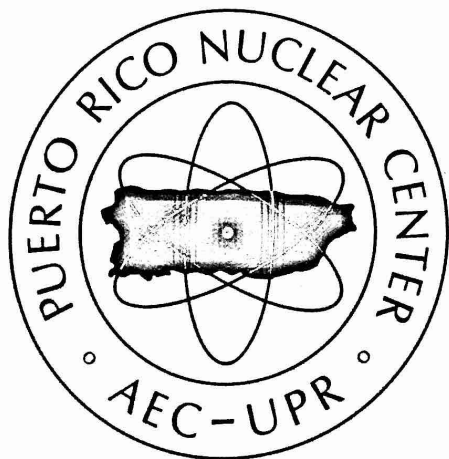


# PUERTO RICO NUCLEAR CENTER

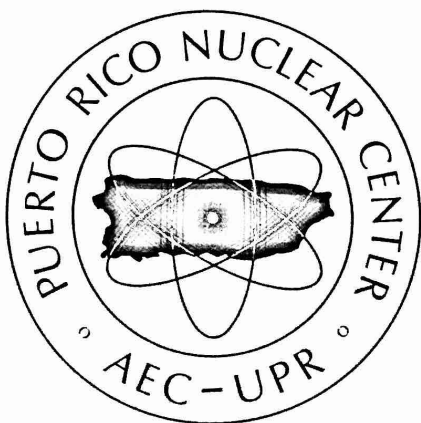
## ANNUAL REPORT, 1971



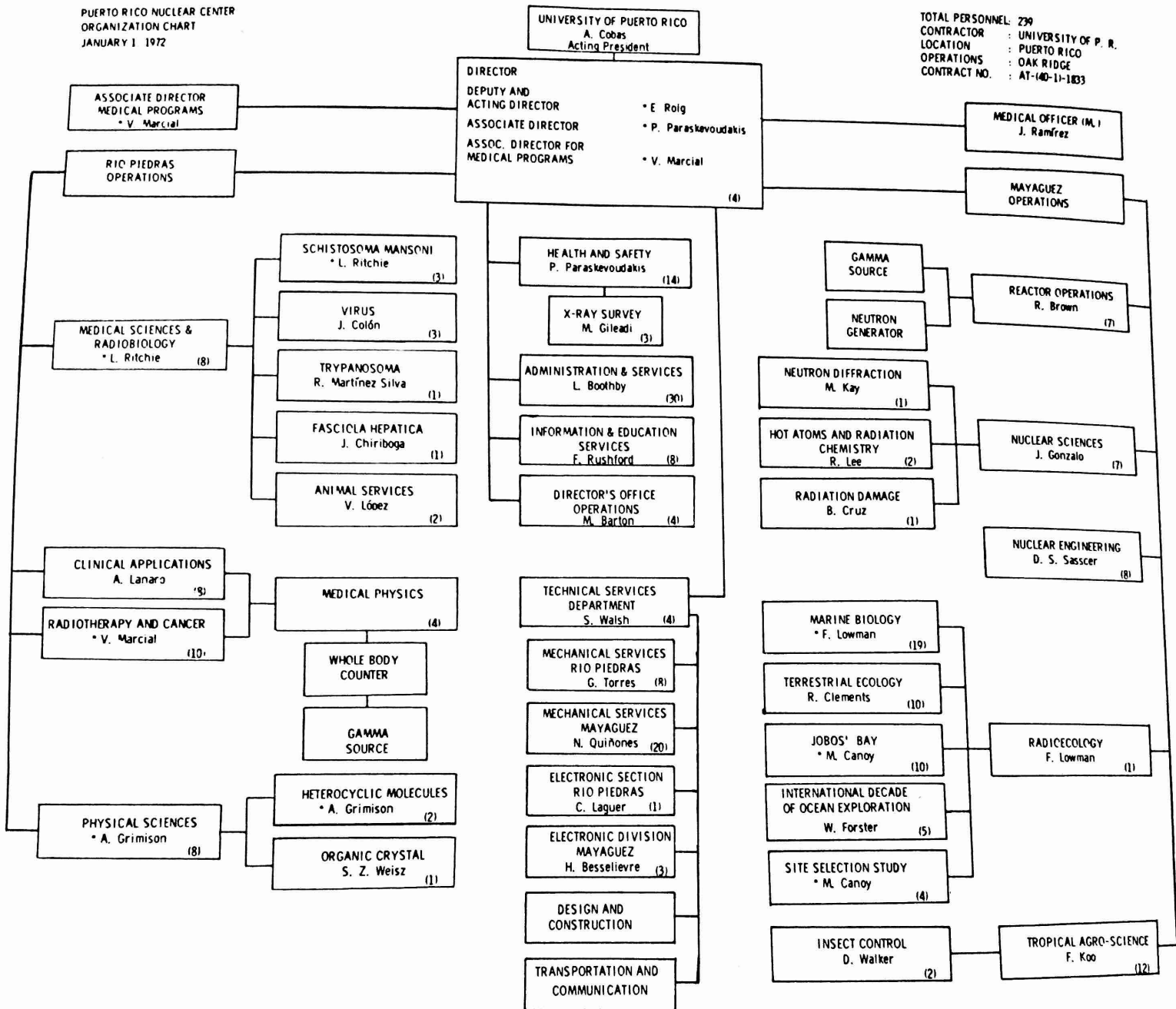
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# PUERTO RICO NUCLEAR CENTER

## ANNUAL REPORT, 1971



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*John Morgan*  
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 PUERTO RICO AREA OFFICE

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*Edwin Roig*  
 ACTING DIRECTOR  
 PUERTO RICO NUCLEAR CENTER

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Mr. Aurelio Mercado, graduate student in Physics,  
using laser beam for Brillouin scattering studies.

# 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 post-doctoral 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 1971 eight graduate courses were taught by PRNC personnel, with academic credit given by UPR:

Course	Professor	Enrollment
587 and		
597- Introduction to Solid State Physics	Dr. J. A. Gonzalo	4
608- Radiation Chemistry	Dr. R. A. Lee	7
673- Chemical Kinetics	Dr. R. A. Lee	4
Graduate Seminar	Dr. B. A. Cruz	2
550- Teoría Cinética y Mecánica Estadística	Dr. M.E. Abu-Zeid	4
434- Classical Theory of Fields	Dr. M. Gómez	6
451- Quantum Mechanics	Dr. M. Gómez	8

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

Student	Thesis Title	Advisor
Genaro Coronel Martínez	Thermal conductivity of ferro-electric triglycine sulfate (TGS)	Dr. J. A. Gonzalo
Bernabé Zuluaga	Gamma-induced copolymerization of crotonic acid with styrene	Dr. R. A. Lee
Raúl Marco	Gamma-induced copolymerization	Dr. R. A. Lee

Luis C. Hernández	Electron spin resonance (ESR) spectra from ferroelectrics	Dr. F. Cesaní
Braulio F. Mercado	Electrical conductivity of TGS near the transition temperature	Dr. F. Vázquez Dr. J. A. Gonzalo Dr. M. Kay

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

María García	Hot-atom reactions of $^{18}\text{F}$ with aromatic compounds	Dr. R. A. Lee
Edward Lyons	Radiolysis of fluoroform	Dr. R. A. Lee
Josefina Rodríguez	Radiolysis of fluorotoluenes	Dr. R. A. Lee
Roberto F. Amaris	ESR studies of irradiated organic sulfur compounds	Dr. R. A. Lee
Aurelio Mercado	Static and dynamic critical behavior of ferroelectrics, using Brillouin scattering	Dr. J. A. Gonzalo
Prudencio Martínez	Thermoluminescence spectra from ferroelectric $\text{NaNO}_2$	Dr. J. A. Gonzalo
Aníbal Camnasio	Specific heat measurement near $T_c$ from ferroelectric triglycine fluoroberillate	Dr. J. A. Gonzalo
Ramón E. Irizarry	Electroreflectance and thermorefectance in barium titanate	Dr. F. Vázquez
José M. Ortíz	Mechanism of radiolytic decomposition of phospholipids	Dr. O. H. Wheeler
José Escabí	ESR spectra of cyclic amides	Dr. O. H. Wheeler
Alberto J. Moreno	The study of the ESR spectrum of antiferroelectric $\text{KH}_3(\text{SeO}_3)_2$	Dr. F. Cesaní

## RESEARCH COMPLETED

**Gamma-Ray Induced Copolymerization of Vinyl Acetate and Crotonic Acid –**  
R. Rodríguez (UPR Mayagüez) and R. A. Lee (PRNC Mayagüez). Various mole fractions of vinyl acetate and crotonic acid have been copolymerized by irradiation with  $^{60}\text{Co}$  gammas. Addition of scavengers ( $\text{CCl}_4$ ,  $\text{H}_2\text{O}$ , and DPPH) to the above mixtures before irradiation has revealed the mechanism of copolymerization to be free radical. An  $r_1 \sim 0.35$  has been obtained by means of both a conventional plot and the Fineman-Ross plot.

**Thermal Conductivity of TGS Near the Curie Point** — G. Coronel (UPR Mayagüez) and J. A. Gonzalo (PRNC Mayagüez). Measurements of thermal conductivity by the comparative method have been performed on single crystals of triglycine sulfate along the  $a$ ,  $b$ , and  $c$  axes, in the vicinity of the transition temperature. The experimental results (relative accuracy of  $\sim 1\%$ ) indicated no anomaly around  $T_c$  along the ferroelectric  $b$  axis, a possible weak dip along the  $c$  axis, and a weak but more definite step-like anomaly along the  $a$  axis. No trace of a small peak at  $T_c$  along the  $b$  axis, as suggested by Dimarova and Poplavko, was detected. The values observed just below  $T_c$  for thermal conductivity along the three axes:  $K(a) = 1.35 \times 10^{-3}$ ,  $K(b) = 1.36 \times 10^{-3}$ ,  $K(c) = 1.81 \times 10^{-3}$  cal/cm-seg- $^{\circ}$ C, show marked anisotropy. A satisfactory interpretation of the weak observed anomalies involves considerable complications. However, present thermal conductivity results are discussed in the light of previous data on other dynamical physical properties and compared with those obtained for other ferroelectrics.

**Gamma-Irradiation Effects on the Dielectric Properties of KDP** — J. A. Gonzalo (PRNC Mayagüez) and I. Nazario (UPR Mayagüez). Single-crystal samples of ferroelectric  $\text{KH}_2\text{PO}_4$  were irradiated below and above the transition temperature ( $T_0 \approx 122^{\circ}$  K.) The dielectric constant and the hysteresis loop characteristics were measured in the interval between  $100^{\circ}$  and  $130^{\circ}$  K. For samples irradiated below the transition temperature the dielectric constant peak value diminished steadily with increasing dose, but the transition temperature did not change noticeably. Thermal annealing was observed when the doses were not too large. The hysteresis loops of samples irradiated below the transition showed pronounced increase of coercive field but only minor changes in spontaneous polarization. This behavior differs somewhat from that observed in other ferroelectrics, like TGS or Rochelle salt, probably because of the deviations from typical second-order characteristics in the KDP transition.

**Frequency Dependence of Dielectric Constant in TGS in the Range 0.4 to 2.0 GHz** — B. Mercado, J. A. Gonzalo, and F. Vázquez (PRNC Mayagüez). The temperature dependence of the high frequency (0.4 to 2.0 GHz) dielectric constant of TGS has been accurately determined ( $\Delta T \sim 0.5^{\circ}$  C). A perfect Curie-Weiss behavior has been observed at both  $T < T_c$  and  $T > T_c$ . The ratio of Curie constants  $C^+/C^-$  is, within experimental uncertainty, equal to 4.25, higher than the isothermal value of 2. This ratio has been previously measured at low frequencies (1 kHz). The fact that the experimental conditions at these low frequencies were not ideally adiabatic caused a ratio  $C^+/C^- \sim 2.4$  to be measured. Present results give a higher value because the experimental conditions are more truly adiabatic. A rounding of the peak is observed (especially at 2.0 GHz) due to the presence of higher transmission modes which become noticeable when  $\epsilon$  is very large. The influence of these modes could have been lowered by using a sample radius smaller than that of the center conductor of the transmission line by an amount comparable to the thickness of the sample. This would produce considerable attenuation and minimize interference with the main mode ( $m = 0$ ,  $K_z = 0$ ).



**Wavelength Modulations of Silicon** – F. Vázquez (PRNC Mayagüez). Considerable attention has been given to the interpretation of the structure that appears around 3.5 eV in the transitions between the valence and conduction band in silicon. Wavelength modulation has been applied to study the reflectivity of silicon samples at 90°K between 3 and 4 eV. Pressure was applied in several directions, and reflectivity was obtained from (001), (011), and (111) surfaces. Changes in intensity and the splitting and shifting of the peaks allow interpretation of the transitions involved.

**Wavelength Modulation System** – F. Vázquez (PRNC Mayagüez). It is well known that derivative spectroscopy enhances structure because of overlapping spectral bands and allows extraction of relatively weak structure from large reflectivity or absorption backgrounds. A system was developed that can be incorporated into a monochromator and gives the derivative spectrum over a wide wavelength region.

**Continuum Shell-Model Calculation for  $^{208}\text{Pb}$**  – R. F. Barrett (University of Frankfurt) and P. P. Delsanto (PRNC Mayagüez). Results of a continuum shell-model calculation of the total photoabsorption cross section for  $^{208}\text{Pb}$  are presented and compared with the results of experiments and of bound-state calculations.

**$^{28}\text{Si}$  and  $^{32}\text{S}$  in a Continuum Shell-Model Calculation** – R. F. Barrett, A. Rabie (University of Frankfurt), P. P. Delsanto (PRNC Mayagüez), and A. Piazza (Istituto de Fisica dell' Università, Cagliari, Italy). The total photoabsorption cross sections of  $^{28}\text{Si}$  and  $^{32}\text{S}$  have been calculated in a 1p-1h continuum shell-model approximation using the eigen-channel reaction theory.

**Labeling of Iodocytosine and Iodouracil** – O. H. Wheeler and Ileana Casanova de Brás (PRNC Mayagüez). The rate of exchange of iodocytosine and iodouracil with radioiodine ( $^{131}\text{I}$ ) was studied. Optimum conditions were pH 7 at 100° for 2 hr for iodocytosine and 30 min for iodouracil. The rate constant for exchange was greater for iodouracil than for iodocytosine. The method was used to prepare  $^{128}\text{I}$  and  $^{132}\text{I}$  labeled compounds.

## RESEARCH IN PROGRESS

**Critical Behavior of Triglycine Fluoroberillate** – A. Mercado and J. A. Gonzalo (UPR and PRNC Mayagüez). Dielectric constant and hysteresis loop measurements in TGFB are in progress in the vicinity of  $T_c \approx 73.2^\circ\text{C}$ . The results confirm the typical second-order ferroelectric transition in this compound and are similar to those previously observed in TGS. At temperatures far below  $T_c$ , the characteristics of the hysteresis loops are dependent on the previous heat treatment of the sample. Measurements of  $\epsilon$  at high frequencies ( $10^8$  to  $10^{10}$  Hz) will be performed. We are waiting for components for a Brillouin scattering system to study the dynamic critical behavior.

**Thermoluminescence Studies on  $\text{NaNO}_2$**  - P. Martínez and J. A. Gonzalo (UPR and PRNC Mayagüez). An apparatus previously developed for measuring glow curves from irradiated samples in the temperature range  $77^\circ$  to  $500^\circ\text{K}$  is being used to study the defects produced. Special attention will be given to possible changes in the spectra obtained from samples irradiated just below and just above  $T_N \approx 162^\circ\text{C}$ , to determine the influence of crystal structure on the kind and number of defects produced.

**Calorimetric Studies of Ferroelectric Transitions** - A. Camnasio and J. A. Gonzalo (UPR and PRNC Mayagüez). Previous attempts to develop a system for specific heat measurements in ferroelectric transitions were unsuccessful in attaining the desired accuracy. A modified system is being developed which improves considerably the accuracy of the measurements ( $\sim 1\%$  for a standard of copper metal). This modified system will be used to study single-crystal samples of several ferroelectrics under various dc bias and uniaxial stress conditions.

**Experimental Testing of Neutron-Mirror Monochromatizing Systems (NMMS) of Advanced Design** - H. L. Foote, Jr. (BNL) and W. Fiala (PRNC Mayagüez). Different designs of "integrated" double-mirror, i.e., multiple layer mirrors, are currently being developed and tested. A further effort is being made to develop the techniques for the production of very thin neutron mirrors to be incorporated into the system.

**Theoretical Analysis of NMMS** - W. Fiala and P. P. Delsanto (PRNC Mayagüez). Computer simulation of the beam experiments suggests various mirror configurations and analyzes the experimental data obtained from actually tested configurations.

**The ESR Spectrum of Antiferroelectric  $\text{KH}_3(\text{SeO}_3)_2$**  - F. Cesaní and A. J. Moreno (PRNC and UPR Mayagüez). In order to study the ESR spectrum of crystals of  $\text{KH}_3(\text{SeO}_3)_2$ , both pure and doped with metallic ions, a rotary crystallizer has been constructed, and its capabilities and reliability are being tested by growing common single crystals. We hope the crystallizer can be used to grow large single crystals by controlling the temperature. The data taken last summer at the University of South Carolina on the ESR spectrum of pure crystals of  $\text{KH}_3(\text{SeO}_3)_2$  irradiated with x-rays at room temperature are being analyzed.

**Reflectivity and Wavelength Modulation Spectrum of  $\text{BaTiO}_3$**  - F. Vázquez (PRNC Mayagüez). Barium titanate has a ferroelectric transition from a cubic to a tetragonal phase. This transition is accompanied by movements of the ions within a single unit cell relative to one another. This lattice polarization causes splitting and shifting of the critical points. The temperature dependence of this effect is going to be studied with the reflectivity and the derivative of the reflectivity through the transition temperature.

**Reflectivity and Wavelength Modulation of SbSI** – F. Vázquez (PRNC Mayagüez). The reflectivity of the crystals has a direct relationship to the dielectric constant. Since the SbSI crystal is ferroelectric, a large peak of the dielectric constant is observed at the transition temperature. We are going to study how interband transitions are affected in the transition from the ferroelectric to the paraelectric phase.

## STAFF

Genaro Coronel Martínez completed his M.S. Degree in Physics under Dr. J.A. Gonzalo, and in April 1971 he rejoined the staff of the Physics Department at the Instituto de Ciencias, Asunción, Paraguay.

Bernabé Zuluaga completed his M.S. degree in Chemistry under Dr. R. A. Lee, and in May he rejoined the staff of the Chemistry Department of the University of Medellín, Medellín, Colombia.

Carlos Hernández Pardo, who was working towards an M.S. degree in Physics under Dr. Fernando Cesaní, rejoined the Physics Department of Universidad Nacional, Bogotá, Colombia, in July.

Dr. Mohyi Eldin Mohamed Abu-Zeid, who held a joint appointment in the Nuclear Science Division, was transferred to the Health Physics Division on July 1.

Mr. Hernán G. Vera Ruiz, a Bolivian on an IAEA fellowship, arrived on October 20 to take special training in radiochemistry under Dr. R. A. Lee.

Joint appointments were given to Dr. F. Cesaní and Dr. E. Bailey from the UPR Physics Department to work in this Division. Dr. Cesaní is working on the ESR spectrum of anti-ferroelectric  $\text{KH}_3(\text{SeO}_3)_2$  and Dr. Bailey on the development of an ENDOR system to investigate free radicals in crystals.

*Ad honorem* appointments were given to Dr. W. Fiala, Dr. P. P. Delsanto, and Mr. L. Vargas Viña from the Physics Department, UPR Mayagüez.

**Meetings.** Dr. R. A. Lee attended the 6th Caribbean Chemical Conference in Trinidad in January and presented a paper.

A local meeting of the American Association of Physics Teachers was held in January at UPR Mayagüez with participants from Río Piedras, San Germán, Ponce, and Mayagüez. Drs. M. Gómez, M. E. Abu-Zeid, B. Cruz, W. Fiala, E. Bailey, P. P. Delsanto, and J. A. Gonzalo from the Physics Department (UPR Mayagüez) and the Nuclear Science Division (PRNC) presented brief reports on their current research.

Dr. W. Fiala and Dr. P. P. Delsanto attended the April meeting of the American Physical Society in Washington and presented papers.

Dr. J. A. Gonzalo gave four lectures on Physics and Philosophy as part of a course on the Philosophy of Science at the Humanities Department, UPR Mayagüez, during April.

Dr. M. Gómez attended the Gordon Conference on Dynamics of Quantum Solids and Fluids in Milwaukee, August 9-13.

Dr. P. P. Delsanto attended the Gordon Research Conference on Photonuclear Reactions at Beaver Dam, Wisconsin, in August.

Dr. J. A. Gonzalo and Dr. M. Gómez attended the International Conference on Light Scattering in Solids in Madrid in August. While in Madrid, they also visited Dr. Jiménez Díaz and the Solid State Group, National Research Council; and Dr. J. L. Alvarez, National Nuclear Energy Establishment.

At the ACS Junior Technical Meeting held in Ponce in November, papers were presented by R. Marco, E. Lyons, and María García.

**Visitors.** Dr. Richard J. Kandel, Chief, Radiation, Isotope and Physical Chemistry Branch, Division of Research, AEC, Washington, visited Dr. R. A. Lee at PRNC Mayagüez on January 12.

Dr. G. C. Lalor, Head of the Chemistry Department, University of the West Indies, Jamaica, visited PRNC on January 15.

Dr. I. Lefkowitz of the Pitman-Dunn Research Laboratories, a well-known authority in the field of ferroelectricity and editor of the international journal *Ferroelectrics*, visited PRNC and the Physics Department at UPR Mayagüez. He held discussions with Drs. B. Cruz, W. Fiala, F. Vázquez, and J. A. Gonzalo on their current research, and he provided several single crystals of SbSI and  $WO_3$ .

Dr. Henry L. Stadler of the Ford Scientific Laboratory visited PRNC on February 26 and discussed phosphors.

Dr. R. W. Gammon, Assistant Professor, Physics Department, Catholic University of America, Washington, D.C., visited PRNC Mayagüez in May. He gave a seminar and held discussions with Drs. Vázquez, Gómez, and Gonzalo on current research and experimental techniques for light-scattering studies of ferroelectric transitions.

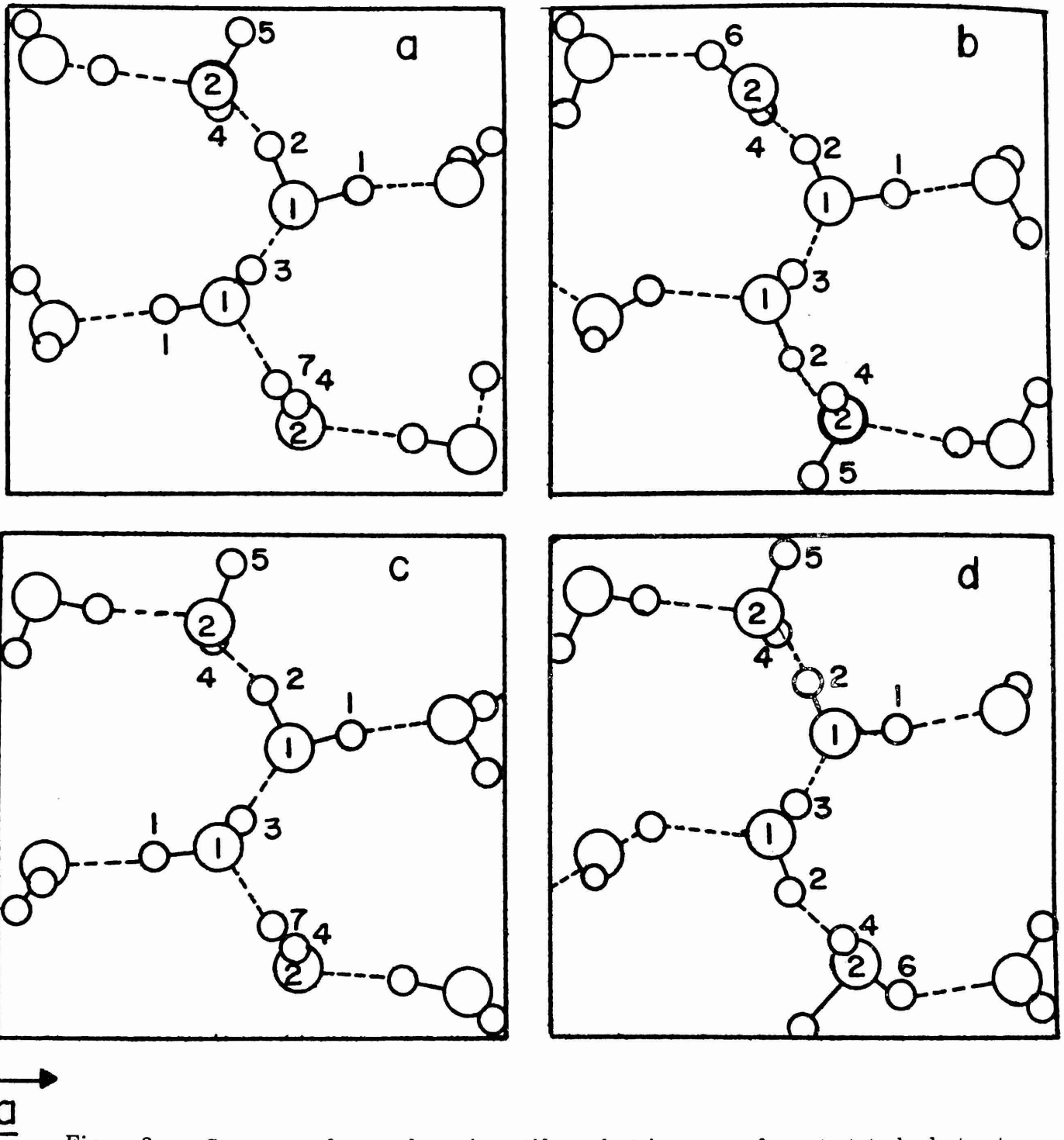


Figure 3. *a*. Structure of water layer in antiferroelectric copper formate tetrahydrate at  $Z = 1/4$ . This, together with the water layers shown in *b*, *c*, and *d* and their centric pairs, may be superposed to give the paraelectric structure (see text).

# Neutron Diffraction

The objective of the neutron diffraction group of the Nuclear Science Division is to determine atomic positions and thermal vibration amplitudes in physically important crystalline materials; currently ferroelectric materials are being studied.

This year we have reported the determination of the structure of the antiferroelectric phase in copper formate tetrahydrate. A clue to the mechanism of the transition in sodium nitrite has been extracted from the data taken at 150°C. A partial analysis of the structure of triglycine sulfate has been reported.

Structural data of this type provide the necessary starting point for a theoretical understanding of the phase transitions given. Materials showing effects similar to those mentioned above have practical uses in optical and electronic devices.

## EDUCATIONAL ACTIVITIES

The neutron diffraction group has cooperated closely with the PRNC Nuclear Science Division and with the UPR Physics Department within the scope of its research activities. Dr. R. Kleinberg taught in the UPR Physics Department 75% and did research in neutron diffraction 25%. Mr. B. F. Mercado did his thesis work on a problem common to nuclear science and neutron diffraction. He measured the high frequency dielectric response of triglycine sulfate while the structure was studied on the diffraction project. The project x-ray unit has been opened to various UPR teaching and research activities.

**Students.** Mr. B. F. Mercado (Puerto Rico) worked on the project as both technician and research student in electrical engineering. He had an AEC-ORAU graduate fellowship. His research is described in more detail in the Nuclear Science section of this report.

**Staff.** Dr. R. Kleinberg terminated 6-30-71. Mr. B. F. Mercado terminated 7-31-71.

## RESEARCH IN PROGRESS

**Structure and Thermal Vibrations in Sodium Nitrite ( $\text{NaNO}_2$ ).** A report of work in progress and the basic structural information on sodium nitrite at 150°, 185°, and 225°C were given in last year's *Annual Report*. The information presented there has been found to be substantially correct. The following is an extension of the previous analysis.

A partial objective was to try to discern a mechanism for the ferroelectric phase transition. It is known that at room temperature  $\text{NaNO}_2$  is ordered with all dipoles pointing in a single direction. The pattern along the  $b$  axis is depicted schematically as follows:  $\cdot > \cdot > \cdot > \cdot >$  where the dot denotes a sodium ion, the apex of the angle is a nitrogen, and the ends of the lines are oxygen atoms. As the transition is approached, the nitrites begin to reverse direction. At  $150^\circ\text{C}$  about 13% of the nitrites are reversed.

Published diffuse scattering and spectroscopic data indicate that the motion giving rise to the polarization reversal is a very low frequency mode. Our data above the transition, as noted before, show only disorder. The thermal vibrations demonstrate a slight discontinuity at the transition reflecting a slight reduction of the normal mode frequencies noted in the inelastic scattering measurements of Saccauri et al.

After final refinements of the  $150^\circ\text{C}$  results, a Fourier map and a difference map were calculated, which show respectively the distribution of scattering material and the difference in the distribution of observed and calculated scattering densities. A section of the difference map in the  $X, Y$  plane at  $Z = 0$  (Figure 1) shows a peak on the  $a$  axis whose maximum is 3% of the nitrogen maximum at  $\sim X = 0, Y = 0.07$  and is connected to the region of the nitrogen maximum. This region of high density has been associated with rotational motion of the nitrite group.

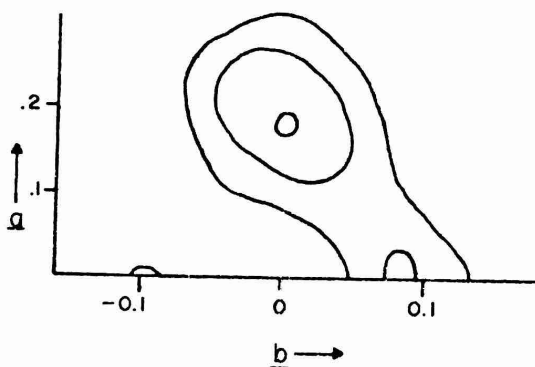


Figure 1. Highest peak in  $\text{NaNO}_2$  difference map after final standard refinement. Section through  $Z = 0$ . Peak height is about 3% that of the nitrogen peak in the Fourier map. Most of the nitrogen is at  $0, 0.07, 0$ . Data taken at  $150^\circ\text{C}$ . The peak was associated with torsional motion.

A least-squares fit has been carried out on the following model. A set of  $f_1$   $\text{Na}^+\text{NO}_2$  ions are in obverse position, and a set of  $f_2$  are in reverse position reflected across the (010) plane at  $Y = 0$ . There are  $f_3$  atoms undergoing hindered rotation in a 4-fold well.  $f_1 + f_2 + f_3 = 1$ . This model, which includes rotation, was found to fit the data slightly but significantly better than the results reported last year:  $f_1 = 0.79, f_2 = 0.05, f_3 = 0.16$ . The barrier to rotation,  $V/2kt = 0.18$ , is very low.

Since the nitrite group cannot be in ordered positions at the same time it is rotating in a very low potential, the data may be interpreted in two ways. One is that the disorder causes regions of low barrier where there are mistakes in the lattice. The other is that the rotational model is approximating a different physical situation such as tunneling. Statistically, the probability is about 4% that the improvement in data fit is caused simply by having more parameters.

**Copper Formate Tetrahydrate.** The high temperature (paraelectric) phase of copper formate tetrahydrate was reported in PRNC-84. Two sets of two-dimensional neutron diffraction data were taken at 77°K in the antiferroelectric phase.

The room temperature phase consists of alternate layers of copper formate and water. Hydrogen atoms in the water layers are disordered.

Reports by Turberfield, Lomer and Low, and Soda and Chiba based on neutron diffraction, x-ray diffraction, and deuteron magnetic resonance respectively, indicate that the *c* axis doubles in the low temperature antiferroelectric phase. The space group is, to a very good approximation,  $P2_1/n$ .

A diagram of the copper formate layer is given in Figure 2. These layers are found at  $Z = 0$  and  $1/2$  in the enlarged cell. The water layer at  $Z = 1/4$  is shown in Fig. 3a (p. 8). The layer at  $Z = 3/4$  may be generated by inversion through a center of symmetry at  $X = 1/2, Y = 1/2$ . The present report confirms Soda and Chiba's deuteron magnetic resonance results. The atomic positions reported here are, however, more accurate. We note some shifts in water oxygen position from the high temperature phase. Such shifts are unavailable to the magnetic resonance technique.

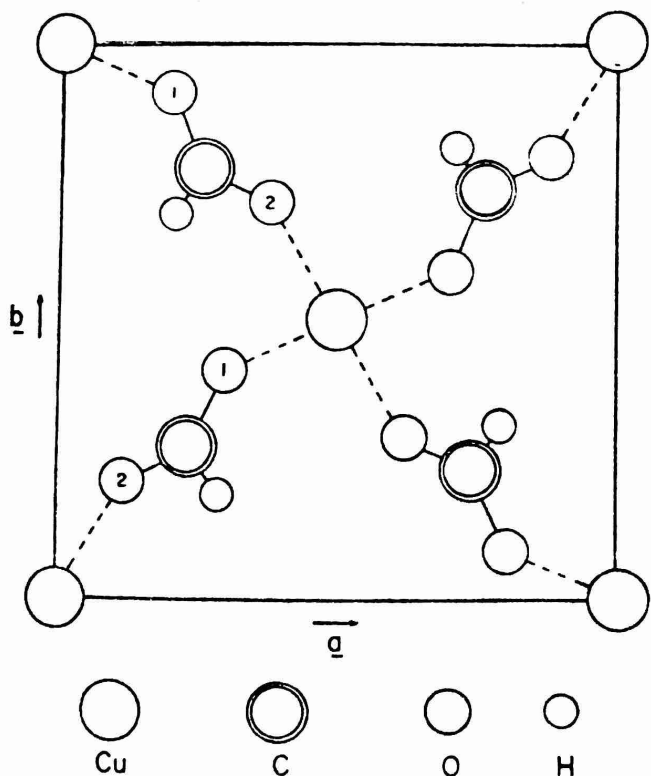


Figure 2. Copper formate layer in copper formate tetrahydrate. (From PRNC-84.)

The high temperature phase could consist of a superposition of the structures shown in *a*, *b*, *c*, and *d* of Figure 3 and their centric pairs. In PRNC-84 it was predicted that *c* plus *d* could add to give the results found in the high temperature structure; *a* plus *b* give identical results. A 2 or 3 to 1 ratio of *a* (or *c*) to *b* (or *d*) fits the paraelectric phase hydrogen occupancies quite well. It may be seen that *a* and *b* have  $2_1$  symmetry (at  $X = 1/4$ ) whereas *c* and *d* have glide symmetry (at  $Y = 1/4$ ). Since recent results, including those



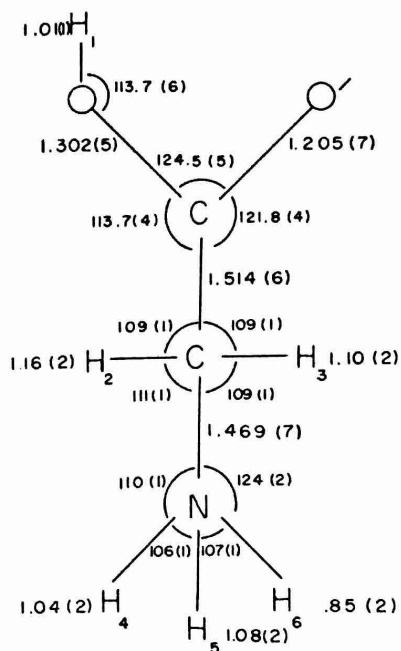
reported here, indicate that the screw axis remains through the transition, it is likely that *a* and *b* superpose in the disordered paraelectric phase.

