kept at the same level as in previous years. A few samples a month of soil, water, and vegetation in the vicinity of PRNC and water from the India brewery's well were analyzed. The laboratory is capable of performing full surveillance if required. Division personnel maintain an environmental sampling station (air and rain) for the Environmental Protection Agency Radiation Alert Network.

General Safety. Personal safety and fire-fighting equipment are provided by the Division as needed. Working areas are checked after hours for potential fire hazards, and grounds and facilities are inspected weekly.

The Division supervises the safe operation of the 4605-Ci ^{60}Co irradiator facility and also of the medical radiation units at the Radiotherapy Division. The ^{60}Co source is used extensively in the various irradiation programs of different divisions. The Division is also responsible for the health physics aspects of the TRIGA reactor, the L-77 reactor, the neutron generator facility, and the gamma pool facility.

The Division's emergency plan covering any catastrophic event in Mayagüez and relating PRNC problems and competencies to the surrounding community was approved in June 1972 after final AEC and PRNC Safety Advisory Committee revisions.

The Division continues to provide radiological safety and dosimetry service at the Veterans Administration Hospital in San Juan and the Andrés Grillasca Oncologic Clinic in Ponce.

A complete surveillance of the BONUS power plant was made in December 1972; this will be repeated yearly.

Indoctrination. Indoctrination of personnel is done through safety institutes in conjunction with the Puerto Rico Labor Department and through lectures, films, personal contact, and printed material. National Safety Council publications are circulated to each member of the Safety Coordinating Committee.

Four fire drills, two with Fire Department participation, were conducted at both Mayagüez and Río Piedras, and two high level radiation evacuation drills were conducted at Mayagüez.

EDUCATION AND TRAINING

The education program serves students planning a career in health physics by providing graduate training leading to the M.S. degree and other advanced training. It serves students in other fields and also PRNC personnel by providing formal courses and informal indoctrination in radiation safety and general safety.

In conjunction with the UPR Department of Biology, Mayagüez, an M.S. degree program in Health Physics has been offered since 1959. One student is currently enrolled.

In conjunction with the UPR School of Public Health, Department of Environmental Health, San Juan, an M.S. degree program in Radiological Health is offered, which was described in detail last year. This program is now in its fifth year and 25 persons have graduated. Six students are enrolled for the 1972-73 academic year: Hilda Colón Plumey, P.R. (BRH, sponsor), Asterio Santos Portalatín, P.R. (BRH), Nimia Irizarry Cancel, P.R. (AEC), Víctor Velázquez Casillas, P.R. (GI Bill), Santiago Gómez Figueroa, Colombia (OAS), and Hazin Clovis, Brazil (self). In 1970, the Public Health Service awarded this program a training grant of \sim \$50,000/year for five years.

A graduate course at UPR Mayagüez and one at the School of Public Health in San Juan for students not specializing in health physics cover basic nuclear physics, radioactivity, interaction of radiation with matter, biological effects of radiation, instrumentation and methods of measurement, and principles of handling radiation in all its forms. The Mayagüez course includes laboratory work on radiation detection, and the San Juan course emphasizes the public health aspects of radiation. The 14 students taking the latter course in 1972 were Blance E. Barreras Rivera, Ada V. Caro Ruiz, Zaida Clas Figueroa, Enid G. Díaz Dávila, Benjamín Hernández Nieves, Hernán Horta Cruz, Mildred Huertas Solá, Jorge E. Huyke Luigi, Héctor Laracuenta Santana, Nelda M. Méndez González, Carlos E. O'Neill Ortiz, Carmen E. Reverón Rivera, Charles Romney López, and Vivian D. Silvestry Hernández.

Student Research. Dr. Peter Paraskevoudakis is supervising the following M.S. thesis research:

1. Possibilities of Existence of Partially Damaged Molecules — Jorge Pérez. Study of the changes in enzyme molecules resulting from monochromatic x-radiation may reveal a special kind of interaction of radiation with macromolecules. A stress other than x-radiation, namely heat, is applied to irradiated and non-irradiated enzymes (such as peroxidases and catalases), and the inactivation pattern is studied. The radiation dose chosen permits at least 90% of the enzymes to remain active. It was found that the irradiated molecules are less resistant to heat than the non-irradiated ones. Damage can be detected even when the absorbed dose in solution is as low as 200 rads. The degree of damage is higher above the *K*-edge of iron, i.e., above 7.11 keV. It is concluded that the enzyme molecules exist in a partially damaged condition but the damage is not prohibitive to biological function of the enzyme. (The experimental work has been completed.)

2. Determination of ^{41}A Concentration in the Reactor Building and Total Radioactivity Released to the Atmosphere from the PRNC 2-MW TRIGA-FLIP Reactor — Efigenio Rivera. A new method was used for absolute measurements of airborne radioactivity produced during operation of the PRNC TRIGA reactor. Spectrometer measurements showed this radioactivity to be due mainly to ^{41}A . The rate of production of ^{41}A gas was measured, and it was found to stabilize after 6 hr of operation at full allowable power (1.2 MW). The method was standardized and the radioactivity of a known volume of gas was measured accurately. In a separate experiment, by releasing this known amount of activity into the reactor off-gas monitoring system, with a Kanne chamber as detector, calibration of the system with ^{41}A gas was achieved. Thus the concentration of ^{41}A in the reactor building and the total amounts of radioactivity released by the reactor in the atmosphere were measured with a high degree of accuracy. (The experimental work has been completed)

Student Seminars and Special Projects. Students in the M.S. program in Radiological Health enrolled in course PMPH-562 presented the following seminars, which included experimental data as well as library work, under the supervision of Dr. Peter Paraskevoudakis, Dr. Theodore Villafaña, Dr. Eugene Theodore Agard, and Mr. Heriberto Torres:

1. Calibration of the PRNC Whole-Body Counter — Etienne Rodríguez.
2. The Cell: Radiation Effects — Ingrid Erdelyi.
3. The Electron Microscope and Its Applications — Nayda Figueroa.

The following students undertook special projects in addition to the normal workload:

1. Ingrid Erdelyi — Sensitivity of Reused TLD (LiF) Dosimeters.
2. María Amaro — Decontamination Problems in the Whole-Body Counter.

RESEARCH

Radiation Damage to Macromolecules — Mohyi-Eldin M. Abu-Zeid and P. Paraskevoudakis. Hematin, hematoporphyrin dihydrochloride, and hemin chloride are irradiated with gamma rays, neutrons, and ultraviolet. The absorption spectra are then recorded, and the lifetimes are measured by pulsed nanosecond-decay-time fluorometry equipment with a red-sensitive detector. This equipment is capable of measuring decay times as short as 1.7 nanoseconds and as long as 10 milliseconds directly and very accurately by using a matching signal technique.

The fraction of the molecules damaged during irradiation is a function of the dose delivered to the sample. The damaged molecules act as impurity centers and were found to affect both absorption spectra and lifetime values according to the following relation:

$$1/\tau_{qm} = 1/\tau_{0m} + \kappa_{qm} [Q]$$

where

- τ_{qm} = decay time of molecule m in the presence of impurity centers Q formed after irradiation, and is given by $\tau_{qm} = 1/(\kappa_{fm} + \kappa_{im} + \kappa_{qm})$ where κ_{fm} , κ_{im} , κ_{qm} are the respective rate constants for molecule m emission, internal quenching, and quenching impurities Q ;
- τ_{0m} = decay time of m in the absence of impurity centers Q , and is given by $\tau_{0m} = 1/(\kappa_{fm} + \kappa_{im})$;
- κ_{qm} = the quenching rate parameter of m (constant); and
- $[Q]$ = concentration of impurity centers in the sample.

Although hematin in metal complexes is not fluorescent and has been used as a quencher for proteins, the fluorescence appears when iron is detached from the molecule. The data obtained so far are encouraging and show some interesting characteristics of the three molecules being studied. At low irradiation doses, especially with UV irradiation, the relative fluorescence intensity increases. As the dose is increased, impurity centers start to form and consequently the relative fluorescence intensity is reduced. More details will be obtained after the data are further analyzed.

Neutron Dosimetry — Peter Paraskevoudakis and Efigenio Rivera. The objectives of this project have not yet been met, partly because of problems developed by the TRIGA reactor. Mr. Rivera completed his thesis work (see above) on another subject. This project will continue as soon as the reactor power problem is solved.

Calorimeter — Peter Paraskevoudakis and Roberto Ortiz, Jr. Because of technical difficulties, the expected results were not obtained, but we hope to complete the data in the near future.

STAFF

Mrs. Lillian Vargas resigned as Division secretary and Mrs. Migdalia Mercado took this position. Mr. Porfirio Toledo, a 1972 M.S. in Radiological Health, joined the Division in Río Piedras in August. Mr. Víctor Cintrón left in November and Mr. Rafael Mora took this position. Mr. Efigenio Rivera presented a lecture on general principles of radiation safety at the Mayagüez Fire Department in February.

Dr. Peter Paraskevoudakis attended the Health Physics Society Symposium on Radiation Standards and Regulations in Oak Ridge in April, and the Fourth Annual National Conference on Radiation Control and Project Directors' Meeting in New Orleans, April 30 to May 4. In June, Dr. Paraskevoudakis and Mr. Efigenio Rivera attended the Health

Physics Annual Meeting in Las Vegas, Nevada, and then Mr. Heriberto Torres and Mr. Rivera attended a one-week orientation period sponsored by the AEC Oak Ridge Operations Office. In July Dr. Paraskevoudakis served as chairman at a meeting of the N44-3.2 Task Group and attended conference sessions of the ANSI N44-3 Subcommittee on Nuclear Medicine in Boston. In November he attended a meeting on Emergency Preparedness at the US AEC Headquarters in Germantown and the Radiological Society of North America meeting in Chicago. He also chaired a series of meetings of the N44-3.2 group organized in conjunction with the RSNA meeting. In December he presented a paper at the Seventh Midyear Topical Symposium of the Health Physics Society in San Juan.

Dr. Paraskevoudakis was Chairman of the Seventh Midyear Topical Symposium of the Health Physics Society, *Health Physics in the Healing Arts*, as well as Chairman of the Program Committee. Other members of the Division contributed to the success of the Symposium, including Mr. Efigenio Rivera, Chairman of the Special Events Committee, Mr. Heriberto Torres, Mr. Antonio Vega, and Mr. Porfirio Toledo. The Symposium was well attended with 437 persons registered.

A Colloquium in Health Physics at PRNC in Río Piedras, April 11-12, 1972, was organized by Dr. Paraskevoudakis for the students in the M.S. program in Radiological Health; the students and faculty of the School of Medicine and the School of Public Health were invited, as well as PRNC personnel.



Mr. Efigenio Rivera inserting sample into proportional counter.



Dr. José A. Alvarez de Choudens, Secretary of Health of Puerto Rico (second from right) receives the Island-wide Joint Dental Radiation Survey from its author, Michael Gileadi. At far left is Dr. Carlos Náter, Assistant to the Secretary for Hospital Operations, and at far right is Dr. José Saldaña, Assistant to the Secretary in Dental Health.

X-Ray Radiation Survey

The purpose of the radiation survey, sponsored jointly by PRNC and the P.R. Department of Health, is to evaluate the health and genetic hazards arising from unintentional gonadal irradiation of patients during certain diagnostic x-ray procedures. The procedures chosen as representative include nine abdominal and three thoracic examinations. It has been established that these cause $\sim 90\%$ of the genetically significant dose. A series of reports is being published, which present per capita annual gonadal doses and genetically significant doses associated with the selected procedures. The first (PRNC-132, 1969) dealt with the Western Region, the second (1970) with the Southern Region, and the third (1971) with the Northern Region except for the San Juan Metropolitan Area.

During 1972 statistical data concerning the San Juan Metropolitan Area were collected, analyzed and tabulated, and prepared for publication, and a preliminary report on island-wide results was prepared.

DENTAL SURVEY

Statistical and dosimetric information was collected, processed and tabulated, and prepared for publication on the use of dental x rays in Puerto Rico. The information collected included numbers of dental x-ray units operative in Puerto Rico by model, make, and operational characteristics; annual rate of dental x-ray examinations (by region and by type of examination); and somatic and genetic doses associated with various types of dental examinations. Average exposures were determined for the skin, testicles, and ovaries from both single-film and full-mouth (14-exposure) dental x-ray examination.

COMPREHENSIVE REPORT

All the data obtained during the joint radiation survey and the joint dental survey are being computerized, and the final results will be published in a comprehensive, bilingual report on the status of all medical x-ray procedures and associated health hazards in Puerto Rico. Genetically significant doses are being tabulated by geographic location, by type of x-ray diagnostic procedure, and by sex of patient. The report will include detailed information on x-ray units and radioisotope source units used in therapy and on therapeutic procedures current in Puerto Rico in 1968.