**Triglycine Sulfate.** A three-dimensional structure of ferroelectric triglycine sulfate has been determined. Distances and angles are given in Figure 4, and hydrogen bond distances in Table 1. The distances involving hydrogen in the figures are corrected for "riding motion." The results agree very well with the x-ray determination reported by Hoshino, Okaya and Pepinsky in 1957. The present neutron result has unambiguously added the hydrogen positions and found all hydrogen to be bonded. Thermal vibration amplitudes are now being examined for evidence of a transition mechanism.

Table 1  
Hydrogen Bonds

$O_iS$  refers to sulfate oxygen *i*. I, II, III denote glycine group. O-H distances are uncorrected for thermal motion. Corrected distances and numbering scheme are given in Figure 4. First distance given is left-hand bond  $r(1)$ ; then the longer hydrogen bond  $r(2)$ ; then the angle with hydrogen at its apex.

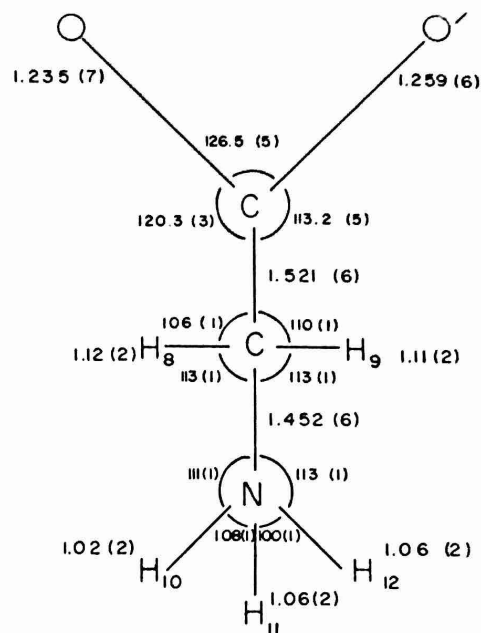
Hydrogen bond	$r(1)$	$r(2)$	Angle
From Group I			
O-H <sub>1</sub> - - - - O <sub>1</sub> S	1.00	1.52	174
N-H <sub>4</sub> - - - - O' II	1.02	1.80	169
N-H <sub>5</sub> - - - - O <sub>3</sub> S	1.07	1.73	176
N-H <sub>6</sub> - - - - O'I	0.83	2.01	157
From Group II			
N-H <sub>10</sub> - - - - O <sub>4</sub> S	0.98	2.03	148
N-H <sub>11</sub> - - - - O <sub>3</sub> S	1.03	2.06	155
N-H <sub>12</sub> - - - - O <sub>2</sub> S	1.01	1.90	154
From Group III			
O'-H <sub>7</sub> - - - - O'I	1.09	1.41	174
N-H <sub>15</sub> - - - - O <sub>3</sub> S	1.03	2.04	139
N-H <sub>16</sub> - - - - O <sub>4</sub> S	1.00	2.01	161
N-H <sub>17</sub> - - - - O <sub>2</sub> S	1.03	1.84	151



OTHER ANGLES:

H <sub>2</sub> -C-H <sub>3</sub>	107 (1)
C-C-N	112.2 (4)
H <sub>4</sub> -N-H <sub>5</sub>	98 (2)
C-N-H <sub>5</sub>	110.5 (6)

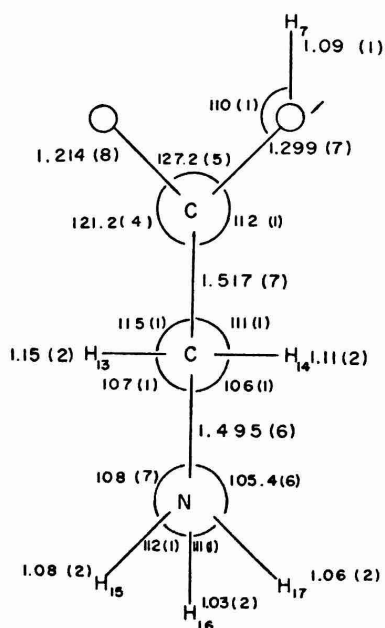
GLYCINE GROUP I



OTHER ANGLES:

H <sub>8</sub> -C-H <sub>9</sub>	103 (1)
C-C-N	111.6 (4)
H <sub>10</sub> -N-H <sub>11</sub>	113 (1)
H <sub>11</sub> -N-C	112 (1)

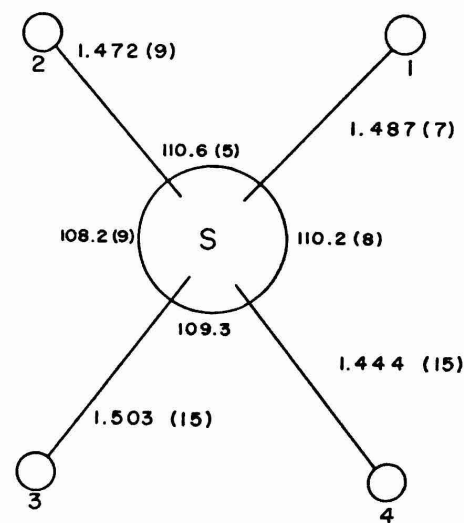
GLYCINE GROUP II



OTHER ANGLES:

H <sub>13</sub> -C-H <sub>17</sub>	107 (1)
C-C-N	110.7 (4)
H <sub>16</sub> -N-C	110 (1)
H <sub>15</sub> -N-H <sub>17</sub>	110 (1)

GLYCINE GROUP III



OTHER ANGLES

O <sub>1</sub> -S-O <sub>3</sub>	105.5 (8)
O <sub>2</sub> -S-O <sub>4</sub>	112.7 (8)

SULFATE GROUP

Figure 4. Triglycine sulfate groups. Distances and angles are given with standard deviations in parentheses. C-H, O-H, N-H distances are corrected for "riding motion."

# Cold Neutron Spectroscopy

The program on cold neutron spectroscopy was discontinued in the summer of 1971. It had involved the development of advanced neutron-mirror monochromatizing systems of good resolution and reasonable cost, the feasibility of which has been demonstrated. This work is being continued on a limited scale under the auspices of the Investigations Committee of UPR Mayagüez.

## RESEARCH COMPLETED

**A Detailed Evaluation of Neutron-Mirror Monochromatizing Systems.** Different configurations involving two or more neutron mirrors were analyzed numerically. The results show that, to obtain reasonable resolution, the original design involving two neutron mirrors has to be modified by incorporation of a third reflecting neutron mirror, which improves the cutoff against short-wavelength neutrons.

**Production and/or Analysis of Monochromatic Cold Neutron Beams by Neutron Total Reflection.** The principle setup of a neutron-mirror monochromatizing system involving two mirrors was tested at a tangential beam-hole of the BNL HFBR. The experimental tests support the general claims on neutron-mirror monochromatizing systems.

**Cold-Neutron-Mirror Monochromatizing Systems.** The cutoff behavior of physical neutron mirrors incorporated in neutron-mirror monochromatizing systems was studied in detail. Different mirror configurations were tested, and satisfactory agreement between theoretical and experimental data was established. Work was performed during summer 1971 in collaboration with H. L. Foote, Jr., at Brookhaven National Laboratory.

# Radiation and Hot Atom Chemistry

The studies carried out in the field of hot atom chemistry are mainly concerned with the reactions of  $^{18}\text{F}$  with aromatic compounds in the liquid phase. The  $^{18}\text{F}$  is being produced by two independent methods: (a) the  $^{19}\text{F}(n,2n)^{18}\text{F}$  reaction performed with 14-MeV neutrons from a neutron generator; (b) the  $^{16}\text{O}(\text{T},n)^{18}\text{F}$  reaction carried out in a nuclear reactor. The T is obtained from the  $^6\text{Li}(n,\alpha)\text{T}$  reaction.

In the field of radiation chemistry, simple organic fluorides are being studied in both the gas and liquid phases. Deaerated solutions of organic sulfur compounds are also being investigated.

Apart from the usual equipment for handling radioactive compounds (vacuum systems, glove boxes, and counters) an electron spin resonance (ESR) spectrometer and an EM 600 mass spectrometer are available for studying the intermediates and products formed during radiolysis.

## WORK COMPLETED

**Gamma-Induced Copolymerization of (a) Styrene and (b) Methyl Acrylate with Crotonic Acid.** These compounds have been irradiated in various mole fractions, and the copolymers thus formed have been analyzed for crotonic acid content. By means of the Fineman and Ross plot, reactivity ratios  $r_1$  have been calculated to be about 18 for system (a) and 44 for system (b). These ratios indicate that very little of the crotonic acid monomer is incorporated into the copolymer. Scavenger studies were carried out with carbon tetrachloride and DPPH. No copolymer can be precipitated when the irradiation is done in the presence of DPPH, and the presence of  $\text{CCl}_4$  does not affect the  $r_1$  ratios to any appreciable extent. These results indicate that the copolymerization occurs via free radical chain mechanisms.

**Radiolysis of Methyl Fluoride.** Methyl fluoride has been irradiated with  $^{60}\text{Co}$  gammas and the  $G(\text{H}_2)$  value was determined to be 4.0 by two independent methods. Neither a pressure effect nor a dose effect was seen in the ranges investigated. Sulfur hexafluoride and ethylene have been used as electron and hydrogen atom scavengers respectively. The  $\text{SF}_6$  reduces the hydrogen yield 25%, whereas the  $\text{C}_2\text{H}_4$  scavenges about 70%. Both scavengers are very effective at 0.1 mole % concentration.

## CURRENT RESEARCH

The following research projects are being carried out under the supervision of Dr. R. A. Lee.

**Hot Atom Chemistry.**  $^{18}\text{F}$  reactions with benzaldehyde are being investigated to determine which positions of the benzene ring are being substituted. The  $^{18}\text{F}$  is being generated by introducing a small amount of  $^6\text{Li}_2\text{CO}_3$  to effect the  $^6\text{Li}(n,\alpha)\text{T}$  reaction which will be followed by the  $^{16}\text{O}(\text{T},n)^{18}\text{F}$  process. Our preliminary results have shown that all positions in the ring are being substituted. From the percentages of substitution in the various positions (*ortho*, *meta*, and *para*) we are able to conclude that some thermalized  $^{18}\text{F}$  atoms are also reacting.

Fluorobenzene and *ortho*-, *meta*-, and *para*-fluorotoluenes are being irradiated with 14-MeV neutrons from a neutron generator. The  $^{18}\text{F}$  is being produced by the  $^{19}\text{F}(n,2n)^{18}\text{F}$  process. In this study the  $^{18}\text{F}$  is being produced intramolecularly in contrast to the benzaldehyde case above. Also, the  $^{18}\text{F}$  in the two cases is formed with different energies.

**Radiation Chemistry.** *Radiolysis of  $\text{CHF}_3$ .* The effects of pressure, dose, and scavengers ( $\text{SF}_6$  and  $\text{C}_2\text{H}_4$ ) on the radiolysis of fluoroform are being investigated.

*ESR Studies.* ESR measurements are being made on homocysteine, methionine, and ethionine after irradiation with both x rays and UV. These three compounds have similar structures except for the end group attached to the sulfur atoms.

*Radiolysis of Fluorotoluenes.* *Ortho*-, *meta*-, and *para*-fluorotoluenes are being irradiated and  $G(\text{H}_2)$  measurements are being made.

## STAFF

Besides the students working on their theses, Dr. E. Bailey has joined the project on a part-time basis to assist with the ESR studies. Mr. Hernán Vera, an IAEA fellow from Bolivia, will be assisting with the work involving the F reactions using the neutron generator.

# Radiation Damage

The research project on radiation damage was started in July 1970. Its purpose is to study the effect of radiation on rare gas solids (Ne, Ar, Kr, and Xe crystals), the nature and structure of radiation-induced defects, and the effect of such defects on crystal properties. The choice of crystals for the research is based on the relative convenience of theoretical calculations in these crystals. Thus, experimental information on defects can help generate through theoretical developments fundamental understanding of defect properties in crystals with more complicated or stronger interatomic forces.

This year has been one of preparation. No graduate students have been assigned to this project as actual experimental work has not started.

During the first half of 1971 necessary supplies and components were ordered, and a new research Dewar was designed and ordered. During May and June a Collins helium liquefier, transferred from Argonne National Laboratory, was installed. Later a nitrogen liquefier belonging to UPR was installed in the same room.

During the second half of 1971 data were analyzed and two papers were written.

We expect delivery of the new research Dewar early in 1972. The research system will then be installed and preliminary runs will be made. The major remaining limitation anticipated is limited sensitivity of the available temperature controller.

Good photometric equipment (a vacuum ultraviolet monochromator and a Cary 14 spectrophotometer), which will be available for our project, have been ordered by UPR Mayagüez.

## RESEARCH COMPLETED

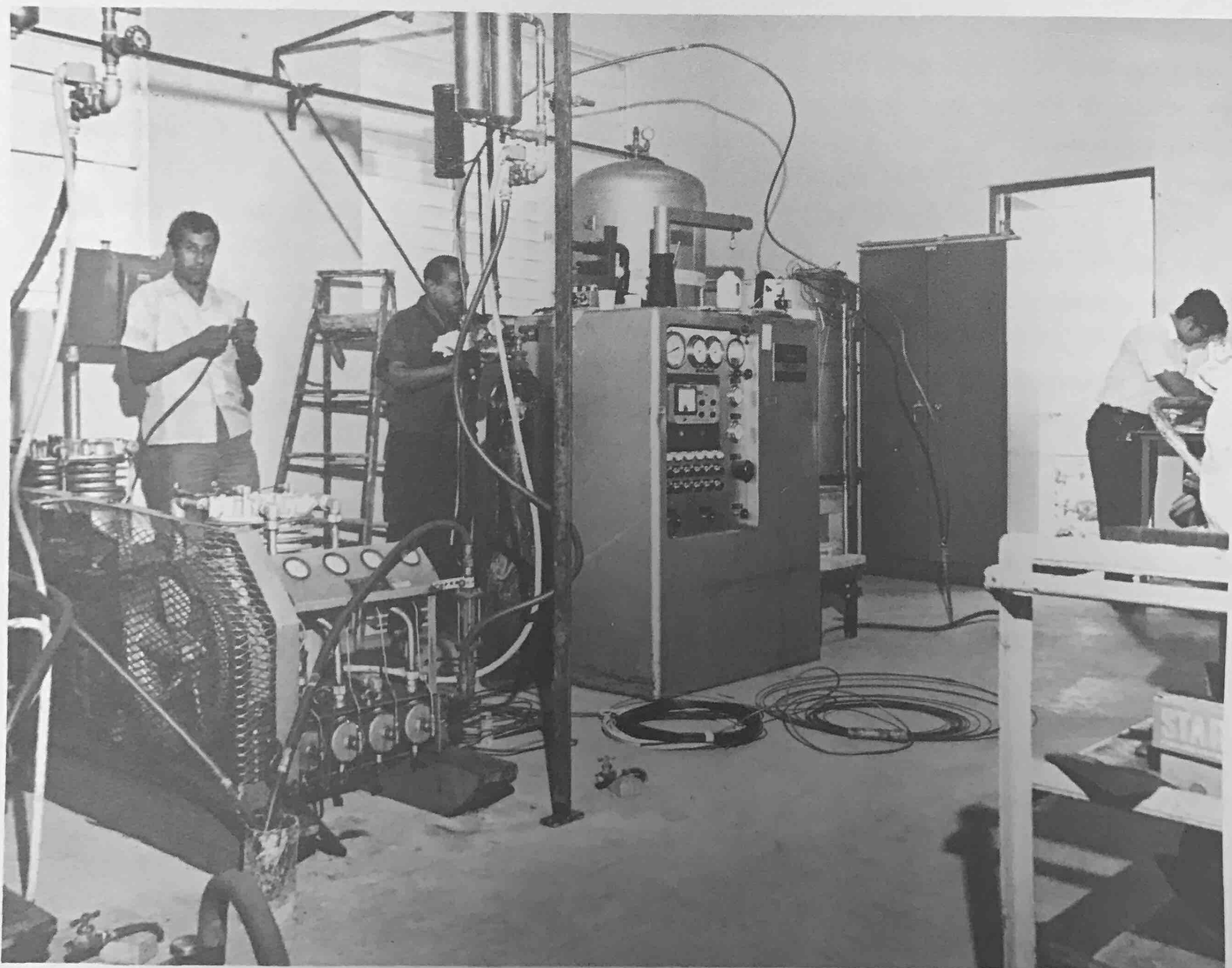
Measurement of Stored Energy of (1) KBr and (2) KCl after 4.6°K Reactor Irradiation — B. A. Cruz (UPR and PRNC Mayagüez) and G. Wehr, K. Böning, and G. Vogl (Technical University, Munich). Two papers on differential calorimetry measurements between 10° and 70°K after reactor irradiation of KBr and KCl at 4.6°K were completed during the year and will be sent for publication early in 1972 after review by the coauthors in Munich. The results indicate that all defects are produced in the halogen sublattice. Five recombination stages were observed. For the observed recombination stages the activation energies and reaction orders were determined. The results agree with published thermal luminescence measurements on KBr and KCl after low temperature x-ray irradiation.

## RESEARCH IN PROGRESS

**Radiation Damage in Rare Gas Solids (Ar, Kr, Ne) — B. A. Cruz (UPR and PRNC).** Preparation has been continued for a series of experiments to measure the light emission during low temperature x-ray and ultraviolet irradiation and the thermal luminescence of irradiated rare gas solids. The research has been planned to obtain maximum possible information on the nature and structure of radiation-induced defects in rare gas solids.

## STAFF

Dr. B. A. Cruz visited Prof. K. J. Teegarden, Institute of Optics, University of Rochester, on January 6, and Prof. R. O. Simmons, Physics Department, University of Illinois, on January 13-14. He attended the American Physical Society meeting in New York, February 1-4.



A view of the helium liquefier apparatus used by Dr. Baltazar Cruz.

# 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 hold joint appointments at PRNC and the University of Puerto Rico. The faculty of the UPR Nuclear Engineering Department is composed largely 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, equipment, and administrative personnel required for the education and training of the graduate students at the UPR Nuclear Engineering Department.

Short courses covering a variety of topics related to Nuclear Engineering are offered from time to time for scientists, engineers, technicians, etc.

**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.

**Students.** During 1971, 18 students participated in the M.S. program (Table 1), of whom 7 completed the M.S. degree and the rest are working on their thesis projects and/or completing their course work; 15 additional students took semester-length courses taught by the Division staff (Table 2). The Division staff taught 11 graduate courses and one advanced undergraduate course for which academic credit was given by UPR (Table 3).

Thesis research projects in progress or completed during the year under the supervision of the Division staff are listed in Table 4.



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

Name	Citizenship	Sponsoring Organization
Alcaraz, Juan R.	U.S.	GI Bill
Alvarado, José	U.S.	UPR
Alvarez, Vicen	U.S.	US Army
Arenas Rosillo, G.	Colombia	MMP
Benítez, Jaime	U.S.	AEC
Caro, Juan R.	U.S.	UPR
Griffin, Luciano	Venezuela	IVIC
Lebrón Pitre, D.	U.S.	AEC
Luongo, Albert	U.S.	UPR
Musalem, Abraham	Dominican Republic	UPR
Ortiz Torres, Julio	U.S.	AEC
Plá Barby, F.	U.S.	AEC
Kuppusamy, N.	India	Self
Ríos Dávila, R.	U.S.	UPR
Rodríguez Perazza, M.	U.S.	UPR
Rodríguez, T.	U.S.	UPR
Rosado Meléndez, M.	U.S.	AEC
Sardina, R.	Cuba	UPR

Table 2  
Students Not in Degree Program Who Have Taken Courses Offered by Nuclear Engineering Division

Name	Citizenship
Calderón, Colón Andrés	U.S.
Castro Cedeño, Mario	U.S.
Ferrer Pi, Omar E.	U.S.
Huertas del Toro, Alfredo	U.S.
Guzmán Colón, Héctor I.	U.S.
Maestre Koppish, E.	U.S.
Martínez Figueras, Edmundo	U.S.
Lara Carrasquillo, A.	U.S.
Michelen Embarek, Jesús	Dominican Republic
Pagán Feliciano, Luis M.	U.S.
Rivera Nieves, Neftalí	U.S.
Reyes Vega, Angel B.	U.S.
Salichs Sotomayor, Luis G.	U.S.
Santana Castro, David A.	U.S.
Soto Tur, Ramón	U.S.

Table 3  
Courses Taught by Division Staff

Course	Professor	Enrollment
Elements of Nuclear Engineering	D. S. Sasscer	6
Mathematics of Modern Science I	A. E. Gileadi	11
Reactor Theory	K. B. Pedersen	6
Nuclear Meas. & Instrumentation	H. Plaza	6
Advanced Reactor Theory	K. B. Pedersen	6
Mathematics of Modern Science II	A. E. Gileadi	11
Nuclear Reactor Technology II	H. Plaza	6
Reactor Laboratory	H. Plaza	6
Seminar	Staff	5
Introduction to Nuclear Eng.	E. Ortiz	4
Nuclear Technology	F. Muñoz Ribadeneira	7



Mr. José Mireles Sahagun, an OAS Fellow from Mexico,  
working in the Nuclear Engineering Division laboratory.

Table 4  
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 $(n, \gamma)$ Reactions	H. Plaza
Alvarado Cruz, J.	Determination of Total Cross Sections Using the UPR-RUM Texas Nuclear Model 9400 Neutron Generator	E. Ortiz
Alvarez, Vicen	* A Technique for Measuring the Photoelectric Mass Absorption Coefficient Using the Fluorescent Radiation from Various Elements	E. Ortiz
Benítez, Jaime	Determination of Trace Elements in Some Foods in Puerto Rico Using Neutron Activation Analysis Techniques	K. Pedersen
Caro, Juan R.	* Experimental Investigation of Neutron Detector Interaction	H. Plaza
Ortiz, Julio	* Possibilities of Recovering Copper from Chalcopyrite by Leaching with Seawater Sulfuric Acid Solutions	F. Muñoz
Plá, Fernando	* Effect of Gamma Radiation on Organic Materials in Aqueous Solution	K. Pedersen
Ríos, Rafael	* A Time-of-Flight Experiment To Determine the Neutron Spectrum from a Pu-Be Neutron Source	E. Ortiz
Rodríguez, Manuel	* Time, Space, and Energy Dependent Neutron Densities Following a Fast Neutron Burst at a Given Point	A. Gileadi
Rodríguez, T.	Determination of the Sedimentation Rate in the Mouth of the Guanajibo River by Activation Analysis	K. Pedersen
Sardina, Rafael	* Activity Ratio Technique for Measuring Thermal Neutron Flux Using Activation Detectors	H. Plaza

\* Completed

## RESEARCH PROJECTS

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

**Activity Ratio Technique for Measuring Thermal Neutron Flux Using Activation Detectors** — H. Plaza and R. Sardina. A novel technique for determining thermal neutron flux by means of activation detectors consists of irradiating a sample of an element with thermal neutrons and measuring the activity of two of the isotopes produced. The ratio of the two activities is proportional to the thermal neutron flux. (Completed.)

**Experimental Investigation of Neutron Detector Interaction** — H. Plaza and J. Caro. The change in response of a foil used as a neutron flux detector due to another foil detector placed near it was determined experimentally. The parameters included foil size, thickness, and distance between foils. From the experimental results a correction factor to account for the detectors' interaction was calculated as a function of these parameters. (Completed.)

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

**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 will be measured with gold wires by the cadmium ratio technique. Absolute flux measurements at certain positions inside the reactor core with gold foils will be attempted by  $\beta$ - $\gamma$  coincidence counting techniques. (In progress.)

**Temperature Distribution in a Lead Shield Irradiated by a Mixed Field of Neutrons and Gammas** — H. Plaza. The temperature distribution inside a lead shield will be experimentally determined by irradiation with a mixed field of neutrons and gammas. A theoretical model will be fitted to the experimental results to determine the distribution of the volumetric heat source in the shield. (In progress.)

**Time-of-Flight Experiment To Measure the Speed of Gamma Radiation** — F. Ortiz and R. Ríos. The method consisted of placing a gamma source between two short-decay-time plastic scintillators. A time to pulse-height converter was used to measure the shift in the time taken by a gamma ray to travel a given distance. (Completed.)

**A Technique for Measuring the Mass Absorption Coefficient Using Fluorescent Radiation** — E. Ortiz and V. Alvarez. The mass absorption coefficient of various foils,

and at different energies, was measured with a nondispersive fluorescent spectrometer. The energies were obtained by exciting the fluorescent spectrum with  $^{109}\text{Cd}$  on a radiator made of various elements. The radiation transmitted through a foil was studied via the spectrum obtained from a multichannel analyzer having a proportional counter as detector. By obtaining the spectrum at various foil thicknesses the attenuation at each energy can be obtained and the mass absorption coefficient calculated. (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 will be 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 will be used as the source of neutrons, and a plastic scintillator will be used to measure the transmitted beam. (In progress.)

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

**Energy, Space, and Time Dependent Neutron Fluxes in Rocky Media Following a Fast Neutron Burst** — A. Gileadi and M. Rodríguez Perazza. A computer code was developed that will predict space, time, and energy dependent neutron densities in rocky media following a fast neutron burst. A fast point burst was used as source. The problem has been solved for (a) infinite homogeneous rocky media, (b) a finite homogeneous sphere embedded in an infinite homogeneous medium composed of different materials, and (c) a cylindrical void embedded in an infinite homogeneous medium. Configurations (a) and (b) were chosen because of their relevance to underground bursts characteristic of Plowshare oriented applications. Configuration (c) was chosen because of its applicability to neutron logging problems. (Completed.)

**Gamma Dose Determination by Means of a Cylindrical Calorimeter** — A. Gileadi and L. Griffin. The relationship between the amount of gamma radiation absorbed and the heat produced as a result is being determined. A mathematical model to describe this relationship is being developed and its validity tested. A cylindrical calorimeter has been constructed, consisting of a lead core surrounded by a borated paraffin layer (for neutron absorption) and enclosed in an aluminum jacket. Temperature changes are recorded by high precision thermocouples embedded in the calorimeter. Mr. Griffin has returned to Venezuela and is completing measurements at the IVIC reactor site. (In progress.)

**Computerized Quantitative Analysis by Gamma-Ray Spectrometry** — A. Gileadi and N. Kuppusamy. A computer program is being developed for analysis of gamma-ray spectra obtained from mixtures of radioactive species such as fission products. The validity of

the program will be tested on typical cases using the Nuclear Engineering Division's multi-channel equipped crystal spectrometer. (In progress.)

**System Analysis of Strontium and Manganese Dynamics in a Tropical Rain Forest\*** — C. F. Jordan, J. R. Kline, and D. S. Sasscer. A kinetic equation model assuming a linear mathematical system was developed for the strontium and manganese in a tropical rain forest ecosystem, and the dynamics of the strontium and manganese movement was determined. (Completed.)

**Tritium in an Old-Field Ecosystem Determined Experimentally\*** — C. F. Jordan, J. P. Kline, and D. S. Sasscer. The tritium movement in an old-field ecosystem on the ANL site was determined. Tritiated water was applied to a 2-m<sup>2</sup> plot and collected at various depths, and the samples were counted by the liquid scintillation technique. (Completed.)

**A Mathematical Model of Tritiated and Stable Water Movements in an Old-Field Ecosystem\*** — D. S. Sasscer, C. F. Jordan, and J. R. Kline. A kinetic model assuming a nonlinear mathematical system was developed for the water movement in an old-field ecosystem. The model consisted of 50 compartments, infinite in extent and finite in thickness, and the parameters used were soil water diffusion, rainfall, transpiration of the vegetation, evaporation from the surface, deep drainage, and radioactive decay. (Completed.)

**Mineral Cycling and Ecosystem Stability\*** — C. F. Jordan, J. R. Kline, and D. S. Sasscer. The model discussed above was used to determine which types of ecosystems are stable. The parameters used were input to the system, output from the system, transfer among compartments, feedback, and relative size of compartments. (Completed.)

**Dynamic Model of Water Movement in Soil Under Various Climatological Conditions\*** — D. S. Sasscer, C. F. Jordan, and J. R. Kline. The verity of the mathematical model discussed above was determined by using large variations of the parameters and then was validated by comparing the prediction of the model with the results obtained experimentally in Illinois, in the rain forest of Puerto Rico, and in the Nevada desert. (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 cm and if chloride ion is used in addition to sulfuric acid in the leach solutions. Leaching rates were shown to 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. (In progress.)

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\* Work performed at the Radioecology Division, Argonne National Laboratory, while Dr. Sasscer was on leave there.

**Gamma Irradiation of Waste Water Effluents** — K. B. Pedersen, A. Ray, and F. Plá. Samples of effluent from a sewage treatment plant were irradiated at the PRNC 1300-curie  $^{60}\text{Co}$  source, and the amount of degradation was measured in terms of the chemical oxygen demand. Samples with varying degrees of aeration, chlorination, and pH adjustment were irradiated. Degradation could be enhanced by lowering the pH when this was combined with the other treatments. (Completed.)

**Activation Analysis as Used in a Study of Sedimentation** — K. B. Pedersen and T. Rodríguez. The feasibility of using Al as a labeling element for tracing sediment motion in a river and a river-ocean interface is being studied as part of a research project sponsored by the Office of Water Resources Research on evaluation of techniques for tracing sediments. This method was first explored by taking samples from the ocean at the outlet of a river at increasing distances from the river mouth, activating the filtrates in a reactor, and analyzing the resulting gamma emitters by means of a 1000-channel analyzer. The outputs from the analyzer were displayed as x-ray plots for easy comparison. (In progress.)

**Determination of Trace Elements in Some Foods in Puerto Rico** — K. B. Pedersen and J. Benítez. The contamination by selected elements in some foods considered to be staples in the Puerto Rican diet are to be determined. Methods of direct nuclear instrumental analysis for some of these elements will be investigated. (In progress.)

## STAFF

Dr. A. E. Gileadi served as Acting Head of the Division during the first half of the year in the absence of Dr. Sasscer. Dr. Sasscer returned on July 1 from Argonne National Laboratory, where he spent a year doing system analysis in the Division of Radioecology.

Dr. Eddie Ortiz presented a paper to the American Association of Physics Teachers in New York in January.

Dr. A. E. Gileadi and Dr. D. S. Sasscer attended the Annual Nuclear Engineering Education meeting at ANL in February and the Tenth Inter-American Congress of Radiology in San Juan in May. Dr. Sasscer presented a paper at the Third National Symposium on Radioecology held at ORNL in May.

Dr. Knud B. Pedersen presented a paper at the ANS topical meeting in Columbia, Missouri, in August.

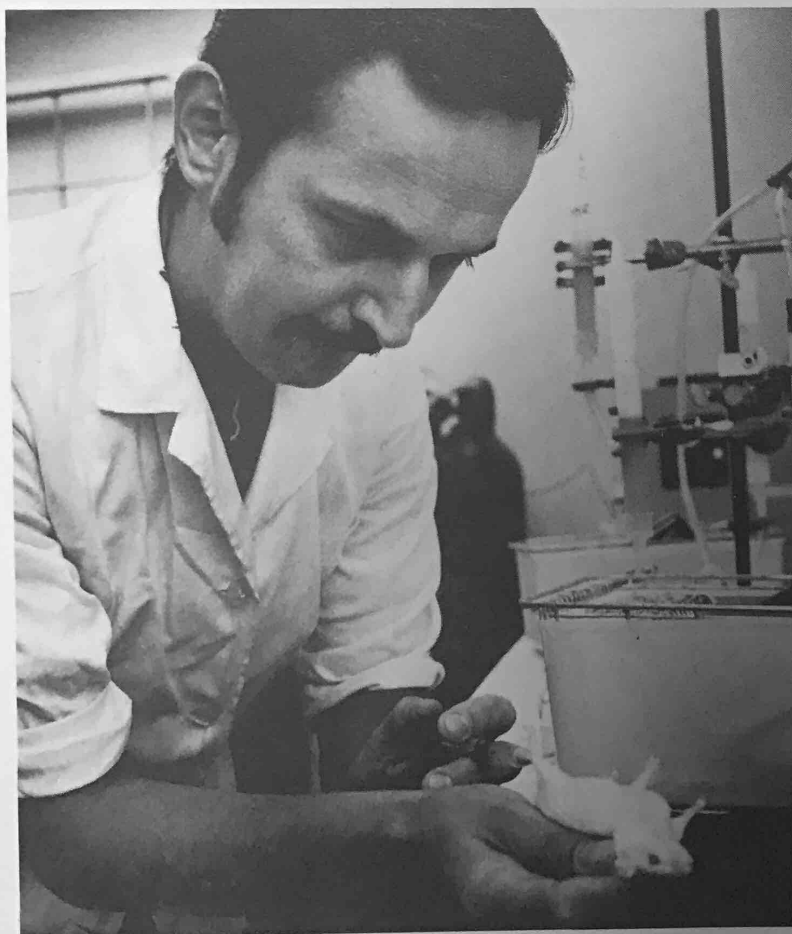
Dr. Donald S. Sasscer presented a paper at the Tritium Symposium of the Environmental Protection Agency held at the Western Environmental Research Laboratory in Las Vegas in September. Dr. Sasscer presented a paper to the Phi Kappa Phi Society of Puerto Rico in Mayagüez in November.

# 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. The 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 non-credit 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 1971. The distribution of the fifteen trainees by geographical origin is shown in Table 1.

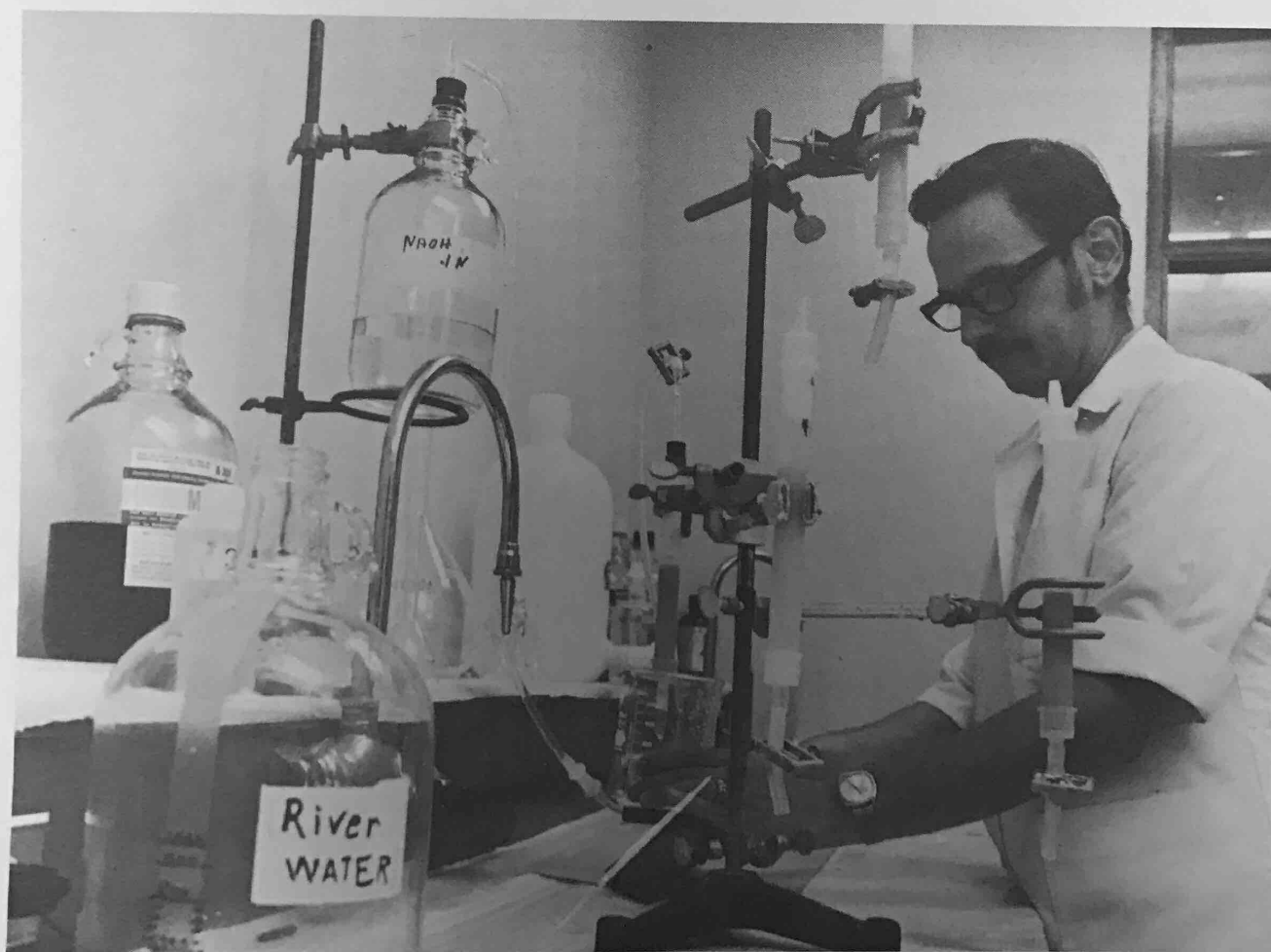


Dr. Arthur McB. Block, preparing to inject a mouse with a sample of water slightly contaminated with benzothiophene, a suspected waste product from petroleum refineries.



Table 1  
Participants in Basic Course in Radioisotope Techniques, 1971

Name	Country	Field of Interest	Financial Sponsor
Célica Barbosa Pereira	Uruguay	Biochemistry	PRNC Student Aid
Nayda R. Figueroa Vallés	Puerto Rico	Chemistry	Self
Elvira Giambartolomei	Argentina	Internal medicine	PRNC Student Aid
Ingrid Mai Pinkes	Bolivia	Radioisotope tech.	" " "
Beatriz Martínez Delgado	Puerto Rico	Chemistry	School of Medicine
Carlos Méndez Bryan	Puerto Rico	Radiology	P.R. Medical Center
Aristides H. Sarmiento	Argentina	Internal medicine	Ejército Argentino
Gerardo Valverde Aguilar	Costa Rica	Radioisotope tech.	PRNC Student Aid
Helena Bedoya Narváez	Peru	Nuclear medicine	" " "
René Dietrich Ormachea	Bolivia	Radioisotopes	IAEA
José Calixto García	Honduras	Medicine	Univ. Nacional de Honduras
Marcos Luján Villamil	Colombia	Radioisotopes	PRNC Student Aid
Ilia Torres Marcano	Puerto Rico	Radiology	P.R. Medical Center
Virgilio Vargas Benavides	Costa Rica	Nuclear medicine	PRNC Student Aid
José M. Pizarro Lago	Puerto Rico	Radiology	P.R. Medical Center



Dr. Arthur McB. Block, adjusting the flow rate of an ion-exchange column used to concentrate inorganic components in water from the Sonadora River, El Verde rain forest.

The following University courses were given:

1. Advanced Physical Chemistry (Chem. 464, three credits). A one-semester graduate course. Dr. Alec Grimison.
2. Graduate Research (Chem. 599 or Phys. 501, one to six credits). Graduate students supervised by PRNC personnel. (See Thesis Research, below).
3. Quantum Chemistry (Chem. 565, three credits). A one-semester graduate course. Dr. Alec Grimison.
4. Undergraduate Physical Chemistry (Chem. 463, three credits). The first half of a two-semester undergraduate course. Dr. Rafael Arce.
5. Undergraduate Research Training. One undergraduate science student took advantage of PRNC training opportunities during 1971: Felipe Cardona, supervised by Dr. S.Z. Weisz.
6. Intermediate Laboratory (Physics 219, 220). A two-semester course. Dr. S.Z. Weisz.
7. Advanced Laboratory (Physics 406, 407). A two-semester course. Dr. S.Z. Weisz.

**Thesis Research.** The following thesis research was sponsored by the Division during 1971 (see also Radiation Chemistry and Solid State Physics).

1. Radiation-Induced Hydroxylation of Aromatic Compounds — Yoshida Masayoshi (Brazil) for the Ph.D. degree (University of São Paulo); completed December 1971; under Dr. Manfred Eberhardt.
2. Influence of Chemical Structure on Quenching — Elsa Gómez (Venezuela) for the Ph.D. degree; to be completed 1972; under Dr. José Castrillón and Dr. Martin Pope.
3. Substituted Benzotriazoles as Scintillation Solvents — Lydia Scarano (Puerto Rico) for the M.S. degree; to be completed 1972; under Dr. José Castrillón and Dr. M. Pope.
4. Aromatic Nitriles as Scintillation Solutes — Carmen Velázquez (Puerto Rico) for the M.S. degree; to be completed 1972; under Dr. José Castrillón and Dr. Martin Pope.
5. Relation Between Quenching and Molecular Structure in Liquid Scintillation Counting — Hilda Aledo (Puerto Rico) for the M.S. degree; completed June 1971; 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. This project receives support from the AEC Division of Biology and Medicine and is described elsewhere in this *Annual Report*.

2. Use of Single-Center Wave Functions in Scattering and Photoionization Studies — A. Grimison and W. Adam. A set of computer programs, designed to produce numerical single-center wave functions from molecular orbitals of diatomic molecules expressed as a linear combination of Slater atomic orbitals, has been implemented on the I.B.M. 360/40. The resulting single-center wave functions will be used for theoretical calculations of scattering and photoionization cross sections.

3. Radiation-Induced Aromatic Substitution — M. Eberhardt. The work on radiation-induced hydroxylation of nitrobenzene, chlorobenzene, and toluene was completed and submitted for publication. The graduate student trainee, Massayoshi Yoshida, who worked at PRNC from August 1970 to April 1971, used the results of this research in obtaining his Ph.D. degree from the University of São Paulo.

4. Radiation Damage in Organic Crystals — S. Weisz. This project receives support from the AEC Division of Physical Research and is described elsewhere in this *Annual Report*. Graduate student trainees: León Pereira and Lisandro Vargas.

**Radioisotopic Studies. Liquid Scintillation Counting** — J. P. A. Castrillón and M. Pope. 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  $\beta$ -spectrum of  $^{14}\text{C}$ . Graduate student trainee: Elsa Gómez.

b. A study of the effect of both series of compounds on the internal conversion electron spectrum of  $^{139}\text{Ce}$  has been completed. Graduate student trainee: Hilda Aledo.

c. New Solvents and Solute. 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. Selected organic structures with cyano substituents have been synthesized and used as efficient scintillation solutes. Graduate student trainees: Lydia Scarano and 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 Studies of Natural Water Bodies — A. McB. Block. The turbidity and dissymmetry of stream samples taken from the Río Sonadora—Espíritu Santo River system during the dry season were measured by precise techniques. It has been shown that turbidity can be used to estimate sediment loading during these periods. Dissymmetry measurements show little correlation with dissymmetries calculated for suspended spherical particles. If the spherical particle scattering model is to be applied, the results obtained indicate that relative intensities of scattered radiation at angles  $>90^\circ$  will give better cor-

relations. The results will be utilized in the research projects of the terrestrial ecology program at PRNC. Undergraduate student trainee: Félix Santos.

2. Structure of Phenanthrene — A. Grimison. As described in the last *Annual Report*, theoretical studies are being made on geometrical effects in phenanthrene observed in the neutron diffraction program. The earlier published results obtained with the CNDO-2 (complete neglect of differential overlap) formalism have been repeated by the EHT (extended Huckel theory) approximation. The minimum energy conformation of the molecule is found to be slightly nonplanar, in agreement with experiment. This confirms the earlier suggestion that the overcrowded H-H repulsion potential has considerable anisotropy, which can not be accounted for in the CNDO method because of the rotational invariance restrictions.

3. Electrophilic Aromatic Triphenylmethylation — M. Eberhardt. This project is a joint effort of PRNC and IVIC (Instituto Venezolano de Investigaciones Científicas). SCF-MO (CNDO-2) calculations on a series of anilines, alkoxybenzenes, and *ortho*-alkoxyphenols were carried out at PRNC. Experimental work on the triphenylmethylation of these compounds was done at IVIC by Dr. G. Chuchani. The results of the calculations are in perfect agreement with the experiments. In *ortho*-alkoxyphenols hydrogen bonding was found to be responsible for substitution *para* to the OH group. The results have been submitted for publication.

4. Coating Effects on Light Scattered from Polystyrene — A. McB. Block and A. Grimison. Calculations were made of the angular scattering of light from spherical polystyrene particles to see whether the angular functions could be influenced by very thin coatings. The coatings having a refractive index between those of polystyrene and of the dispersant (aqueous medium) were found to exhibit small displacements of some of the peaks in the angular scattering function, except for certain wavelengths of source radiation. At some wavelengths the angular scattering function changed dramatically with particle layering. Work is in progress to determine whether this change is a resonance effect or a computational artifact. Graduate student trainee: N. K. Mehta.

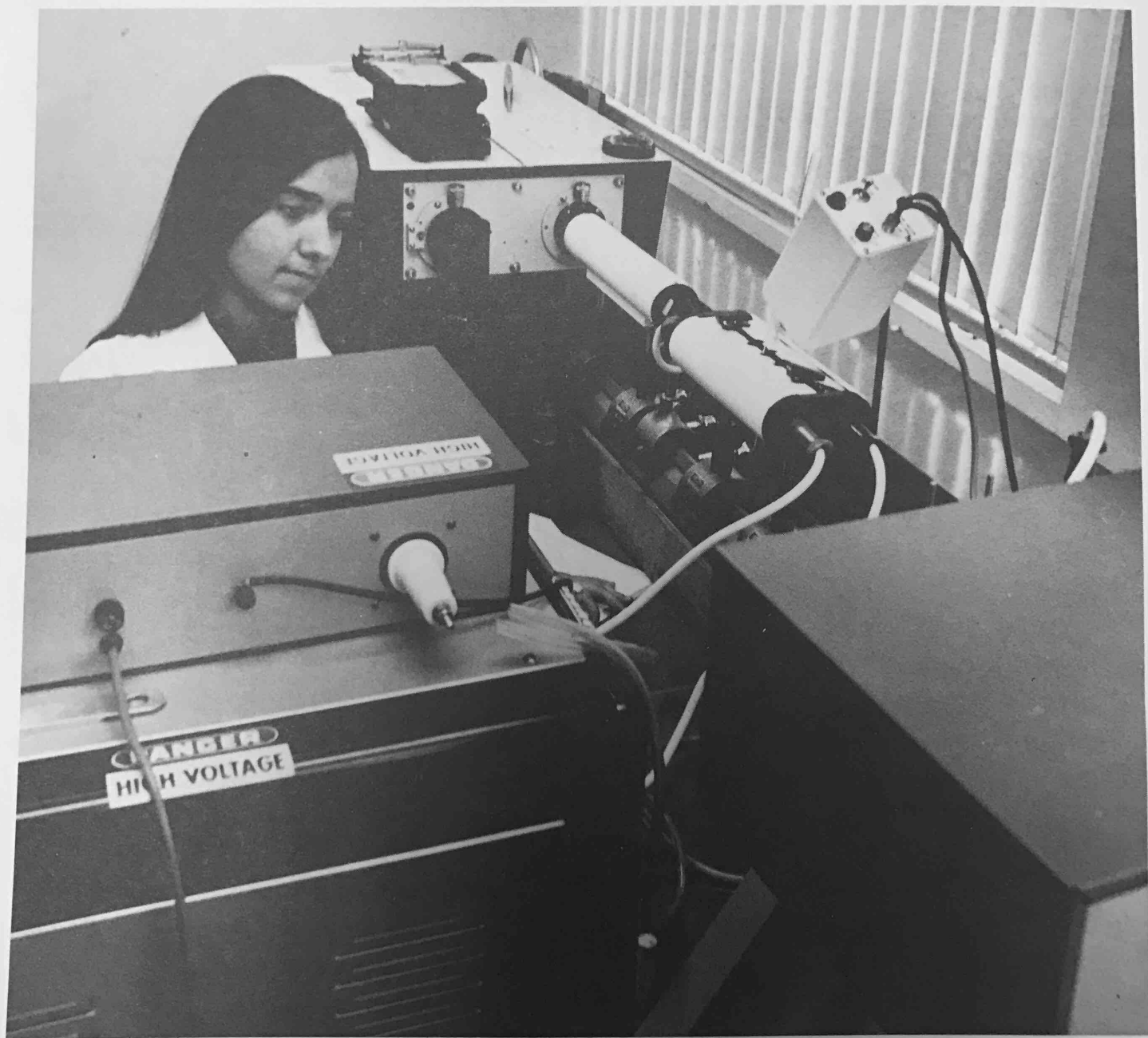
5. Coating Thickness of Trypsin Adsorbed to Silica — A. McB. Block and A. Grimison. The turbidity for a spherical model believed to approach the actual average particle size of silica-trypsin adsorption complex in dispersion was calculated as a function of protein thickness and compared with experimental results. In 0.05 M KCl at pH 8.6 the thickness calculated was  $54 \text{ \AA} \pm 10\%$ . Undergraduate student trainee: F. Santos; graduate student trainee: N. K. Mehta.

6. Kinetics of Glycogen Phosphorylase Catalysis — A. McB. Block. A program was written for the calculation of weighted values for  $V_{\max}$  (initial rate) and  $K_m$  (Michaelis constant) for the polymerization (and depolymerization) of glucose catalyzed by glycogen phosphorylase. The program takes into account increased uncertainties in concentration measurements at low concentrations. Graduate student trainee: P. A. Ríos de Santiago.

7. Thiaxanthone and Related Compounds — J. P. A. Castrillón. Studies on the determination of the ultraviolet and infrared spectra of this family of metallic complexes were continued. Graduate student trainee: Sonia Vázquez.

## STAFF

Dr. José Castrillón left in June 1971 for a year's leave of absence at the Institute of Sciences, Asunción National University, Paraguay, sponsored by the Organization of American States, to give courses and to initiate a research program in organic chemistry. During his absence, Dr. Martin Pope of New York University, who is spending his sabbatical year at the UPR Physics Department, will supervise the graduate students working on scintillation counting.



Miss Lorna Ramírez, Ph.D. candidate (UPR), obtaining flash photolysis spectrum of biologically active macromolecules.

# 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

1. Use of Single-Center Expansions in Photoionization Cross Section Calculations — Gladys Rodríguez (Puerto Rico) for the Ph.D. degree; to be completed 1972; under Dr. Alec Grimison and Dr. Waldemar Adam.

2. Flash Photolysis of Heterocyclic Compounds — José Revuelta (Cuba) for the M.S. degree; to be completed 1972; under Dr. Alec Grimison and Dr. Rafael Arce.

### CURRENT RESEARCH

**Electron Spin Resonance Studies at 77°K.** Radical anions have been postulated (PRNC-116) as reactive intermediates in the  $\gamma$ -irradiation of heterocyclic molecules in glassy matrices. They were previously identified by their optical spectra and by the fact that bleaching of the trapped electron band increased the intensity of the band attributed to the radical anion. Work has begun on identification of radical anions by their electron spin resonance (ESR) spectra. After  $\gamma$ -irradiation of pure MTHF (methyltetrahydrofuran) a singlet is observed superimposed on the center of a broad seven-line spectrum at microwave powers of 0.32 milliwatts. The singlet saturates at higher powers (12.5 mW) and could be bleached by using an iodine-tungsten lamp. The seven-line spectrum is probably due to the radical anion of MTHF. A solution of pyridine in MTHF ( $10^{-2} M$ ) irradiated at 77°K at the same total dose as the pure MTHF sample showed the same ESR spectra at low powers, but the singlet intensity was reduced 20%, probably because of the scavenging effect of pyridine capturing electrons to produce radical anions. At low or

high power conditions, no sign of pyridine radical anion ESR spectrum was observed because matrix radicals are in such a high concentration that their spectrum is dominant and interferes with that of the pyridine radical anion.

**Flash Photolysis of Heterocyclic Compounds.** A complete flash photolysis system was purchased in 1971, set up and tested, and is now functioning routinely. One of the first systems being studied is indole, since earlier work here suggested the occurrence of photoionization. Both the photoionization process and the recombination reaction will be investigated by flash spectroscopy. The equipment will be modified to permit low temperature (77° K) flash photolysis.

**Parisier-Parr-Pople Calculations.** The new computer program for calculating theoretical absorption spectra of radical cations and radical anions of heterocyclic molecules described in the last *Annual Report* has been completed. It has been shown to give excellent results for the ground state properties of homocyclic molecules, and is now being tested on heterocyclic systems with encouraging initial results. Among other uses, the program will be employed to analyze published assignments of transient spectra formed by pulse radiolysis of uracil, thymine, and cytosine.

## STAFF

Dr. Rafael Arce Quintero has joined the staff. He received his Ph.D. degree from the University of Wisconsin in November 1971, and holds a joint appointment at PRNC and the UPR Chemistry Department.

# Solid State Physics

## RADIATION DAMAGE IN ORGANIC CRYSTALS

Radiation effects and the possibility of their reversal in organic crystals are being studied on well-defined crystalline structures in order to provide a foundation for studies on more complex materials including those of direct biological interest. Anthracene was chosen as the initial material to be studied because large, very pure anthracene crystals can be obtained; much is known about its electrical and optical properties; and radiation damage due to high doses of neutron and gamma irradiation in anthracene has been studied.

This project is housed at the Natural Sciences Building at UPR, Río Piedras. UPR Physics Department graduate and undergraduate students are encouraged to do their thesis work under the guidance of PRNC staff members.

### STUDENT PARTICIPANTS

**Postgraduate.** Dr. S. Dellonte from the Laboratorio di Fotochimica e Radiazioni D'Alta Energia, Consiglio Nazionale Delle Ricerche, Bologna, Italy, spent a year here working on surface trapping in anthracene crystals. He was on a CNR fellowship which ended in May 1971.

**Graduate.** M.Sc. theses are listed below (sponsors are given in parentheses).

Surface Carrier Generation in Anthracene — Luís Fernando Rojas, Colombia (Instituto Colombiano para el Fomento de la Educación Superior), June-December.

Carrier Trapping Measurement by Continuous Photoinjection — León Pereira, Colombia (OAS), January-June. (Completed.)

A Time-Dependent Calculation of Exciton Diffusion in an Isotropic Crystal — Lisandro Vargas, Colombia (OAS), December-June. (Completed.)

**Undergraduate.** Felipe Cardona, Puerto Rico, September-December.

### RESEARCH

**Transient Photoinjection Currents and Surface Trapping in Anthracene Crystals.** Transient photoinjection current was measured in anthracene by applying under different voltage conditions a microsecond-risetime, strongly absorbed, step-function light pulse that was developed in our laboratory. In one extreme case, the crystal is illuminated for several



seconds with a steady light and then a voltage pulse is applied. The initial value of the current is space-charge limited, and its time dependence is similar to those reported previously by several investigators and analyzed as transient space-charge limited current in presence of trapping. In another extreme case, the crystal first has the voltage applied to it and is then illuminated with the step-function light pulse. Though the light intensity is the same in both cases, the initial value of the current in the second case is smaller, in some crystals by as much as a factor of 50. In both cases the current increases until the transit time and decays thereafter. The current decay near the transit time is much slower in the second extreme case than in the first.

By delaying the voltage pulse beyond the onset of the light pulse, the current curves are spaced in between the two extreme cases. The more time the voltage pulse is delayed, the higher is the initial value of the current, and the more the curve resembles the initially space-charge limited current curve. With the light intensity used, a voltage delay of the order of one second was sufficient in most of the crystals for the current to be initially space-charge limited. All the time-dependent current curves converge to the same value.

The above results can be explained by assuming surface trapping. If the voltage is on when the step-function light is applied, then part of the carriers generated are trapped at the surface and part are injected into the bulk. There is no carrier reservoir and the current is electrode limited. If the light is applied first, then during the interval between application of the light and of the voltage a carrier reservoir is built up. Depending on the surface trapping characteristics, the light intensity, and the voltage delay time, a large enough reservoir can be built for the current to be initially space-charge limited. When the voltage is applied, the reservoir is swept into the crystal. After the reservoir is depleted, the injection rate is the same as in the case of voltage applied first. Hence, the current initially — and for a certain period of time depending on the magnitude of the reservoir — is space-charge limited, and thereafter it is electrode limited. In the steady state the current is again space-charge limited. Since the bulk trapping kinetics when the current is space-charge limited differ from the kinetics when it is electrode limited, in studies of trapping times by the transient injection current method, the limitation on the current must be carefully specified. The surface trapping can also be responsible for the low quantum yield,  $10^{-4}$  to  $10^{-2}$  hole/photon, for single-photon extrinsic hole generation.

That surface and not bulk trapping is responsible for this phenomenon is supported by the experimental finding that illumination of a crystal to which a constant voltage is applied with a short-duration high-intensity light pulse does not diminish the current even at a repetition rate of 1000 pulses/sec.

**Time-Dependent Calculation of Exciton Diffusion in an Isotropic Crystal.** A calculation on the effect of reabsorption on the distribution of the excitons in an isotropic crystal was done by a Green's function technique with special emphasis on the time dependence of the reabsorption processes. The results showed that the effect of reabsorption is more pertinent at larger distances from the absorbing edge than near it.

**Surface Radiation Damage in Anthracene.** The experimental method used in studying surface trapping described above was used to study the extent of damage to the surface. When the crystal was irradiated with gamma rays, the initial value of the current and its subsequent time dependence followed the pattern of the current curves obtained by delaying the voltage pulse with respect to the light pulse. The higher the irradiation dose, the smaller is the initial value of the current. The radiation dose to the crystal at which the initial value of the current is affected is smaller than the dose that affects bulk trapping. Since it is very unlikely that the weakly absorbed gamma radiation would cause more damage at the surface than in the bulk, it is assumed that this phenomenon reflects the mechanism of carrier generation at the surface rather than surface trapping. Experiments on this phenomenon are in progress.



Dr. René Dietrich, at controls of whole-body counter during medical investigation.

# CLINICAL RADIOISOTOPE APPLICATIONS

The major function of the Clinical Radioisotope Applications Division is to train physicians and technicians in the diagnostic 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 last year's *Annual Report*. This year eleven students took the course (country of origin and sponsor follow each name):

February 8—April 2, 1971

José C. García, Honduras, National Autonomous University of Honduras

Virgilio Vargas, Costa Rica, PRNC

René C. Dietrich Ormachea, Bolivia, IAEA

Helena Bedoya (Feb. 5-19), Peru, PRNC

Marco A. Luján, Colombia, PRNC

José A. Pizarro, Puerto Rico, UPR School of Medicine

July 6—August 27, 1971

Elvira Giambartolomei, Argentina, PRNC

Ingrid Mai, Bolivia, PRNC

Célica Barboza, Uruguay, PRNC

Gerardo Valverde Aguilar, Costa Rica, Mexican Hospital of Costa Rica and PRNC

Aristides H. Sarmiento, Argentina, Argentine Army

**Lung Scanning Course.** A special two-week course in lung scanning, taught by Dr. Vicente López Majano of the Hines Veterans Administration Hospital, Hines, Illinois, was started on May 24, with the following participants:

Dr. Evelyn Cintrón, District Hospital, Ponce, Puerto Rico

Dr. Julio V. Rivera, VA Hospital, San Juan, Puerto Rico

Dr. Ramón Figueroa, VA Hospital, San Juan, Puerto Rico

Dr. Aristides H. Sarmiento, General Military Hospital, Buenos Aires, Argentina

Dr. René C. Dietrich, Camira Hospital, Sucre, Bolivia  
 Dr. Marco A. Luján, University of Cartagena, Cartagena, Colombia  
 Dr. Mario Iturralde, Atomic Energy Commission, La Paz, Bolivia  
 Dr. Arturo Valencia, Evaristo García Hospital, University of Valle, Colombia  
 Mr. Virgilio Vargas, School of Medicine, University of Costa Rica, San José de  
 Costa Rica, Costa Rica

The course included instruction in the preparation of microspheres, gammagraphy with perfusion, gammagraphy with aerosols, gammagraphy of aerial cavities with  $^{133}\text{Xe}$  by intravenous and respiratory routes, studies of regional ventilation, and clinical study of patients and interpretation of results. The work accomplished is tabulated below.

Gammagraphy in dogs	3
Studies of dogs in the Anger chamber	3
Gammagraphy in patients	9
Studies of patients in the Anger chamber	24
Discussion (analysis) of previous cases	25
Regional ventilation studies	3

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

Virgilio Vargas, April 5—June 25  
 René Dietrich, April 5—May 31  
 Ingrid Mai, August 29—September 30  
 Elvira Giambartolomei, August 29—December 12  
 Elisa Trabal, June 1-30

Marco A. Luján took training in metabolism, endocrinology, and nephrology, April 5—June 18.

**Research Training.** René Dietrich did clinical investigations with the whole-body counter and on utilization of the Anger chamber in the study of congenital cardiovascular abnormalities, June 1, 1971—June 30, 1972.

**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 L. Alcalá Collazo	Zarachí M. Belén Rivera
Bethzaida Alvarez Martínez	María T. Berríos Ramos
Evelyn Asencio Orlang	Carlotita Blanco Ramos

Isabel Candelario Anguita  
Alma R. Cañuelas León  
Julio Carrero Rivera  
Maritza Cartagena Palmer  
Agnes Cintrón Santiago  
María de los A. Colón  
Aurea E. Correa Maldonado  
Margarita Crespo Rosa  
Elizabeth Cruz Dandys  
Lourdes D'Acosta Nazario  
Migda M. Dieppa Mendoza  
Ida González Ortega  
Nydia Irizarry Montalvo  
Sandra Lynae Likus  
Evelyn Meléndez Ramos  
Marisol Méndez Rosa  
Juan Ramón Miranda Reverón  
María E. Ojeda Rentas  
Cándida Pagán Reyes  
Noelia Pérez Arriaga  
Olga Pérez Pérez

Carmen Pescador Vélez  
Ana María Pietri Padilla  
Ana L. Prieto de Jesús  
Evelyn Reyes García  
Miriam Ríos Serrano  
María Cristina Rivera Luna  
Carmen Rivera Marcano  
Jaime Rodríguez Colón  
María T. Rodríguez Malavé  
Magda S. Rodríguez Malavé  
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 H. Vila Pérez  
Maga Visbal Avilés

This course was repeated, November 22—December 3, for another 48 students:

María M. Alvarez Alayón  
Ana Irma Arroyo Massa  
Edwin Baez Montalvo  
Carmen Benítez Castro  
Margarita Braña Nieves  
Patsy Carrasquillo Seda  
Carmen Alicia Colón  
Carmen Ivette Colón Marrero  
Magda Costa Soto  
Norma Cumba Marrero  
Pablo Defendini Susoni  
Margarita Díaz Centeno  
Paulino Dorta Pérez  
Mirta Duarte Acosta  
Alma Vanessa Figueroa Ríos  
Elizabeth Flores Cotté  
Nellie Fonollosa Ramírez  
María de los Angeles Gándara

Teresita Garrido Mancini  
Milagros del Carmen Gerardino  
Nancy Irizarry Díaz  
Sandra Lisboa Morales  
Annettie Lugo Ortiz  
Alodía Marcial Soane  
Myrta Marín Olmedo  
Rosa Martínez  
Carlos Montero Torres  
Jack Negrón López  
Olga Oliver Orraca  
Brunilda Pagán Ramos  
Nancy Pereira López  
Francisca Perelló Segarra  
Zwinda Quijano Pesante  
Marina Quirós Solá  
Gail Ramos Martínez  
Pedro María Rivera Matos

Nitza Rivera Pacheco  
Alba Rodríguez Arrufat  
Carmen Rodríguez Torres  
Martha Rodríguez Xiques  
Carlos Román Martínez  
Francisca Sevilla Rosado

María Solis Aguiló  
Iris Mirta Solivan Rolón  
Edda Sustache Peña  
Ofelia Torres Poventud  
Gladys Vargas Acevedo  
Ibelissa Vélez Elena

On April 20 a lecture was presented to 25 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.

As part of the summer field training in the M.S. degree program in Radiological Health, Dr. A. E. Lanaro presented a course, June 14-18, which included two lectures on general applications of radioisotopes and five practical demonstrations and films. The seven students were Alvaro Carstens Ramos, Pedro del Valle Suri, Terry Krey, José V. Pérez Bobonis, Pedro J. Rivera, Etienne Rodríguez, and Juan Cabezas.

A general orientation course in Nuclear Medicine was offered for the 30 students enrolled in the Medical-Surgical Nursing Course during the mornings of December 6 and 7. The course included two lectures by Dr. Lanaro illustrated with slides, laboratory demonstrations, and a movie on radiation safety for hospital personnel.

## RESEARCH ACTIVITIES

**Red Blood Cell Survival in the Normal Population in Puerto Rico.** This study was continued (see 1970 *Annual Report*) in collaboration with the Department of Radiotherapy (Dr. A. Bosch and Miss Z. Frías). Tests done last year on six patients in the control group were repeated in order to determine the reliability of the method and evaluate any physiological variations. The following findings were confirmed: Normal survival is 36.6 days with a standard deviation of 4.3, the range being 28.5 to 47.5 days with a 36.5 median.

**Daily Ingestion of Iodine with Natural Diet of Inhabitants of Puerto Rico.** Collection of data for this project was continued (see 1970 *Annual Report*). The following was accomplished during 1971. At PRNC volunteers were interviewed on personal data, pathologic history, and type of food habitually eaten. They were then given instructions for a two-day collection of urine. A total of 320 urine samples was obtained. Urine creatinine levels in the 320 samples were measured in the Endocrinology Laboratory of the Hospital. At the Nuclear Center  $^{131}\text{I}$  uptake was measured in 90 patients, and 81 samples were sent to the Biochemical Procedures Laboratory for determination of total iodine eliminated in 24 hours. Fifteen water samples from different areas of Puerto Rico were sent to the Biochemical Procedures Laboratory for measurement of iodine content. The results obtained are being analyzed and will be published if statistically significant.

**Renal Plasma Flow.** This study (see 1970 *Annual Report*) is being continued with the determination of renal plasma flow in hypothyroid patients given increasing doses of oral thyroid medication. Tests were made on 12 patients. The study will be continued, with the addition of the glomerular filtration ratio test.

**Follow-up of Hyperthyroid Patients Treated with  $^{131}\text{I}$ .** Once again (see 1970 *Annual Report*) hyperthyroid patients treated with  $^{131}\text{I}$  in this Division were asked to come for an annual checkup. Clinical examinations and thyroid uptake tests were made on 76 patients. The condition of these patients at present is as follows: hypothyroid, 20; hyperthyroid, 8; and euthyroid, 48.

**Lung Scanning in Children with Congenital Cardiac Malformations.** This study, begun in 1970, was continued with the collaboration of Dr. A. Martínez Picó of the University Hospital's Pediatrics Department and Dr. René Dietrich. Very satisfactory results were obtained. In all, 21 patients were studied with 24 tests. The diagnoses were as follows:

	Cases	Tests
Fallot's tetralogy	8	8
Interventricular defect	2	2
Rheumatic fever	3	3
Transposition of large blood vessels	1	1
Pulmonary embolism	1	3
Anomalous venous return	1	1
Congenital cardiac insufficiency	1	1
Septal tumor	1	1
Atrial septal defect	1	1
Tricuspid atresia	1	2
Arterial trunk	1	1
Total	21	24

**Evaluation of Splenic Function by External Measurements.** Measurements of splenic function are being carried out in collaboration with Dr. René Dietrich by means of serial extraction of blood from the patients after injection of red blood cells labeled with  $^{51}\text{Cr}$  and damaged by heat, and simultaneously by means of external measurement of the activity in a profusely irrigated area. If the results of the two methods are comparable, it will be possible to dispense with extraction of blood from patients. Five normal volunteers were studied and 11 tests were made. Each patient was tested twice, to verify the accuracy of the method. In addition, 15 patients with conditions that might cause variation in splenic function were studied by both methods. These patients had the following diagnostics: splenectomy, 5; chronic leukemia, 3; polycythemia, 2; splenohepatomegaly, 2; ferropenic anemia, 1; splenic tumor, 1; and aplastic anemia, 1. The total number of patients studied is still too small to allow any conclusions to be drawn. This work is continuing.



**Determination of Splenic Function in Tropical Sprue.** It was reported recently that a change in splenic function had been found in patients with nontropical sprue tested with radioisotopes. In collaboration with Dr. José J. Corcino and Dr. René Dietrich it was decided to duplicate the study with a series of patients under treatment for acute tropical sprue to see whether the same changes would be found. To date 17 patients have been studied, of whom 12 have been under treatment for tropical sprue and 5 have phase 1 tropical sprue. The number of patients studied is small, but the first tests indicate no change in splenic function in these cases. Work is continuing on this project.