In order to evaluate the trends and the progress made in the field it is highly desirable to obtain parallel data for the five-year period 1968-1973. Several members of the Bureau

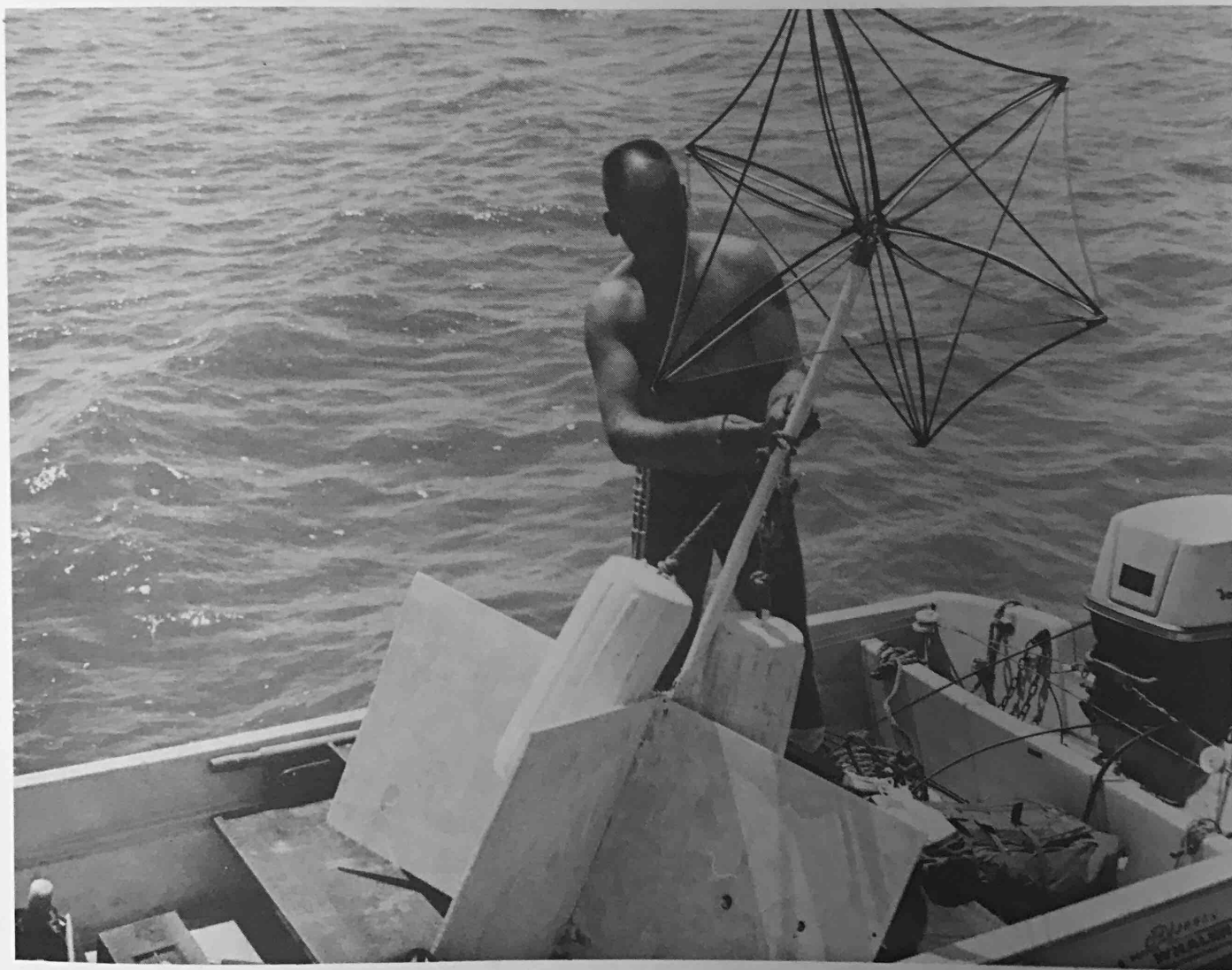
of Radiological Health in Washington agree that the survey should be continued in order to gain further insight into the development of radiation protection practices in Puerto Rico. This survey should contribute significantly to the reduction of unintentional irradiation of patients in Puerto Rico.

STAFF

Mr. Michael Gileadi attended the Seventeenth Annual Meeting of the Health Physics Society in June, in Las Vegas, Nevada, and the Seventh Midyear Topical Symposium of the Health Physics Society in December in San Juan.

RADIOECOLOGY

The Radioecology Division includes research programs supported by the U.S. Atomic Energy Commission, the Puerto Rico Water Resources Authority, the Puerto Rico Department of Fisheries, and the National Science Foundation. The programs sponsored by the AEC include the Bikini Project and the Marine Biology Program under the Division of Biomedical and Environmental Research and a program of ecological research under the Division of Reactor Development. The Division was organized to centralize administrative and logistic support services for environmental and ecological investigations, thus leaving the scientific staff free to devote their time to research activities.



Preparation of radar drogue for tracking currents in Jobos Bay.



Marine Biology

The Marine Biology Program was started in 1961 at PRNC to develop the specific-activity model for predicting hazards from the release of radionuclides into the marine environment (e.g., from canal blasting or from water-cooled nuclear power plants). The basis of this model is that radionuclides and stable elements in sea water are distributed by physical and chemical processes, and that the uptake of radioisotopes by organisms depends on these processes as well as on the ability of organisms to concentrate stable elements and the corresponding radionuclides. Within the limits of natural occurrence of stable elements, the elements and their radionuclides are usually taken up by aquatic organisms in the same proportions as those occurring in the water. However, sometimes the chemical and physical form of the radioisotope differs from that of the stable isotope, and this affects the accuracy of the model; therefore, recent studies have been directed toward defining these error factors. Another factor affecting the accuracy is that the predictions usually are based on a steady state condition. When predictions are required before steady state is achieved, the rate of transfer and isotope dilution of the radionuclide as it passes through critical food webs must be defined. Rarely, if ever, is steady state achieved under natural conditions.

Specific activity and trace element studies have been made under a variety of environmental conditions in Puerto Rico, Panama, and Bikini Atoll in near-shore and offshore marine areas. The specific activity approach appears to be the most realistic method for use at present because of its simplicity and because it takes into account the local environmental conditions.

It has also been found that the results and research methods used in the Marine Biology Program are directly applicable to pollution problems in Puerto Rico and other tropical areas. The distribution and uptake patterns for heavy metals, carbohydrates, and pesticides follow chemical, physical, and biochemical rules similar to those for radioisotopes. Power generating plants and associated industries are growing rapidly to meet energy requirements and so is the pollution associated with them; they also discharge heated water, and this usually has an even greater impact on the aquatic environment. Data collected for specific activity applications in the Marine Biology Program may serve as baselines for the natural levels of trace elements and for species diversity, density, and biomass of different marine organisms.

The studies in the Marine Biology Program are conducted as a team effort between marine chemists, geologists, and ecologists. Special effort is directed toward clarifying the physical and chemical phenomena that occur in tropical coastal areas and in the zone where river water and seawater mix, and to understanding how changes affect the



Operation of a large corer on the *Palumbo* in the Bravo bomb crater on Bikini Atoll. The large white tanks on the left were used to coprecipitate transuranium elements in seawater samples.

concentrations of trace elements and radioisotopes in aquatic organisms. The studies are in three categories: (1) basic marine biological and ecological studies, (2) background oceanographic and limnological studies, and (3) analytical methods for trace elements.

Basic Marine Biological and Ecological Studies. The study areas, located on the south and west coasts of Puerto Rico, include rivers, lagoons, mangroves, swamps, sea grass beds, and coral reefs as well as near-shore open sea areas. The biological communities being studied include plankton, periphyton, marine bacteria and yeasts, benthic communities in muddy and sandy bottoms, turtle grass beds, coral reefs, and mangrove swamps. The subjects being investigated are mineral and nutrient cycling, productivity, biomass and species diversity, foraminiferan assemblages and their mineral inclusions, and the effects of elevated temperatures on turtle grass beds.

Background Oceanographic and Limnological Studies. In the marine areas where ecological investigations have been done, physical and chemical characteristics are being determined, including sediment load, redox potential of sediments, origin and quality of sediments, water currents, and temperatures. The sorption of phosphates and trace elements on clays, in sediments and suspended sediments, as a function of salinity, pH , eH , and dissolved oxygen is under investigation. The concentrations of trace elements and phosphates in sediments and on the interphase between sediments and water have been studied around a coral reef.

Analytical Methods for Trace Elements. Neutron activation analysis, atomic absorption spectrophotometry, x-ray emission spectrography, colorimetry, fluorescence emission, arc spectrography, infrared spectroscopy, isotope dilution, and gas chromatography are being used for the analysis of trace elements and organic compounds. Field studies have been made in two rivers and the coastal areas at their mouths and in the offshore coral reef.

Relationship to Other Projects. Programs have been carried out in cooperation with the University of Miami, the University of Rhode Island, the University of Washington, Oak Ridge Associated Universities, the University of Puerto Rico, Lawrence Livermore Laboratory, the Puerto Rico Environmental Quality Board, the Puerto Rico International Undersea Laboratory (PRINUL), the International Decade of Oceanographic Exploration (IDOE), and the Fisheries Laboratory of the Puerto Rico Department of Agriculture.

Research Vessel *Palumbo*. The research vessel *Palumbo* has made three extended scientific cruises during the year. Two three-week cruises for the IDOE program were made to determine baseline levels of pollutants in the Caribbean as part of the NSF-IDOE program. During these cruises, water, sediments, plankton, benthic organisms, and fish were collected to determine the extent of heavy metal, pesticide, and hydrocarbon pollution in the Caribbean. The most demanding task so far for the *Palumbo* was a 132-day cruise

to Bikini Atoll. During this trip samples of water, sediments, algae, corals, molluscs, crustaceans, sea cucumbers, and fish were collected for analysis for uranium, plutonium, thorium, and americium. The scientists attending this cruise were Drs. F. G. Lowman and S. E. Kolehmainen from PRNC, Dr. V. Noshkin from Lawrence Livermore Laboratory, and Dr. W. Schell and Mr. R. Eagle from the University of Washington.

The construction of a pier and the dredging of a channel for the *Palumbo* were started in February at the Guanajibo Laboratory. The pier facility will also have a small wet laboratory, a net shed, and a shop.

BASIC MARINE BIOLOGICAL AND ECOLOGICAL STUDIES

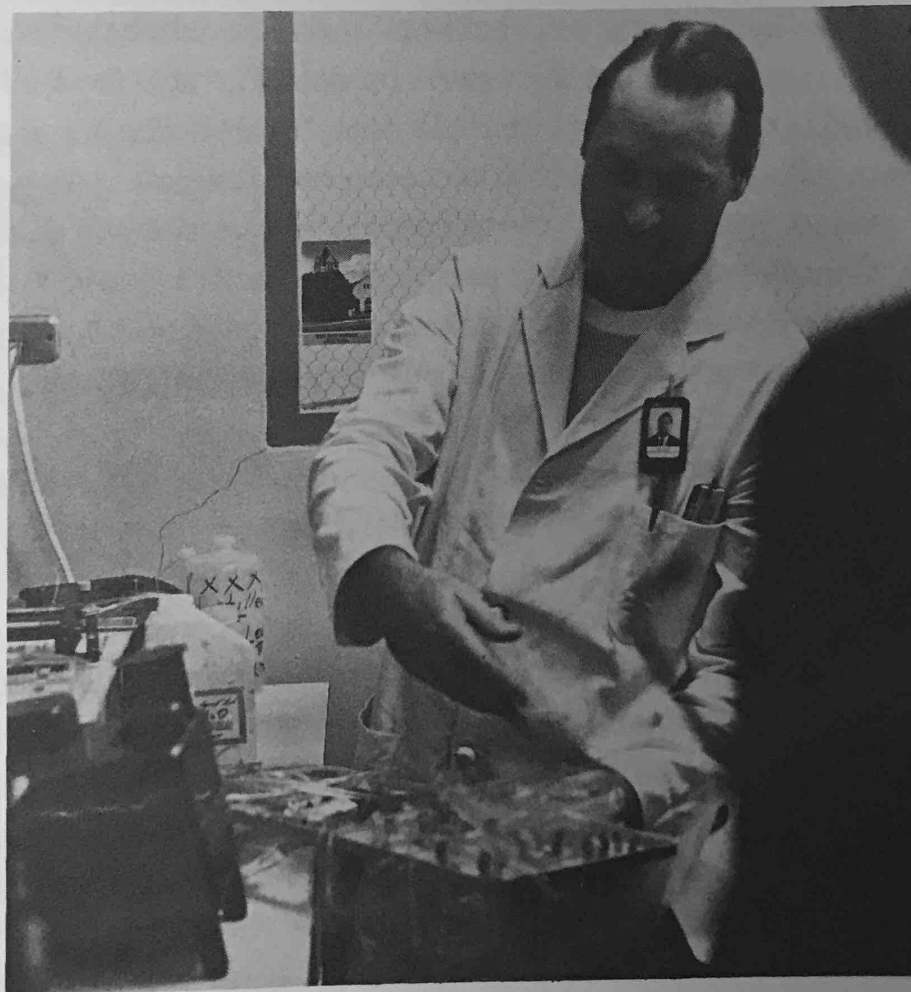
Thermal Studies in Guayanilla Bay. Studies have continued on the effects of elevated temperatures in the eastern part of Guayanilla Bay near a fossil fuel electric plant. In spring 1972 the plant capacity was increased from 300 to 710 MW. The plant takes cooling water from Guayanilla Bay and discharges the effluents into a $\frac{1}{2}$ -mile-long semienclosed cove that empties into the open bay. The ambient water temperature in Guayanilla Bay varies from 25°C in February to 31°C in September on the surface, and the Δt in the heated effluent is +10°C. The biomass and density of turtle grass (*Thalassia testudinum*) and associated invertebrates have been studied around the cooling water intake and near the cove outflow where cove water entrains with bay water with a resulting Δt of +7°C. *Thalassia* beds are surviving at a Δt of +3° to +4°C, but the biomass is less than in areas with a lower positive Δt . However, it has not been determined whether this is a result of the higher temperatures or of the strong water currents. In transplant experiments, sections of turtle grass beds exposed to different temperatures up to a Δt of +10°C in the cove for nine weeks survived in temperatures up to 35°C, but the associated organisms seemed to be less tolerant of the elevated temperatures. Laboratory experiments on the uptake rates of ^{59}Fe , ^{137}Cs , ^{54}Mn , ^{65}Zn , ^{110}Ag , ^{57}Co , and ^{60}Co in *Thalassia* are in progress at temperatures from 20° to 40°C. The uptake rates are expected to demonstrate changes in the trace metal metabolism of *Thalassia* below the upper thermal limit of survival.

Ascidian Fauna of Puerto Rico. Ascidiaceans contribute a significant fraction of the biomass of sessile organisms on mangrove roots and are also important in turtle grass beds, on sand flats, and on coral. The thermal studies at Guayanilla Bay showed ascidiaceans to be sensitive to elevated temperatures. Some ascidiaceans are known to concentrate large quantities of vanadium, an unusual trace element in invertebrates. The crude oil refined in Puerto Rico is imported from Venezuela and is known to have a high vanadium content. Ascidiaceans and water from Guayanilla Bay, and from other areas not subject to oil refinery effluents, are being analyzed for vanadium.

The ascidian fauna of Puerto Rico is not well known. Samples of the species and the biomass of ascidiaceans have been investigated in conjunction with the ecological studies of



Dr. Seppo Kolehmainen determining salinity of sea water with induction salinometer.