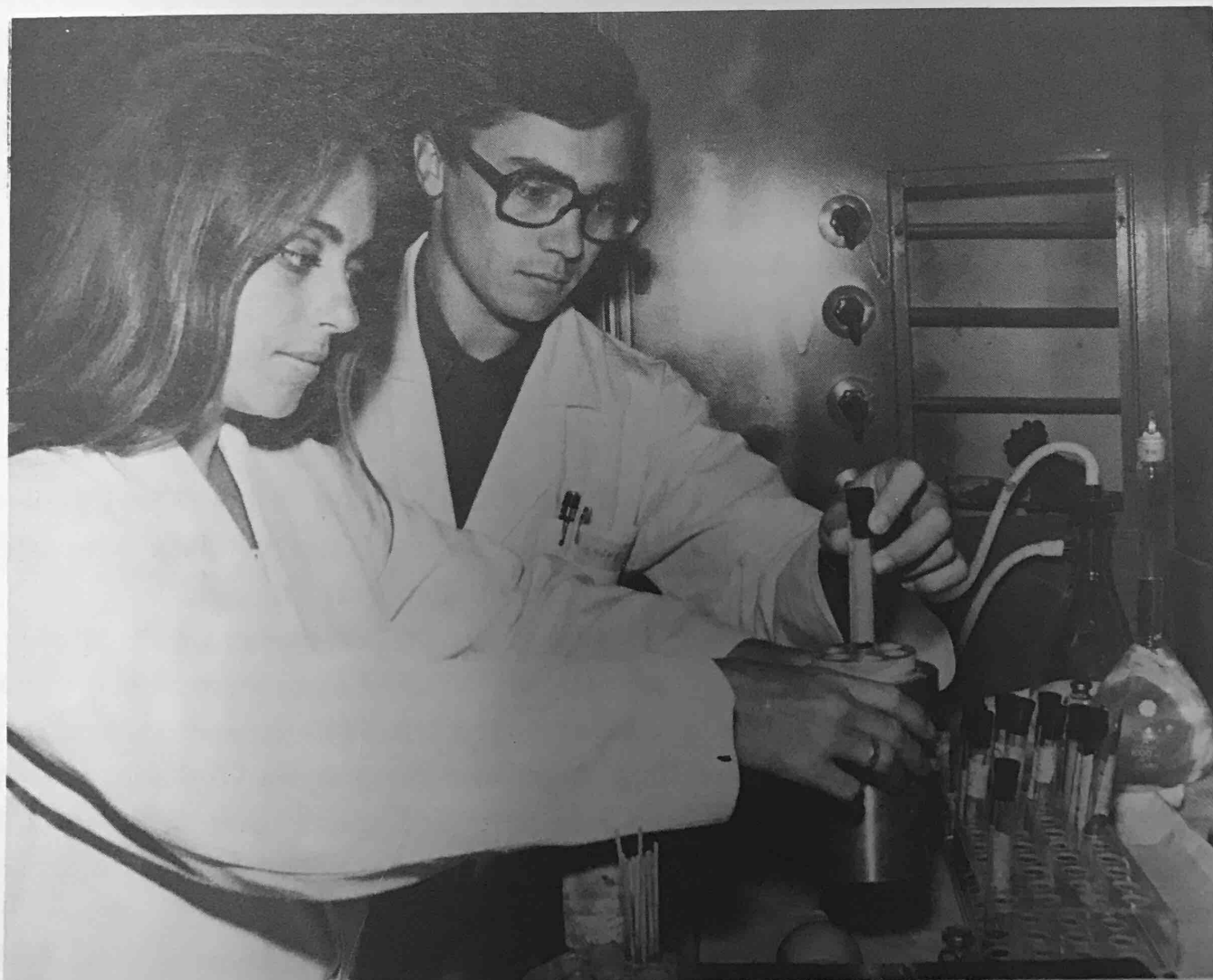
**Measurements with the Whole-Body Counter of Vitamin B<sub>12</sub> Absorption in Patients with Intestinal Malabsorption.** Measurements of intestinal absorption of <sup>57</sup>Co-labeled vitamin B<sub>12</sub> are being made in cooperation with Drs. José J. Corcino and René Dietrich. The technique consists of administering 1/2  $\mu$ Ci of <sup>57</sup>Co-labeled vitamin B<sub>12</sub> and measuring the activity immediately and again six days later, to determine absorption and accumulation of the vitamin in the organism. Fifteen normal volunteers and 33 patients with various types of intestinal malabsorption were studied. In all, 61 tests were made. Patients tested included 20 with acute tropical sprue, 7 under treatment for tropical sprue, and 6 with other types of malabsorption. The results are being analyzed.

**Measurement with the Whole-Body Counter of Vitamin B<sub>12</sub> in Thyroid Dysfunction.** With the objective of determining whether thyroid malfunction influences intestinal absorption of vitamin B<sub>12</sub>, and with the knowledge that the anemia present in some cases of hyperthyroidism may be related to malabsorption of vitamin B<sub>12</sub>, studies are being made on a group of patients with proved hypothyroidism or hyperthyroidism. Absorption of the vitamin is measured before and after treatment by the same procedure as that used in the work on intestinal malabsorption. During 1971, 25 tests were done on 24 patients, 14 hyperthyroid and 10 hypothyroid.

**Isotopic Angiocardiology in Congenital Cardiovascular Diseases.** This work is being done with the cooperation of Dr. René Dietrich and in collaboration with the Department of Pediatric Cardiology, UPR University Hospital (Drs. A. Martínez Picó, A. Muñoz, J. Sánchez, and M. Vega Vidal). A study plan involving the use of radioisotopes of short half-life with the Anger chamber is being worked out for purposes of diagnosis, follow-up, and observation of surgical results in children with cardiovascular malformations. The fundamental objective is to replace the current procedure, which makes use of cardiac catheterization and radiological study, by a method that is less traumatic, simpler, and cheaper, and reduces exposure of the patient to radiation. Work to date has involved 18 normal adults and 23 children with the following cardiovascular anomalies: Fallot's tetralogy, 6; interventricular defect, 5; interauricular defect, 3; mitral insufficiency, 3; arterial duct, 1; aortic insufficiency, 1; arterial trunk, 1; tricuspid atresia, 1; transposition of large blood vessels, 1; rheumatic fever, 1. Results to date are very encouraging, and many good pictures have been obtained. Work on this project is continuing.

Table 1  
Numbers of Teaching and Service Procedures  
Carried out During 1971 (Total, 4133)

Procedure	Service	Training procedures	Clinical teaching
Thyroid studies	900	642	540
Gastrointestinal	3	19	2
Hematology	2	68	0
Circulation studies	30	56	13
Liver studies	1	40	6
Renal studies	83	126	42
Organ and tumor localization	646	394	146
Water and electrolytes	2	22	0
Anger chamber			
Static studies	196	81	16
Dynamic studies	8	48	1
Total	1871	1496	766



Miss Ingrid Erdelyi and Dr. João Soares de Almeida, Brazilian trainees, doing hematology tests at a Clinical Applications Division laboratory.

## STAFF

On January 4, 1971, Mrs. María Luisa Santiago was appointed Research Assistant III in Nursing Services, to work part time as a nurse.

Dr. Michael A. Davis, Department of Radiology, Harvard Medical School, Boston, Mass., visited the Division on February 11-12 to discuss lung scanning with  $^{99m}\text{Tc}$ .

On February 16-18, Dr. Ernesto Rosemblyt of the Municipal Institute of Radiology and Physiotherapy, Buenos Aires, Argentina, visited the Division to discuss treatment with  $^{131}\text{I}$  and the results of tests on patients receiving  $^{131}\text{I}$  and on patients with thyroid disorders.

On May 19-21 the following participants in the Tenth Inter-American Congress of Radiology visited the Division:

Antonio Castiglio	Argentina
Dr. Luis Méndez Collado	Argentina
Mr. W. A. Ridge	U.S.A.
Dr. Ricardo García Martínez	Dominican Republic
Dr. Carlos Santos Morales	Peru
Dr. Augusto Mendoza P.	Peru
Dr. Luis Ricardo Bulla	Argentina
Dr. A. L. Frazer	Australia
Dr. Julio Kieffer	Brazil
Dr. Scocco Enzo	Argentina
Dr. J. P. Brito	U.S.A.
Dr. Alejandro Marquez	Peru
Dr. Luis Alberto Wybert	Argentina
Dr. A. Fernando Corsellas	Argentina
Dr. Raúl M. Bequelin	Argentina
Dr. Pedro Abel Maissa	Argentina
Dr. A. de la Torres	Argentina

On June 26-27, Dr. Aldo E. Lanaro attended the First Meeting of the World Federation of Nuclear Medicine and Biology, Los Angeles, California. On June 28—July 2 he attended the Tenth Annual Meeting of the Society of Nuclear Medicine in Los Angeles.

Dr. Lanaro served as a consultant to the Atomic Energy Commission of Ecuador, August 30—September 1. He met with several officials of the Ecuadorean Social Security Hospital in Quito. From September 5 to 11, he attended the 19th Argentine Workshop in Radiology, Corrientes, Argentina, and the First Argentine-Paraguayan Workshops in Radiology, Asunción, Paraguay. From October 5 to 9 he attended the Second Argentine Congress in Biology and Nuclear Medicine honoring Dr. Jorge E. Varela in San Martín de los Andes, Argentina.

Mrs. Myrta Cancel de Pagán, Laboratory Technician, was at the Laboratory of Nuclear Medicine, St. Joseph's Hospital, Tampa, Florida, from October 11 to October 22 under the auspices of Picker del Caribe, Inc., for training in the operation of the Anger chamber in dynamic studies.

On November 1, Dr. Carlos Enriori, a chemist from the Endocrinology and Metabolism Clinic, Buenos Aires, Argentina, and Dr. Ricardo Petrazzini, a chemist from Rio Cuarto, Argentina, visited the Division to discuss radioimmunity with Dr. Lanaro.

Dr. Ramón Figueroa, Veterans Administration Hospital, San Juan; Dr. Antonio Bosch, Radiotherapy and Cancer Division, PRNC; and Dr. Theodore Villafaña, Health Physics Division, PRNC, participated in the Basic Clinical Radioisotope Applications Course, giving conferences.

The following *ad honorem* appointments were continued for FY 1971-72: For participation in conferences and demonstrations in the Clinical Radioisotope Applications Course — Drs. Pedro J. Santiago, Mario Rosa, Julio Víctor Rivera, and José J. Corsino (who is also taking part in studies of vitamin B<sub>12</sub> absorption in tropical sprue and other intestinal disorders). For participation in research projects — Dr. A. Rodríguez Olleros. For participation in Radioimmunoassay Course — Dr. Francisco Aguiló.

Dr. Lanaro was a member of the committee that drafted the By-Laws for a Puerto Rican Society of Nuclear Medicine established on January 27, 1971. He was appointed the first Chairman. Dr. Lanaro also helped organize the Nuclear Medicine Section of the Tenth Inter-American Congress of Radiology, San Juan, May 16-22, and served as Chairman of the Nuclear Medicine Committee.

Juan Cruz, a student at the Francisco Oller School in Cataño, completed a project on the localization of radioactive elements in various organs of the rat. Dr. Lanaro was presented with a plaque by the Science Club of the school in appreciation of his dedication and spirit of service.



Miss Cecilia Ramírez, giving instructions to Dr. Alvaro Luongo of Montevideo, Uruguay, on calibration of a  $^{60}\text{Co}$  teletherapy unit.

# RADIOTHERAPY AND CANCER

The Radiotherapy and Cancer Division, besides education and research, carries on an advanced cancer therapy service. This Division functions as the Radiotherapy Department of the University Hospital of the UPR School of Medicine and collaborates with the Radiotherapy Department of the I. González Martínez Oncologic Hospital, which is adjacent to the PRNC Biomedical Building. At the Oncologic Hospital the Division staff utilizes equipment and space, operating rooms, hospital beds, outpatient facilities, clinical laboratories, and medical services for the care of cancer patients. The University Hospital provides hospitalization and hostel facilities, ancillary services for diagnosis and patient care, and facilities for the surgical and medical treatment of cancer.

At the academic level, the Radiotherapy Division operates as the Radiotherapy Program of the UPR School of Medicine. It also collaborates with the UPR School of Dentistry, with the Cancer Control Program of the Puerto Rico Department of Health, and with the Puerto Rico Regional Medical Program. It provides radiological physics and radiotherapy consultation services to the Veterans Administration Hospital. Partial support for the program is obtained from the UPR School of Medicine and from the National Cancer Institute through three grants to the School of Medicine.

## EDUCATION PROGRAM

The educational program includes the radiotherapy residency program (long-term training); the short-term radiotherapy training course; in-service training for medical students (on cancer), radiological physicists, and radiotherapy technicians; and lectures in radiotherapy and cancer for third-year medical students and fourth-year dental students.

The radiotherapy residency program, described in detail in last year's *Annual Report*, meets the requirements of the American Board of Radiology.

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.

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, 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) including lectures, seminars, demonstrations, and patient care under supervision with rotation through the various sections of the Division (PRNC and Oncologic Hospital treatment areas, follow-up, hospital and brachytherapy work, 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. Three people took in-service training in radiotherapy dosimetry.

Table 1  
Trainees, 1971

Name	Country	Date	Present position
<u>Short-term Radiotherapy Training</u>			
Dr. Enio Solisio	Argentina	Jan.	Bronx, V.A. Hospital
Dr. Guy Tufau	Haiti	Feb.-Mar.	" " "
Dr. Luis Cid	Cuba	May	" " "
Dr. Ricardo González	Colombia	June	Radiotherapist, Colombia
Dr. Kyu Han	Korea	Dec.	Bronx, V.A. Hospital
<u>Training Course for Medical Students</u>			
Frieda Silva	Puerto Rico	June	UPR School of Medicine
Hipólito Poussin	Cuba	June-July	" " "
David Limbert	Puerto Rico	July	" " "
Jaime Vázquez	Puerto Rico	July	" " "
Efraín Meléndez	Puerto Rico	July	" " "
Pedro Mora	Puerto Rico	July	" " "
<u>Long-term Radiotherapy Training</u>			
Dr. Gladys C. de Valda	Bolivia	Jan. 71-	Radiotherapist, Bolivia
Dr. Luz Toro de Berríos	Puerto Rico	Jan. 71-	3rd-year resident
Dr. Omar Salazar	Cuba	July 70-	2nd-year resident

Table 2  
Case Load of Radiotherapy and Cancer Division, 1970

Site	No. of Cases	
A. New Cases Treated		812
Oral Cavity	38	
Anterior 2/3 of tongue	8	
Floor of mouth	16	
Oral mucosa	1	
Other	13	
Oropharynx	85	
Base of tongue	32	
Tonsil	27	
Faucial arch	22	
Other	4	
Hypopharynx	29	
Pyriform sinus	19	
Other	10	
Nasopharynx	4	
Respiratory System	70	
Bronchus and lung	29	
Larynx	30	
Paranasal sinuses	8	
Other	3	
Digestive System	72	
Esophagus	55	
Other	17	
Breast	91	
Female Genital Organs	185	
Cervix uteri	132	
Endometrium	28	
Ovary	22	
Other	3	
Male Genital Organs	13	
Urinary Organs	20	
Bladder	14	
Kidney	6	
Skin	66	
Brain and Nervous Tissue	16	
Bone and Connective System	24	
Lymphatic and Hematopoietic System	60	
Hodgkin's Disease	13	
Other	47	
Unknown Primary	13	
Other	26	
B. Teletherapy Applications ( <sup>60</sup> Co, x rays, <sup>137</sup> Cs)		25,952
C. Intracavitary and Interstitial therapy		160
D. Follow-up		5,436



## RESEARCH PROGRAM

### Research by Residents

1. Carcinoma of the Cervix in Women 30 Years of Age and Younger — Dr. Luz Toro. A total of 41 cases out of the 1398 cases seen from 1956 to 1966 were reviewed. It was found that age did not influence the prognosis in these cases.

2. Brain Tumors — Dr. Omar Salazar. The experience with brain tumors in this Division is being analyzed for correlation of type of tumor, treatment, and survival. A total of 135 cases have been reviewed.

3. Tumor Immunology — Dr. Omar Salazar. The published data are being extensively reviewed.

4. Ureteral Obstruction in Carcinoma of the Cervix — Dr. Gladys C. de Valda. This study, in collaboration with Dr. Antonio Bosch and Miss Zenaida Frías, is described below.

### Research by Medical Students

1. Etiological Factors of Leukemia.
2. Treatment of Kaposi Sarcoma.
3. Management of Ewing's Sarcoma.
4. Nephrogenic Tumors in Children.
5. Cancer and Allergy.
6. Epidemiology of Cancer of the Penis.

### Division Research Completed

1. Optimal Irradiation in Carcinoma of the Esophagus. The purpose of this study was to test whether booster irradiation (2000 rads in 2 weeks at a rate of 200 rads 5 times per week) added to a standard dose of 5000 rads in 4 weeks for carcinoma of the esophagus would enhance survival. All the patients received the standard dose, and one half also received the booster. Dr. Jeanne Ubiñas found, in a preliminary review of the 60 cases in the study, that the number surviving up to 18 months was higher in the group that had received the booster.

2. Effect of Irradiation on Iodine-131 Uptake by the Normal Thyroid Gland. Thyroid function was studied in a group of 25 patients undergoing radiotherapy for cancer of the head and neck in whom the thyroid was entirely or partially included in the irradiation field. <sup>131</sup>I uptake studies were done before irradiation, at the end of treatment, and after 1, 6, and 12 months. A decrease in uptake levels at the end of irradiation was followed by recovery. The early hypofunction may be due to some inflammatory process in the thyroid tissue due to irradiation. Late effects could not be assessed because of the limited survival of these patients.

3. The Prognostic Significance of Ureteral Obstruction in Carcinoma of the Uterine Cervix. A study of radiology reports of intravenous pyelograms made on 990 of the 1086 patients with carcinoma of the cervix uteri seen from 1956 to 1963 revealed alterations in 143 cases (14%). Alterations in the pyelogram were more often observed in advanced cases. The presence of ureteral obstruction was closely related to stage and to prognosis. Nonvisualization of one kidney or bilateral urinary tract involvement should be considered as an indication to classify the case as a more advanced stage.

### Research in Progress

Floor of the Mouth. The experience with carcinoma of the floor of the mouth in the period 1966 to 1970 is being reviewed, with special attention to regression time of tumors after irradiation and to correlation of tumor control and complications with the irradiation technique used, particularly split-dose treatment.

### Plans for Cooperative Research

Radiation Therapy Oncology Group. This group is made up of academic institutions participating in national prospective clinical collaborative projects, and our Division has been accepted as a participant. Limited funding from the National Cancer Institute beginning in January 1972 will permit hiring of additional clerical and technical personnel for this purpose. Initially the Division will participate in the split-course national project (which is directed by Dr. Víctor A. Marcial), the project on treatment under normobaric oxygen with 5% CO<sub>2</sub>, and the project on treatment of brain metastases. The potential for participation will be enhanced by the accelerator and modern treatment-planning facilities that the Division expects to acquire.

2. Planning, Coordination, and Integration of Cancer Activities at the Puerto Rico Medical Center. Funding from the National Cancer Institute for this project, initiated in June under the direction of the Division, will pay for a core staff, for contracting with a consulting firm, and for consultants' fees. The core staff includes Dr. Víctor A. Marcial, Project Director; Dr. Antonio Bosch, Project Coordinator; and, as UPR School of Medicine Department Representatives, Drs. Enrique Pérez Santiago (Medicine), Enrique Oliveras (Surgery), Pedro J. Santiago (Pediatrics), Juan Velázquez (Pathology), and Eduardo Arandes (Gynecology). A consulting firm, Enviro-med, has been engaged to develop a plan for a cancer research center at the UPR School of Medicine.

### STAFF

Dr. Antonio Bosch transferred to the UPR School of Medicine on a full-time basis, but has continued his work at PRNC on an *ad honorem* basis. Half his time is spent on the cancer center project, of which he is Coordinator.

Effective March 1, 1972, Miss Zenaida Frías, M.S., will have a joint appointment, half at PRNC and half at the UPR School of Medicine; she is the biostatistician for the cancer center project. Effective March 1, 1972, Mrs. Ana H. O'Neill, R.N., chief radiotherapy technician in the Division, will have a similar appointment.

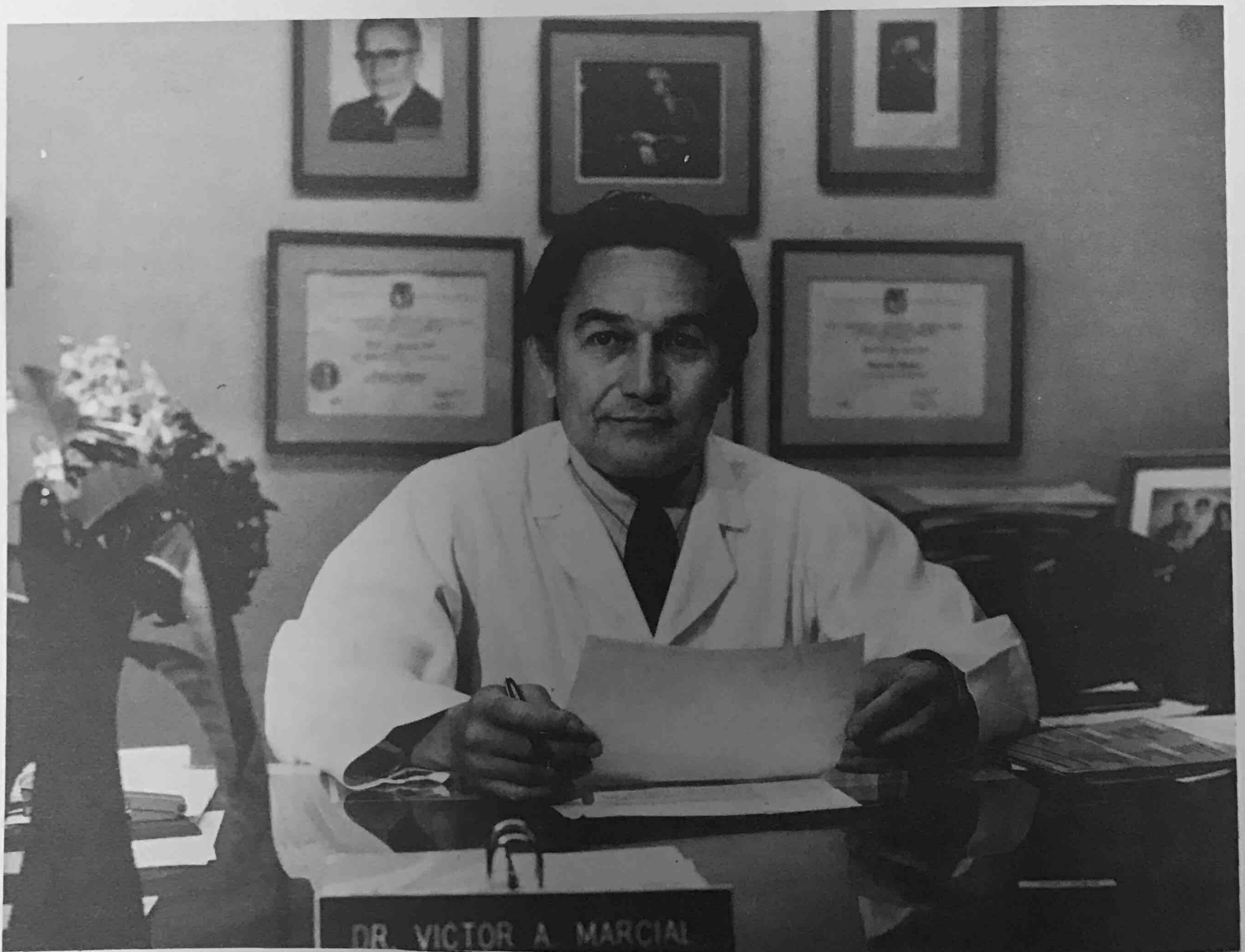
Previously in this Division and now in the PRNC Medical Physics Program are Mr. José C. Pacheco, Mr. Aníbal Bravo, and Miss Cecilia Ramírez.

Dr. Theodore Villafaña resigned his position as Chief of the Medical Physics Program in December. He is now at the George Washington University School of Medicine in Washington, D.C.

Scientists visiting the Division were Dr. Jack Fowler from the Mount Vernon Hospital, London, England, in June; Dr. Robert Kallman from the Stanford University School of Medicine, in August; and Dr. Raúl Mercado from the National Cancer Institute, in December.

Dr. Víctor A. Marcial was Visiting Professor at the Hahneman Medical College of Philadelphia in February, at the University of Minnesota School of Medicine in June, and at Washington University School of Medicine, St. Louis, in November.

In December, Dr. José M. Tomé presented lectures at the Barcelona School of Medicine and at the San Sebastián Institute of Radiosurgery in Spain.



Dr. Víctor A. Marcial, Associate Director for Medical Programs  
and Head of Radiotherapy and Cancer Division.

## Meetings Attended

Dr. Víctor A. Marcial: 53rd Annual Meeting of the American Radium Society, Mexico City, March.

Dr. Marcial: Radiation Therapy Oncology Group, Philadelphia, March.

Dr. Antonio Bosch: 3rd Meeting of Investigators in the International Study of Incidence of Leukemia Following Irradiation for Cancer of the Cervix, Geneva, April.

Dr. Omar Salazar: Radiation Research Society, Boston, May.

Entire staff: Tenth Inter-American Congress of Radiology, San Juan, May.

Dr. Marcial: Post-Graduate Course on Current Concepts in Radiation Therapy, University of Minnesota, Minneapolis, June.

Dr. Marcial: Joint Radiology Workshops of Argentina and Paraguay, Corrientes, Argentina, and Asunción, Paraguay, September.

Zenaida Frías: 72nd Annual Meeting of the American Roentgen Ray Society, Boston, September.

Dr. José M. Tomé: Hodgkin's Disease Symposium, St. Louis, October.

Dr. Marcial and Dr. Luz Toro de Berrios: 2nd Annual Meeting of the American Society of Therapeutic Radiologists, Phoenix, October.

Dr. Marcial: Steering Committee of Split-Course National Project, Phoenix, October.

Dr. Marcial: Puerto Rico Medical Association, San Juan, November.

Dr. Toro, Dr. Salazar, Dr. Gladys C. Valda, and José C. Pacheco: 57th Annual Meeting of the Radiological Society of North America, Chicago, November.

Mr. Pacheco: Winter Meeting of the American Association of Physicists in Medicine, Chicago, December.

Dr. Marcial, Dr. Bosch, and Miss Frías: Conference on Planning for Cancer Centers, Washington, D.C., December.

Dr. Marcial: Meeting of the Radiation Therapy Oncology Group, Denver, December.



Miss Ileana Rivera, measuring height of bean seedling.



Miss Carmen Vega, working with gas-liquid chromatography to separate silyl derivatives of  $^{14}\text{C}$ -labeled amino acids.

# 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 1971, 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 (outlined below).

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 — Mr. J. Cuevas-Ruiz
- Agro 556. Nuclear Techniques in Agriculture — Dr. S. N. Deshpande, Mr. J. Cuevas-Ruiz, and Dr. J. A. Ferrer-Monge
- Hort 605. Nuclear Techniques in Agricultural Research — Dr. S. N. Deshpande, Mr. J. Cuevas-Ruiz, and Dr. J. A. Ferrer-Monge
- Biol 614. Nuclear Techniques in Biological Research — Dr. S. N. Deshpande, Dr. J. A. Ferrer-Monge, and Mr. J. Cuevas-Ruiz
- Biol 618. Cytogenetics — Dr. J. A. Ferrer-Monge
- Biol 660. Special Problems in Biology — Mr. J. Cuevas-Ruiz
- Biol 480. Thesis Research — Dr. F. K. S. Koo (Río Piedras)
- Biol 699. Research (Thesis) — Dr. J. A. Ferrer-Monge
- Chem 566. Food Chemistry — Dr. S. N. Deshpande
- Chem 571. Nuclear Chemistry — Dr. S. N. Deshpande
- Chem 601. Radiochemistry — Dr. S. N. Deshpande
- Chem 699. Chemistry Research (Thesis) — Dr. S. N. Deshpande

**Graduate Research.** During 1971, eight 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. Research topics reflected the broad interests of the Division:

1. The effect of temperature on the mitotic cycle in *Vicia faba* L. — Carmen E. Cintrón, Puerto Rico, under Dr. J. A. Ferrer-Monge.

2. Electrophoretic studies of cytoplasmic and mitochondrial malate dehydrogenase isozymes in soybean seedlings — Isabel Bulla Dueñas, Colombia, under Dr. F. K. S. Koo.
3. 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.
4. Complementary effects of ionizing radiation and lipoxidase activity on the fatty acids of soybeans — Oscar V. Aragón, Nicaragua, under Dr. S. N. Deshpande.
5. Microanalysis of sulfur-containing amino acids by isotopic dilution and neutron activation — Carmen A. Vega, Puerto Rico, under Dr. S. N. Deshpande.
6. Electrophoretic analyses of several seed protein fractions of *Glycine max* L. — Ileana Rivera, Puerto Rico, under Dr. J. A. Ferrer-Monge.
7. Characterization of the degradation products of enzymatic and radiation breakdown of fatty acids by electron spin resonance and gas liquid chromatography — José M. Ortiz, Guatemala, under Dr. S. N. Deshpande.
8. Studies to determine the presence of growth inhibitors in the seminal structures of *Carica papaya* and to improve germination — Nihlson Reyes, El Salvador, under Dr. A. Pérez and Mr. J. Cuevas-Ruiz.

**Special Training.** The Division has been active in technical and scientific training programs. On April 22, Dr. Charles A. Panton, Lecturer at the University of the West Indies in Jamaica, started a six-month special study assignment, under the sponsorship of the International Atomic Energy Agency, on cytogenetics, mutation breeding methodology, and effects of physical and chemical mutagens on soybeans. On August 12, Miss Elaine Montague from the same university, started a one-month training assignment in radiobiology and mutation breeding methodology, partially supported by a grant from the PRNC Student Economic Aid Program.

From August through December special training was given to Miss Elizabeth Pastrana and Mr. Enrique Torres (advanced undergraduate students, UPR) in the use of mitogenic substances (cell division stimulants) in *in vitro* and *in vivo* blood cultures in amphibians.

## RESEARCH ACTIVITIES

**Crop Improvement.** The soybean mutation breeding program has two main objectives: (1) to improve adaptation to tropical environmental stresses and thus improve the yield potential, and (2) to improve the quantity and quality of the seed protein. In the summer of 1971 the late-flowering and/or late-maturing selections and the day-neutral types (in  $M_4$ - $M_6$  generations) from the irradiated Hill and Lee varieties were grown for further selection and observation, and many lines were found to breed true for delayed maturity. The day-neutral selections were again planted in the field in December for further selection and observation. During the same summer season, seeds of the selected high-yielding varieties Hardee and NTU-Kaohsiung 5 were treated with 1 and 1.5 krads of fast neutrons, and the  $M_1$  generation was grown at Isabela as additional mutation breeding material.

Further trials for regional adaptability and yield of five varieties (Hill, Hardee, NTU-Kaohsiung 5, Wakashima, and Tainung 3) were conducted at Isabela and Las Mariás.

Heat tolerance studies of 15 soybean varieties were made by replicated single dipping tests, as described last year. Again the varietal differences were clearly demonstrated.

Methionine is the most important among the several limiting essential amino acids in soybean protein. To facilitate selection for mutants with high methionine content, an analytical procedure for amino acids based on isotopic dilution was developed, and further improvements in the procedure have been made in recent months. The method consists of hydrolysis, removal of the electrolytes from the hydrolyzates, isotopic dilutions with  $^{14}\text{C}$ -labeled methionine, separation by thin-layer chromatography or thin-layer electrophoresis, and finally assay of the radioactivity of the labeled material by liquid scintillation counting. So far, the following facts have been established. Compared with reflux treatment or enzymatic hydrolysis, autoclaving the samples in ampules for 4 hr is the most efficient as well as the most rapid method of hydrolysis. The nuclear techniques of isotopic dilution are far more sensitive than the classical colorimetric techniques. A sample of soybean meal as small as 50 mg can be used for hydrolysis, whereas other methods require 0.5 to 1.0-g samples. Judging from the levels of the sulfur-containing amino acids used as internal standards, the recovery is  $> 97\%$ . Despite the reduction in hydrolysis time from 24 to 4 hr, and in the sample size from 500 to 50 mg, the nuclear techniques have proved to be the most sensitive, precise, and rapid. A single technician can analyze about 48 samples in a day without the expense involved in an amino-acid analyzer.

The feasibility of improving the nutritive value of plantain by selection is being explored. Clones of 6 varieties (Guayamero, Harton, Enano, Maricongo, Congo Blanco, and Congo Colorado) collected from various farms were analyzed for carotenoid and ascorbic acid contents in 90 to 120-day-old fruit, and significant and highly significant differences were found. The fruit pulp-to-peel ratio of different clones also showed differences. These preliminary results indicate that improvement of plantain quality can be achieved by selection among the clones. Additional collections are being made to increase the source material for further selection.

Studies on yield improvement in yams by low radiation dose stimulation (2 krads) were continued. Yield increase in the range 25 to 74% over the controls was observed in all three experiments. In similar studies with two varieties of soybeans, Hill did not respond favorably, but Hardee showed 7% increase in yield over the control at 4 krads although not at 8 and 12 krads. The seed size of Hardee was also found to increase with radiation.

**Food Science.** The green soybean may be preserved by freezing, but off-flavor and rancidity may develop during extended storage. Such deterioration may be due to attack of the lipids in the seeds by lipoxidase. It is of interest whether gamma radiation can inactivate the enzymes so that the period of frozen storage can be greatly extended. Three varieties (Hardee, Sankou, and Wakashima) were subjected to gamma radiation of 500, 1000, and 2000 krads. The samples were then stored at  $< 0^{\circ}\text{C}$  for 30 weeks and analyzed at weekly intervals. Five fatty acids were found predominantly in both the control and



irradiated material: linoleic, stearic, palmitic, oleic, and linolenic acids (in ascending order of concentration). With increased radiation dose a corresponding reduction was seen in the concentrations of all five. Compared with the control, 500 krads seemed to suppress the activity of lipoxidase, but the higher doses apparently caused radiolysis of linoleic acid, as its concentration fell steeply. After higher doses, no significant change in linolenic and oleic acid concentration was seen during extended storage, but a noticeable decrease in stearic acid took place, in particular after 2000 krads. Relatively little change occurred in the concentration of palmitic acid regardless of storage time or radiation dose. Varietal differences were also observed. Hardee retained the highest concentrations of the five principal fatty acids and seemed relatively resistant to both the radiation and the enzyme activity; next was Wakashima; and Sankou was the least resistant to radiolysis of fatty acids and the most susceptible to enzymatic breakdown. These results indicate that a compromise is needed such that the radiation suppresses the enzyme activity but does not cause radiolysis of the lipid structure.

Preservation of yams (variety Florido) by gamma irradiation was initiated recently in cooperation with the UPR Agricultural Experiment Station. Radiation appears to be far more effective in preventing sprouting than the chemical isopropyl N-(3-chlorophenyl)-carbamate, especially at a dose level of 10 krads, for yams stored at ambient temperatures.

**Radiobiology.** Additional studies of radiation effects on soybean malate dehydrogenase were made with the anionic gel system polyacrylamide gel plus disc electrophoresis. The seeds of the variety Hill were exposed to 1.5 krads of fast neutrons or 15 krads of gamma rays. The seedlings were grown under light or in the dark for 14 to 15 days, and the cytoplasmic fraction of the enzyme was extracted from the roots, hypocotyl, cotyledons, epicotyl, and leaves. The basic pattern of MDH isozymes consists of 4 bands; however, in cotyledons and leaves an additional band was observed, indicating the existence of tissue specificity. Radiation and growth conditions also appear to affect the isozyme pattern formation in terms of increasing the number of bands (from 4 to 5) and modifying the staining intensity.

Further studies with soybean esterases revealed the following: (1) esterase was present in all tissues of developing plants (up to 22 days old), (2) this enzyme was most abundant and persistent in the cotyledons and least abundant in the roots, and the amount in the first pair of leaves, hypocotyl, and epicotyl was intermediate, (3) with development there was a gradual decrease in quantity in the tissues, (4) the isozyme patterns in soybeans seem to be different from those in several other plants as both anodic and cathodic bands were observed, and (5) in contrast to other similar studies, no clear-cut effect of radiation was observed on the overall isozyme patterns.

**Cooperative Research.** The Division continued to promote cooperative investigations with other institutions. Several programs were in progress in 1971, including (1) adsorption of <sup>14</sup>C-labeled herbicides by different types of Puerto Rican soils (with UPR Agricultural

Experiment Station), (2) feasibility of yam preservation by radiation (with UPR AES, see above), (3) relation of pectic enzyme activity to fungal infection in vanilla roots (with Federal Experiment Station), and (4) yam improvement (with FES).

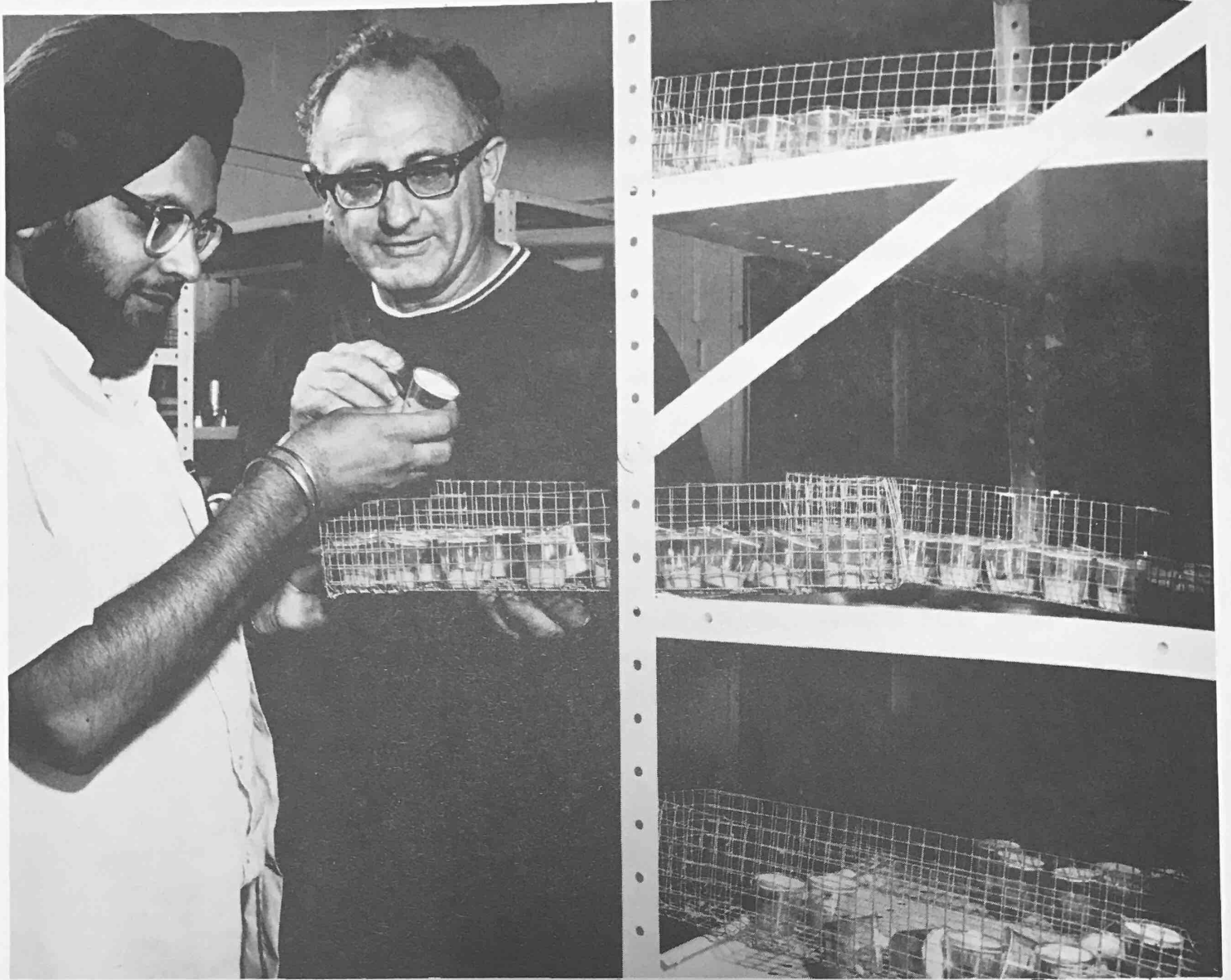
In the study of differential adsorption of 2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine (Atrazine) and 3-*t*-butyl-5-chloro-6-methyluracil (Terbacil), 34 Puerto Rican soils showed large variations. The Caño Tiburones soil was the most adsorptive for both herbicides; the Toa sandy loam was the least adsorptive for Atrazine and the Talante sandy loam for Terbacil. Atrazine was consistently adsorbed to a greater degree, and its adsorption was correlated positively with organic matter content, cation exchange capacity, and magnesium and silt content but negatively with sand content. Adsorption of Terbacil was positively correlated with organic matter, cation exchange capacity, soil pH, and content of phosphorus, calcium, magnesium, and clay but negatively with sand content. Representative adsorption isotherms of Atrazine and Terbacil on several important Puerto Rican soils used for sugarcane cultivation were also analyzed.

In the study of pectolytic enzymes in vanilla roots infected by *Rhizoctonia solani*, the activities of pectin methyl esterase, pectin polygalacturonase, and  $\alpha$ - $\beta$  transeliminase were measured by determination of the methoxyl content of the substrate solution used, by viscometry, and by colorimetry of the complexes produced by reaction with thiobarbituric acid, respectively. The results indicate that the pathogenic and symbiotic associations led to the elaboration of higher concentrations of these enzymes than in uninfected healthy controls. This is further supported by the finding that the kinetics of the action of these enzymes was accelerated in the infected plants.

## STAFF

On October 27, the entire scientific staff of the Division participated in a panel discussion, organized jointly by the Division and the UPR College of Agricultural Sciences and held at PRNC Río Piedras, on Agricultural Research Coordination and Cooperation, with the objective of finding ways to produce more and better food.

Dr. Ferrer-Monge continued to serve as a member of the Radiation Advisory Group to the Puerto Rico Commission for Radiation Control. He attended three meetings including one public hearing on the new law for regulating the use of x-ray machines and radioisotopes in medicine and industry.



Dr. Harpal Singh, ORAU research participant, and Dr. David Walker, Director of the Insect Sterility Project, examining *Diatraea saccharalis* laboratory colonies growing on artificial media.

# Induced Sterility in Insects

The original purpose of this program was to determine whether the sugarcane borer, *Diatraea saccharalis* (Fab.) (Crambidae: Lepidoptera), could be sterilized and subsequently released in nature to achieve eradication. In the earliest phases we concentrated on artificial rearing methods with the objective of mass rearing, and on establishing dosage sterility response and other aspects of biology and reproduction essential to a field release program. We found that low doses of gamma radiation to P generation parents had only a small effect on F<sub>1</sub> embryo development and also a small lethal effect on survival of F<sub>1</sub> larvae and pupae. In the F<sub>2</sub> generation embryo survival was lower and there was also death in F<sub>2</sub> larval stages. This was traced out with inbreeding and outbreeding for several generations. We called this phenomenon *delayed lethality* since it occurred in the F<sub>1</sub> generation and in subsequent generations to F<sub>9</sub>, and later used the term *inherited partial sterility* (IPS).

The aspect of IPS originally of interest was its relation to eradication or suppression of pest insects; however, its relation to the capability of organisms for retaining a gene load over several generations is important to both entomologists and geneticists. We believe the phenomenon to be related mainly to the specific type of chromosome found in the lepidopterans: the chromosome is holokinetic, i.e., it has diffuse kinetochores. Other orders of insects having this type of chromosome are the Homoptera and Hemiptera. Some of the most important agricultural crop pests are in these two orders and in the Lepidoptera.

The present widespread and intense interest in the quality of the environment together with the continuing need for high yields of high quality agricultural products raises the serious problem of maintaining high agricultural production with minimal environmental damage from pesticides. The first stage in reducing environmental contamination is switching to specific, low-toxicity pesticides with short residual decay time, e.g., using insecticides that cause minimum damage to nontarget species and are rapidly degraded in the field. Another step is to use smaller amounts of the toxicant (low volume sprays) and to apply it directly to the pest's micro-environment in order to avoid contamination to nontarget species and to nontarget environments. The liberal and intelligent use of predators, parasites, and insect diseases, the use of crop plants selected for resistance to pest attack, improved cultural practices, use of oviposition or mating lure traps, and finally the release of sterile or semisterile individuals into the environment to suppress or eradicate the pest species are other methods for solving the pest control dilemma. This concept of pest management practices, developed by Dr. E. F. Knipping of the ARS, USDA, is called *integrated control*.

In the induced sterility program we have concentrated our efforts on the last phase of this method, namely suppression and eradication of pests with holokinetic chromosomes.

During 1971 we worked mainly with four species of insects: three Lepidoptera (sugarcane borer, bean leaf sticker, and yellow-striped armyworm) and a Hemipteran (southern green stink bug). We have concentrated on the following problems: artificial diets and handling methods for rearing in the laboratory, gamma exposure in relation to dominant lethality and to IPS, fractionated dosage and sterility effect, effect of hormones and radiation in combination, and host plant choice (i.e., ovipositional choice determination).

## LEPIDOPTERA

**Sugarcane Borer (*Diatraea saccharalis*).** We have improved the rearing method by using one-ounce plastic jelly dispensing cups with carton lids or plastic dishes. The latter method was developed by Dr. A. N. Sparks at the USDA Southern Grain Insects Laboratory in Tifton, Georgia. Survival is fairly good in both types of containers when a modification of the Shorey bean diet is used.

The IPS test data from experiments done in 1963 through 1970 were organized and transferred to IBM cards for study by computer methods. Flow diagrams and hereditary lines were set up for 18 of these experiments. Further analysis of these data will provide the basis for a series of papers on genetic collapse of insect populations.

A series of preliminary experiments has been done on the effect of fractionated doses in relation to dominant lethality effects and IPS effects; these will allow additional critical evaluations. The effect of juvenile hormone (Cal Biochem B) and moulting hormone (Ecdysterone) applied to third, fourth, and fifth stage larvae and to young pupae was evaluated in preliminary tests for dominant lethality, development rate, survival, and IPS effect. Juvenile hormone is reported to cause chromosome "puffing."

Dr. Niiko Virkki of the Agricultural Experiment Station, UPR, Río Piedras, who has an *ad honorem* appointment to the program, is studying cytological abnormalities, particularly chromosome abnormalities, and meiotic disturbances in IPS borer larvae. No translocations have been observed (at meiotic metaphase) even when there is an IPS effect. Differences in hemolymph protein between IPS and normal lines are being studied by disc gel electrophoresis.

The indigenous pathogens of sugarcane borer larvae are being studied in cooperation with Dr. Goru Kuno of the Biology Department, UPR, Mayagüez, who has an *ad honorem* appointment to PRNC. Preliminary observations have not demonstrated bacteria, rickettsia, fungus, or protozoan organisms in diseased larvae. This leads us to suspect virus infection(s). Unfortunately the cultures isolated were destroyed before testing was completed, but new cultures are being collected as diseased larvae become available.

**Bean Leaf Sticker, "Pega Pega" (*Lamprosema indicata*).** The bean diet proved to be nutritionally reasonably satisfactory for the third, fourth, and fifth instars of this species so that a combination of leaf material for the first and second instars followed by bean diet allowed maintenance of a larval population. Getting the adults to mate under laboratory conditions was very difficult, partly because this species apparently needs considerable horizontal air space in which to perform its prenuptial courtship. Because of this difficulty we have discontinued our laboratory colony.

The data accumulated about the life cycle and biology of the bean leaf sticker will be published, but the data from radiation experiments were not sufficiently critical to warrant further evaluation. Further radiation tests are impractical until the species can be reared artificially with a predictable survival rate.

**Yellow-striped Armyworm (*Prodenia ornithogalli*).** The armyworm was raised on the bean diet and is now being cultured on a modification of the bean diet in plastic dishes and jelly cups. Preliminary IPS tests at exposures of 4, 6, 8, and 10 krads resulted in complete mortality of F<sub>1</sub> larvae before pupation.

## HEMIPTERA

**Southern Green Stink Bug (*Nezara viridula*, Pentatomidae).** The stink bug is being cultured on a combination of bean pods from a local legume that grows wild here, cabbage leaves, snap bean pods, and acerola and guava juice. Colonies have been maintained for four successive generations in the laboratory. The rate of predation on eggs and on younger nymphs has been high. P generation adult females were exposed to 1.5, 7.5, or 15.0 kR, and we are maintaining F<sub>2</sub> offspring survivors from the lowest dose. With higher doses none of the F<sub>1</sub> offspring survived to the adult stage. The developmental rate, life stages, mating and courtship behavior, and embryonic development were studied also. Mr. Rubén Restrepo has prepared a report on the preliminary experiments on laboratory rearing methods and diet tests for *Nezara*. Mr. Restrepo has been working with the program and pursuing his studies for the M.S. degree in entomology while on leave from the Universidad Nacional, Bogotá, Colombia.

**Other.** In addition to the above species, diets and artificial rearing methods were tested with the following insects:

Coleoptera:	Fam. Chrysomelidae:	<i>Systema basalis</i>
	(flea beetles)	<i>Ceratoma ruficornis</i>
		<i>Epitrix cucumeris</i>
	Scarabiidae:	<i>Phyllophaga vandenei</i>
	Curculionidae:	<i>Diaprepes abbreviatus</i>
		<i>Cosmopolites sordida</i>
		<i>Metamasius hemiptera</i>
<i>Cylas formicaria</i>		
	<i>Anthonomus spp.</i>	
Hemiptera:	Fam. Pentatomidae:	<i>Acrosternum marginatum</i>
		<i>Leptoglossus gonagra</i>
Lepidoptera:	Fam. Phalaenidae:	<i>Trichoplusia ni</i>
		<i>Prodenia eridenia</i>

All the above are pests of major crops in Puerto Rico and cause considerable losses.

## STAFF

In December Miss Alba Rivera-Detres began her M.S. thesis research on the isolation and identification of the haemolymph proteins of *Diatraea* larvae by disc electrophoretic and other methods.

Dr. Walker continued his cooperative work with Dr. Nader Vakili, USDA Crops Research Division, Federal Experiment Station, Mayagüez, on the development of varieties of beans and cowpeas resistant to disease and pest insect attack. Dr. Walker's function is advisory, and he cooperates in the field work on insect problems.

In June, Dr. Walker visited Professors Derek Campion and Clifford Lewis at the Imperial College of Agriculture Field Station in Ascot, England. He also visited Dr. Rolando Dietz at the Max Planck Institute, Tubingen, Germany, who is working with spindle fibers in Nematocerans (Diptera). Dr. Walker attended the Entomological Society of America Meeting in Los Angeles, November 28 through December 2.



Dr. David Walker, Dr. Harpal Singh, and Mr. Kenneth MacKay, examining *Diatraea saccharalis* adult moths and eggs in a laboratory colony.

# 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  $^{60}\text{Co}$  radiation source, a mouse colony, and snail colonies.

A new project on tumor radiobiology has been proposed, to provide for the training and research needs of medical residents in the PRNC Radiotherapy and Cancer Division and to strengthen the radiobiology program of this Division. Another proposal is to elevate immunology to project level, since it is basic in relation to tropical diseases and is therefore a unifying discipline for this Division. Knowledge of immune mechanisms against parasites is urgently needed for the development of vaccines. These mechanisms and those imposed against tumors may have common features.

## EDUCATIONAL ACTIVITIES

### M.S. Thesis Research.

1. Search for plants toxic to snails (see section on Fascioliasis, below) — 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 L. Borrero, UPR School of Medicine.

3. Genetics analysis of the *Microsporium gypseum* complex at the molecular level — José A. Carrasco, UPR School of Medicine.

**Formal Courses for Academic Credit.** PRNC 510, Radiation Biology, was taken by one student from Bolivia, one from Paraguay, one from Brazil, and eight from Puerto Rico. PRNC 515, Radiation Effects on Mammals and Humans, was taken by one student from Venezuela, one from the U. S., and three from Puerto Rico.

### Special Training.

Use of Radioisotopes for the Study of Intermediary Metabolism — Angela E. Caldes Castillo, Puerto Rico.



*Fasciola hepatica* — Dr. Plinio Gomes, Brazil, and Dr. Alfredo Velarde, Peru (fellowships sponsored by the Pan American Health Organization).

Biochemistry — Ana María Viader, Puerto Rico.

Schistosomiasis and Fascioliasis — Mercedes Vargas, Dominican Republic (3 months on-the-job training in research methods, including clinical observations on schistosomiasis in humans).

Virology — Lillian Casanova, Puerto Rico, and Mary Ann Rodríguez, Puerto Rico.

**Science Fairs.** William Wilson, high school student, was assisted in demonstrating that cercariae can be filtered from water by a column of fine sand less than 1 ft high. With this simple scientific observation he won top honors at science fairs in Puerto Rico and in Kansas City. He was awarded a trip to Sweden to a youth conference on pollution. Other students were also so assisted with work for local science fairs.

## 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 Dr. Jorge Chiriboga, Dr. Raymond A. Brown, and Dr. 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.

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

Puerto Rican Committee for Bilharzia Control — This Committee includes agencies that might aid in or benefit from the control of bilharzia. Division staff members participate in the Committee's programs, and Dr. L. S. Ritchie is currently Chairman. He also served as chairman of a subcommittee to review possible hazards of bilharzia from use of Puerto Rican lakes for recreation.

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.

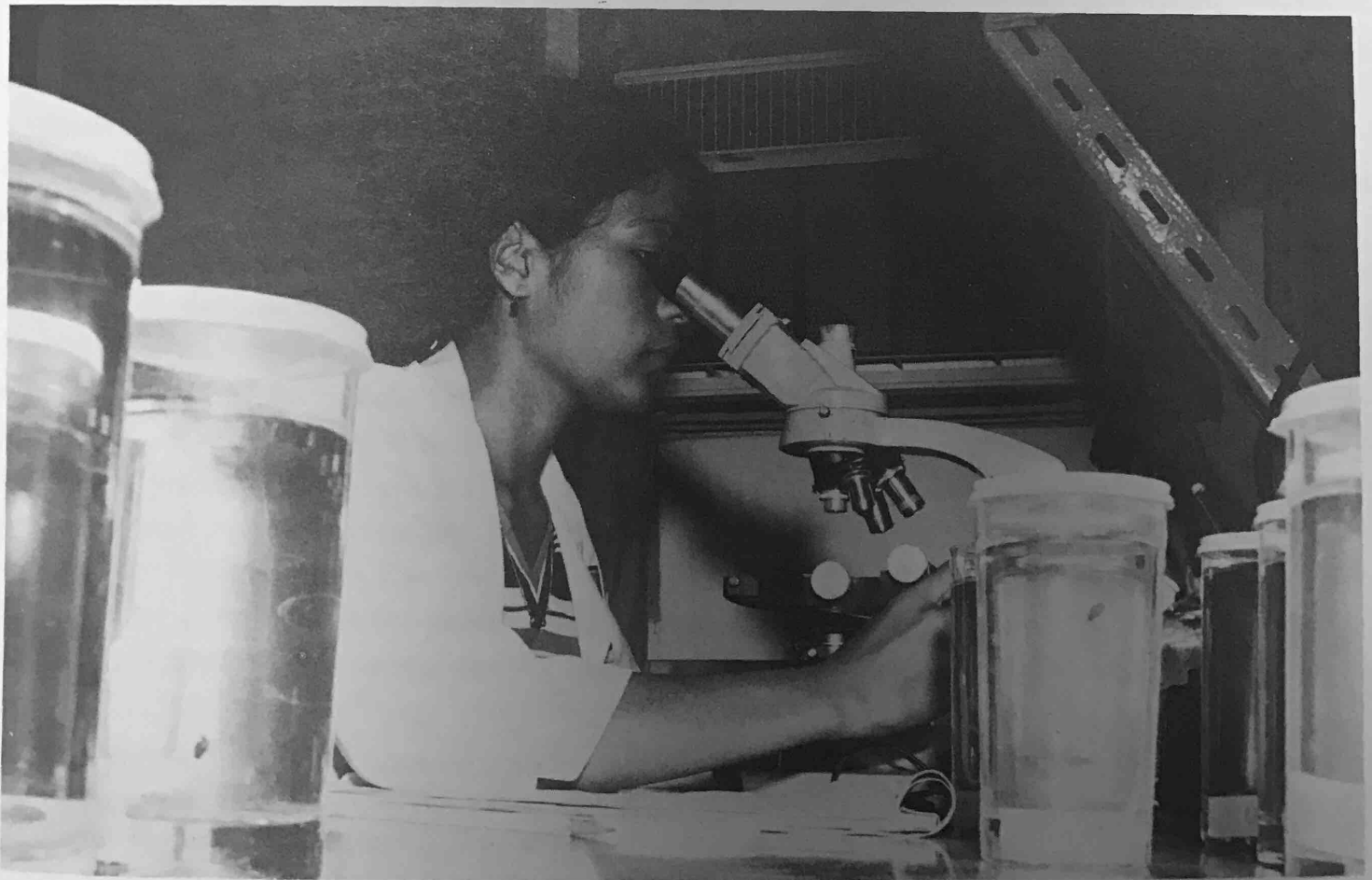
Puerto Rico Department of Agriculture — The Division's research on *Fasciola hepatica*, one of the most important parasites in Puerto Rican and South American agriculture, is done in collaboration with the Department of Agriculture. Under a research proposal approved by the US AEC Division of Biology and Medicine, radiation is used in studying immunity and isotopes in studying the biology and population dynamics of the snail vector. This program is accepted by the Pan American Health Organization and the UN Food and Agriculture Organization for international training.

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.

Pan American Health Organization — The cooperation for research and training includes support by the Organization of two trainees, one each from Brazil and Peru, for a year's training on fascioliasis in the Division.

National Institutes of Health — Dr. Ramiro Martínez-Silva is doing a year of research at the National Institutes of Health, Baltimore, on *Trypanosoma cruzi* in collaboration with Dr. James A. Dvorak. He is also familiarizing himself with toxoplasmosis, a protozoan parasitic infection, for which a project proposal has been prepared.

Academic Institutions — Division staff members provide demonstrations for classes in biology and parasitology at UPR and at Inter-American University of Puerto Rico. They also give invited lectures at these universities and at the Medical School. These contacts attract students to the Division for training and graduate research.



Miss Enid Acosta, measuring size and growth rate of *Physa cubensis* snail.

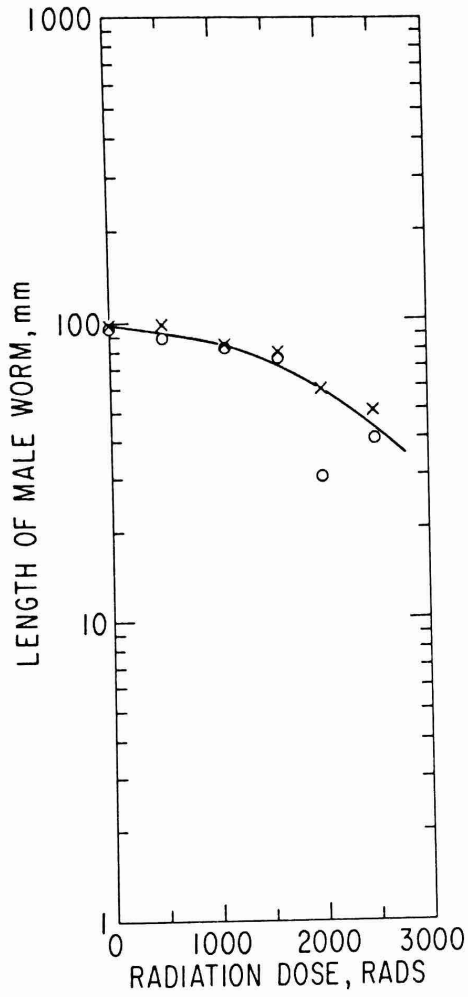


Figure 1. Percent of adult worms surviving, as a function of radiation dose to cercariae.

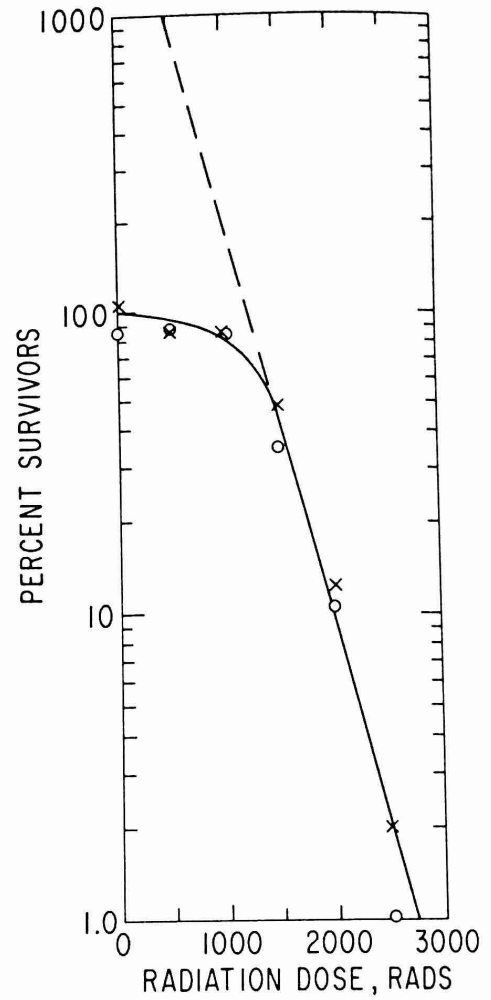


Figure 2. Length of adult male worms, as a function of radiation dose to cercariae.

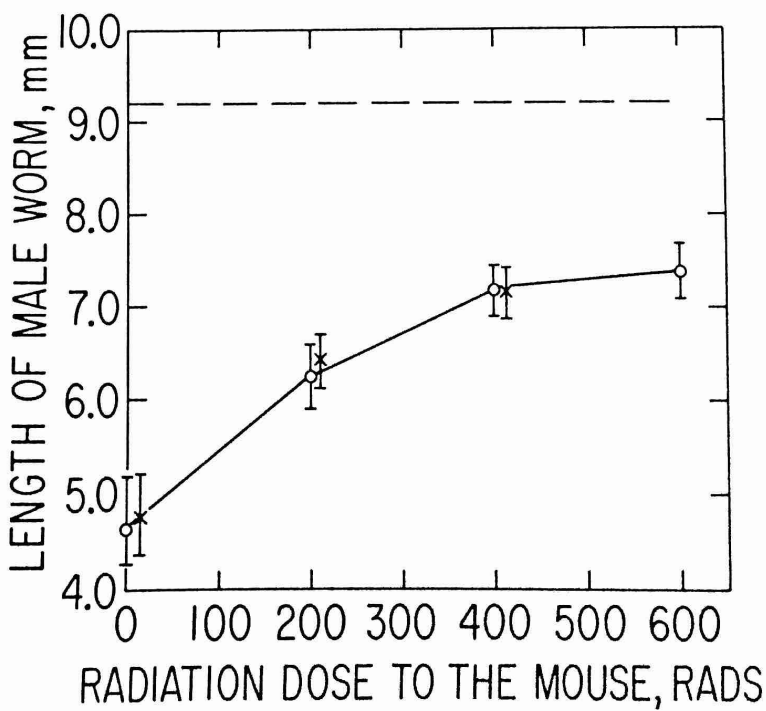


Figure 3. Length of adult male worms from cercariae that had received 2000 rads, as a function of radiation dose to the host mice.

# Schistosomiasis

## DIFFERENTIATION OF *SCHISTOSOMA MANSONI* SCHISTOSOMULES

The rapid adaptation of *Schistosoma mansoni* cercariae to the mammalian environment upon passage through the skin provides an interesting example of developmental differentiation. Using Clegg's techniques, we have been able to transform large numbers of cercariae into schistosomules by passing them through freshly excised mouse skin. The flukes can be grown *in vitro*, which permits study of the biochemical, immunological, and morphological changes accompanying their development.

**Metabolism.** There is some circumstantial evidence that cercariae are capable of anaerobic metabolism. However, with substrates of uniformly labeled  $^{14}\text{C}$ -glucose or pyruvate labeled in the second carbon, very low yields (0.36%) of  $^{14}\text{CO}_2$  were obtained. The glycoprotein envelope surrounding the cercariae may act as a barrier to the passage of substrate into the parasite; the cercaria must then use its endogenous glycogen as a source of energy. Furthermore, we have been unable to detect any production of lactic acid from  $^{14}\text{C}$ -glucose, which indicates that this phase of anaerobic metabolism is not operational in the cercarial stage of *S. mansoni*.

Our experiments have demonstrated, however, that lactic acid production becomes operational as soon as the parasite passes through the mammalian host's skin and becomes a schistosomule. Three cultures were tested in a medium consisting of Earle's balanced salt mixture in which the nonlabeled glucose had been replaced by 2.0  $\mu\text{Ci}$  of uniformly labeled  $^{14}\text{C}$ -glucose, and essential amino acids and vitamins were used instead of lactalbumin hydrolysate and mammalian serum. Two of the cultures were first maintained in a normal medium with human serum for 6 and 5 days, respectively; the third consisted of freshly harvested schistosomules. The first contained 300 schistosomules; the second, 500; and the third, 400. All three were washed 6 times in the normal medium with 100 units of penicillin and streptomycin per milliliter and then cultured for 24 hr in the medium containing  $^{14}\text{C}$ -glucose. The lactic acid conversion was 9.6% for the 6-day culture, 3.0% for the 5-day, and 2.2% for the freshly harvested. Besides lactic acid, paper chromatography shows two other small peaks due to radioactive materials of unknown chemical composition.

**Delayed Effect of Radiation on the *S. mansoni* Worm.** Experiments on immunizing mice with irradiated cercariae of *S. mansoni* have shown that the irradiation not only reduced the number of worms but also caused stunting of the worms that survived. The results of a dose-response study of these phenomena is shown in Figures 1 and 2.

The curve for survivors is a typical multihit curve with a large extrapolation number suggesting that the cercariae may be able to repair the radiation damage. The plot of the length of the male worms against radiation dose does not become linear at high doses.

The length of adult male worms surviving irradiation of the cercariae with 2000 rads depends also on the irradiation of the mice (Figure 3). The data are highly significant ( $p < 0.001$ ). The number of worms surviving to adulthood did not change with irradiation of the mice. The most obvious explanation of the data from the double irradiation experiment is that irradiation of the cercariae makes it possible for the immune system of the mouse to attack the worm and cause stunting; therefore, suppression of the immune system by irradiating the mice reverses the stunting. To test this hypothesis, antilymphocyte serum instead of irradiation is being used for immunosuppression.

It has been shown that the parasite makes an immunological adaptation to the host by coating its surface with host antigens. Possibly irradiation of the parasite interferes with this process. Studies of immunological transformation *in vitro*, by the culture techniques outlined above, are in progress. We plan to study the effect of irradiation on immunological differentiation of the worm.

**An Exoantigen of *S. mansoni* Cercariae.** Published reports and informal comments by other investigators suggest that antigens secreted or excreted by the worm into the host's circulatory system have an important immunological function. Both the circumhullen reaction and the circumoval test probably involve such exoantigens. Preliminary data from  $^{131}\text{I}$ -labeled cercarial excretions suggest that the globulins of infected mice and humans do bind specifically certain fractions of the cercarial excretions. It would be useful to develop a radio-immune assay for accurate diagnosis with  $^{131}\text{I}$ -labeled purified antigen, but purification appears to be difficult.

## MULTILEVEL CHEMICAL CONTROL OF SCHISTOSOMIASIS

Prolonged low-concentration release of chemicals into the snail habitat, in addition to killing snails, might affect various aspects of the parasite, e.g., infectivity of the cercariae and of the miracidia and development of the parasite in the snail, and several stages of snail propagation such as oviposition, development and hatching of eggs, and growth and development of newly hatched snails. Some of these possibilities have been discussed in the literature, but were not feasible until the recent development of new chemical formulations, especially a toxic rubber. Initially rubber impregnated with bis(tributyltin) oxide (TBTO) was used to keep marine organisms off hulls of ships and pilings; the effect lasts for several years. Continuous low-concentration release of TBTO has been field-tested against hatched snails with encouraging results, but none of the possible effects mentioned above has been fully evaluated. They are under intensive study, and unformulated TBTO is being used to assure exactness of concentrations. The initial results are as follows.

*Cercariae*: Treatment of cercariae with TBTO at a concentration of  $10^{-8}$  (10 ppb) for 30 min, before mice were exposed to them, completely suppressed their infectivity. Concentrations of  $10^{-9}$  and  $10^{-10}$  reduced recovery of worms from mice infected six weeks previously by about 50%.

*Miracidia*: Immobilization tests showed a slight rounding of the miracidia after 40 min exposure to 100 ppb of TBTO. Infectivity tests are pending.

*Snail eggs*: Development of eggs at different stages is arrested by 0.1 ppb TBTO. After 14 days in this concentration, development resumed in untreated water; with 1 ppb it did not. Embryos whose development appeared complete did not hatch in 0.1 ppb.

*Newly hatched snails*: Newly hatched snails placed in 10 ppb TBTO were killed within 48 hr, but with 1 ppb, only 17% were dead after 6 days' exposure. The extent to which time can serve as a reciprocal of concentration is an integral part of this study.

Table 1  
Variation of Number of *L. cubensis* Snails on Six Farms in the Dorado Area,  
March 1971 — January 1972

Month	Snail colonies		Total quadrats	Total snails counted	Mean per quadrat
	No. examined	No. containing snails			
Mar.	29	29	232	4900	22.0
May	26	11	208	755	3.6
Aug.	28	5	224	102	0.5
Oct.-Nov.	27	4	216	238	1.1
Dec.	24	7	192	234	1.2
Jan.	25	8	200	385	1.9

Table 2  
Incidence of *F. hepatica* in the Dorado Area in 1970 and 1971

Farm	No. of cows tested		Percent infested	
	1970	1971	1970	1971
A	75	142	80	96.5
B	54	50	26	94.0
C	70	74	51	78.4
D	54	74	33	74.1
E	50	40	18	75.0
F	59	70	56	81.0

# Fascioliasis

The parasitology group is collaborating with the Agricultural Experiment Station and the Puerto Rico Department of Agriculture in developing better methods for control of *Fasciola hepatica* (liver fluke) in Puerto Rico, where it occurs commonly, especially in the northern areas. Effort is concentrated against the intermediate hosts, *Lymnaea cubensis* and *L. columella*. Since these snails are hardy and can live under dry conditions for 6 to 8 months, the lack of a prolonged dry season in northern Puerto Rico adds to the difficulty of their control. The use of molluscicides is dubious not only because little is known about them but also because of increasing public concern about pollution. An anthelmintic effective against the liver fluke is not available; even if it were, the liver of an affected animal would be damaged before treatment began.

## EPIDEMIOLOGICAL OBSERVATIONS

*Lymnaea cubensis* was found in remarkable numbers in the Dorado area during February and March 1971. This was correlated with near-record rainfall that kept the fields wet from September 1970 to March 1971. Any low spot where water collected, even a hoof print, became a snail habitat suitable for propagation. A normal infection rate of *F. hepatica* in such large numbers of snails was deemed likely to account for an increase in fascioliasis in the cattle.