Mr. Russel W. Davis doing analytical work.

mangrove root communities, *Thalassia* beds, and coral reefs in various PRNC Radioecology Division programs. In a cooperative program with PRINUL, the species distribution and biomass of ascidians were studied on a coral reef and on an algal-sponge-ascidian flat near the reef. Five new species of ascidians for Puerto Rico were found. The biomass of ascidians was $23.6 \pm 12.0 \text{ g/m}^2$ (wet wt.) on the reef and 35.0 ± 18.1 on the flat.

Foraminiferan Assemblages in Mayaguez Bay. Investigations on live and dead foraminiferan populations in sediments have been continued. Species diversity and density, the size and shape of individuals, and inclusions in the shells of foraminiferans are related to the environmental conditions, chiefly to chemical and organic pollution. The size of the shell of *Fursenkoina pontoni*, a major species in polluted areas, is inversely related to the pollution level. In cores from Mayagüez Bay there is a change in the dead foraminiferan fauna at a depth of 4 m which is considered to be the result of a change in the environmental conditions about 3000 years ago. Another change at a depth of 30 cm indicates the time when pollution of the bay started. The percentage of *Fursenkoina pontoni* in the living population is larger than in the dead population; this change is attributed to the present heavy pollution.

Trace Element Studies in the Food Chains. Samples of phytoplankton, zooplankton, benthic organisms, and fish were taken for trace element analysis by the Marine Biology Program aquanauts during their stay in the PRINUL undersea laboratory. Sampling of single species of large zooplankters that are eaten by specific species of fish make it possible to follow trace elements through a complete simple food chain: seawater—phytoplankton—zooplankton—fish. Phytoplankton and zooplankton samples were collected eight times during a 24-hr period to study the diurnal cycle in the species diversity and biomass in the coral reef area. Samples of plankton, periphyton, benthos, and fish have been collected in the Guanajibo River and in the near-shore areas around its mouth to study the effects of varying trace element concentrations in water on those in the food chains.

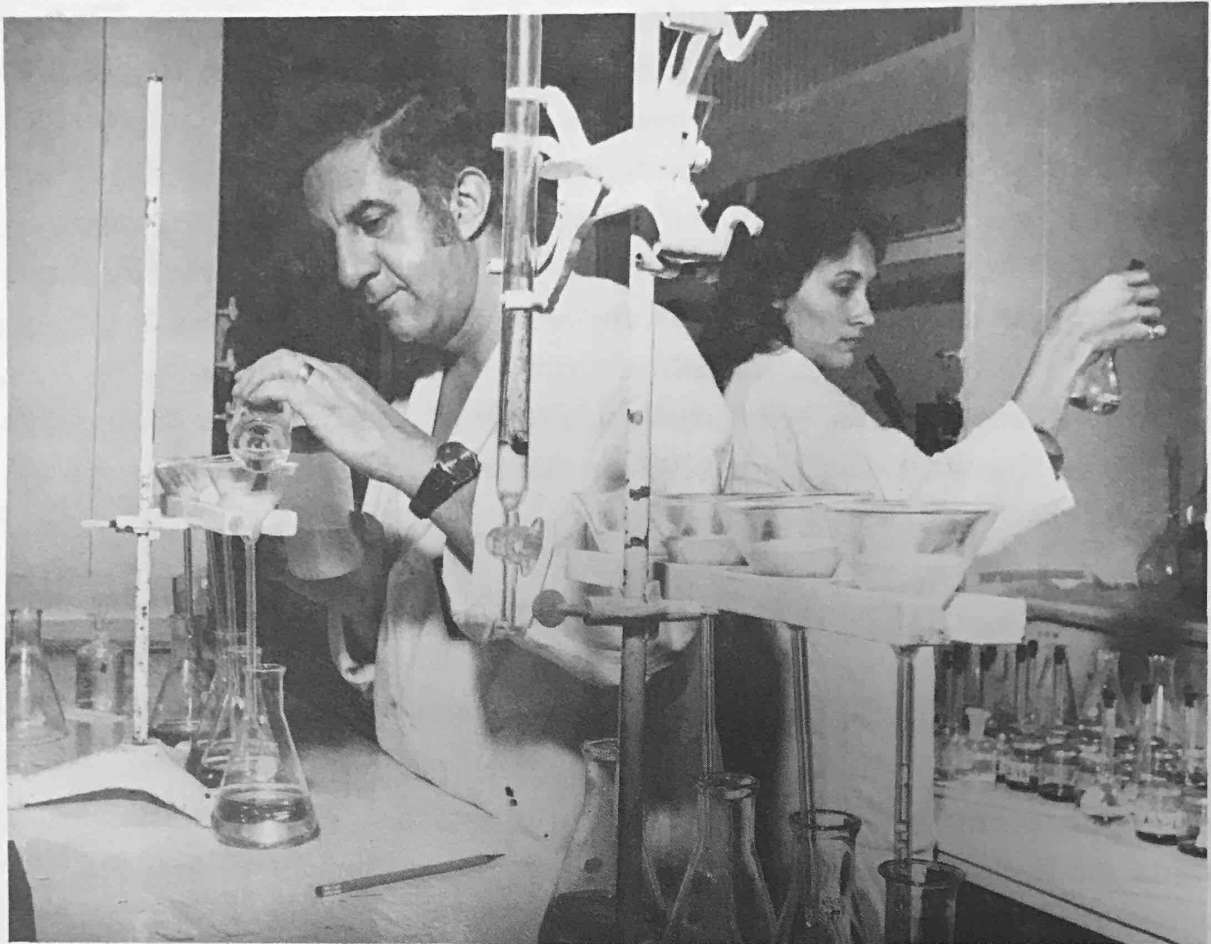
Influence of Periphyton on the Chemical and Physical Form of Cobalt in Estuarine Waters. Earlier investigations have shown a broad pattern of discrimination by marine organisms between the uptake of ionic and organically complexed cobalt. Some organisms, including marine phytoplankton and zooplankton, discriminate by a factor of 15 in favor of complexed cobalt, but pelagic and benthic crustacea preferentially accumulate the ionic form. Most of the ^{57}Co , ^{58}Co , and ^{60}Co introduced into the marine environment from weapons tests and other nuclear technology becomes ionic in sea water and, in estuarine waters, becomes associated mainly with the bottom sediments. The periphyton on these sediments appear to provide the major mechanism for converting ionic cobalt to the complexed form. Experiments done over a 230-day period have shown that marine periphyton convert complexed cobalt (as vitamin B_{12}) to the ionic form ~ 1.5 times as fast as they convert ionic cobalt to the complexed form. In contrast, the complexed cobalt tag occurs

in the periphyton at levels only about half those of the ionic tag (^{60}Co). Thus, the flux of the two forms of cobalt through the periphyton exhibits an inverse relation to the levels contained in the organisms. In the present experiments, particulate matter was present in the water in addition to the periphyton. The particles differed from the attached organisms, however, in that the amount of cobalt tag derived from the complexed metal was present at levels about ten times those of the ionic cobalt. The investigations have not shown whether the suspended particles are composed of unicellular living organisms different from the periphyton, organic debris from the periphyton, or inorganic aggregates. In separate studies it has been shown that about 60% of the cobalt in the estuarine waters of Puerto Rico is in the ionic form and 40% in the complexed state.

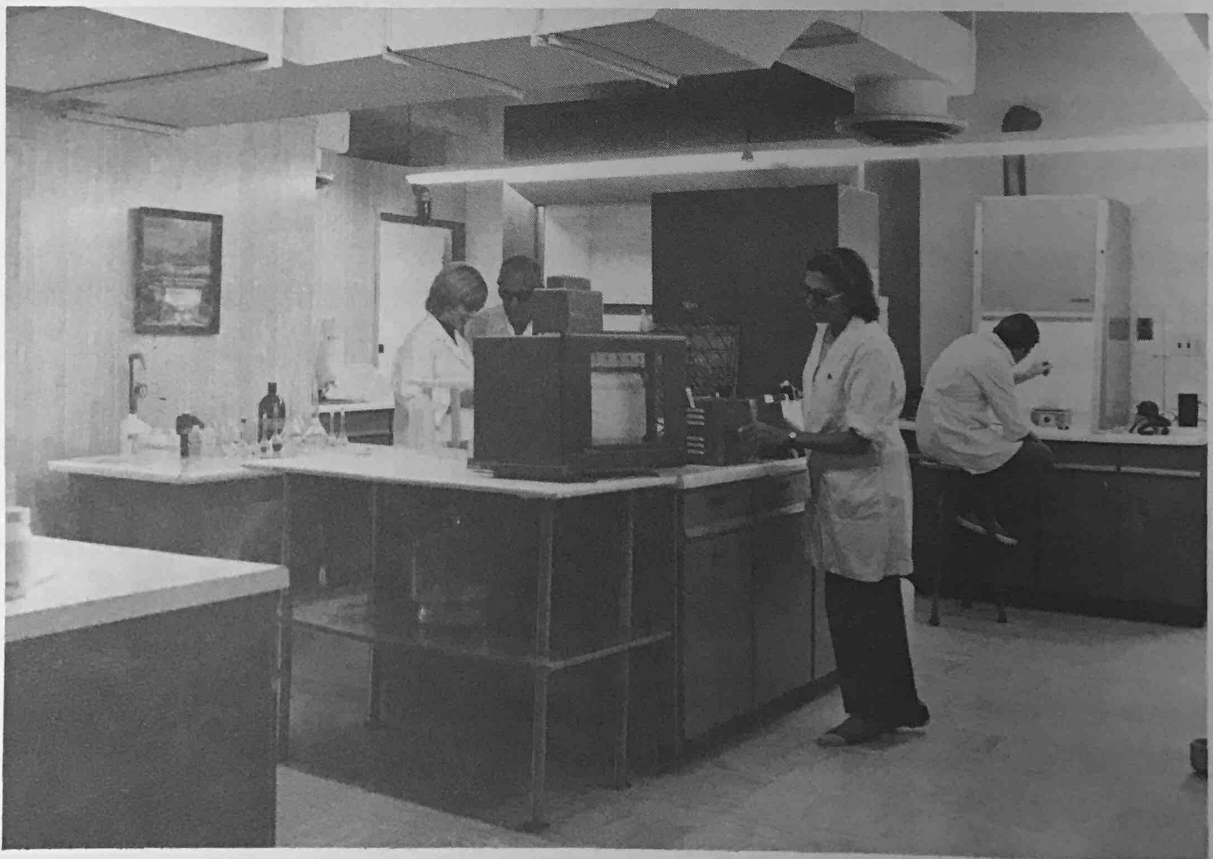
BACKGROUND OCEANOGRAPHIC AND LIMNOLOGICAL STUDIES

Trace Element Distribution in Añasco Bay Sediment Samples. Sediments collected on a 1000-m grid in Añasco Bay have been analyzed for elemental content by atomic absorption spectrophotometry and neutron activation analysis. The results suggest that most of the elements studied are being carried in suspension, rather than dissolved, in the river. A positive relationship has been found between the concentrations of Ca, Sr, Cd, and Pb in one group and between Mn, Fe, Cr, Co, Ni, Cu, and Zn in another group. Magnesium shows poor correlation with all these elements. Concentrations of Ca, Sr, Cd, and Pb are positively related with depth in the sediments and with distance from the river mouth, but Mn and Fe have negative correlation with these two factors. The content of Cr, Co, and Ni decreases at a somewhat lower rate with distance from the river mouth. The distribution of elements in Añasco Bay is greatly dependent on currents, which flow most of the time to the northwest, part of the time to the southwest, and occasionally to the west. Copper distribution in the sediment showed a positive relationship with the current patterns of river water in the bay. Experiments are being carried out on the flocculation of suspended matter with varying salinities in both unfiltered and filtered mixtures of river water and seawater.

Nutrient and Trace Element Concentrations in Water, Sediments, and Organisms in the Guanajibo River and Its Mouth. The concentration of soluble phosphates and trace elements in the Guanajibo River is influenced by the presence of suspended sediments. Suspended particles sorb both orthophosphates and trace elements, to a degree apparently dependent on environmental conditions: dissolved oxygen, $p\text{H}$, $e\text{H}$, and salinity. In the Guanajibo River the quantity of suspended sediments varies greatly between the rainy and dry seasons. The concentration of soluble orthophosphates in the river water is lower during periods of high rainfall. During the dry season, the levels of phosphates in the water are higher but the flow rates of the river are reduced, and, with sugar mills operating, the river becomes anoxic because of a heavy load of organic pollutants. The values



Prof. Muñoz-Ribadeneira and assistant doing chemical extractions.



Cornelia Hill laboratory. In foreground, Mrs. Zaida Carbonell de Padilla at auto-analyzer.

of pH and eH decrease, and phosphates are redissolved from sediments. Iron, manganese, and copper react readily with hydrogen sulfide and turn the water black. The concentration of soluble orthophosphates increases toward the lower reaches of the river, probably because of nutrients from town sewage and from sugar cane fields. From kilometer 38 downstream to the mouth of the river the concentration of soluble inorganic phosphates increases from 1 to 6 μg atoms of phosphate per liter; in the sea, within a mile from the river mouth, the concentration varies from 0.4 to 1.3. The concentration of soluble silicates in the Guanajibo River varies from 700 to 900 μg atoms of silicon per liter, and no increase occurs from the headwaters toward the mouth. Controlled laboratory experiments are in progress on the effects of dissolved oxygen, pH , eH , and salinity on the sorption of phosphates and trace elements on suspended sediments in the river.

ANALYTICAL METHODS FOR TRACE ELEMENTS AND NUTRIENTS

Coprecipitation of Trace Elements. The efficiency of coprecipitation with $Fe(OH)_3$ has been studied for several trace elements whose concentrations in seawater are too low for atomic absorption spectrophotometry without preconcentration. The coprecipitation yield depends on the final pH , and the maximum yield is obtained at different pH for different elements. The maximum yields are for Pb 100% and for Cu 93% at pH 9.0, for Zn 95% at pH 9.4, for Co 88% and for Ni 87% at pH 9.7, for Mn 95% at pH 9.8, and for Cd 65% at pH 10.0. The optimum for this whole group, except Cd, appears to be pH 9.4. At higher pH values the yields of Co, Ni, and Mn increase slightly but the yields of Zn, Pb, and Cu decrease.

Neutron Activation Analysis. Neutron activation, with computer analysis of the data, has been developed for the trace elements Sc, Cr, Fe, Co, Zn, Se, Ru, Cd, Sb, Te, Cs, Hg, Tl, and U in seawater, sediments, and biological samples. Freeze-dried samples are irradiated in quartz ampoules in a neutron flux of 8×10^{12} $n\ cm^{-2}\ sec^{-1}$ for 60 hr. Samples are allowed to cool for one week and then counted with a 44-cm³ Ge(Li) detector. The spectra are punched on IBM cards and analyzed by a computer program which determines peaks, areas under the peaks, and counting errors, and then matches the peaks to a library of peaks and gives the possible nuclides for each peak along with the absolute activity corrected for the decay. These data are further computed to give concentration as ppm. The sensitivities obtained (in ppb) are Cd, 15; Co, 0.002; Cr, 0.2; Cs, 0.003; Fe, 800; Hg, 0.1; Rb, 0.25; Sb, 0.05; Sc, 0.002; Se, 0.01; Zn, 0.1.

Preconcentration of Phosphates. Preconcentration of soluble inorganic phosphates in offshore water samples is necessary because of the low phosphate levels in the Caribbean. An ion exchange method has been developed, based on an ammonium molybdophosphate reaction in a Dowex 1X8 column, that gives concentrations >50 times those in the water. The phosphates are eluted from the column by 1 N NaOH in 90% yield.



Scientific assistants prepare a recording current temperature meter for submersion.

Jobos Bay Energy Center

In September 1970 a research project, sponsored by the U.S. Atomic Energy Commission and the Puerto Rico Water Resources Authority (PRWRA), was started, to determine the ecological effects of the energy center being built at Bahía de Jobos on the south coast of Puerto Rico. The center will have two conventional plants with possible expansion. The plans for the project were presented in detail in the 1970 *Annual Report*.

The determination of proper placement of intake and discharge pipes for cooling water requires studies of physical and chemical hydrology and of native marine ecosystems. For these, detailed knowledge is needed of the currents in the area and the effects, if any, of the power plants. The oceanography of the area has been defined and modeled; this has resulted in major engineering alterations in consideration of the environment. In addition to engineering considerations, some of the studies have given data which may be used in the evaluation and modeling of the ecosystem dynamics. The basis for this effort was presented by Dr. M. J. Canoy in a paper before the American Association for the Advancement of Science, in which present and future changes in the Bay system were explored in terms of ecosystem theory and modeling. The total result is the most extensive single ecological study ever conducted in the American tropics. Already the species records include several unknown or previously unreported species for the area.

Studies, described in 1970, are continuing on the concentrations of stable elements in sea water, sediments, and organisms. Monitoring stations for air, plants, ground water, and bay water are in operation for species diversity, biomass, heavy metals, and nutrients. The effects of elevated temperatures on marine organisms are also being studied. For ecological research on the mangrove forests, turtle grass beds, and coral reefs surrounding the plant site, a detailed ecological baseline has been established, with attention to predictive as well as evaluative parameters.

The PRWRA participation has doubled with each year of the program until at present the Jobos 51 budget approximates \$388,000. Of this, \$52,000 is contributed by the AEC. The AEC share is used for basic research in the following areas:

Plankton. The dynamics, species diversity, and biomass of the plankton system are being studied with special attention to species distribution and possible effects of pumping on the planktonic population. The importance of the plankton to the food web and its contribution to fisheries are being evaluated. The plankton studies have been intensified, and several previously undescribed species for Puerto Rico have been described. Programs are also under way to determine possible population shifts toward detrimental planktonic bluegreen algae in thermal effluents, potential beneficial effects of pumping, and energetics of plankton production.



Radar drogue for tracking currents.

Mangrove and *Thalassia*. Species diversity, biomass, and chemical and physical parameters of the mangrove and *Thalassia* systems are being worked out. The importance of these systems relative to other ecosystems of the area, such as coral reefs and fisheries, is being defined. These studies are being correlated with the work begun by Dr. Kohlemainen, now supervised by Dr. F. D. Martin, at Guayanilla Bay on the south coast, which has received thermal additions for 15 years. These studies are showing surprising results in terms of effects of thermal effluents far in excess of commonly accepted "limits" or legal definitions. Mangroves have been found to survive and reproduce at 38°C, well above their previously "known" lethal limit. In addition, the mangrove root communities remain essentially normal up to 32°C (8° to 9°F above ambient). The alteration of fish and fisheries is not detectable statistically except in the range of 36° to 39°C. This may mean that the role of "thermal pollution" has been overrated and in small amounts might even be termed "thermal enrichment" since at 2°C above ambient shellfish grow larger, faster.

Coral Reefs. The major parameters of interest in coral reef ecosystems are species diversity, distribution, and biomass. The degree of interfacing with systems such as *Thalassia* beds is under consideration. The coral reef as a feedback multiplier in this ecological system is being studied by Dr. M. J. Canoy. The reefs form an essential barrier against waves and tides and serve to alter the chemistry.

Fish. Fishery research has provided a baseline of some 139 species common in the area. Species distribution and diversity are being worked out. Although the fish production is average for a tropical area, and is diverse, the yield to man is low. Few commercial species are numerous enough to be profitable, and sport fishing facilities are poor. The only potential in this area appears to be creation of areas of artificial "upwelling." One way to do this might be to use deep, colder Antarctic midwater with its greater nutrient level to cool power generators, and to release effluents at ambient levels.

Thermal Studies. In addition to the field project at Guayanilla Bay, observations are being made at Jobos Bay, where mangrove root communities are naturally subjected to fluctuation of as much as 5° to 6°C. Laboratory research includes respiratory and radioisotope uptake studies at elevated temperatures on organisms maintained in 15-gal aquaria. In addition a 750-lb constant temperature block has been constructed for respiration and developmental studies of fish and brachyuran larvae, corals, and plankton. These preliminary studies have shown larval stages of tropical organisms to be much more sensitive than adults to temperature changes.

Other Studies. These include the radiological monitoring program; working out an energy budget and model for the ecosystems of the area; determination of heavy metals

accumulations in the air, water, and biota; and cooperation in the PRWRA Site Selection Survey, in which eight potential power generator sites are being studied with regard to ecological and oceanographic parameters. Bird counts are being made in the southwest region of Puerto Rico and in the Jobos Bay area.

THERMAL STUDIES IN GUAYANILLA BAY

It has been claimed that tropical marine organisms live at temperatures very close to the upper limit of their thermal tolerance. In the tropics they are exposed to very small seasonal changes in temperature. In Puerto Rico both the diurnal and the seasonal temperature change in the surface water is about 5°C, but information on the thermal tolerance of local species has been lacking. In Florida the temperature tolerance of a few tropical marine organisms has been studied; however, since Florida is subtropical, the environmental conditions differ greatly from those in Puerto Rico. Many of the species in Florida are actually temperate species at the southern extremity of their range. Because of the higher annual temperatures, species in Puerto Rico may be genetically hardier toward high temperatures than the same species in the subtropics. Also, experiments have shown that the upper thermal tolerance increases with increased acclimation temperature. Therefore, the maximum temperature at which a given species can survive could be higher in the tropics than in the subtropics.

Thermal studies were started in 1972, under a one-year contract between PRNC and PRWRA, in Guayanilla Bay, where PRWRA has a fossil-fueled thermoelectric plant that has been discharging cooling water for 15 years at a rate of 715 m³/min at 10°C above the ambient into a 14.3-hectare cove that opens to the Bay. This contract now appears to be an on-going study. The cove has mangroves growing on one side along its entire shoreline and extending far beyond along the shoreline of the Bay. Just outside the cove are beds of turtle grass (*Thalassia testudinum*). Since the ecosystems in Guayanilla Bay are similar to those in Jobos Bay, the information gained here will be directly applicable to Jobos Bay.

The studies in Guayanilla Bay include standard oceanographic measurements and analyses for nutrients, trace elements including heavy metals, and hydrocarbons in water, organisms, and sediments. Effluents into the Bay from petrochemical and chemical industry necessitate study of the extent of chemical pollution also. Temperature distribution in the plume area has been measured 4 times: October 9, 1971, January 13, 1972, March 10, 1972, and August 16, 1972. The ambient temperatures were 30° to 25.7°C.

The effects of elevated temperatures on marine organisms have been studied by determining the species diversity, density, and biomass in plankton, benthos, benthic foraminifera, turtle grass community, mangrove root community, and fish. Studies of marine organisms coming through the condensers and discharge canal were described last year.

Studies of biomass and species diversity in fish populations showed that they are not significantly different from those in Jobos Bay. This was a totally unexpected result.

Studies on the effect of temperature on species diversity of organisms living on mangrove roots were described last year.

Fish are abundant in the cove and have a somewhat higher biomass there than outside. In general, species in Guayanilla Bay have been found living at higher temperatures than in temperate or subtropical climates. Living populations have been observed in water at temperatures only 1.5° to 3.0°C below the known upper short-term thermal limits of the species.



Coral reef in Jobos Bay, with elkhorn corals, gorgonians, and small wrasses (fish).

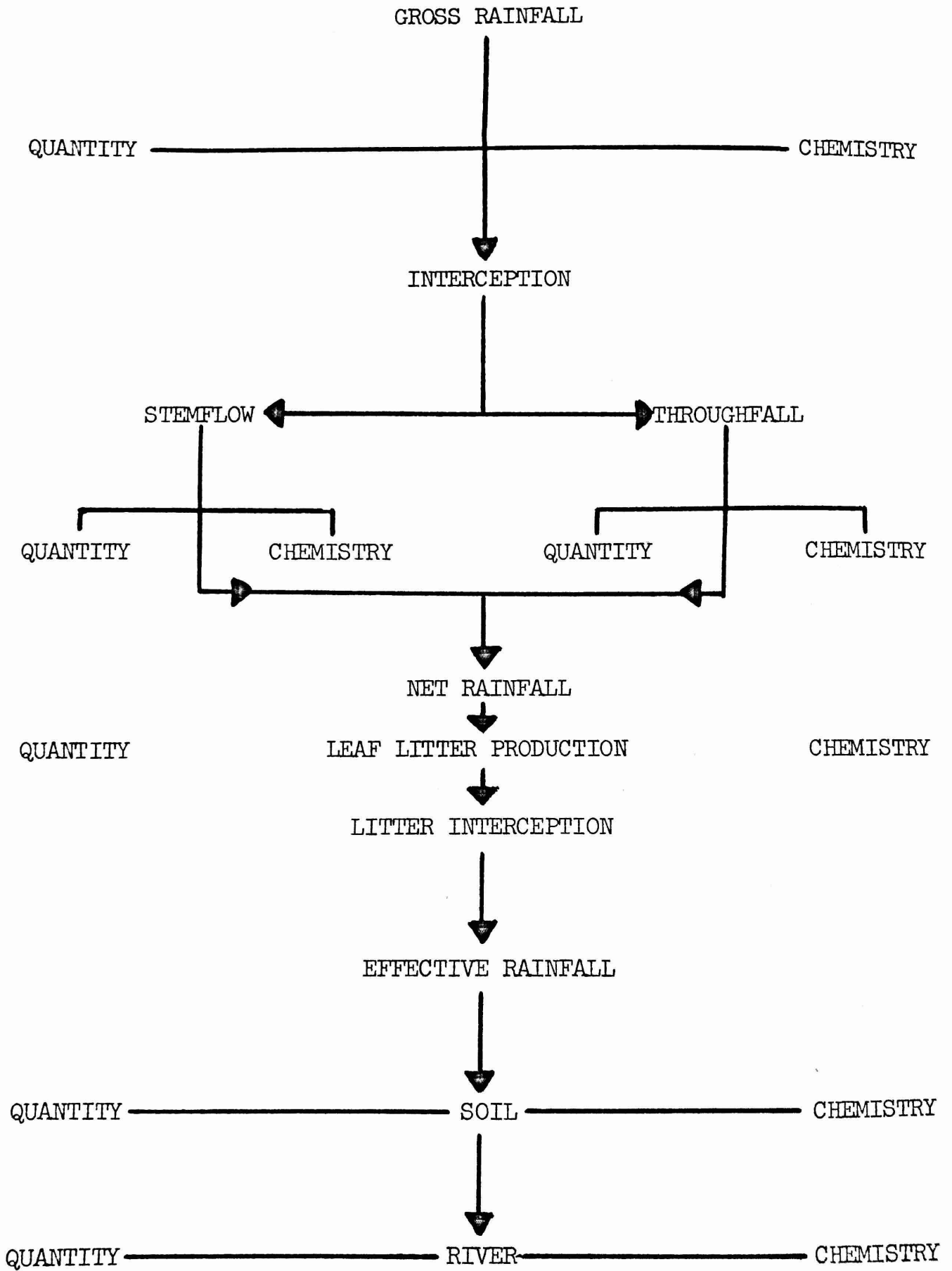


Figure 1. Schematic diagram of the comprehensive rainfall interception study at El Verde.

Terrestrial Ecology

The movement and transfer of isotopes, both stable and radioactive, in a tropical forest system continues as the main focus of the Terrestrial Ecology Program. In addition, investigations are being conducted in the areas of animal ecology and the recovery of the forest from gamma irradiation.

The interception study initiated in 1970 is a multifaceted study designed to elucidate the hydrologic cycle and subsequent movement and transfer of isotopes in the forest system. The study has the following four objectives:

1. To determine the quantitative relationships between gross rainfall as measured above the canopy and the parameters of throughfall and stemflow yield, litter interception and evaporation, and soil moisture changes.

2. To determine the chemistry of each parameter and define the chemical changes that occur as rainfall is intercepted and redistributed as throughfall and stemflow. The elements of concern are calcium, magnesium, sodium, potassium, phosphorus, manganese, iron, copper, cobalt, and strontium.

3. To develop predictive equations through correlation-regression analysis on the relationships between gross rainfall and the associated interception parameters.

4. To utilize the information obtained for the design of future cycling studies at the watershed level with radioisotopes used to measure transfer rates.

A schematic diagram of the comprehensive study is shown in Figure 1. Preliminary results dealing with various phases of the study down to and including net rainfall were reported last year (PRNC-157). Progress this past year has been centered on (1) leaf litter production and chemistry and (2) chemical analysis of stream water.