Since no previous data were available on the snail population, periodic collections were started to use for comparison in subsequent years. Data on *F. hepatica* in cows had been taken on 19 herds in 1970, and 6 herds were chosen for reexamination in 1971.

Twenty-nine colonies of snails were selected, and snail counts were made in eight 17-sq-in. quadrats, containing maximum numbers of snails, within a few feet of each marking stake. Most of the snails disappeared from the colonies on five farms between March and May 1971. By August the overall reduction exceeded 95%, and only a minimal increase was seen through January 1972 (Table 1). Obviously the snail "explosion" of March 1971 will not be repeated in 1972.

All six herds of cattle examined in 1971 showed considerable increase in the occurrence of *F. hepatica* compared with that in 1970. The least increase in a herd was from an 80% to a 96.5% infection rate; the greatest, from 18% to 75%. The average change for the six herds was from ~ 40% to 80% (Table 2).

These findings emphasize that the seriousness of fascioliasis in Puerto Rico cannot be evaluated on the basis of data from one or two years. Moreover, if snail control were undertaken



in a relatively dry year, only a low percentage of the potential colonies would be detected. During a wet year (about once in 5 years), the time available for finding the colonies would be limited to a few months. The climatic conditions in Puerto Rico make control of *L. cubensis* very complicated. The need for exploring all possible measures for controlling *F. hepatica* transmission is apparent.

## RESISTANCE OF SNAILS TO DRYNESS

In September 1971, after the spectacular rise and subsequent decline in numbers of *L. cubensis* on most of the dairy farms in the Dorado, Toa Baja, and Toa Alta areas, dry soil samples, each about 1 sq ft × 3 in. deep, were taken in separate plastic boxes from 10 places where snails had been seen on each of 9 farms. In the laboratory, dechlorinated tap water was added to each sample. Three weeks later young snails (1 to 2 mm) were seen in 14.5% of the samples; these represented soil from 7 of the farms (78%). Tests are being made to determine whether the young snails survived in the dry soil or hatched from eggs in it. Survival of dryness (cryptobiosis) appears to be a basic factor in the epidemiology of fascioliasis and warrants thorough study.

## VACCINATION AGAINST *F. HEPATICA*

Previous attempts to induce immunity to fascioliasis in animals have resulted in no significant acquired resistance. Rats that we infected three times with gamma-radiated metacercariae (2500 R, <sup>60</sup>Co) showed complete protection against challenge infection. Thirty healthy rats were divided into 3 groups of 10. Group I served as control (not given irradiated metacercariae); groups II and III were given 3 oral doses of 30 gamma-irradiated metacercariae at 2-week intervals. Group II was not challenged. Groups I and III were challenged with 30 normal metacercariae on the 92nd day of the experiment. On the 159th day, all the rats were sacrificed and examined for worm count, pathology, worm morphology, and immunity. The control animals, group I, had a total of 25 adult worms. In contrast, group III (immunized and challenged) had only one stunted worm; and a similar single specimen was found in the group II rats that had received only irradiated metacercariae.

## COLLECTION, EMBRYONATION, AND CONSERVATION OF *F. HEPATICA* EGGS

The production of irradiated metacercariae will require large numbers of infected snails. The best source of miracidia for infecting the snails is collection of *F. hepatica* eggs from the gall bladders of cattle at an abattoir. The eggs are separated from the bile by sedimentation and decantation, and further purified by filtration through a 100-gauge sieve. The

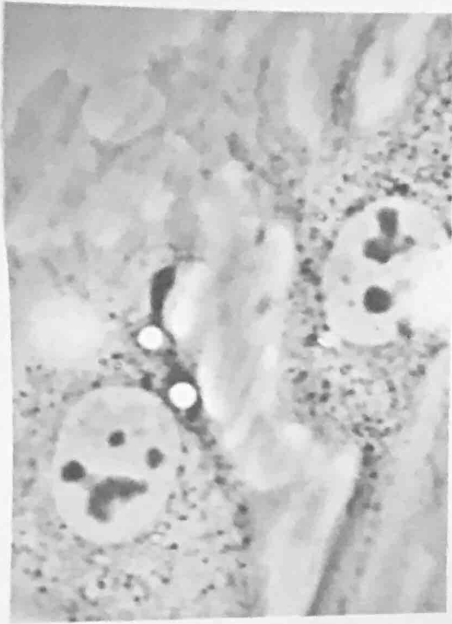
clean eggs remain viable for one year at 5° to 6°C. Development and embryonation of eggs is induced by incubation in Erlenmeyer flasks with light and heat; they are ready to hatch after 11 or 12 days. The fully developed eggs remain viable for 100 days if kept in the dark at 24°C. Mass hatching follows transfer of the eggs to a watch glass in dechlorinated tap water.

## EVALUATION OF TOXIC PLANTS FOR SNAIL CONTROL

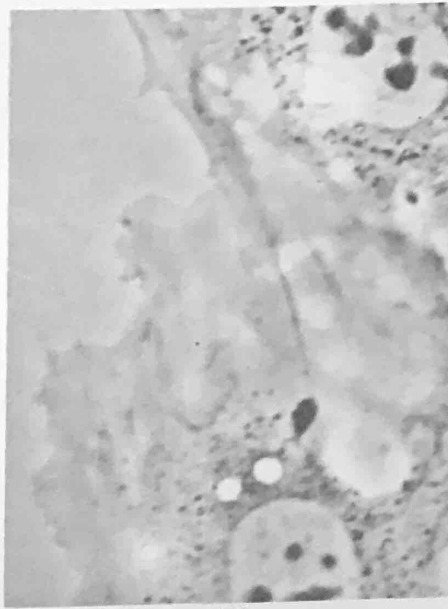
Possible control of snails by rearing toxic plants in their habitats has been proposed, but no search for specific plants has been reported. Lemma (*Bull. WHO* 42, 597, 1970) found the berries of *Phytolacca dodecandra* (Endod or pokeweed) to be sufficiently toxic when crudely processed for use as a molluscicide against the snail hosts of schistosomes. Rearing of toxic plants in snail habitats should be less controversial in relation to pollution than use of commercial molluscicides, and would probably cost less.

We have tested more than 100 plants against lymnaeid snails (hosts of *F. hepatica*) and found 15 toxic at 1000 ppm or less. Of these several were toxic at 100 ppm, and one (flowers of *Solanum caribaeum*) at 25 ppm (Table 3) — this is as toxic as Endod. The toxic agent appears to be fairly stable. Its presence in the roots may afford continuous activity against growth and survival of snails, oviposition, egg development and hatching, and infectivity of miracidia and cercariae. It will be important to learn whether domesticated animals will eat the plant and whether it is harmful to them.

Part of plant	Percent snail mortality	
	At 50 ppm	At 25 ppm
Mature fruit	100	40
Flowers	100	100
Leaves	60	20
Roots	100	40



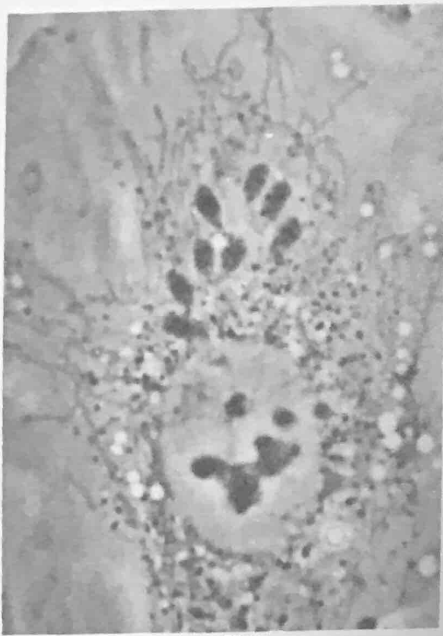
(A)



(B)



(C)



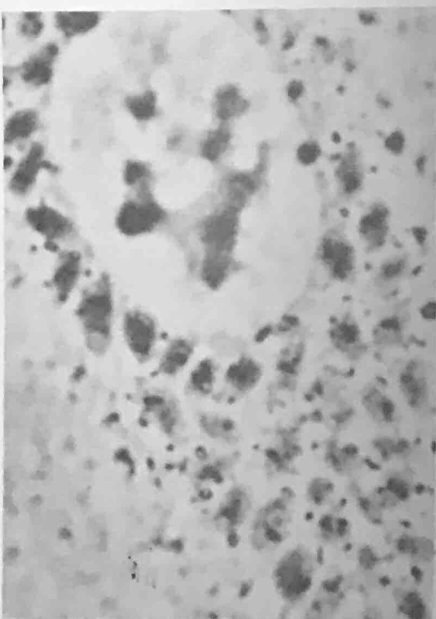
(D)



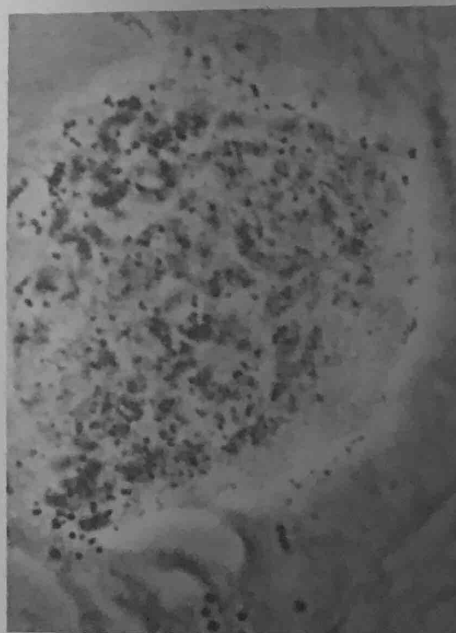
(E)



(F)



(G)



(H)



(I)

# Trypanosomiasis

## STUDIES AT THE ANIMAL LEVEL

Mice immunized to *Trypanosoma cruzi* by inoculation with an avirulent strain were exposed to 400 R gamma radiation ( $^{60}\text{Co}$ ). These and immunized but unirradiated controls were challenged with the virulent Tulahuen strain ( $4 \times 10^5$ ). The irradiated mice showed higher and earlier mortality, and their parasitemia appeared earlier, reached higher levels, and lasted longer. Since radiation did not decrease antibody levels in the immunized animals, it is likely that suppression of resistance relates to inhibition of cellular factors responsible for clearing the infection.

## STUDIES AT THE CELLULAR LEVEL

**Infectivity of Epimastigotes.** The epimastigote stage (Crithidia) of *T. cruzi* has been considered non-infective to the vertebrate host, but some published data indicate that epimastigotes are able to invade cells and undergo an intracellular cycle with eventual liberation of trypomastigotes. Since the question of infectivity of these stages is more than theoretical, direct observations with phase contrast microscopy and photography were made in a Dvork perfusion chamber of the events taking place in a cell culture after inoculation with the parasites. Epimastigotes of the H 510 strain of *T. cruzi* from the intestine of *R. prolixus* or from *in vitro* cultures (first 10 passages) were able to penetrate embryo muscle cells. In general, a cell is invaded by a single parasite, even if its multiplicity is high (from 500 to 2000). On one occasion more than 2 epimastigotes were observed invading a cell. It is interesting that a cell can be invaded simultaneously by a trypomastigote and an epimastigote. The time taken by an epimastigote to penetrate a cell is variable — 5 to 18 hr in our observations.

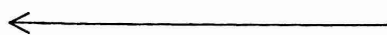


Figure 1. (A) Penetration of cell by parasite, hr 0. (B) Change of parasite into leishmanioid form, hr 3. (C) First amastigote division, hr 42. (D) Eight amastigotes, hr 59. (E) Amastigotes spreading out, hr 61. (F) Sixteen amastigotes, hr 68. (G) Detail of nucleus, hr 82. (H) Cell collapsing, hr 91. (I) Cell after rupture, hr 98.

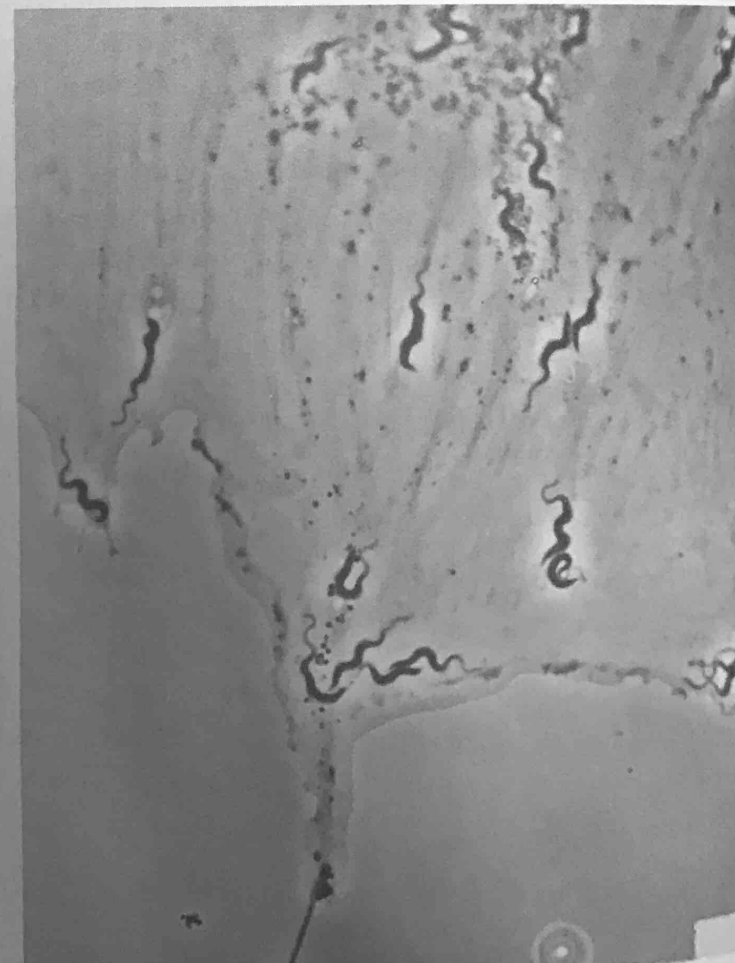
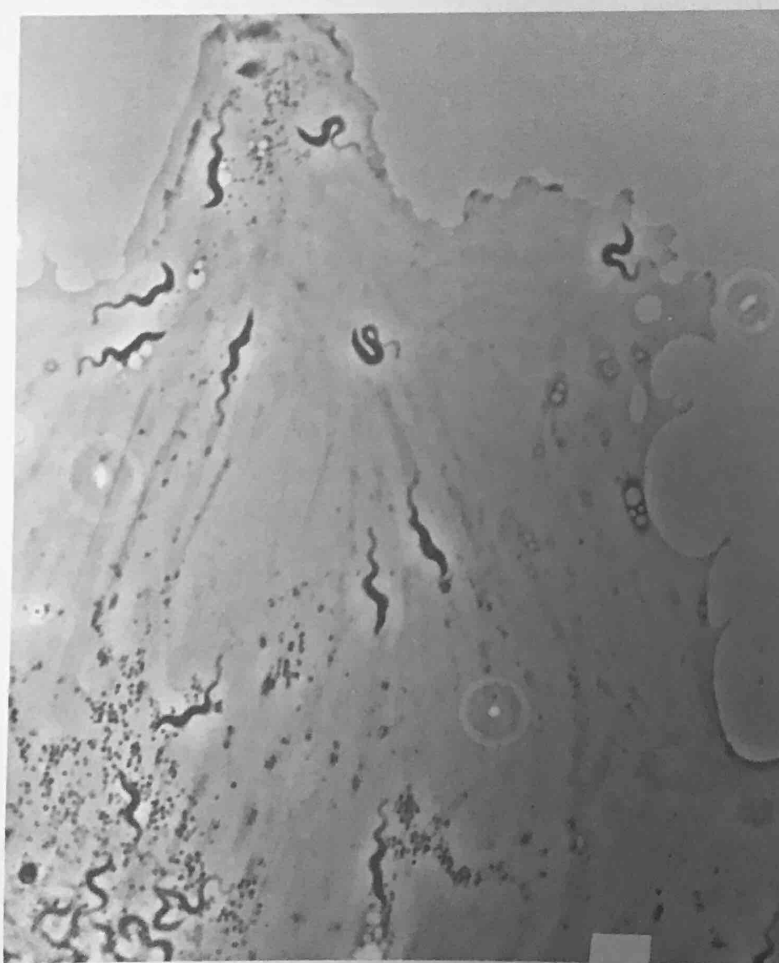
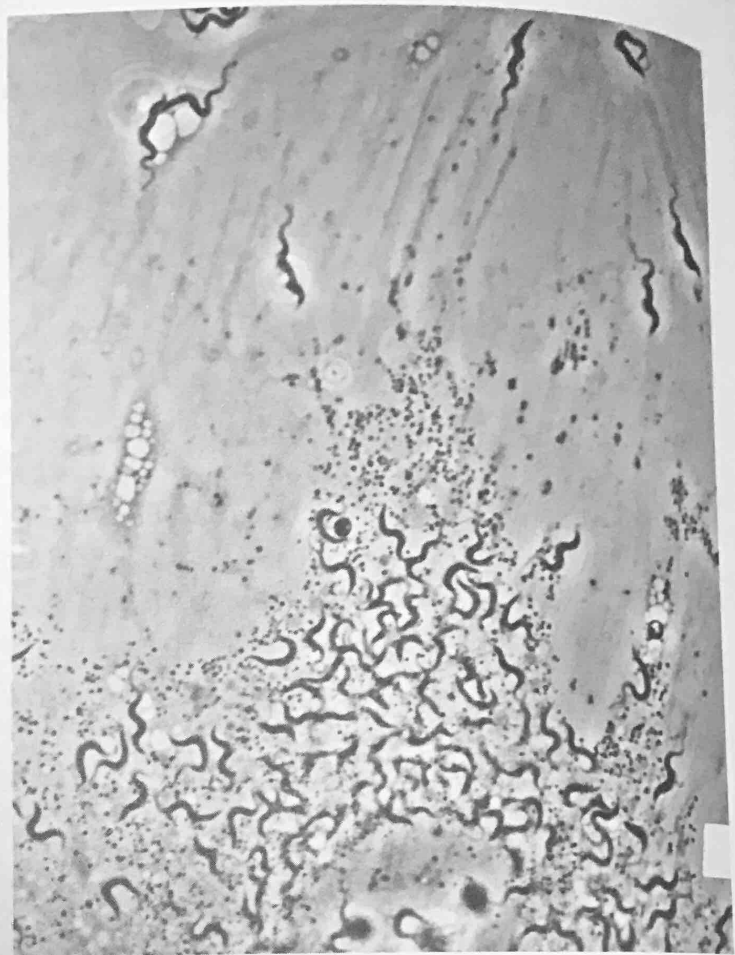
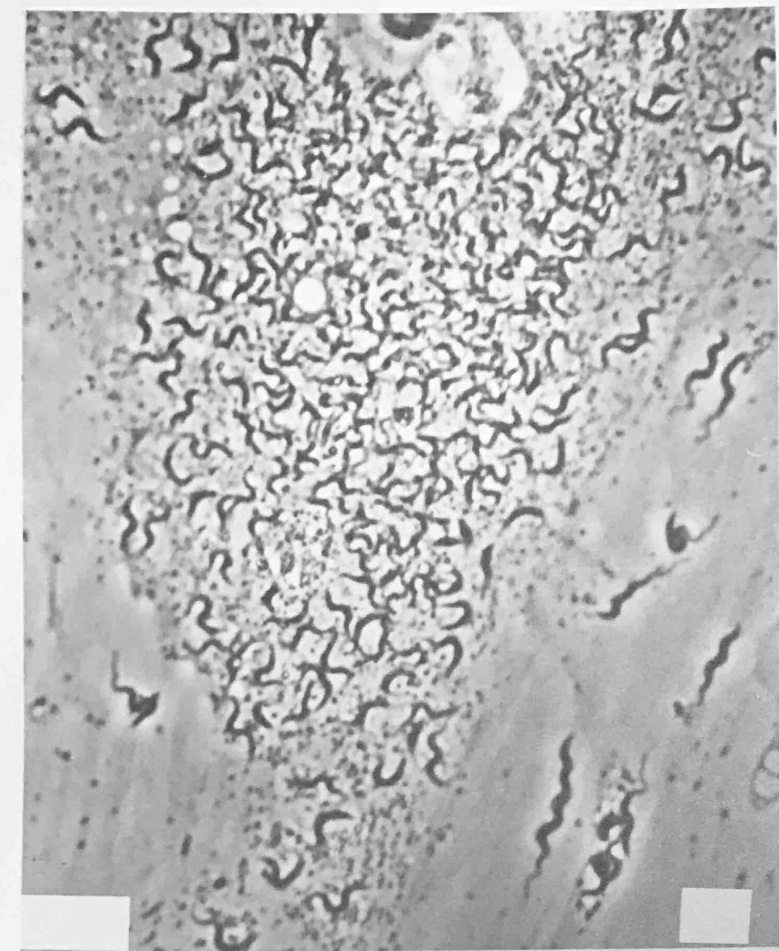


Figure 2. Cell ready to rupture with parasites escaping.

**Multiplication.** The classical intracellular cycle of *T. cruzi*, in which the trypomastigote transforms into an amastigote that divides by binary fission and then differentiates into trypomastigotes that escape the cell, has been observed with epimastigotes. Figure 1 shows a single epimastigote transforming into an amastigote, which, after a lag period of 28 hr, starts the first division; division proceeds with a doubling time of  $\sim 8$  hr until the parasites almost fill up the cell and then start to differentiate into the trypomastigote stage. This process is asynchronous: at the time the first parasites exhibit trypomastigote morphology and even while they are escaping the cell, some are still dividing in the amastigote stage (Figure 2). Normally the cycle requires 5 days, as does the trypomastigote stage. The fate of the epimastigotes once they are inside the cells is not sharply defined and may be highly variable even in a single cell. Infected cells with various numbers and configurations of parasites may experience mitotic division.

**Resistance of Infected Cells in Suspension.** Cells from the line DC2 infected with *T. cruzi* can be detached from the vessel where they are growing by means of trypsin or other agents such as versene. The cells can be kept in suspension for up to 14 days at suitable temperature and pH, and they will grow again if properly seeded. Since work on the molecular aspects of the host-parasite relationship requires large amounts of material, it would be advantageous to have readily available a material made up only of infected cells. Taking advantage of the resistance of infected cells, we have started preliminary work, using differential centrifugation and electrophoresis, to develop a method yielding homogeneous populations of parasitized cells.

**Growth at 37°C.** In cultures of *T. cruzi* without cells *in vitro* at 37°C, virulent strains propagate better than avirulent ones. Factors such as pH, type of serum, initial inoculum, etc., appear critical. The test for determining virulence should be standardized.

## HOST-PARASITE RELATIONSHIP AT THE MOLECULAR LEVEL

Studies on the metabolism of macromolecules by *T. cruzi*-infected cells have been lacking, even though they could well provide the clue to rational treatment of the disease. A study has been undertaken to determine what modifications in the cellular synthesis of ribonucleic acid and proteins are induced by penetration and growth of the parasite. A cell line, Vero, was grown in 32-oz bottles (at least 5 bottles per group) at 37°C with Eagle's minimum essential medium supplemented with 5% fetal bovine serum. A confluent monolayer (about  $10^6$  cells) was inoculated with  $2 \times 10^7$  trypomastigotes (Tulahuen strain) from tissue culture. Acrylamide gel electrophoresis of RNA extracted from normal and infected cells showed that the parasite induced changes in the synthesis of ribosomal RNA. Further studies are in progress.

Table 1  
Isolation of Active Coxsackie Virus from Inoculated Mice  
Showing No Viral Activity at Time of Irradiation

Rads	Organ Tested					
	Blood	Spleen	Brain	Heart	Liver	Pancreas
6	-	-	-	-	-	-
400	+	-	+	-	+	+
500	+	-	-	-	-	-
600	-	+	-	+	-	-

The purpose of this project is to study the impact of gamma irradiation on virus infections in wild arthropods and vertebrates. Wild rats in a small irradiated portion of the rain forest had been observed to sicken and die. Coxsackie type A10 virus was isolated from the blood of the sick and from some of the organs of the dead ones. This 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.

One of the most interesting problems of virology is that organisms can be infected with a virus without showing any ill effect. This extremely common phenomenon is called latency, and many types are known. Gamma radiation is being used to elucidate the mechanisms by which latent infections are established and activated.

It has been reported that adult wild and laboratory animals (rats and mice) after certain doses of whole-body gamma radiation (100 to 600 rads) became susceptible to infection with Coxsackie virus. This was shown by a high titer viremia in the irradiated animals and none or very low titer viremia in the unirradiated. These animals never die of the infection and develop antibodies in 7 to 14 days.

## ACTIVATION OF COXSACKIE VIRUS

Gamma radiation activates Coxsackie virus in inoculated animals which, at the time of irradiation, show no active virus in the blood or feces. In this experiment, adult (30-week-old) white mice (Bagg Swiss) were inoculated with  $10^7$  suckling mice  $LD_{50}$  Coxsackie virus. After 21 days no viral activity could be detected in the blood or in any of the organs tested of some animals that were sacrificed. The mice were divided into groups and irradiated (whole body) with 400, 500, and 600 rads.

The animals were sacrificed 24 hr after irradiation, and homogenates of several organs were tested for viral activity in suckling mice. Virus was isolated from the blood, spleen, brain, liver, and pancreas of mice that were inoculated and irradiated (Table 1). No virus was isolated from the mice that were not irradiated or from the mice that had not been inoculated but were irradiated. Therefore, either the virus was present in such a low concentration that it could not be demonstrated by our method (newborn mice), or the virus



was in a latent state and was activated by the radiation. To resolve this dilemma, various experiments were done on immune animals with gamma radiation.

## ACTIVATION OF COXSACKIE VIRUS BY GAMMA RADIATION IN IMMUNE ANIMALS

Adult (8-week-old) Bagg Swiss mice were immunized with Coxsackie virus type A10 by 3 intraperitoneal inoculations with 0.2 ml of a dilution containing  $10^{7.7}$  (suckling mice  $LD_{50}$ ) at 7-day intervals. The animal developed neutralizing antibodies to titers up to 1:256. Fifty-one days after the last inoculation, no virus was isolated from the blood of any of the mice. Also, no virus was isolated when homogenates of the organs from sacrificed mice were inoculated in suckling mice. The remainder of the immune mice were divided into 3 groups and treated as follows: (a) not irradiated, (b) irradiated with 400 rads (whole body), (c) irradiated with 800 rads (whole body). Nonimmune animals of the same age and similarly treated served as controls. The mice were bled immediately after irradiation, and 48 hr later they were bled again and sacrificed, and organs were individually homogenized and inoculated in newborn mice. Coxsackie virus was isolated from immune mice irradiated with 400 and 800 rads. No viral activity was found in immune animals that were not irradiated, or in the control mice that had not been immunized and were irradiated or unirradiated. The animals from which active virus was isolated had circulating antibodies before and immediately after the radiation.

## NECESSITY OF PRESENCE OF ANTIBODIES (ACTIVELY PRODUCED) BEFORE IRRADIATION FOR VIRUS ACTIVATION

White Bagg Swiss mice (8 weeks old) were immunized as described in the previous experiment and were observed for 8 months after the last inoculation. They were then bled and tested for the presence of antibody. In addition to these mice (a) with antibodies and (b) without antibodies, a group of mice (c) had antibodies passively transferred by intravenous inoculation of each mouse with 0.2 ml of hyperimmune serum immediately before irradiation, and the control group (d) was not immunized. Half of each group was irradiated with 400 rads (whole body) and the other half was left unirradiated for comparison. The mice were necropsied 24 hr after irradiation, and organs were tested for viral activity. The Coxsackie virus was isolated from only one group of animals — irradiated mice that had been actively immunized and had circulating antibodies at the time of irradiation; the organs with viral activity were the spleen and pancreas.

## EFFECT OF GAMMA RADIATION ON CIRCULATING NEUTRALIZING ANTIBODIES *IN VIVO*

Alterations in the rise and fall of the initial antibody response were studied by immunizing a group of rats with 2 intraperitoneal injections, 2 weeks apart, of Sindbis virus AR86 ( $2 \times 10^6$  plaque-forming units per rat). Twenty-one days after the last inoculation, the rats were bled from the heart and the neutralizing antibody titer was determined by the plaque reducing method in chick fibroblast monolayers. Rats with antibody titer  $> 1:64$  were irradiated with 1000 rads (whole body). They were bled immediately after irradiation, and the serum was separated and titrated individually by the plaque number reducing technique. Figure 1 shows the results of a typical experiment. The titer of the neutralizing antibodies was not affected during the first 5 hr after the irradiation; after 6 hr, it decreased and in some animals disappeared completely; after 12 hr, it increased, reaching the control value at 28 to 30 hr and remaining there for the duration of the experiment.

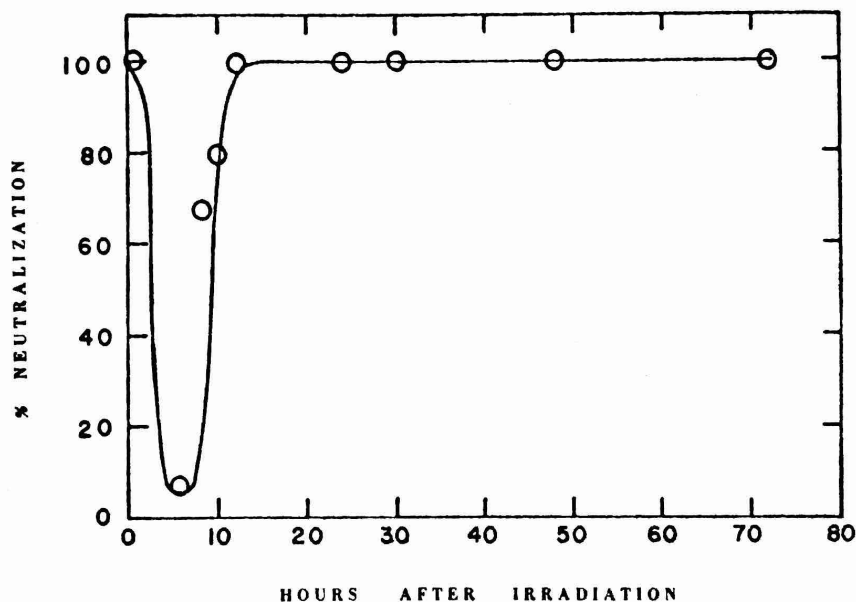


Figure 1

The decrease or disappearance of the antibody titer 6 hr after irradiation could be due to diminution of gamma globulins caused by changes in permeability of the vessels of the intestines, or it could be due to damage to the antibody forming cells. The return of the titer of the neutralizing antibodies to control values is probably due to recovery of the injury to the immunologically competent cells and/or to the amnestic response caused by the presence of virus activated by the radiation. There is no question that the virus is reactivated, since in this type of experiment antigens such as albumin or red blood cells give a completely different type of curve, with the antibody titer decreasing after radiation and never again reaching control values.

## RESISTANCE OF ANTIBODIES TO RADIATION

To test the *in vitro* resistance of neutralizing antibodies to gamma radiation, aliquots of serum with a neutralizing titer of 1:64 were irradiated with the doses shown in Table 2. The irradiation was done in disposable Wasserman tubes at 50 cm from the  $^{60}\text{Co}$  source. Immediately after irradiation the serum samples were titrated by the plaque reducing technique in chick fibroblast monolayers. Samples irradiated with 400, 800, and 1000 rads showed no change in antibody titer (Table 2). Doses of 5,000 to 300,000 rads caused a 50% decrease in the antibody titer. This experiment was done to demonstrate that radiation has no effect on the antibody molecule *per se* in the experiments done *in vivo* in rats and mice.

A large number of viral and rickettsial diseases almost invariably confer long-lasting immunity after a single attack of the agent; examples are smallpox, measles, mumps, polio, yellow fever, and epidemic typhus. Most persons who recover from any of these have circulating antibodies for years. A possible explanation of the long-lasting immunity could be repeated contact with the agent, but this is not adequate to account for the persistence of antibodies in persons who recover from yellow fever and then live in regions where its virus is not present. In such a case it would have to be assumed that the agent persists in the person who has recovered. The experiments described above demonstrate that the virus persists in immune animals and that it can be reactivated by exposing the animals to gamma radiation.

Table 2  
Effect of Gamma Radiation on the Neutralizing Activity of  
Immune Serum Against Sindbis Virus

Radiation, rads	Antibody titer*	Percent inactivation
0	64	0
400	64	0
800	64	0
1,000	64	0
5,000	32	50
10,000	32	50
25,000	32	50
50,000	32	50
75,000	32	50
100,000	32	50
150,000	16	75
300,000	16	75

\* Reciprocal of the serum dilution that reduces the number of plaques to 50% of the original number.

# REACTOR

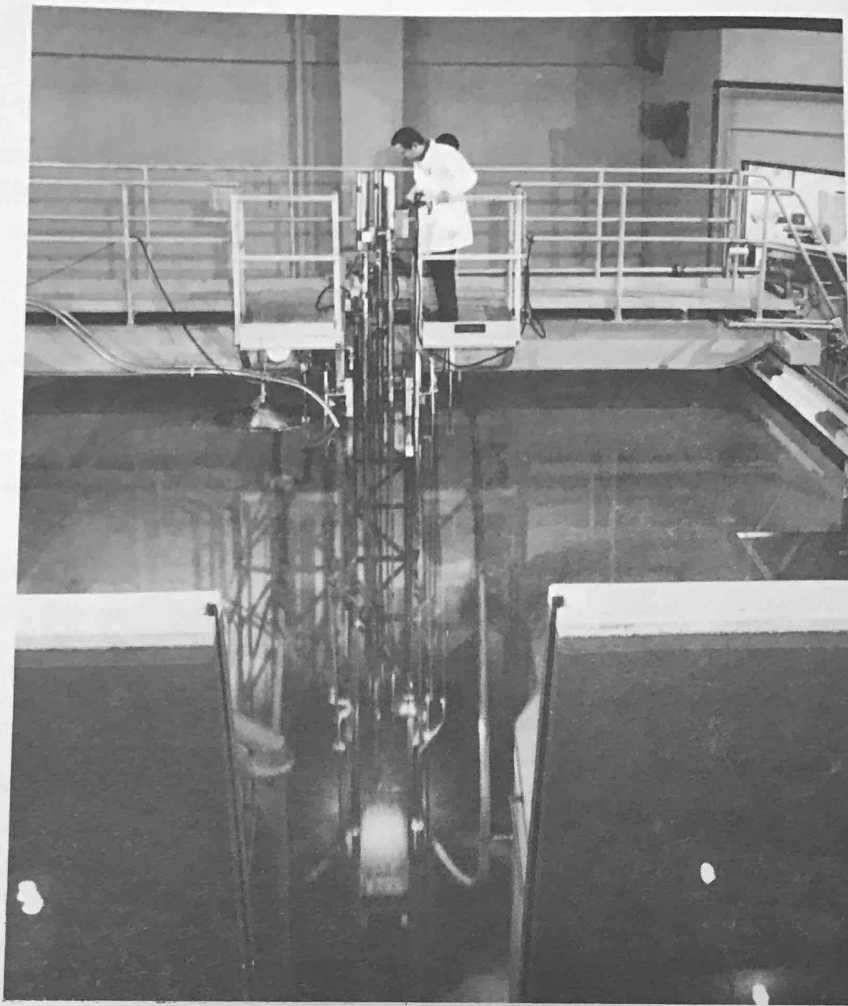
The Reactor Division provides neutron and gamma irradiation services to other PRNC divisions as well as training and education in reactor operations and related subjects. The Division operates and maintains (1) a 2-MW t pool-type research reactor with 2000-MWt pulsing capability; (2) a 10-W aqueous homogeneous 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. 293 megawatt-hours of operation of the 1-MW MTR-type-fueled reactor (operation ended March 12 for start of reactor conversion).
2. 90 side-of-core irradiations accumulating a total of 526 hours of irradiation time.
3. 111 short irradiations on the side-of-core pneumatic rabbit accumulating a total of 7 minutes.
4. 172 watt-hours of operation of the L-77 reactor during which 14 neutron irradiations were performed accumulating a total of 20 hours of irradiation time.
5. 313 samples irradiated in the gamma pool facility accumulating a total of 1966 hours of irradiation time.
6. 30 neutron irradiations in the neutron generator accumulating 8 hours of irradiation time.



View from reactor bridge, looking down at TRIGA reactor core.



View of PRNC TRIGA reactor pool, showing the reactor bridge and suspended core during operation. Reactor control room with console is visible in upper right corner.

## TRIGA REACTOR INSTALLATION

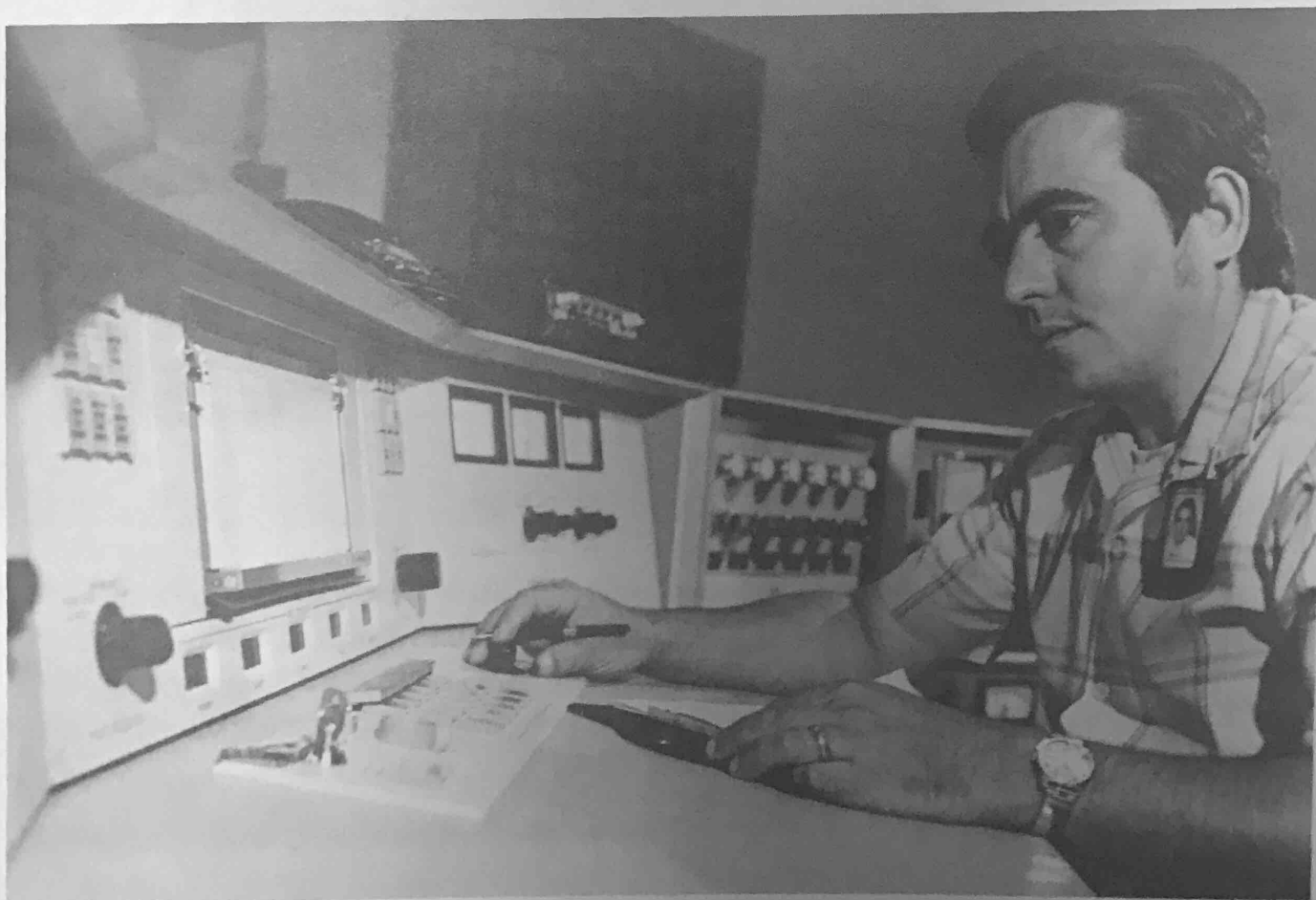
In March 1971 the MTR-type-fueled, 1-MW reactor was shut down and disassembled in preparation for conversion of the facility into a 2-MW TRIGA reactor. Installation of the new reactor began in April and continued throughout the year. The major activities were (1) design, selection, installation, and testing of the cooling tower and pumping equipment for the secondary cooling system; (2) modification of the reactor bridge structure; (3) modification of the reactor grid plate for future installation of fueled follower control rods; (4) replacement of one of the side-of-core pneumatic rabbit systems; (5) installation of mechanical, electrical, and electronic equipment for the reactor's control and instrumentation system; (6) modification of electrical wiring diagrams. The new TRIGA reactor will operate at a power level of 2 MW with a pulsing capability of 2000 MW. Initial criticality and tests are scheduled for January 1972.

## EDUCATIONAL ACTIVITIES

During the first semester of 1971 the training course started in 1970 for five reactor operators from the Instituto Venezolano de Investigaciones Científicas (IVIC) was finished. One week of review and a final examination were held at the RV-1 reactor installation in Venezuela in February. Ing. Jesús Sanabria-Lares, also from IVIC, took a reactor supervisor training course, modified to include wider coverage of nuclear reactor controls and instrumentation. He finished in September. The Division gave a course in Nuclear Reactor Safety, PRNC 555, as part of the Radiological Health curriculum for the M.S. degree, offered in Río Piedras in conjunction with the Puerto Rico School of Public Health.

During the second semester preliminary discussions were held with representatives of the Puerto Rico Water Resources Authority (PRWRA) to explore the possibilities of PRNC conducting the academic phase of two courses, one for reactor supervisors and another for reactor operators associated with the nuclear power plant to be built at Jobos Bay. A retraining program for the PRNC reactor operators and supervisors was instituted and successfully completed. Its purpose was to upgrade the operating crew to meet the new AEC qualifications for reactor operators and senior reactor operators.

In November 1971 Mr. Richard Brown participated in the IAEA Study Group on Reactor Utilization in Santiago, Chile, and discussed the PRNC reactor utilization program and future developments.



Mr. Juan Jesús Pérez, Reactor Operator, at console of TRIGA research reactor.



Students enrolled in the M.S. degree program in Radiological Health, 1971-72.  
From left to right: Etienne F. Rodríguez, Efraín Bonilla Santiago, Ingrid Erdelyi,  
Eleuterio Molinas Villasanti, Porfirio Toledo Charneco, Nayda Figueroa Vallés,  
María de los A. Amaro, José M. González, and David Saldaña Cruz.

# HEALTH AND SAFETY

The Health and Safety Division provides, at both Río Piedras and Mayagüez, the services needed for safe operation of the Puerto Rico Nuclear Center and implements the radiation, industrial, and fire safety regulations; it also contributes to PRNC's educational and research programs. The services, 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 materials handling

Environmental surveillance

Dosimetry

Decontamination and waste disposal

Industrial hygiene

General laboratory safety, industrial safety, and fire safety

Consultation with and indoctrination of staff on safety matters, especially radiation

To implement and enforce safety regulations, the Division maintains regular inspections and monitoring and cooperates with safety committees within each Division. Indoctrination on safety, especially on radiation protection, is offered to PRNC personnel through special courses, lectures, and films and through the Safety Coordinating Committee, which meets monthly.

The education and research program includes:

1. An M.S. degree program in Health Physics at UPR Mayagüez, started in 1959. One student is currently enrolled.

2. An M.S. degree program in Radiological Health at UPR San Juan, offered by the School of Public Health in conjunction with PRNC, from which 15 students have graduated. Ten students are currently enrolled.

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 the students, particularly from Latin America.

5. Basic research as permitted by budget and time limitations.

This year a special effort was made to improve the safety consciousness of personnel and to raise safety standards, with special emphasis on emergency planning within and outside PRNC.



## SERVICES

Service functions are continuously being improved. Two committees with members in Mayagüez and Río Piedras deal with all safety problems. One, the Safety Advisory Committee, consisting of all division heads and one member from the Director's Office, approves general safety policy and regulations; the other, the Safety Coordinating Committee, having members from each division representing the division heads, implements regulations within the divisions.

Monthly meetings of the Safety Coordinating Committee provide for enhanced communication between the divisions and Health and Safety personnel and have been quite successful in bringing potential safety problems to the attention of the Division.

**Personnel Exposure.** The reporting of personnel exposure has been greatly improved with the established computer program. A new densitometer with digital voltmeter display was purchased to facilitate and expedite film readings. Personnel exposure has been minimized so that no one received  $> 1$  rem during 1971. Personnel monitoring films are being supplied for several outside institutions in addition to PRNC personnel (see Table 1).

Table 1  
Health and Safety Services, 1970

	Neutron	Beta, Gamma
1. Film service:		
PRNC	636	3371
Oncologic Hospital		1672
University Hospital		138
Instituto Nacional de Energía Nuclear, Guatemala		384
Military and Rosales Hospital, El Salvador		403
Medical Center, Mayagüez		144
Local Civil Defense		50
Total	636	6262
2. Radiation survey meters calibrated:		
Gamma		225
Neutron		40
Total		265
3. Area monitoring samples analyzed:		
Smears		190
Water		16
Air		0
Total		216
4. Review of questionnaires for reactor experiments:		101
5. Review of requests for use of irradiation facilities other than reactor:		8
6. Review of requests for radioisotopes procurement:		102
7. Medical Dispensary cases seen:		
Minor accidents		52
Physical exams		31
Vaccinations (tetanus toxoid)		9
Total		92

The film badge laboratory at Cornelia Hill also services some programs in San Salvador and Guatemala. Thermoluminescence dosimetry was supplied for the Instituto Venezolano de Investigaciones Científicas.

**Environmental Surveillance.** The environmental surveillance program was kept at the same level as last year. A few samples of water from the India brewery's well were analyzed. The laboratory is capable of full surveillance if required. An environmental sampling station for air and rain is maintained for the Environmental Protection Agency Radiation Alert Network, but service was partially suspended during construction and remodeling.

**General Safety.** The industrial safety and fire protection program continued to improve. Personal safety and fire-fighting equipment are provided by the Division as needed. Trained personnel check working areas after hours for potential fire hazards, and grounds and facilities undergo a weekly fire safety inspection. During the PRNC reactor conversion program, started in March 1971, the Division is keeping personnel exposure and contamination to a minimum. No major surface contamination has occurred, and personnel exposure has not exceeded 3.50 mR.

The 4500-Ci  $^{60}\text{Co}$  source installed in Río Piedras was calibrated and operated for a time by the Division; a special operator was trained and has taken charge. The Division is responsible for the safe operation of this facility as well as all the medical radiation units in the Radiotherapy Division.

The Texas Nuclear Neutron Generator in Mayagüez was installed, and the Division made a complete radiation survey with both deuterium and tritium targets. The facility started normal operation after the safety regulations and procedures were approved.

The Division's emergency plan covering any catastrophic event in Mayagüez and relating PRNC problems and competencies to the surrounding community has been reviewed by the AEC. Approval of the final document by the PRNC Safety Advisory Committee is expected early in 1972.

The Division continues to provide, by contract, a complete radiological safety and dosimetry program at the Veterans Administration Hospital in San Juan.

At the request of the AEC a complete surveillance of the BONUS power plant was made in December 1971 and will continue on a yearly basis.

**Indoctrination.** Indoctrination of personnel is done through safety institutes in conjunction with the Labor Department of the Commonwealth of Puerto Rico, 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 is offered.

With the UPR School of Public Health, Department of Environmental Health, San Juan, an M.S. degree program in Radiological Health is offered (Table 2). This program is now in its fourth year and 15 persons have graduated. Ten students are enrolled for the 1971-72 academic year, seven from Puerto Rico — Nayda Figueroa Vallés (BRH, sponsor), José L. González Rivera (BRH), María de los Angeles Amaro (BRH), Porfirio Toledo Charneco (UPR), Efraín Bonilla Santiago (BRH), David Saldaña Cruz (Dept. of Health), and Etienne Rodríguez Rodríguez (BRH) — and three others — Eleuterio Molinas Villasanti, Paraguay (OEA), Ingrid Erdelyi, Brazil (Women's Assoc.), and Darío Jordán Medrano, Bolivia (PAHO). In 1970, the Public Health Service awarded this program a training grant of  $\sim$  \$50,000/year for five years.

A course at UPR Mayagüez and one at the School of Medicine in San Juan for students not specializing in health physics (mainly physicians or sanitary engineers) 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 12 students taking the latter course in 1971 were Salvador Pérez Mayol, Lolita Zeno, Migdalia Aponte Kamarauskas, Ilsa N. Delgado Salgado, Angel Rodríguez Nieto, Florilda Forestier Díaz, Juan José López, Miguel A. Rodríguez Lugo, Gregorio Rodríguez Alonso, Anita A. González, Carmelo Camacho, and Ileana G. Bayona.

**Student Research.** Dr. Paraskevoudakis is supervising the following M.S. theses:

1. Measurement of Neutron Spectra of the PRNC 2-MW TRIGA Reactor — Efigenio Rivera. A neutron spectrometer was set up consisting of  $^6\text{Li}$  sandwiched between two surface barrier detectors of  $240\text{-mm}^2$  active area and  $400\text{-}\mu$  sensitive depth, a coincidence system, and a multichannel analyzer. Neutron spectra will be measured at the beam tubes and possibly in certain areas of the pool. The experimental program has been delayed because of the reactor conversion program.

2. 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, mainly heat, is applied to irradiated and non-irradiated enzymes (such as peroxidases and

Table 2  
Courses for the M.S. Program in Radiological Health

Required	Semester	Credits*
PRNC 501 Radiation Physics	I	2
PRNC 505 Radiation Chemistry	I	2
PRNC 510 Radiation Biology	I	2
PRNC 515 Radiation Effects on Mammals and Humans	II	2
PRNC 520 Radiation Detection	I	2
PRNC 525 Radiation Dosimetry	II	2
PRNC 530 Radiation Hazards and Protection	II	2
PRNC 535 X-Ray Protection	II	1
PRNC 540 Decontamination and Waste Management	II	1
PRNC 545 Laws and Regulations on Radiological Health	II	1
PRNC 565 Basic Nuclear Electronics	II	2
PMPH 470 Environmental Health	I	3
PMPH 556B Industrial Hygiene and Industrial Accident Prevention	I	2
PMPH 540 Biostatistics	I	2
PRNC 599 Field Practice	Summer	4
Elective **		
PRNC 550 Radioactivity of the Environment	II	2
PRNC 555 Safety in Reactor Operations	II	1
PRNC 560 Reactor Technology	II	2
PMPH 476 Seminar	I, II	1
PMPH 489 Basic Epidemiology		2
PMPH 420 Fundamentals of Public Health Administration		2
PMPH 430 Social and Cultural Aspects of Public Health		2
PMPH 562 Seminar on Radiation Health		1-4

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

\*\* Other graduate elective courses can be chosen from the UPR catalog with the permission of the program director.

catalases), and the inactivation pattern is studied. The radiation dose chosen permits at least 90% of the enzymes to remain active. The enzymes are irradiated both dry and in solution.

## RESEARCH

**Neutron Dosimetry** — Peter Paraskevoudakis and Efigenio Rivera. The solid state neutron spectrometer has been calibrated with a Pu-Be neutron source and is ready to be used (see E. Rivera's thesis, above). Emphasis will be on measuring neutron spectra (when the reactor becomes available) for chemical, biological, and radiography studies in the beam tubes and the neutron generator. These data will be useful for the TRIGA reactor.

**Radiation Damage to Macromolecules** — Mohyi-Eldin, M. Abu-Zeid and P. Paraskevoudakis. Radiation damage to macromolecules is being investigated with x-rays, ultraviolet, neutrons, and  $\gamma$ -rays. A simple technique is used to analyze the data. If  $t_o$  represents the decay times of undamaged molecules and  $t_Q$  the lifetimes of damaged molecules, then the relation between  $t_o$  and  $t_Q$  is

$$1/t_Q = 1/t_o + K_Q[Q] \quad (1)$$

where  $K_Q$  is the quenching rate parameter and  $[Q]$  is the concentration of damaged molecules in the sample. The relation governing the fluorescence quantum yields of damaged and undamaged molecules,  $I_o$  and  $I_Q$  respectively, is

$$I/I_Q = 1 + t_o K_Q [Q]; \quad (2)$$

in Eqs. (1) and (2) the damaged molecules are assumed to act as impurity centers and to trap some of the emitting and exciting radiation. By measuring  $K_Q$  and the dosage given to the sample, one can calculate the fraction of molecules damaged.

A pulsed nanosecond apparatus in conjunction with an analogue computer and a dual beam oscilloscope is being used for measuring fluorescence decay times as short as a few nanoseconds and as long as ten milliseconds with great accuracy in the visible, ultraviolet, and infrared ranges of the spectrum. The combined response function of the apparatus and sample emission is fed to channel A of the upper beam of the oscilloscope, and the response function of the equipment alone to channel B. Two signals from analogue computers fed to channels A and B of the lower beam are used to match the corresponding signals of the upper beam. The decay time can be calculated directly by using these matching processes. The equipment for measuring emission spectra is being assembled and should soon be in operation.

## STAFF

Dr. Theodore Villafaña resigned as Deputy Head of the Health and Safety Division to accept a position at the George Washington University Medical Center. Mr. Heriberto Torres was promoted to Assistant Head of the Division in charge of Río Piedras operations.

Mrs. Isaura González left in July; Mr. Víctor Cintrón joined the Division and is partially filling this position. Mr. Prudencio Martínez resigned to devote full time to the Physics Department, UPR Mayagüez. Mr. Francisco Cánepa left in May after graduation from college, and Mr. José A. Vargas took his position. Mr. Roberto Ortiz Aguiar joined the Division on October 1 to continue the calorimetry project.

Dr. Peter Paraskevoudakis participated in a meeting of the N44-3 Subcommittee on Nuclear Medicine (ANSI) and chaired the N44-3.2 Subcommittee on Standardization of Phantoms (ANSI); he also visited the Bureau of Radiological Health (HEW) in Washington, D.C., in March. In May he attended a meeting in London at the United Kingdom Ministry of Health on Standardization of Phantoms; presented a paper at an IAEA Panel in Vienna on Thyroid Uptake in Neck Phantoms; and gave a seminar at the Democritus Center in Athens.

Dr. Paraskevoudakis and Dr. Villafaña attended the Health Physics Society Meeting in New York in June. Mr. Heriberto Torres attended the Biannual Meeting of the Campus Radiation Safety Officers at Purdue University in September. Dr. Villafaña also attended the Semiannual Meeting of the Medical Association of Puerto Rico in Ponce in June and the American Association of Physicists in Medicine Meeting in Houston in July.



Miss Ingrid Erdelyi, a Brazilian graduate student in Health Physics, working with radiation survey meters.

# 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, and the second (1970) with the Southern Region.

The third report (May 1971) presents data for four areas of the Northern Region, the Arecibo, Caguas, Fajardo, and Bayamon areas, which make up the whole Northern Region except for the San Juan Metropolitan Area.

The surveyed areas have a combined population of 1,168,500 and a total of 150 diagnostic x-ray units (excluding dental units). During 1968, x-ray diagnostic examinations totaled 459,434, including 111,204 abdominal examinations termed "genetically hazardous." The mean absorbed dose per abdominal examination was computed to be 521.7 millirads.

Data collection in the San Juan Metropolitan Area is in progress.

## STAFF

In October Mr. Gileadi met with the staff of the Bureau of Radiological Health in Washington to discuss methods of applicable dosimetry and data collection and the possibility of including certain results of the radiation survey in the general U.S. survey on exposure of the population to x-ray radiation.

# RADIOECOLOGY

The Radioecology Division includes the Marine Biology, Terrestrial Ecology, Jobos Bay, and International Decade of Oceanography Programs. The Division has been organized to centralize the administrative and logistic support services and thus leave the program leaders and senior investigators free to devote their time to scientific research.



Oceanographic research vessel *R. F. Palumbo* cruising in Mona Pass.





Mr. Peter Schroeder, a doctoral candidate at the University of Miami assigned to the PRNC Marine Biology Program under the auspices of the ORAU Laboratory Graduate Participation Program, filtering turtle grass sediments picked up in the auger.



Mr. Jim Patus, Technician, and Mr. Peter Schroeder (U. of Miami), taking bottom samples in a turtle grass bed.

# Marine Biology

The Marine Biology Program was started in 1961 at PRNC and was directed toward the development of a specific-activity model for the prediction of hazards from the release of radionuclides into the marine environment. The method has since been applied by this laboratory to a feasibility study for a sea-level isthmian canal in Central America and to predictions for human radiation dose from radionuclides released by water-cooled power reactors. One of the basic premises of the model is that the physical and chemical processes in the marine environment determine the distribution patterns of the radionuclides and their corresponding stable elements in the environment and that food webs leading to man merely reflect these patterns to varying degrees, dependent upon the ability of each web to concentrate the naturally occurring stable elements and similarly the radionuclides.

One of the major functions of the programs was, and is, to define the variables which limit the accuracy of the predictions made by the specific-activity approach. The investigations continue to emphasize the relative influence of environmental and biological mechanisms upon the transport, distribution, dilution, and progressive decrease in specific activity of the radionuclides introduced into the marine biogeochemical systems — mainly in estuarine and other near-shore marine areas.

At present the specific-activity approach appears to be the most realistic method for predicting hazards from the introduction of radionuclides into marine environments because of its relative simplicity in comparison with the complex compartment models, which emphasize biological mechanisms rather than geochemical processes. However, the data now available allow only for simplified models and their similarity to the real conditions in the natural environment and in the contained ecosystems is often subject to question. Differences in behavior of the naturally occurring elements and the introduced radionuclides may occur if the added material is in a different chemical or physical form. The naturally occurring elements in sea water may be partly complexed to dissolved organic molecules, which are usually accumulated at different rates and to different levels by the biota than are radionuclides of the same element in the ionic form. In addition, increases in temperature of the water resulting from the introduction of cooling waters from electrical generating facilities may alter the rate and degree of uptake of radionuclides and the corresponding trace metals by marine food webs. In contrast, marine organisms often exhibit reduced uptake of added radionuclides with increased amounts of the total available element in the water. Investigations of these processes are included in the field and laboratory studies now in progress in the marine areas near Puerto Rico.

The individual projects of the senior investigators of the Marine Biology Program are integrated into a team effort for the study of the transport and distribution patterns of

radionuclides and stable trace elements in rivers, in the contained organisms and river sediments, and in the environment and biota of the near-shore marine areas where fresh and salt water mix. Each investigator contributes from a different background based on his specialty.

The research may be summarized into three categories as follows:

**Basic Marine Biological and Ecological Studies.** These investigations are conducted in marine bays with high rates of sediment deposition from rivers, in anoxic basins surrounded by mangroves, in coral reef areas, in near-shore open-sea regions, and in semi-enclosed coves which have elevated water temperatures caused by the addition of cooling water from electrical generating plants. The biological systems under investigation include benthic foraminiferans and turtle grass, coral reef, mangrove, pelagic, and mud bottom ecosystems. The areas of research include measurements of the transfer of energy, biomass, carbon, nitrogen, and trace elements between trophic levels in food webs; the relationship of foraminiferan assemblages, their mineral inclusions, and trace element composition with the characteristics of the environment; the measurement of concentration factors and turnover rates in selected organisms for radionuclides in ionic, colloidal, and complexed form; and the influence of elevated temperature on the species composition and species survival in mangrove and turtle grass communities.

**Background Oceanographic and Limnological Studies.** These studies include the measurement of physical and chemical characteristics of the marine areas needed for the biological and ecological investigations and studies in sedimentation of river-borne suspended particles. Studies on the physical and chemical forms of elements transported into estuarine areas and the influence of soluble organic compounds on the reactivity of trace elements with the electrolytes of sea water have been continued.

**Analytical Methods for Trace Elements.** Neutron activation analysis, flame spectrophotometry, atomic absorption spectrophotometry, x-ray emission spectrography, colorimetry, fluorescence emission, arc spectrography, isotope dilution, and gas chromatography are being used for trace element analysis.

The field areas under investigation include three river outflows, and mangrove forests. The three rivers drain limestone, volcanic, and serpentinite substrata respectively and empty into a 17-mile stretch of coast bordering on Mona Pass. The same groups of major and minor elements are present in all three rivers, but the ratios of abundance vary. Thus, within a small geographical area, a variety of near-shore environments may be studied. In addition, the chemical and physical forms and transport rates and distribution patterns of the naturally occurring elements are under investigation in the three river systems and in the near-shore areas.



Mr. David Brunet, Engineer, and Mr. Edwin Jusino, Mate, in charge of sampling gear aboard the research vessel *R. F. Palumbo* working with Shipek bottom grab in Mona Pass. Bottom samples are later prepared for trace element analyses.

The work of the Marine Biology Program continues to be directed toward the development of the specific-activity approach. However, it has become increasingly apparent that the mechanisms which control the transport and dilution of radionuclides in marine biogeochemical systems are directly applicable to the pollution problems of Puerto Rico and the United States which result from the introduction of heavy metals, pesticides, petroleum products, and excessive amounts of plant nutrients into marine areas. We believe that the work of the Marine Biology Program should continue to elucidate the ecological, geochemical, and geophysical mechanisms which control the behavior of contaminant radionuclides. Investigations on nonradioactive pollutants, utilizing the techniques developed in the Marine Biology Program, have been started with support from other Federal and Commonwealth Agencies.

**Relationship to Other Projects.** Cooperative programs with the University of Miami, the University of North Carolina, the University of Wisconsin, the University of Oregon, Florida State University, Queens College, the Bureau of Commercial Fisheries Laboratories in Beaufort, N.C., and the former U. S. Naval Defense Radiological Laboratory in San Francisco have been done in the past. Cooperative work is planned this year with the University of Washington, the University of Miami, the University of Puerto Rico, the University of Wisconsin, Lawrence Livermore Laboratory, and the Environmental Quality Board of the Commonwealth of Puerto Rico.

**Research Vessel *Palumbo*.** The research vessel *Palumbo*, constructed by the Tatco Shipbuilding Corporation, was christened on January 23, 1971, in San Diego, California, and was dedicated on June 4, 1971, in Mayagüez, Puerto Rico. The *Palumbo* has an operating crew of 7 and can accommodate a scientific staff of 9. It has a fuel range of about 15,000 miles, contains three laboratories totaling ~ 800 feet of deck space, and walk-in freezer space for scientific samples. The ship is named after the late Dr. Ralph E. Palumbo, of the University of Washington, one of the pioneer radioecologists in US AEC research at the Pacific Proving Ground.

**Guanajibo Laboratory.** In August 1971 the main laboratory of the Marine Biology Program was moved to the Pta. Guanajibo building south of Mayagüez. The new facilities have 2700 square feet of laboratory and 1700 square feet of storage space and are located on a 20-acre site. Laboratories for neutron activation analysis were kept at the Mayagüez Laboratory.

## BASIC MARINE BIOLOGICAL AND ECOLOGICAL STUDIES

**Temperature Studies in Mangroves.** Investigations have been started on the influence of elevated temperatures on mangrove and turtle grass communities in and near a semi-enclosed cove on the south coast of Puerto Rico. The water in the cove is heated by the introduction of cooling water from fossil fuel electric plants. The intake water varies from 26.6° to a maximum of 31°C. The water introduced into the cove is heated 10° above ambient. At the outflow of the heated cove the water temperature is 5.5° above ambient. Turtle grass beds are not present in the cove, but are found outside in areas where the maximum water temperature reaches 32° to 33°. The shores of the cove are lined with red mangroves, which appear not to be affected at maximum water temperatures of 37°. Species composition studies suggest that the elevated temperatures have little effect on the mangrove root communities below 34°; however, at 35° the species diversity drops suddenly. The "root species" that make up most of the biomass at higher temperatures, the barnacles (*Balanus eburneus*) and the oysters (*Isognomon alatus*), appear to benefit from the absence of competition by tunicates and sponges.

**Foraminiferan Studies.** Studies have been started on the epibenthic and bottom sediment environments inhabited by living foraminiferans and on the species distribution and elemental content of these animals. Several species of foraminiferans are capable of living on and in anoxic sediments containing trace amounts of oxygen and large amounts of hydrogen sulfide. Anaerobic conditions exist within the tests of the foraminiferans, as evidenced by the formation of iron sulfides in the living forms. Some species contain symbiotic algae which may provide oxygen for metabolism. Samples of living and dead pyritized foraminiferans have been separated for trace element analysis.

Investigations of cores from a contaminated bay show a sudden change in foraminiferan facies in the upper sections of the core corresponding to increased pollution and anoxic conditions. The foraminiferan *Fursenkoina ponti* constitutes about 16% of the population in the sediments deposited under oxidizing conditions and 66% under reducing conditions. In areas now heavily polluted the foraminiferan populations are smaller and *Forsenkoina* is the predominant living form.

**Transfer of Elements Through Trophic Levels.** Contrary to popular belief, most radio-nuclides and the corresponding stable elements, with the possible exception of iron and zinc, are not concentrated as they pass through marine food webs. Studies of trace element, caloric, carbon, and nitrogen contents have been continued in fishes representing herbivores, omnivores, and carnivores. The species under investigation include mullet, Pacific thread herring, sea trout, sand perch, yellowfin tuna, and skipjack tuna.

**Effect of Chemical and Physical Form of Cobalt on Incorporation by Organisms.** Experiments have been continued to determine the relative availability of ionic and organically complexed cobalt to marine and fresh water organisms. The results are as follows:

<u>Sample type</u>	<u>Uptake ratio complexed Co/ionic Co</u>
marine phytoplankton	15
marine zooplankton	15
brine shrimp	15
crab larvae	5
soft parts, marine clam	5
marine periphyton	4
marine pelagic crustacea	0.9
molted carapace, spiny lobster	0.7
spiny lobster	0.4
estuarine sediments	0.5
shell, marine clam	0.2
fresh water phytoplankton	0.2

Estuarine sediments with their associated periphyton discriminate 2:1 in favor of the uptake of ionic cobalt over organically complexed cobalt, but marine periphyton grown on glass plates discriminate 4:1 in favor of the organically bound cobalt. Fine marine sediments, without periphyton, discriminate 4:1 in favor of ionic cobalt.

Phytoplankton equilibrate with organically complexed cobalt in sea water in about 30 hours, but require much longer to equilibrate with ionic cobalt.

**Modeling of Biological Systems.** A mathematical model has been developed for descending vertical transport of radionuclides and stable trace elements by marine zooplankton. The model takes into account vertical migration with biological turnover and transport of molts, dead organisms, and fecal pellets by gravity.

## BACKGROUND OCEANOGRAPHIC AND LIMNOLOGICAL STUDIES

**Preconcentration of Ionic and Organically Complexed Metals from Sea Water.** Investigations have been continued on preconcentration methods for ionic and complexed cobalt and other trace metals in sea water. Most of the preconcentration methods commonly used, including precipitation by ferric hydroxide, manganese dioxide, saturated sodium carbonate, and *α*-nitroso-*β*-naphthol; adsorption to chelating resin; and liquid-liquid extraction with dithizone, APDC-MIBK, or *α*-nitroso-*β*-naphthol, remove 83 to 100% of the ionic

cobalt but less than 2% of the complexed metal. In contrast, sulfide precipitation with thioacetamide removes 62% and activated charcoal 100% of the organically bound metal. Activated charcoal also removes about 67% of the ionic cobalt from sea water.

A continuous-flow method has been developed for analyzing the particulate, ionic, and complexed metals in natural waters. The water is passed through a three-stage system comprising an acid-treated Millipore filter followed by beds of chelating resin and activated charcoal. Ionic metals are stripped from the chelating resin by hot HCl and complexed metals from the charcoal by organic solvents. The organic solvents are passed through a small column of chelating resin to remove ionic metals present from the charcoal. Tests for optimum flow rates are under investigation.

**Trace Element Interactions Between River and Sea Water.** The studies on the interaction of river water and suspended sediments with sea water have been continued. For carrier-free radionuclides of cobalt, zinc, manganese, and europium added to river water (previously passed through a 0.45- $\mu$  filter), 11% of the cobalt, 4% of the zinc, 17% of the manganese, and 85% of the europium remain in solution after a period of one week. In filtered river water added to an equal amount of sea water, only 1% of the cobalt, 1.5% of the zinc, 3% of the manganese, and 22% of the europium remained soluble after one week. About 10% of soluble cobalt, 40% of soluble zinc, 20% of soluble manganese, and 30% of soluble europium in river water is precipitated by electrolyte interaction in sea water.

Investigations on the influence of fresh water periphyton on the distribution of trace elements in suspended and bottom sediments and water have been continued with long-term equilibration times.

#### **Trace Characterizations of Four Puerto Rican Rivers and Their Effects Offshore.**

Sampling was done upstream to the headwaters of four western Puerto Rican rivers for dissolved and particulate material in the water, the soils adjacent to the rivers, river sediments, and the river organisms. In addition, the estuary of each river was sampled as well as offshore high-salinity water. The data include measurements of temperature, salinity, conductivity, pH, dissolved oxygen, flow rates of rivers, the nutrients  $\text{NO}_3$ ,  $\text{NO}_2$ ,  $\text{PO}_4$ , and  $\text{SiO}_3$ , alkalinity, turbidity, and trace elements in the waters of the rivers and estuaries, sediments, soils, and organisms.

## **ANALYTICAL METHODS FOR TRACE ELEMENTS**

**Extraction of Trace Elements by APDC-MIBK.** Ammonium pyrrolidine dithiocarbamate (APDC)—methyl isobutyl ketone (MIBK) is used to separate many metal ions from environmental and biological samples prior to their analysis by atomic absorption spectrophotometry. Extraction at pH 3 to 3.5 is recommended. Studies made this year show, however,



that the pH must be adjusted for individual elements to obtain maximum yield. Zinc is separated in 98% yield at pH 1.5 to 2, but the yield drops to 25% at pH 4. The yield for cobalt is 70% at pH 1.5, 50% at pH 3, and 75% at pH 4. Other elements showing pH dependence for extraction include iron, manganese, cerium, silver, antimony, and tin.