LEAF LITTER

Leaf fall is the major factor in input of isotopes to the forest ecosystem. Although leaf fall is continuous, the subsequent decomposition of leaves and turnover of isotopes at the forest floor level is the least understood part of the system. It is generally accepted, since leaf litter *per se* does not accumulate from one year to the next, that the decomposition process takes less than a year. Leaf fall shows variations seasonally within a given year and also between years, but it cannot be said with certainty what factors are controlling it.

Twenty-five 1-m² leaf collection baskets were randomly placed throughout the 80X 80-m study area in January 1970. The leaf litter production for 1970, 1971, and 1972

Table 1
Elemental Composition (ppm) of Leaf Litter for First 24 Months
(Average of Monthly Analyses)

Element	Average	S.E.	Minimum	Maximum
Phosphorus	218	± 5	172	284
Potassium	1300	55	812	1980
Sodium	940	56	544	1486
Calcium	15253	738	9118	21358
Magnesium	1904	74	1290	2526
Manganese	349	6	264	411
Copper	7.3	0.1	5.9	9.7
Cobalt	10.8	5.0	4.6	16.1
Strontium	70	1	59	81
Iron	143	86	88	272

Table 2
Contribution of Leaf Litter to the Elemental Budget
of a Tropical Rain Forest (kg/hectare/yr)

Element	1970	1971
Phosphorus	1.25	1.10
Potassium	7.27	6.73
Sodium	5.31	4.82
Calcium	70.49	93.22
Magnesium	9.31	11.15
Manganese	1.86	1.89
Iron	0.80	0.74
Copper	0.04	0.04
Cobalt	0.05	0.06
Strontium	0.39	0.36

was 5525 ± 488 , 5246 ± 389 , and 4663 ± 259 kg/hectare respectively. The decline in leaf fall was no doubt coupled to moisture conditions. Overall records showed a decrease in annual rainfall from 155 inches in 1970 to 100 in 1971 and 86 in 1972. However, the drier months of February, March, and April that preceded maximum leaf fall may have controlled leaf fall. Total rainfall during this three-month period for the years 1970, 1971, and 1972 was 10.4, 19.6, and 20.0 inches respectively. Thus the above-normal rainfall during this period in 1971 and 1972 may have been responsible for the decrease in production of leaf litter. Production measurements will be continued for one more year and then reevaluated.

Chemical analyses have been completed on leaf litter collected during the first 24 months. Analysis of the litter collected during the last 12 months will be available by March 1973. The monthly data averaged in Table 1 suggested that the lowest contents of elements were associated with the drier months and the highest, with the months preceding maximum leaf fall. The contents of potassium and sodium did not follow this rule but varied considerably from month to month. Whether elemental concentrations in rainfall or throughfall affect the final concentrations in leaf litter as it accumulates during each collection period is not known. In rains received from a northerly direction rather than the normal easterly direction, the sodium and potassium concentrations were higher by a factor of 10.

By combining data on the chemistry of leaf litter and on its production, one can obtain an estimate of the contribution of leaf litter to the annual input of each element to the forest system (Table 2). The input from this source was relatively low on an annual basis. Final interpretation will depend on an evaluation of all inputs to the system such as contributions from rainfall, throughfall, stemflow, and soil. These data are now being put on IBM cards for final analysis, and the formulation of preliminary models describing the cycling of elements will begin next year.

STREAM WATER

The chemistry of two freshwater streams continues to be monitored on a routine basis. The Rio Sonadora flows through the project area and the Quebrada Grande is adjacent to it on the east. Since September 1971 samples have been taken Monday through Friday of each week from the Rio Sonadora; sampling of the Quebrada Grande began in March 1972. The results for the Sonadora, representing 56 weeks of observations or ~ 230 determinations, showed a remarkable constancy in concentrations throughout the year. The average concentrations in ppm for sodium, potassium, calcium, and magnesium were found to be 4.62 ± 0.06 , 0.28 ± 0.02 , 1.34 ± 0.10 , and 1.47 ± 0.04 respectively. The results from the Quebrada Grande over seven months reflect the same constancy but at a higher level: 7.76 ± 0.15 , 0.48 ± 0.03 , 3.80 ± 0.35 , and 4.26 ± 0.18 . The ratios Na:K and Mg:Ca were practically identical in the two rivers. Preliminary determinations showed

dissolved oxygen values to be near maximum for the existing conditions: 8.2 ppm. In-stream pH measurements gave identical results of 7.7. Water temperatures recorded in the Quebrada Grande were 25°C, 3° warmer than in the Sonadora (22°); this is to be expected because of the degree of shading of the latter. The higher concentrations of elements in the Quebrada Grande may be due to the grasslands on either side of it above the sampling point. The area above the sampling point on the Sonadora is covered completely by forest. Thus we may be seeing the effects of cleared versus uncleared areas on the export of elements from the system. Similar observations have been reported at the Coweeta Hydrological Laboratory in South Carolina.

This past year a series of cooperative research efforts were begun between the Terrestrial Ecology Program and the Division of Physical Sciences at PRNC. A proposal was submitted to the University of Puerto Rico to study atmospheric pollutants by neutron activation. Because of lack of funds, the proposal was not accepted, but we were requested to re-submit it next year. A series of studies were initiated to investigate the electronic properties of plant hormones and inhibitors produced in the decomposition of forest leaf litter. Personnel participating in these studies are Drs. Grimison, Block, Eberhardt, and Clements.

Cooperative work was done this year with scientists from the University of California, Ohio State University, Florida State University, the University of North Carolina, the University of New Hampshire, and the University of Puerto Rico. This cooperative work will continue.

Currently four students are conducting thesis research at the El Verde station. Three are M.S. candidates, two from the University of Puerto Rico and one from the University of New Hampshire. The fourth is a doctoral candidate from the University of North Carolina.

INFORMATION AND EDUCATION SERVICES

The Information and Education Services Division provides centralized direction and coordination for information and education activities of the Puerto Rico Nuclear Center.

In the information field the Division maintains master files on all publications originating at PRNC, prepares manuscripts for patent clearance and publication release in accordance with US AEC procedures, operates a US AEC Film Library, maintains technical reading rooms, handles the majority of PRNC duplicating and copying needs through its reproduction facilities, assists in the preparation of PRNC reports, education and training bulletins, brochures, press releases, and other documents, provides editorial and translation services, and assists visitors.

In the education field the Division maintains master files on all PRNC training and education activities, prepares reports on educational activities required by the US AEC, schedules utilization of classroom and audiovisual facilities, assists students in such matters as immigration, housing, academic information, etc., assists in the preparation of special courses, institutes, meetings, and other educational activities as required, and administers the PRNC Student Economic Aid Fellowship Fund and the OAS Regional Scientific and Technical Development Program activities at PRNC. Tables 1 and 2 summarize recent activities in these fellowship programs.

STAFF

On June 1, Mr. Frederick E. Rushford was given a joint appointment as Coordinator for Nuclear Programs for the Office of the President of the University of Puerto Rico and as Educational Officer of PRNC. Mr. Rushford now devotes 67% of his time to PRNC as Head of this Division and Educational Officer. On August 24 and 25 he met with officials of the Organization of American States to review the participation of PRNC in the OAS Regional Scientific and Technological Development Program in Nuclear Energy. He also visited the Pan American Health Organization and the American Association of University Women Educational Foundation. On November 2-3 Mr. Rushford represented PRNC at a US AEC Technical Information Program Meeting offered by the Office of Information Services at the US AEC Technical Information Center in Oak Ridge.

Table 1
PRNC Student Economic Aid Program - Fiscal Year 1973 - \$10,000.00

Name	Country	Training	Inclusive Dates	Grant
1. Percy C. Naranjo Williams, M.D.	Peru	Clinical Radioisotope Applications	Jul 72 - Aug 72	300
2. Jorge D. Caputto Escudero, M.D.	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	775
3. Ricardo G. Decillis Caló, M.D.	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	675
4. Luisa N. E. Pérez	Argentina	Clinical Radioisotope Applications	Jul 72 - Sep 72	100
5. Joao Soares Almeida, M.D.	Brazil	Clinical Radioisotope Applications	Jul 72 - Aug 72	300
6. Freddy Medina	Dominican Republic	M.S. in Biology	Jul 72 - Sep 72	600
7. Alberto J. Moreno	Colombia	M.S. in Physics	Jul 72 - Sep 72	600
8. Assad Sabag Tiscareño	Mexico	Radiation Therapy	Aug 72 - Mar 73	2,400
9. Gilberto Arenas Rosillo	Colombia	M.S. in Nuclear Engineering	Oct 72 - Dec 72	300
10. Eddie Ríos Olivares	Nicaragua	Special Training in Virology	Nov 72 - Dec 72	250
11. Alejandro Trigo Chávez	Bolivia	Clinical Radioisotope Applications	Feb 73 - Mar 73	500
12. Gentil Estevez	Colombia	M.S. in Physics	Apr 73 - Jun 73	1,250
13. Luciano Griffin	Venezuela	M.S. in Nuclear Engineering	Jun 73	250
14. I. K. Lingappan	India	M.S. in Nuclear Engineering	Jul 73	300
15. Jesús E. Michelen	Dominican Republic	M.S. in Nuclear Engineering	Jul 73	300
16. Abraham Musalem	Dominican Republic	M.S. in Nuclear Engineering	Jul 73	300
17. Eduardo M. Durán	Panama	Special Training in Fascioliasis	Jul 73 - Aug 73	400
18. Moisés Camacho	Colombia	M.S. in Chemistry	Jul 73 - Aug 73	400

Table 2
OAS Regional Scientific and Technological Development Program - Nuclear Energy - Fiscal Year 1973

Name	Country	Training	Inclusive Dates
1. Eleuterio Molinas Villasanti	Paraguay	M.S. in Radiological Health	9 Aug 71 - 5 Aug 72
2. Angel B. Reyes Vega	Ecuador	Special Training in Reactor Control	10 Jan 72 - 9 Sep 72
3. Gentil A. Estevez Gómez	Colombia	Special Training in Nuclear Physics	10 Jan 72 - 10 Apr 73
4. José Mireles Sahagun	Mexico	Special Training in Nuclear Engineering	10 Jan 72 - 16 Oct 72
5. Santiago Gómez Figueroa	Colombia	Training in Agricultural and Biological Sciences; M.S. in Radiological Health	12 Jan 72 - 31 Jul 73
6. Aníbal J. Camnasio Simoni	Argentina	Special Training in Nuclear Physics	1 Jan 72 - 30 Jun 73
7. Ariel Alonso Oroz	Uruguay	Special Training in Nuclear Reactor Operation and Supervision	1 Feb 72 - 9 Feb 73
8. Clovis Abrahao Hazin	Brazil	M.S. in Radiological Health	15 Feb 73 - 15 Aug 73

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 the center for internal and external communications and for management of meetings and conferences. The staff also participates in the teaching and research activities of several PRNC divisions.

JOHN C. BUGHER MEMORIAL LECTURE

At the invitation of UPR President Amador Cobas, Dr. Charles L. Dunham presented the second John C. Bugher Memorial Lecture on September 29, 1972, in the auditorium of the University's Agricultural Experiment Station. Dr. Dunham is Director of Medical Sciences at the National Research Council in Washington, D.C., and former Director of the AEC Division of Biology and Medicine (now Division of Biomedical and Environmental Research). His topic was "The Atomic Bomb Casualty Commission and the Late Effects of Ionizing Radiation." Following the lecture, President and Mrs. Cobas held a reception at their residence in honor of Mrs. John C. Bugher, who came to Puerto Rico to attend the lecture, and Dr. and Mrs. Dunham.



Mrs. John C. Bugher (left) with Dr. & Mrs. Charles Dunham and UPR President Amador Cobas at Bugher Memorial Lecture.

MEETINGS

The US AEC Bio-Medical Program Directors' Meeting was held at the Puerto Rico Nuclear Center in San Juan on February 7-8. Current research activities at PRNC sponsored by the US AEC Division of Biology and Medicine were summarized for the visiting participants during the meeting.

The PRNC research vessel *Palumbo* was made available for a visit following presentations of the Radioecology Division. The social activities included an invitation from the Governor of Puerto Rico, the Hon. Luis A. Ferré, to a reception at La Fortaleza, the Executive Mansion. The University offered a luncheon at its Experiment Station in Río Piedras.

A colloquium in Health Physics was held at the Puerto Rico Nuclear Center in Río Piedras on April 11-12, 1972.

The Tenth Annual Meeting of the Caribbean Food Crops Society was held June 11-17 at UPR Mayagüez. Dr. F. K. S. Koo, Dr. S. N. Deshpande, Dr. D. W. Walker, Mr. J. Cuevas-Ruiz, Miss Carmen Asencio, and Miss Carmen A. Vega attended the scientific sessions on June 12 and 14.

The Nuclear Medicine Society of Puerto Rico held a meeting at the Puerto Rico Nuclear Center in Río Piedras on June 19. Dr. Aldo E. Lanaro and Dr. René C. Dietrich discussed the importance of lung scanning in the study of cardiovascular malformations.

The Eighth Meeting of the Inter American Nuclear Energy Commission of the Organization of American States was held at the Caribe Hilton Hotel in San Juan on July 12-14, 1972. The United States Government was official host of the meeting, and the Puerto Rico Nuclear Center provided local supporting services for the meeting Secretariat.

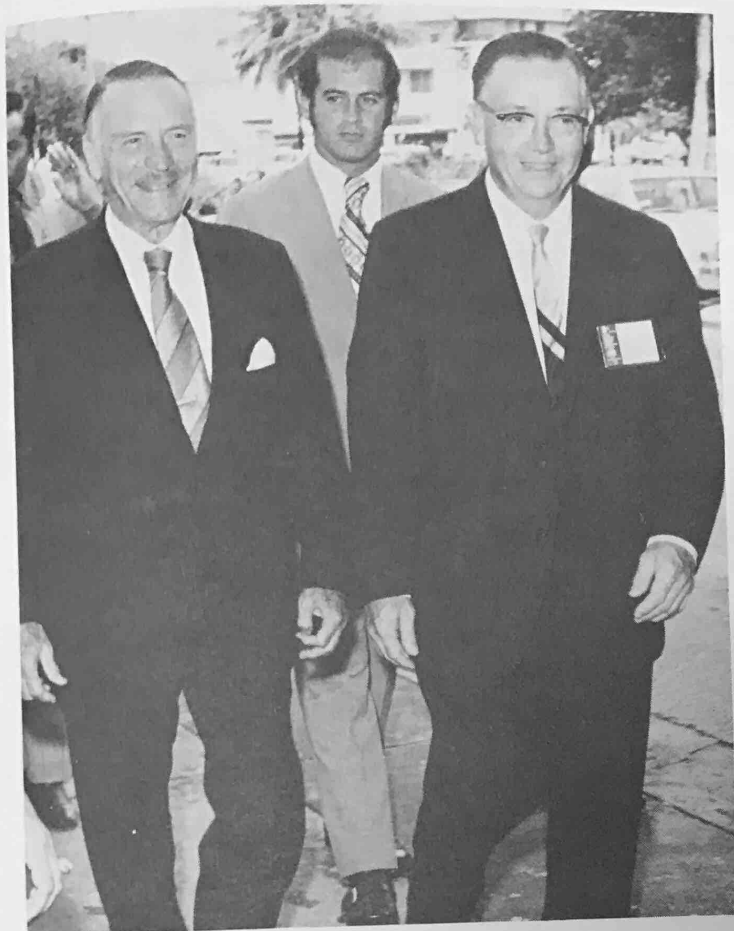
The AEC Division of Operational Safety held its Fifteenth Annual Health Protection Meeting at the San Jeronimo Hotel in San Juan on December 7-9, 1972.

The Health Physics Society held its Seventh Midyear Topical Symposium, *Health Physics in the Healing Arts*, at the San Jeronimo Hotel in San Juan on December 11-14, 1972. The Symposium was sponsored by the Puerto Rico Chapter of the Health Physics Society and cosponsored by the US AEC/UPR Puerto Rico Nuclear Center and the US PHS Bureau of Radiological Health. More than 300 scientists and students registered for the Symposium, and an additional 120 ladies participated in the Ladies' Program.

STAFF

On February 22, Dr. Amador Cobas was appointed President of the University of Puerto Rico by the Council on Higher Education. Dr. Cobas had been serving as Acting President of the University for approximately four months, on leave from the Puerto Rico Nuclear Center.

Dr. Edwin Roig, Acting Director of PRNC, was recently appointed a member of the Executive Committee of the Puerto Rico Undersea Research and Development Company, Inc.



Governor Luis A. Ferré
(followed by his aide,
Mr. Duffy) and US AEC
Commisioner James T.
Ramey arriving at IANEC
meeting.



Dr. J. P. Morgan, Area Manager
PRAO, US AEC (left), Commis-
sioner Ramey, and Dr. Edwin
Roig, Acting Director of PRNC,
at IANEC meeting.

The Executive Committee will establish guidelines and priority for the use of the underwater habitat based on present and future needs of the Commonwealth of Puerto Rico and adjacent Caribbean regions.

Dr. Roig attended the annual meeting of University Consortia and Laboratory Education Directors held in Albuquerque, New Mexico, October 25-27.

Dr. Aldo E. Lanaro was appointed Head of the Clinical Radioisotope Applications Division effective March 1. He has served as Acting Head of the Division since October 1, 1969. He was appointed Treasurer of the Asociación Latino Americano de Biología y Medicina Nuclear by the Executive Council of the Association. The Puerto Rico Society of Nuclear Medicine, of which Dr. Lanaro is President, was incorporated into the Association at its annual meeting in Santiago, Chile, on October 27, 1972.

Dr. Frank G. Lowman was appointed Associate Director for Environmental Sciences on February 10, but continued as Head of the Radioecology Division and Head of the Marine Biology Program. The additional research projects initiated in the Radioecology Division during the past few years, plus the demand for Dr. Lowman's guidance on immediate environmental problems of concern to Puerto Rico, increased his responsibilities substantially. The position of Associate Director more accurately reflects the reputation Dr. Lowman has earned as the leading resident authority in his field.

Dr. Lawrence S. Ritchie, who has been Acting Head of the Division of Medical Sciences and Radiobiology since June 1971, was appointed Head of the Division on June 1st.

On June 1, Mr. Frederick E. Rushford, Head of the Information and Education Services Division, was given a joint appointment which will permit him to devote one-third of his time to assisting President Cobas in the coordination of nuclear programs at the University.

Dr. Alec Grimison, who assumed responsibility for the Division of Physical Sciences in October 1971, was appointed Head of the Division on June 1, 1972. He accepted an appointment from the UPR President to coordinate all academic and research use of the university data processing systems and computers, effective December 1, 1972. Dr. Grimison continued his duties at the UPR Chemistry Department under a joint appointment with the UPR President's Office, but his official appointment at PRNC has terminated.

Dr. Seppo E. Kolehmainen, who has shown unusual ability as a scientific investigator and the capacity to direct field operations during the three years he has worked in the programs of the Radioecology Division, was appointed Head of the Marine Biology Program, on Sept. 1.

COMMITTEES

The new Liaison Committee between the Puerto Rico Nuclear Center and the UPR School of Medicine has the following members:

Dr. Conrado Asenjo, Chairman*

Dr. Carlos Girod, *ex officio*

Dr. José E. Sifontes

Dr. Mario R. García Palmieri

Dr. Julio E. Colón

Dr. Edwin Roig, *ex officio*

Dr. Víctor A. Marcial

*Dr. Sifontes took over as Chairman in August.

The committee membership was announced by Dr. Carlos E. Girod, Dean of the UPR School of Medicine, on January 20, 1972. The purpose of this Committee is to establish and maintain a strong and fruitful collaboration between the Puerto Rico Nuclear Center and the UPR School of Medicine.

Dr. Julio Colón, Associate Professor of Microbiology at the School of Medicine and Director of the Virus Project at PRNC, has been appointed by Chancellor Adan Nigaglioni as Chairman of the Graduate Studies Committee which coordinates graduate studies on the Medical Sciences Campus. The Committee will emphasize integration of research resources available within the University and at other institutions in order to strengthen graduate programs on the Medical Sciences Campus.

VISITORS

During his stay in Puerto Rico, Commissioner James T. Ramey visited the PRNC laboratory at the Río Piedras Medical Center on February 14. Commissioner Ramey had an opportunity to review current activities of the laboratory and to visit the new facilities at the Bio-Medical building.

Mr. Robert J. Hart, Manager, Oak Ridge Operations, US AEC; Dr. Elliot Pierce, Director, Division of Nuclear Education and Training, US AEC, Washington, D.C.; and Dr. J.C. Kirby, Assistant Director for Biological Sciences, Division of Biology and Medicine, US AEC, Washington, D.C., visited the PRNC facilities in Río Piedras on May 18-19. This was Mr. Hart's first visit to PRNC since becoming Manager of ORO.

Two visitors from the US AEC, Washington, D.C., met with members of the PRNC staff the week of September 25 to review current activities: Mr. John Cera, Assistant to the Director of the Division of Nuclear Education and Training, and Mr. Justin L. Bloom, Policy Planning Advisor in the Division of International Programs.

On November 13-17, Dr. Claude L. Yarbrow, from the Research and Development Branch of the Research and Technical Support Division at the AEC Oak Ridge Operations Office, visited PRNC facilities in Río Piedras and Mayagüez to acquaint himself with present programs and activities.

Dr. Elliot Pierce, Director of the AEC Division of Nuclear Education and Training, was in San Juan on November 13-14 to visit UPR President Amador Cobas and to discuss the DNET program with Acting Director Edwin Roig.

Publications

1. *Annual Report 1971*, PRNC-157.
2. Alegría, J. L. (AEC of Argentina), Cunha, O. (AEC of Brazil), Graef-Fernández, C. (AEC of Mexico), and Chiriboga, J., *Report on Possible Peaceful Uses of Atomic Energy in Latin American Countries* (in Spanish) (IANEC, Meeting of Group of Four Experts in Nuclear Affairs, Aug 28-30, 1972), OAS/Ser. L/IV.2.8 IANEC/doc.18, 19 Oct. 1972.
3. Arce, R., Eberhardt, M.K., Grimison, A., and Simpson, G.A., *Gamma Radiolysis of Heterocyclic Molecules, Progress Report No. 6, September 1972*, PRNC-159.
Bosch, A. - See Lanaro, A. E.
4. Brown, R.A., Knight, W.B., and de León, D., The Apparent Density of *Schistosoma mansoni* and *Fasciola hepatica* eggs, *J. Agr. Univ. P.R.* 56, 324-6 (1972).
Brown, R.A. - See also Ritchie, L.S.
5. Brown-Campos, R. and Rivera, J.E., *Operating Procedures for the PRNC TRIGA FLIP Reactor*, PRNC-158, August 1972.
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6. Castrillón, J.P.A., Nitriles as Scintillation Solvents and Solutes (assigned to US AEC), U.S. Patent 3,671,455, June 20, 1972.
7. Chiriboga, J., de León, D., and Ritchie, L.S., *Fasciola hepatica Program in Puerto Rico, Progress Summary Report, December 1971*, PRNC-156.
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8. Coronel, G. and Gonzalo, J.A., Thermal Conductivity of TGS Near the Curie Point, *Ferroelectrics* 4, 19-22 (1972).
9. Cuevas-Ruíz, J., Effects of Gamma Radiation on the Biochemical Components of Mangoes Grown in Puerto Rico, *J. Agr. Univ. P.R.* 56, 26-31 (1972).
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10. de León, D., Ritchie, L.S., and Chiriboga, J., Fascioliasis in Dairy Cattle in the Dorado Area, *J. Agr. Univ. P.R.* 56, 88-92 (1972).
de León, D. - See also Brown, R.A.; Chiriboga, J.
Dellonte, S. - See Weisz, S.Z.
11. Dorian, J.F. (Penn. State), Newnham, R.E. (*ibid*), Smith, D.K. (*ibid*), and Kay, M.I., Cristal Structure of $\text{Bi}_4\text{Ti}_3\text{O}_{12}$, *Ferroelectrics* 3, 17-27 (1971).
12. Eberhardt, M.K. and Chuchani, G. (IVIC), Electrophilic Aromatic Triphenylmethylation. Self-Consistent Field—Molecular Orbital Calculations on Aniline, *N*-Methylaniline, *N,N*-Dimethylaniline, and Ortho-Substituted Anilines. *J. Org. Chem.* 37, 3649-53 (1972); Phenol, Alkoxybenzenes and Ortho Alkoxyphenols, *Ibid.* 3654-7.

- Eberhardt, M.K. - See also Arce, R.
 Feliú, L.A. - See Wheeler, O.H.
13. Ferrer-Monge, J.A., A Rapid Method for Making Permanent Squash Slides (in Spanish)
Acta Cient. Venez. **22**, 219-20 (1971).
 Frías, Z. - See Lanaro, A.E.
 Gileadi, A.E. - See Gileadi, M.; Pedersen, K. B.
 14. Gileadi, M., *Joint Dental Radiation Survey, Puerto Rico, 1968*, for Dept. of Health,
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 15. Gileadi, M. and Gileadi, A.E., Methods and Results—Joint Radiation Survey, Puerto
 Rico, 1968, in *Proc. 6th Int. Congr. New Trends in Radiation Protection*,
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 17. Jordan, C.F. (ANL), Kline, J.R. (ANL), and Sasscer, D.S., Relative Stability of Min-
 eral Cycles in Forest Ecosystems, *Amer. Natur.* **106**, 237-53 (1972).
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 Knight, W.B. - See Brown, R.A.
 19. Lanaro, A.E., Bosch, A., and Frías, Z., Effects of Irradiation on the Normal
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 20. Lee, R.A., Radiolysis of Methyl Fluoride, *Rev. Latinamer. Quim.* **2**, 159-62 (1971).
 Levinson, J. - See Weisz, S.Z.
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 22. Pedersen, K.B., Sasscer, D.S., Plaza, H., Gileadi, A.E., Brown-Campos, R., and
 Holyoak, R.H. (Commonwealth Edison Co., Chicago), *Applied Nuclear
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 23. Ritchie, L.S., Chiriboga, J., and Brown, R.A., *Studies on Schistosomiasis, Progress
 Summary Report, December 1971*, PRNC-154.
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 Rivera, J.E. - See Brown-Campos, R.
 Sasscer, D.S. - See Jordan, C.F.; Pedersen, K.B.

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25. Seiglie, G.A., A Preliminary Note on the Relationships Between Foraminifers and Pollution in Two Puerto Rican Bays, *Carib. J. Sci.* 11, 93-8 (1971).
26. Seiglie, G.A. and Bermúdez, P.J. (Univ. Cent. Venez.), An Additional Note on the Foraminiferal Genus *Glaucoamina* and *Reophax caribensis*, *Tulane Stud. Geol. Paleontol.* 8, 221-2 (1971).
27. Seiglie, G.A. and Bermúdez, P.J. (Univ. Cent. Venez.), Foraminifers of Mayaguez and Añasco Bays and Their Surroundings. I. *Ehrenbergina scamnicola* sp. nov. (in Spanish), *Rev. Espan. Micropaleontol.* 3, 67-70 (1971).
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28. Walker, D.W., *Insect Sterility Program, Technical Report No. 6, September 1970—January 1972*, PRNC-151.
29. Weisz, S.Z., Dellonte, S., Levinson, J., Cobas, A., and Pereira, L., Surface Trapping in Anthracene Crystals, in *Proc. 2nd Int. Conf. Conduction in Low-Mobility Materials, Eilat, Israel, Apr. 1971*, pp. 361-2, N. Klein et al., Editors, Taylor & Francis, London, 1972.
30. Weisz, S.Z., Levinson, J.Y., and Cobas, A., Interaction of Triplet Excitons with Trapped Electrons in Anthracene Crystals, in *Proc. 3rd Photoconductivity Conf., Stanford, Aug. 1969*, pp. 297-301, Erik M. Pell, Editor, Pergamon Press, Oxford and New York, 1971.
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Papers Presented

1. Agard, E.T., Measurement of Calcium in the Lower Legs by Neutron Activation Analysis Using an α, n Source, presented at Health Phys. Soc. 7th Midyear Topical Symp., San Juan, Dec. 1972.
2. Alconero, R., Deshpande, S.N., and Santiago, A., Pectolytic Enzymes in Infected Vanilla Roots, presented (by R.A.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
3. Aragón, O. and Deshpande, S.N., Complementary Effects of Ionizing Radiation and Lipoxidase Activity on Fatty Acids of Soybeans (in Spanish), presented (by O.A.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
Asencio, C.I. - See Deshpande, S.N.
4. Beck, B.F., Features of Limestone Solution, Erosion, and Precipitation Along the Southwest Coast of Puerto Rico, presented at Nat. Speleol. Soc. Conv., White Salmon, Oregon, Aug. 1972.
5. Beck, B.F., Two Types of Speleogenesis in Comal County, Texas, presented at Nat. Speleol. Soc. Conv., White Salmon, Oregon, Aug. 1972.
6. Canoy, M.J., Accumulation of Certain Heavy Metals in a Tropical Fishery, presented at Ichthyology and Herpatology Meet., Boston, Mass., June 1972.
7. Canoy, M.J., Ecological Systems and Energy Flow of Jobos Bay, presented at Amer. Ass. Advan. Sci. Meet., Washington, D.C., Dec. 1972.
Castrillón, J.P. - See Scarano, L.; Velázquez, C.
Chiriboga, J. - See Gómes, P.; Ritchie, L.S.
Cora, J.M. - See Ritchie, L.S.
8. Corcino, J.J. (UPR Hosp.), Dietrich, R.C., and Lanaro, A.E., Assessment of Vitamin B₁₂ Absorption in Tropical Sprue Utilizing a Whole-Body Counter, presented (by J.J.C.) at 70th Annu. Meet. P.R. Med. Ass., San Juan, Nov. 1972.
9. Corcino, J.J. (UPR Hosp.), Dietrich, R.C., and Lanaro, A.E., The Whole-Body Counter in the Evaluation of Vitamin B₁₂ Malabsorption in Tropical Sprue (in Spanish), presented (by A.E.L.) at 4th Lat. Amer. Congr. Ass. Soc. Nucl. Biol. Med., Santiago, Chile, Oct. 1972.
10. Cuevas-Ruíz, J. and Koo, F.K.S., Quality Improvement in Plaintains by Selection, presented (by J.C.R.) at Carib. Food Crops Soc. Meet., Mayagüez, June 1972.
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de León, D. - See Gomes, P.; Ritchie, L.S.

11. Deshpande, S.N., Vega, C.A., Asencio, C.I., and Koo, F.K.S., Microanalysis of Sulfur-containing Amino Acids by Isotopic Dilution and Neutron Activation, presented (by S.N.D.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
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 Dietrich, R.C. - See Corcino, J.J.; Lanaro, A.E.; Sánchez, J.
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12. Gileadi, M., Methods and Results — Joint Radiation Survey, presented at 7th Mid-year Topical Symp. Health Phys. Soc., San Juan, Dec. 1972.
13. Gileadi, M. and Gileadi, A.E., Methods and Results — Joint Radiation Survey, Puerto Rico, 1968, presented (by M.G.) at Congr. Int. Radioprotection, Bordeaux, France, Mar. 1972.
14. Gómez, P., Velarde, A., de León, D., and Chiriboga, J., A Simple Method of Mass Production of *Fasciola hepatica* Miracidia, presented (by D.D.L.) at Amer. Ass. Vet. Parasitol. Conv., Athens, Georgia, June 1972.
 Gómez, P. - See also Ritchie, L.S.
15. Gonzalo, J.A., Current Developments in Solid State Physics, presented at Annu. Conf. Sci. Teachers Ass. P.R., San Juan, May 1972.
 Gonzalo, J.A. - See also Kay, M.I.; Mercado, A.
16. Kay, M.I. and Kleinberg, R., A Neutron Diffraction Study of the Antiferroelectric Phase of Copper Formate Tetrahydrate, presented (by M.K.) at 9th Int. Congr. Crystallogr., Kyoto, Japan, Aug. 22-Sept. 10, 1972.
17. Kay, M.I. and Kleinberg, R., A Neutron Diffraction Study of Triglycine Sulfate, presented (by M.K.) at Amer. Crystallogr. Ass. Meet., Albuquerque, New Mexico, Apr. 1972.
18. Kay, M.I., Kleinberg, R., and Gonzalo, J.A., Neutron Diffraction Phase Transformation Studies of Several Ferroelectric Materials, presented (by M.K.) at 7th Carib. Chem. Conf., Mayagüez, Jan. 1972.
 Kleinberg, R. - See Kay, M.I.
19. Koo, F.K.S. and Cuevas-Ruíz, J., Exploratory Induction of Solid Mutations in Yams by Gamma Irradiation, presented (by F.K.S.K.) at 12th Congr. Int. Biol. Básica, Cali, Colombia, Nov. 27-Dec.1, 1972.
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 Lagunas, M. - See Lee, R.A.
20. Lanaro, A.E., Dietrich, R.C., Muñoz, A. (UPR School of Med.), and Martínez-Picó, A. (UPR Hosp.), Pulmonary Gammagraphy in Congenital Cardiovascular Diseases, presented (by A.E.L.) at Annu. Meet. P.R. Heart Ass., San Juan, Sept. 1972.
21. Lanaro, A.E., Dietrich, R.C., Muñoz, A. (UPR School of Med.), Martínez-Picó, A. (UPR Hosp.), and Sánchez, J. (UPR Hosp.), Pulmonary Perfusion Evaluation by Gammagraphy in Congenital Heart Diseases (in Spanish), presented (by A.E.L.) at 10th Pan Amer. Congr. Pediatrics, 3rd Lat. Amer. Congr. Pediatrics, and 2nd Argent. Congr. Pediatrics, Cordoba, Argentina, Nov. 1972.

- Lanaro, A.E. - See also Corcino, J.J.; Sánchez, J.
22. Lee, R.A. and Lagunas, M., Radiolysis of Deaerated Aqueous Solutions of Thiourea and Tetramethyl Thiourea, presented (by R.A.L.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
- López, V.A. - See Ritchie, L.S.
23. Lowman, F.G. and Ting, R.Y., The State of Cobalt in Seawater and Its Uptake by Marine Organisms and Sediments, presented (by F.G.L.) at IAEA Symp. Interaction of Radioactive Contaminants with the Constituents of the Marine Environment, Seattle, Wash., July 1972.
24. Maglic, R., The Isomeric Shift Anomaly in Iron Near T_c , presented at 18th Conf. Magnetism, Denver, Nov. 1972.
25. Marcial, V.A., Recent Developments in Radiation Therapy of Pelvic Malignancies, presented at 7th Nat. Cancer Conf., Los Angeles, Sept. 1972.
26. Martin, F.D., A Comparison of a Polluted and a Nonpolluted Tropical Bay, presented at Ichthyology and Herpetology Meet., Boston, Mass., June 1972.
27. Mercado, A. and Gonzalo, J.A., Critical Behavior of Triglycine Fluoberyllate, presented (by J.A.G.) at Amer. Phys. Soc. Meet., Washington, D.C., Apr. 1972. Abstract, *Bull. Amer. Phys. Soc.* 17, 497 (1972).
28. Muñoz-Ribadeneira, F.J., Effects of Thermal Activation in Chalcopyrite (CuFeS_2), presented at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
29. Muñoz-Ribadeneira, F.J., A Statistical Study of the Leaching of Copper from Chalcopyrite Using Seawater—Sulfuric Acid Solutions, presented at 7th Carib. Chem. Conf., Mayagüez, Jan. 1972.
30. Muñoz-Ribadeneira, F.J. and Ortiz-Torres, J., Dissolution of Copper from Different Size Chalcopyrite Ore Particles in Seawater—Sulfuric Acid Solutions (in Spanish), presented (by F.M-R.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
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- Ortiz-Torres, J. - See Muñoz-Ribadeneira, F.J.
31. Paraskevoudakis, P., A Twelve-Month Program in Radiological Health — Four Years of Experience, presented at Health Phys. Soc. 7th Midyear Topical Symp., San Juan, Dec. 1972.
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34. Ritchie, L.S., López, V.A., and Cora, J.M., The Effect of an Organotin on Biological Stages of *Schistosoma mansoni* and *Biomphalaria glabrata*, presented (by V.A.L.) at 21st Annu. Meet. Amer. Soc. Trop. Med. Hyg., Miami Beach, Nov. 1972.
35. Sánchez, J. (UPR Hosp.), Dietrich, R.C., Lanaro, A.E., and Martínez-Picó, A. (UPR Hosp. Pulmonary Gammagraphy in Fallot's Tetralogy (in Spanish), presented (by A.E.L.) at 4th Lat. Amer. Congr. Ass. Soc. Nucl. Biol. Med., Santiago, Chile, Oct. 1972.
Santiago, A. - See Alconero, R.
36. Sardina, R., Plaza, H., and Sasscer, D.S., Absolute Flux Measurements Using the Activity Ratio Technique, presented (by H.P.) at Conf. Research and Training Reactor Utilization, College Station, Texas, Feb. 1972. Abstract, *Trans. Amer. Nucl. Soc.* 15, Suppl. No. 1, 18 (1972).
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37. Scarano, L., Velázquez, C., and Castrillón, J.P., New Scintillation Solvents and Solutes, presented (by J.P.C.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
Ting, R.Y. - See Lowman, F.G.
38. Vakili, N.G. (USDA/AID Mayagüez) and Walker, D.W., Differences in Susceptibility of Bean Varieties to Pega-Pega, presented (by N.G.V.) at Carib. Food Crops Soc. Meet., Mayagüez, June 1972.
39. Vakili, N.G. (USDA/AID Mayagüez) and Walker, D.W., Varietal Susceptibility of Cowpeas to Pod Borer, presented (by N.G.V.) at Carib. Food Crops Soc. Meet., Mayagüez, June 1972.
40. Vázquez, F., Reflectivity on SbSI, presented at Amer. Phys. Soc. Meet., Washington, D.C., Apr. 1972. Abstract, *Bull. Amer. Phys. Soc.* 17, 594 (1972).
Vega, C.A. - See Deshpande, S.N.
Velarde A. - See Gómez, P.; Ritchie, L.S.
41. Velázquez, C. and Castrillón, J.P., Aromatic Nitriles as Scintillation Solutes, presented (by J.P.C.) at 11th Lat. Amer. Congr. Chem., Santiago, Chile, Jan. 1972.
Velázquez, C. - See also Scarano, L.
42. Walker, D.W. and Vakili, N.G. (USDA/AID Mayagüez), Bean Pod and Seed Damage by Bean Pod Borer, presented (by N.G.V.) at Carib. Food Crops Soc. Meet., Mayagüez, June 1972.
Walker, D.W. - See also Vakili, N.G.

APPENDIX 3

Seminars

RIO PIEDRAS

- Dr. Víctor A. Marcial, "Present Concepts in the Management of Prostate Cancer" (January 14).
- Dr. Aklilu Lemma, Haile Selassie I University, Addis Ababa "Studies on Leishmaniasis and Schistosomiasis in Ethiopia" (February 15).
- Dr. Michael A. Davis, Children's Hospital Medical Center, Boston, "Demonstration: The Preparation of Technetium — Iron Hydroxide Macro-Aggregates for Lung Scanning" (March 1); "Recent Advances in Radiopharmaceuticals" (March 2); "The Chemistry and Physiology of Technetium — Iron Hydroxide Macro-Aggregates: A New Lung Scanning Agent" (March 3); "Refresher Course in Radiopharmaceuticals" (March 6); "Radiopharmaceuticals of the Future" (March 7).
- Dr. Karl Z. Morgan, ORNL, "The Bases of Standards for Radiation Protection" (April 4).
- Dr. Henry Wellman, Indiana University, "Present and Future Importance of Cyclotron-Produced Radionuclides for Nuclear Medicine" (April 12).
- Dr. Isidro Martínez, Puerto Rico Department of Health, "Oral Cancer" (April 14).
- Dr. Steven Lunzer, V.A. Hospital, Bronx, N.Y., "*In situ* Carcinoma of the Larynx" (April 22).
- Dr. Seymour H. Levitt, University of Minnesota, "The Role of Radiation Therapy in Organ Transplants" (May 5).
- Dr. John I. Bruce, Walter Reed Army Institute of Research, "Ultra Structure Study of the Migration of *Schistosoma mansoni* Through Host Tissues" (May 23); "Physiology and Biochemistry of the Life Cycle Stages of *Schistosoma mansoni* and *Schistosoma japonicum*" (May 25); "Drug Screening Program for *Schistosomiasis*" (May 30).
- Dr. Giulio J. D'Angio, Memorial Hospital for Cancer and Allied Disease, New York, "Special Considerations in the Management of Children with Neoplastic Diseases" (August 4).
- Mr. Peter A. Willman, "New PRNC Computer Configurations" (September 21).
- Dr. Helmut C. Heinrich, University of Hamburg, Germany, "Clinical Applications of Whole-Body ^{59}Fe Turnover Rate Measurements" (October 20).
- Dr. Aviva Gileadi, "Energy, Environment, Economy" (November 27).
- Dr. Ralph E. Johnson, National Cancer Institute, "Treatment of Non-Hodgkin's Lymphoma" (December 8).

MAYAGUEZ

- Dr. Floyd Smith, U.S. Department of Agriculture, "Screwworm Eradication Program in the United States and Puerto Rico" (January 14).
- Dr. Joel E. Gordon, Amherst College, "Low Temperature Specific Heat of Actinide Metals" (January 18).
- Prof. Eugene Merzbacher, University of North Carolina, "Quantum Mechanics and Electronics" (March 15).
- Dr. Robert Kleinberg, Albuquerque, N.M., "The Meteorological Phenomenon and Large Induced Optical Lateral Waves at Dielectric Air Interfaces" (March 16).
- Dr. Karl Z. Morgan, ORNL, "Criteria for the Control of Radioactive Effects, Appropriate for Nuclear Power Reactors and for Other Peaceful Applications of Radiation" (April 4).
- Dr. R. S. Singh, National Bureau of Standards, "Lattice Dynamics and Phase Transitions in Crystals" (May 2).
- Dr. Manuel Gómez Rodríguez, UPR, "Static Theories of Phase Transition: Mean Field Theory and Ornstein Zernike Theory" (May 9); "Static Scaling Laws, The Kadanoff Construction, and Estimates for the Applicability of Mean-Field Theory" (May 18); "Theory of Second-Order Ferroelectric Transitions" (May 25).

Staff

Edwin Roig, Acting Director
 Peter Paraskevoudakis, Associate Director
 Frank G. Lowman, Associate Director for Environmental Sciences
 Víctor A. Marcial, Associate Director for Medical Sciences
 Luis E. Boothby, General Administrative Officer
 Marie Barton, Executive Assistant to Director

Abu-Zeid, Mohyi E. M., Scientist	*Cruz Vidal, Baltasar, Scientist
Acosta Servera, Ileana, Adm. Assoc.	Cuebas Ruiz, José, Sen. Assoc.
Agard, Eugene T., Scientist	Davis, Russel W., Res. Assoc.
*Alemañy, Juan Carlos, Reactor Operator	de León, Delfín D., Sen. Scientist
Alfaro Méndez, Aura N., Adm. Assoc.	Delsanto, Pier Paolo, Scientist
Arce Blanco, Rafael, Scientist	Deshpande, Shreekant N., Scientist
Arce Quintero, Rafael, Scientist	Dietrich Ormachea, René C., Scientist
*Bailey, Carroll Edward, Scientist	Dietsch, Jean M., Adm. Assoc.
Bajandas, Nydza, M., Res. Assoc.	*Dirk, William, Eng. Assoc.
Banuchi de Gómez, Nérida, Adm. Officer	*Dodds, James, E., Res. Assoc.
*Beck, Barry F., Scientist	Drewry, George, Scientist
Besselievre, Henry L., Engineer	Eberhardt, Manfred, Scientist
Bosch, Antonio, Sen. Scientist	Engleson, Jerome J., Scientist
Boyko, Alberta, Adm. Assoc.	Ferrer Monge, José, Sen. Scientist
Bravo, Anibal, Tech. Assoc.	Forster, William O., Sen. Scientist
Brown, Raymond A., Sen. Scientist	Frías Monserrate, Zenaida, Scientific Assoc.
Brown Campos, Richard, Head, Reactor Division	*Galantai, Ferne Louise, Adm. Assoc.
Brunet Brunet, David, Sen. Assoc.	*Gaztambide, Germán, Tech. Assoc.
Canoy, Michael, Scientist	Gileadi, Aviva E., Sen. Scientist
*Carmona Trutten, Alfredo, Eng. Assoc.	Gileadi, Michael, Sen. Assoc.
Carrión Bonano, René, Eng. Assoc.	*Gómez, Manuel, Scientist
Castrillón, José P. A., Scientist	González Pérez, Alberto, Tech. Assoc.
Cesani, Fernando, Scientist	Gonzalo González, Julio A., Head Nuclear Science Division
Chiriboga, Jorge M., Sen. Scientist	Green, David H., Engineer
Clements, Richard G., Sen. Scientist	*Grimison, Alec, Acting Head Physical Sciences Division
Colón, José Antonio, Res. Assoc.	Hernández, Cayetano, Tech. Assoc.
Colón de Villodas, Carmen, Res. Assoc.	Hernández de Rivera, Norma, Adm. Assoc.
Conant, David S., Res. Assoc.	Hufty, Richard Renwood, Eng. Assoc.
Correa López, Sylvia, Adm. Assoc.	Jusino Laboy, Edwin, Tech. Assoc.
Crespo de García, Leila, Scientific Assoc.	Kay, Mortimer I., Sen. Scientist
*Cruz Gonzalez, Pedro, Reactor Operator	

Kolehmainen, Seppo E., Scientist
 Koo, Francis K. S., Head,
 Tropical-Agro Sciences Division
 Kovarna, John T., Scientist
 Laguer, Carlo J., Eng. Assoc.
 Lanaro, Aldo Ernesto, Head,
 Clinical Radioisotope Applications Div.
 Lee, Rupert, Scientist
 Lequerique, Víctor, Scientific Assoc.
 Liard Bertin, Félix, Res. Assoc.
 López, Leonardo, Reactor Operator
 López de Velázquez, Irene, Res. Assoc.
 López Santiago, Víctor A., Adm. Assoc.
 Lowman, Frank G., Head,
 Radioecology Division
 Marcial, Víctor A., Head,
 Radiotherapy and Cancer Division
 Marrero Sullivan, Gloria M., Res. Assoc.
 Martin, Floyd Douglas, Scientist
 Martin, Stephen, Scientist
 Martínez Silva, Ramiro, Sen. Scientist
 Montgomery, John T., Res. Assoc.
 Muñoz, Ramón Jr., Adm. Officer
 Muñoz Ribadeneira, Fausto, Sen. Assoc.
 Mackay, Kenneth P., Res. Assoc.
 Ortiz Aguiar, Roberto, Sen. Assoc.
 Ortiz de Caraballo, Alice, Res. Assoc.
 Ortiz Muñoz, Eddie, Sen. Scientist
 Ortiz Muñoz, Gabriel, Scientist
 *Ortiz Muñoz, Roberto, Sen. Scientist
 Pacheco Díaz, José G., Res. Assoc.
 Padilla Escabí, Lila R., Res. Assoc.
 Paraskevoudakis, Peter, Head,
 Health and Safety Division
 Parrish, James D., Scientist
 Pedersen, Knud B., Scientist
 Pérez Matos, Felipe, Acting Adm. Officer
 Pérez Muñoz, Juan Jesús, Reactor Operator
 Plaza Rosado, Heriberto, Scientist
 Ponce de Ramírez, Eugenia, Adm. Assoc.
 Quiñones, Nelson, Engineer
 *Ramos Aliaga, Roger, Res. Assoc.

Ritchie, Lawrence S., Head,
 Medical Sciences and Radiobiol. Div.
 Rivera, Efigenio, Scientific Assoc.
 Rivera Castrolópez, Roberto, Adm. Assoc.
 Rivera Guzmán, José E., Reactor Supervisor
 Rodríguez, Migueal A., Chief Reactor Operator
 Rodríguez, Sergio D., Reactor Operator
 *Rodríguez de Calderón, Adriana, Scientific Assoc.
 Rosa Graniel, Lorenzo, Eng. Assoc.
 Rushford, Frederick E., Head,
 Information and Education Services Division
 Santana de Tirado, Rosa, Res. Assoc.
 Santiago, Rosa Julia, Res. Assoc.
 Sasscer, Donald S., Head,
 Nuclear Engineering Division
 Seiglie, George, Scientist
 *Shearls, Edward A., Res. Assoc.
 Silva Parra, Juan, Sen. Assoc.
 Simpson, George A., Scientist
 Singh, Rammar Shankar, Scientist
 Soto Santana, Luis A., Tech. Assoc.
 Suárez Castro, José A., Scientist
 Szmant, Alina M., Res. Assoc.
 Ting, Robert Y., Scientist
 Toledo Charneco, Porfirio, Scientific Assoc.
 Tomé, José M., Sen. Scientist
 *Toro González, Mirta, Res. Assoc.
 Torres, Sigfredo, Eng. Assoc.
 Torres Carmona, Guillermo, Eng. Assoc.
 Torres Castro, Heriberto, Scientific Assoc.
 *Ubiñas Villeneuve, Jeanne, Sen. Scientist
 Vallecillo, Fernando, Scientific Assoc.
 Vázquez Martínez, Florencio, Scientist
 Vélez Martínez, Elba M., Adm. Assoc.
 Vélez Mendoza, Pedro, Adm. Officer
 *Villafaña, Theodore, Scientist
 Walker, David, Sen. Scientist
 Walsh, Stephen, Head,
 Technical Services Dept.
 *Weisz, Shmvel Zvi, Sen. Scientist
 Willman, Peter A., Scientist
 Wood, Elwyn D., Scientist

APPENDIX 5

PRNC RIO PIEDRAS — STUDENT ENROLLMENT Fiscal Year 1972

Training Activity	Duration (Months)	Enrollment	Student Months
Radioisotope Techniques Course	1	18	18
PRNC Portion-M.S. degree Chemistry - UPR Río Piedras	6-12	4	30*
PRNC Portion-Ph.D. degree Chemistry - UPR Río Piedras	6-12	1	12*
Special Training - Radioisotope Application to Sulfur Bacteria Metabolism	3	1	3
Special Training - Radiation Chemistry	2	1	2
Special Training - Liquid Scintillation	9	1	9
Clinical Radioisotope Applications Course	2	10	20
Orientation Course - Clinical Radioisotope Applications	0.5	47	23.5
Orientation - Nuclear Medicine Nurses	.1	30	3.0
Special Training - Anger Camera	0.4	3	1.25
Special Training - Clinical Radioisotope Applications	5-12	3	41
Radiotherapy and Cancer Residency Program	12	2	24
Special Training - Radiation Protection & Dosimetry	10	1	10
Radiotherapy Training Course - Short Terms	2-5	5	13
Radiotherapy Training Course - One Month	1	10	10
Special Radiotherapy Dosimetry Course	1	1	1
Special Training - Virology	1-5	3	7
Special Training - Biochemistry	2	2	4
Special Training - Radioisotopes for Study of Intermediary Metabolism	2	2	4
Special Training - Fascioliasis and Schistosomiasis	2	1	2
Special Training - <i>Fasciola hepatica</i>	2-12	3	16
Post-Doctoral Training in Biochemistry	12	1	12
Special Training in Schistosomiasis	3	1	3
Effect of Cortisone upon Strongyloide Infections in Mice	6	1	6
PRNC Portion-M.S. degree in Biology - UPR Rio Piedras	6-12	3	24*
PRNC Portion-Ph.D. degree in Microbiology - UPR Med. Sci.	6-12	1	12*
Special Course in General Virology	2	6	12
Research - Egg laying in <i>Physa cubensis</i>	5	1	5
Research - Preliminary Screening of Toxic Plants Against <i>Physa cubensis</i>	5	1	5
Research - Life Cycle of <i>Fasciola hepatica</i>	3	1	3
Research - Reproduction Capacity of <i>Lymnaea cubensis</i>	3	1	3
PRNC Portion-M.S. degree in Radiological Health and Field Training - UPR Med. Sci.	1-12	15	125*
PMPH 561 - Fundamentals of Radiological Health	5	12	60
Special Training - Health Physics	1-2	2	3
Radiotherapy Dosimetry Training Program	3	1	3
Sub- Total		196	530

* Products that are low are due to some students being part-time

APPENDIX 5 (continued)

PRNC MAYAGUEZ — STUDENT ENROLLMENT
Fiscal Year 1972

Training Activity	Duration (Months)	Enrollment =	Student Months
PRNC Portion-M.S. in Physics-UPR Mayaguez	6-12	3	24*
PRNC Portion-M.S. in Chemistry-UPR Mayaguez	6-12	8	54*
Special Training - Neutron Diffraction	2	1	2
Special Training - Radiochemistry	6	1	6
PRNC Portion-M.S. in Electrical Engineering-UPR Mayaguez	4	2	8*
Special Training - Nuclear Physics	6	1	6
PRNC Portion-M.S. in Nuclear Engineering-UPR Mayaguez	12	9	108
Special Training - Nuclear Engineering	6	1	6
Special Training - Cytogenetics, Physical & Chemical Mutagenesis	4	1	4
PRNC Portion-M.S. in Biology - UPR Mayaguez	1-4	3	6*
Special Training - Artificial Rearing Methods of <i>Nezara viridula</i>	2	1	2
One Month Training in Radiobiology and Mutation Breeding	1	1	1
Special Training - Agrobiosciences	.6	1	6
Special Training - Reactor Instrumentation & Control	2-6	3	10
Neutron Activation Analysis in Marine Biology Program	4	1	4
PRNC Portion-Ph.D. in Biology - University of Miami	3	1	3
	Sub-Total	38	244
Oak Ridge Research Participants	2	2	4
	Grand Total	236	778

*Products that are low are due to some students being part-time

APPENDIX 6

PRNC STUDENTS BY COUNTRY

(A student is counted once each fiscal year he is in training)

	1958-67*	1968	1969	1970	1971	1972	Total
Argentina	16	1	3	4	6	6	36
Bolivia	8	1	-	1	5	5	20
Brazil	1	1	1	-	2	2	7
Canada	-	-	-	-	1	-	1
Chile	14	4	3	1	1	1	24
Colombia	44	4	8	10	12	12	90
Costa Rica	5	1	1	1	5	2	15
Cuba	9	-	2	2	1	-	14
Dominican Republic	21	5	6	6	3	4	45
Ecuador	10	1	3	5	4	1	24
El Salvador	8	1	-	-	-	-	9
Formosa	6	6	-	-	1	1	14
Germany	2	-	-	-	-	-	2
Great Britain	4	1	-	-	-	-	5
Greece	-	-	-	2	1	-	3
Guatemala	4	2	2	1	-	-	9
Haiti	1	-	-	-	1	-	2
Honduras	-	-	-	-	1	-	1
Hungary	-	1	-	-	-	-	1
India	9	-	-	1	-	1	11
Indonesia	-	-	-	-	-	1	1
Israel	-	1	1	1	-	-	3
Jamaica	-	-	-	-	1	2	3
Japan	1	-	-	-	-	-	1
Korea	-	-	2	-	-	1	3
Lebanon	1	1	-	-	-	-	2
Liberia	1	1	1	-	-	-	3
Mexico	16	2	1	2	3	1	25
Nicaragua	3	2	2	3	2	-	12
Panama	2	-	1	-	2	-	5
Paraguay	6	-	3	2	2	1	14
Peru	13	-	3	2	1	3	22
Philippine Islands	4	1	1	-	-	-	6
South Africa	1	-	-	-	-	-	1
Spain	15	2	2	1	-	-	20
Thailand	-	-	2	-	-	-	2
Turkey	-	1	-	-	-	-	1
United Arab Republic	1	-	-	-	-	-	1
Uruguay	7	-	1	1	3	2	14
Venezuela	18	3	2	1	14	5	43
Total Non-U.S. Citizens	251	46	50	45	72	51	515
Total U.S. Citizens	1223	167	149	146	115	167	1967
Total Students	1474	213	199	191	187	218	2482

*Total number of students trained at PRNC from its first year of operation FY-58 through FY-67.