**Delayed Neutron Counter.** The construction is almost completed of a delayed neutron counter for the analysis of  $^{235}\text{U}$  by the measurement of delayed fission neutrons.

**Neutron Activation Analysis.** During the months that the PRNC research reactor has been out of operation, new analytical equipment for neutron activation analysis has been developed in the Marine Biology Program. A 45-cc lithium-drifted germanium detector has been enclosed with a 9-in. sodium iodide annulus which may be operated in coincidence or anticoincidence mode. A computer program has been written and tested for analyzing the high resolution gamma spectra.

**Preconcentration of Soluble Inorganic Phosphates in Sea Water.** The phosphate content of many tropical waters is so low that preconcentration methods must be used before analysis. A method providing preconcentration by a factor of 50 has been developed. Dowex 10 (10 g) is washed with 1 N  $\text{H}_2\text{SO}_4$  and saturated with 10% ammonium molybdate. The column is washed with distilled water, and the sea water is passed through at the rate of 10 ml/minute. The ammonium phosphomolybdate is eluted with 10 ml of 1 N NaOH and 20 ml of distilled water. The phosphate is analyzed as molybdenum blue.



Miss Rita Acevedo, working with an atomic absorption spectrometer, doing stable element analysis on biological material and sea water.

# Terrestrial Ecology

The objectives of the Terrestrial Ecology Program remain centered on (1) the movement and transfer of isotopes, both radioactive and stable, in the tropical forest, (2) the recovery of the forest ecosystem after exposure to gamma radiation, and (3) other basic parameters of the forest such as food webs, population dynamics, species diversity, etc. While these goals remain unchanged from year to year, the approach used is modified.

In pursuit of the first objective many approaches are possible. The current one represents a departure from past research and is based on the premise that in order to understand the movement and transfer of isotopes it is necessary to investigate the main driving force: namely, rainfall and its subsequent redistribution as throughfall, stemflow, and subsurface flow. The scope and objectives of this approach were set forth in the 1970 *Annual Report*. The rainfall interception study is divided into seven subprojects and progress to date is reported under each category. New research projects this year include studies on the chemistry of freshwater streams and on the chemistry of incoming rainfall by 0.01-in. fractions.

Work has continued on the recovery of the forest from gamma radiation, and on animal ecology.

## INTERCEPTION STUDIES

1. The preliminary phase of the overall study was finished this year. The results are based on 150 rainfall events during the period July 1970 through June 1971. A multiple regression analysis of the data on the relationship between rainfall and throughfall showed the best fit to be a straight line. The coefficients of determination for timed, nontimed, and combined observations were 0.9823, 0.9865, and 0.9734 respectively. With  $Y$  = predicted throughfall in inches, and  $P$  = precipitation in inches, the predictive equations developed were: Timed:  $Y = 0.954P - 0.028$ ; Nontimed:  $Y = 0.874P - 0.032$ ; Combined:  $Y = 0.884P - 0.024$ . Timed observations were those on events during the day, in which the beginning and ending time of each event was recorded; nontimed observations were those on events which occurred during the night. The importance of timed observations in the evaluation of the rainfall-throughfall relationship becomes apparent upon comparison of the predictive equations. Nontimed observations (the usual method in throughfall studies) were shown in this study to underestimate throughfall by  $\sim 10\%$ . Throughfall was not a constant percentage of rainfall and varied from 67% at 0.1 in. of rain to 92.5% at 1.0 in. of rain. On the average, between 0.03 and 0.04 in. of rain was required to

saturate the canopy before throughfall began. This value, along with intensity, duration, and storm size, would determine the fate of radionuclides in rainfall.

2. Although stemflow constituted a small percentage of the total water reaching the forest soil, it cannot be considered insignificant on a whole plot basis. The correlation between rainfall and stemflow was good, with a coefficient of determination of 0.88, and is described by the equation  $Y = 0.088P - 0.037$  where  $Y$  = estimated stemflow in inches (whole plot) and  $P$  = rainfall. Although individual trees yielded stemflow at lower values, the average value of rainfall on a whole plot basis (400 sq. meters) required to yield measurable stemflow was 0.42 in. Stemflow as a percentage of rainfall varied between 1.4% with a 0.5-in. rain and 5.1% with a 1-in. rain. The importance of stemflow in the fate of nuclides is due to the trees funneling a large quantity of water and depositing it over a small area at the base of each tree. The extreme yield of stemflow by an individual tree during this study was 180 liters as a result of a 1.9-in. rain in a 2-hr period.

3. Storm size distribution of storms is important in understanding the fate of nuclides associated with rainfall. We reported last year that  $\sim 70\%$  of all storms at the El Verde site were 0.5 in. or less. The results of this later study showed the value to be 89%. The number of storms between 0.6 and 1.0 in. accounted for  $\sim 6\%$  of the total and the number  $> 1.0$  in.,  $\sim 5\%$ . Thus, in this area, the larger storms must be treated as the exception rather than the rule, and the fate of isotopes in rainfall would be controlled primarily by the smaller storms. This becomes more evident when considering that in this study 69% of all storms fell in the rain class 0.06 to 0.15 in. The throughfall equation, with the class mean of 0.1 in. used, shows that roughly one-third of the incoming rain was intercepted and retained by the canopy. This information along with the studies on epiphylls associated with the leaves is now thought to explain the levels of radioactivity found by past research at El Verde.

4. The duration and intensity of storms also play an important role in the fate of nuclides associated with rainfall. Light intensity rains combined with long duration would be conducive to foliar absorption, whereas heavy intensity and short duration would result in a transfer of isotopes to the forest floor. A frequency distribution of storm duration showed that 78% of the storms lasted 1 hr or less and 33% lasted 20 min or less. Analysis of storm intensity showed 91.2% of the storms were 0.5 in./hr or less, 41.7% were 0.1 in./hr or less, and 18.7% were 0.05 in./hr or less. Total evaluation of the data has not been completed. The results so far show that frequency of storms and the interval between storms affected not only the throughfall and stemflow yields but also the chemistry of throughfall and stemflow water. Position of a tree with respect to canopy, sub-canopy or understory, or nearest neighbor affected the yield and chemistry of stemflow water. Certain aspects of the study will be continued as we attempt to further elucidate the interception and redistribution processes of the hydrological cycle.

5. Chemical analyses have been completed on rainfall, throughfall, and stemflow water. The data reduction and statistical analyses have not been completed, but the preliminary data summarized in Table 1 show the overall relationships.

Source	Concentration, ppm			
	Ca	Mg	K	Na
Input: Rainfall	0.25	0.78	0.35	6.0
Output:				
Throughfall	1.10	2.02	3.36	10.6
Stemflow				
Primary interceptors	0.90	1.06	3.60	7.6
Secondary "	1.04	1.38	2.69	6.6
Tertiary "	0.65	1.00	2.66	6.4
Sonadora River*	0.91	1.44	0.24	4.60

\*Routine monitoring of river water began in September 1971; these values are averages of >80 observations.

The pH of stemflow water varied between 3.8 and 6.6 on the 45 trees studied; only 8 individuals had pH values > 6.0. The cause of the low pH's was not determined but may have been organic acids. Included also in this study has been the monthly monitoring of 50 litter collection baskets, each one square meter. The average leaf litter production values for 1970 and 1971 were 5370 and 5326 kg/hectare, respectively. Chemical analysis has been completed for the elements Na, K, Ca, Mg, Mn, Fe, Cu, Co, Sr, Zn, and P.

6. A technique for fractionating rainfall by 0.01-in. units was developed this year. Preliminary chemical analysis of these fractions suggested that the concentration of Na, K, Ca, and Mg followed a normal dilution curve with incoming rainfall. The highest concentration occurred in the first 0.04 in., which coincided with the amount of rainfall required to saturate the canopy and produce throughfall. These studies will be continued.

7. A routine sampling program for chemical analysis of Sonadora River water was started this year. This will provide baseline information on the output of isotopes from the forest system. Present analysis includes Na, K, Ca, and Mg. Development of analytical techniques and analysis for trace elements will begin next year. Routine analysis of river water from other major streams in the Luquillo area is also being done. The sampling begins in the high mountain area and extends to the estuary in the lower reaches of the Espíritu Santo River.

## RECOVERY FROM RADIATION

The fifth census of vegetation recovery in the area irradiated in 1965 indicated that the zone is passing from early to middle stages of successional regrowth. It still lags behind a mechanically damaged control area in stage of regrowth, mainly because of the influence

of damaged but still living plants, although convergence continues. The yield of information from this area justifies continuing study at a reduced level.

## ANIMAL ECOLOGY

The major emphasis in animal ecology was in the areas of food web relationships, niche partitioning, and the development of experiments to outline the transfer of energy and nutrients from the terrestrial to the aquatic systems within the rain forest. To test hypotheses drawn from a large-scale analysis of amphibian food preferences, radioactive tags were used to locate concealed frogs during the daylight hours. In contrast to the behavior apparent at night, when territorial and reproductive behavior is observed in the arboreal habitat, *Eleutherodactylus portoricensis* was found to spend the day exclusively on the forest floor, and a significant fraction (more than half) of its feeding is done in this microhabitat. This agrees completely with previous analyses of stomach contents. The closely related *E. coqui*, on the other hand, is strictly arboreal in parts of the forest where *E. portoricensis* also occurs. Without the use of radioisotope tagging this study would have been difficult or impossible, and the explanation of food differences would have remained circumstantial and conjectural. Similar resource partitioning is being found in other frog species by using these techniques. An exact study of amphibian reproductive phenology, growth rate, and life expectancy is now being done with a population of marked frogs. A parallel study involving several species of *Anolis* lizards is being done at El Verde Station by Dr. George Gorman of the College of the Virgin Islands.

Two weeks in the summer of 1971 were devoted to a comparative study of rain forest ecology on several islands of the Eastern Caribbean, with emphasis on Guadeloupe and St. Vincent, which have elevations comparable to that of Puerto Rico but much smaller land areas. Genera of amphibians and their insect prey are the same as in Puerto Rico but species are different, and ecological organization was found to show remarkable parallels but with a diversity reduced in almost perfect proportion to land area. Chromosome techniques developed at PRNC were used to help confirm phylogenetic relationships in amphibian faunas. In contrast to earlier belief, the fauna of the Leeward Islands indicates derivation from Greater Antillean stock, while the two *Eleutherodactylus* species of St. Vincent, although superficially similar, seem to represent one northern and one southern (South American) derivation.

The decapod family Atyidae, with 5 or 6 species in the rain forest, lives close to the interface between terrestrial and aquatic ecosystems. Most of these shrimp species are filter feeders, although one has been shown to be an herbivore, feeding on algae and flooded terrestrial vegetation. The filter feeders exist in large populations in the small brooks within the forest, and the efficiency of their feeding behavior suggests that most of the suspended particulate matter is processed by them except during floods. Experiments begun will use controlled environments and differential radioisotope tagging of algal, fungal, bacterial,

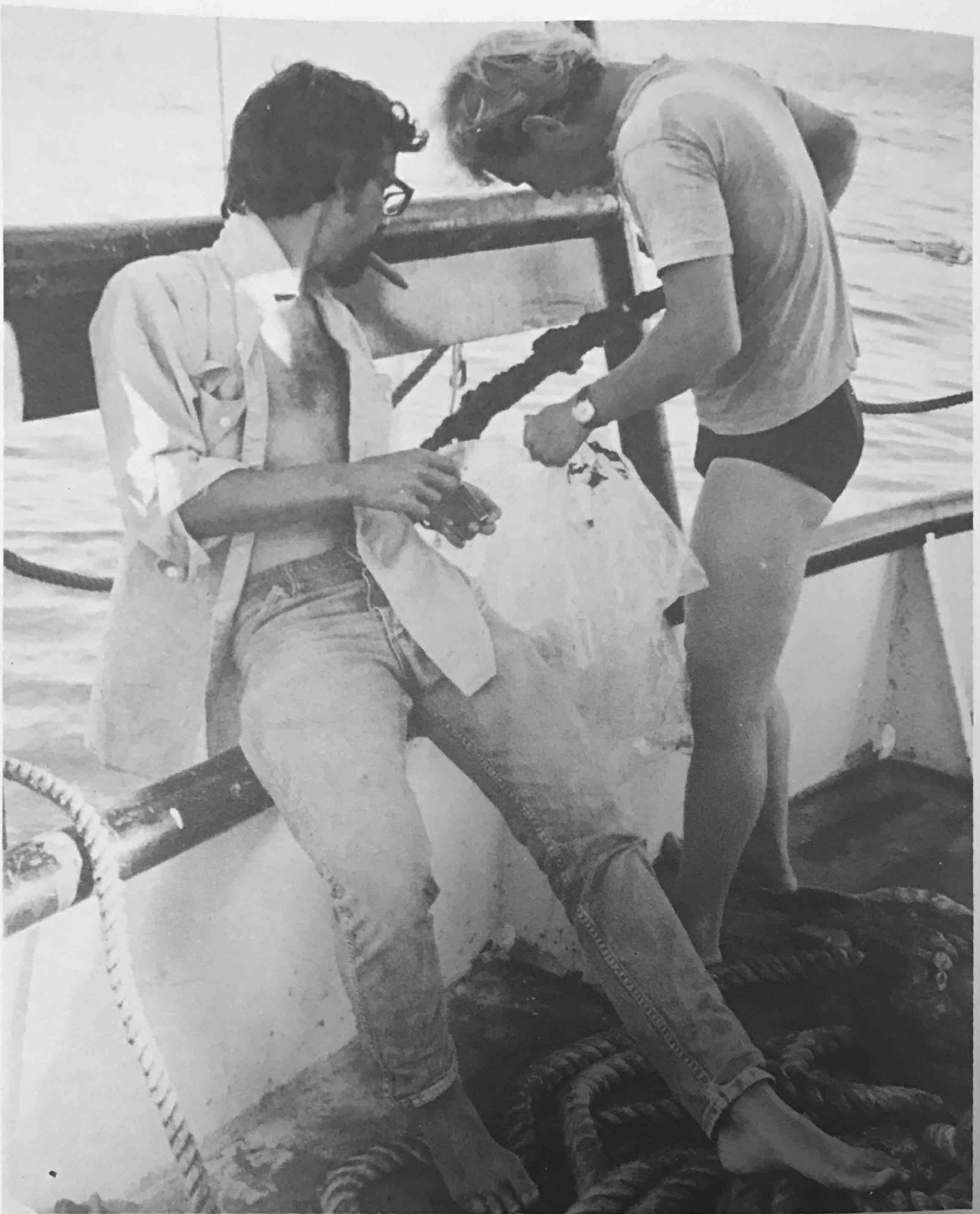
and detrital compartments to elucidate their energetics, their role in the system interface, and their potential usefulness as indicators in the study of certain nutrient pathways.



Elvira Cuevas and Alejo Estrada collecting water samples for water quality measurements at El Verde.



Alejo Estrada recording growth measurements of the Tree Fern, *Cyathea arborea*.



Dr. Seppo Kolehmainen (R.) and Edward Shearls examine a mangrove root sample on board the research vessel *R. F. Palumbo*.

# 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 four conventional and four nuclear power plants; thus, comparison of the environmental effects of the two types will be possible. The plans for the project were presented in detail in last year's *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 (Figure 1). A major effort has been to define and model the oceanography of the area; this has been completed.

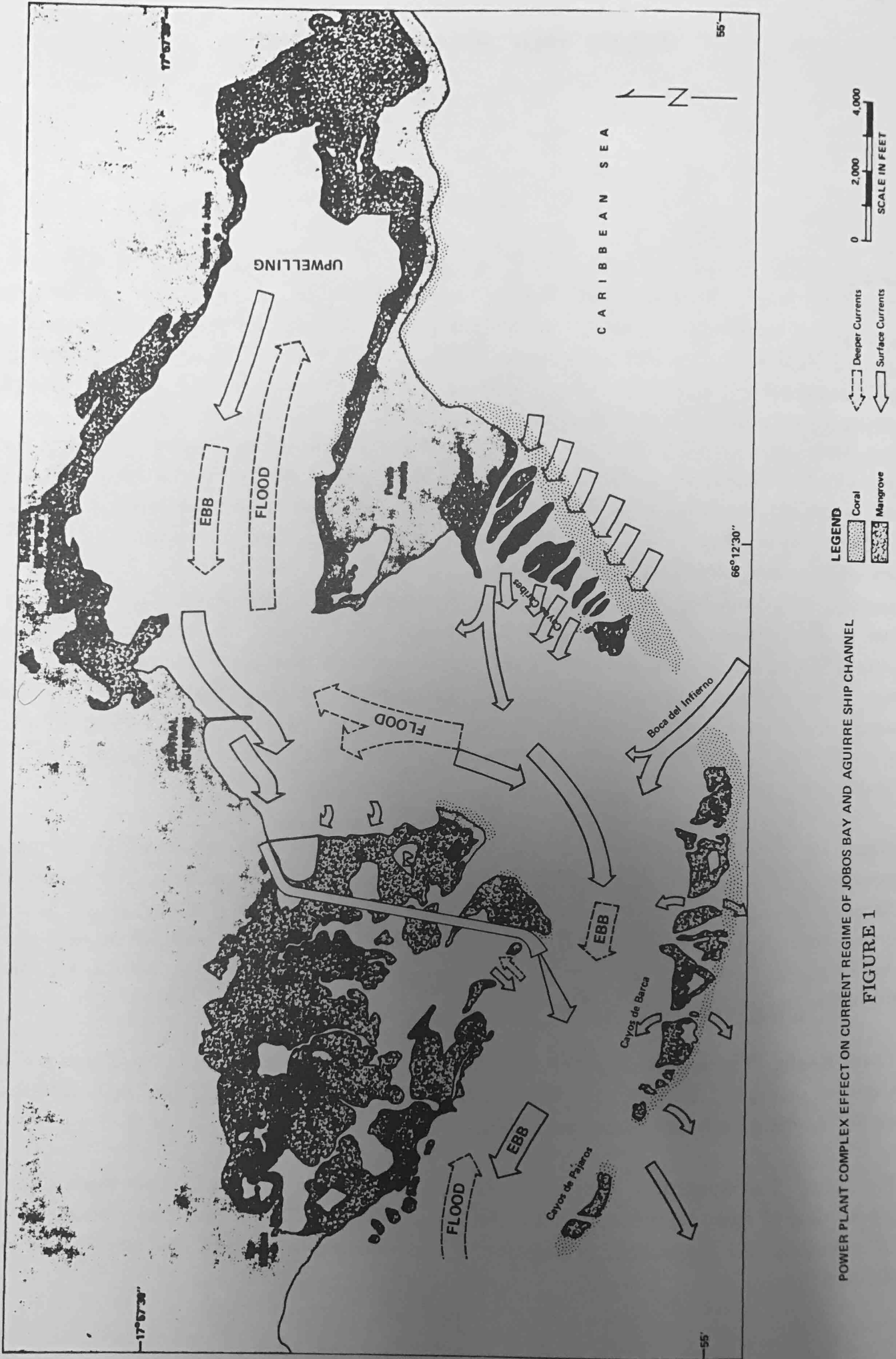
Studies, described last year, are continuing on the concentrations of stable elements whose radionuclides are expected to be discharged, in sea water, sediments, and organisms. Monitoring stations for air, plants, ground water, and bay water are in operation. The effects of elevated temperatures on marine 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.

**Mangrove and *Thalassia*.** Species diversity, biomass (Figure 2), 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 being done (see below) under Dr. Kolehmainen at Guayanilla Bay on the south coast, which has received thermal additions for 15 years.

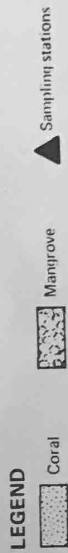
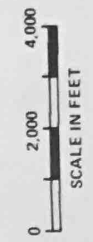
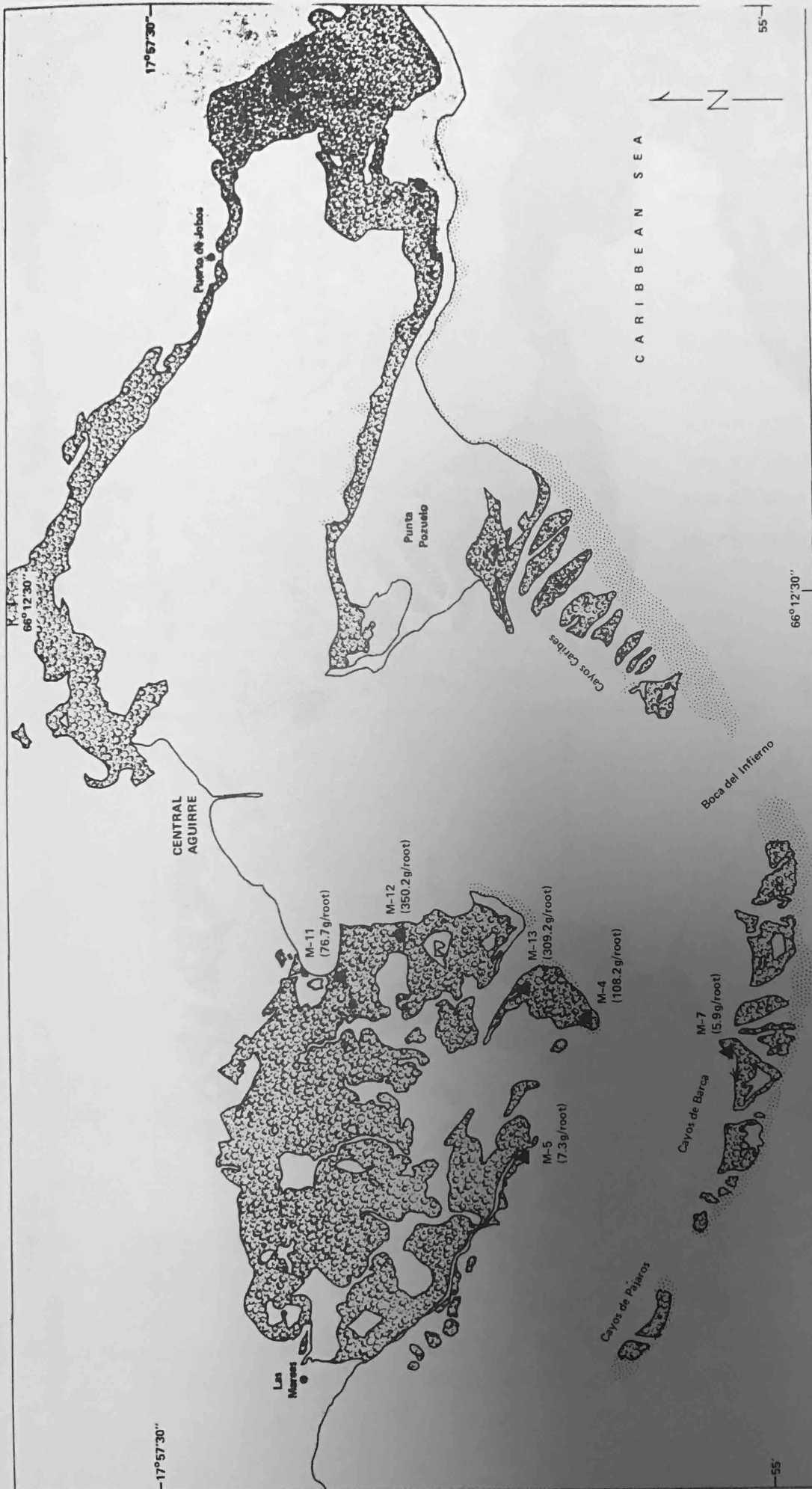
**Coral Reefs.** The major parameters of interest in coral reef ecosystems (Figures 3 to 5) are species diversity, distribution, and biomass. The degree of interfacing with systems such as *Thalassia* beds are under consideration.

**Plankton.** The dynamics, species diversity, and biomass of the plankton system are being studied (Figure 6) with special attention to species distribution and possible effects of pumping on the planktonic population. Food web importance of the plankton is being evaluated.



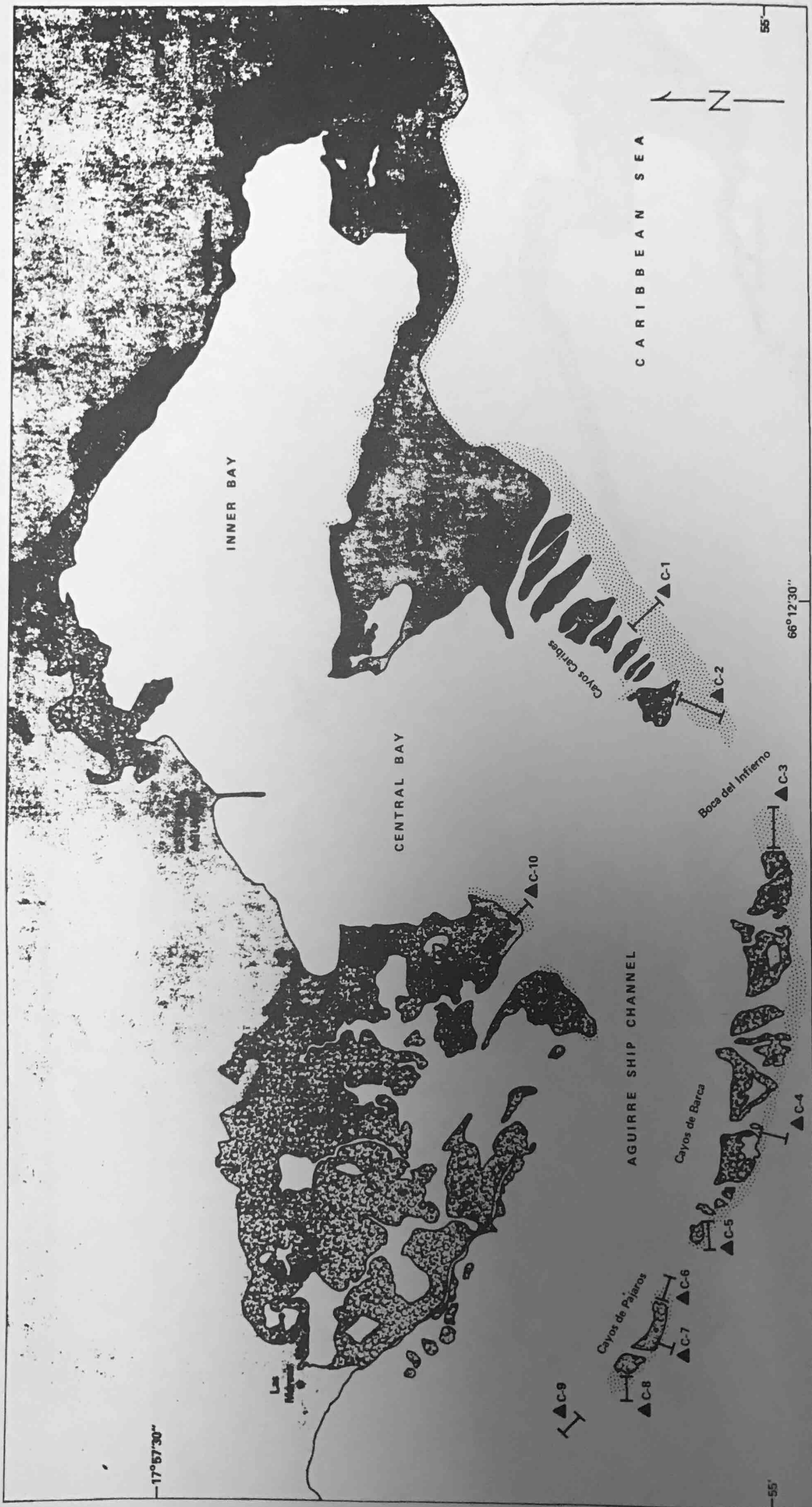


POWER PLANT COMPLEX EFFECT ON CURRENT REGIME OF JOBOS BAY AND AGUIRRE SHIP CHANNEL  
 FIGURE 1



MANGROVE ROOT SAMPLING STATIONS WITH BIOMASS IN GRAMS PER 12-INCH ROOT SECTION

FIGURE 2



CORAL SAMPLING TRANSECTS FOR JOBOS BAY  
**FIGURE 3**

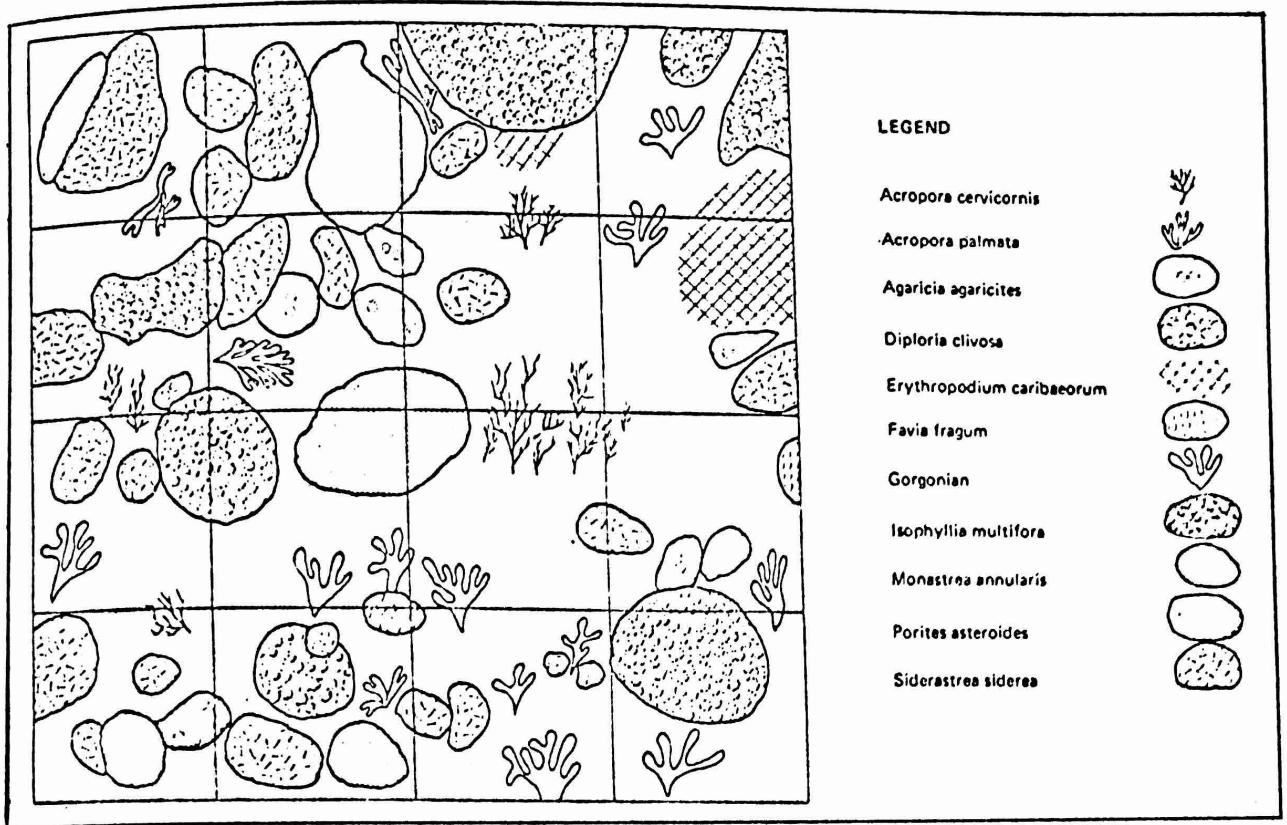


FIGURE 4. TYPICAL DIAGRAM OF CORAL EXAMINATION QUADRAT

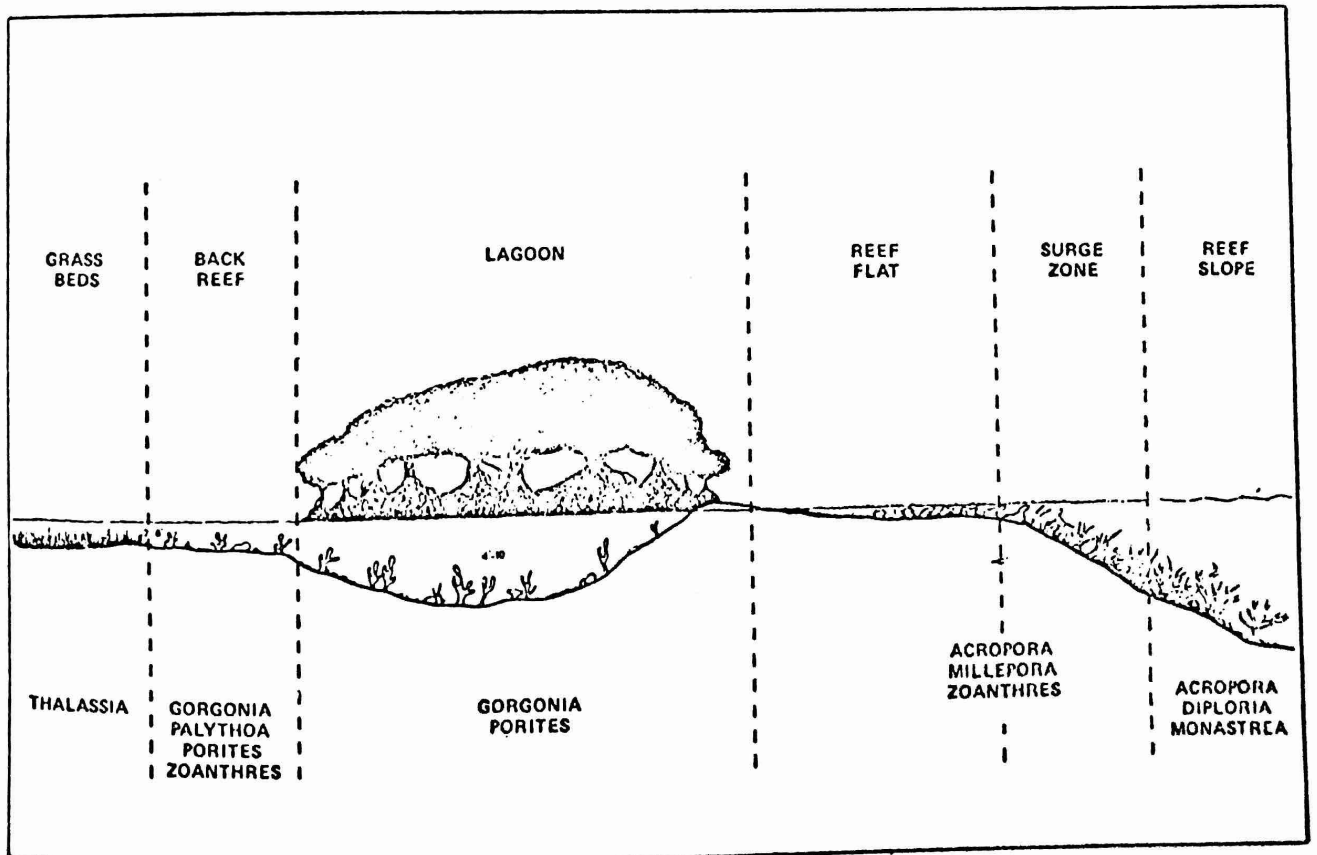
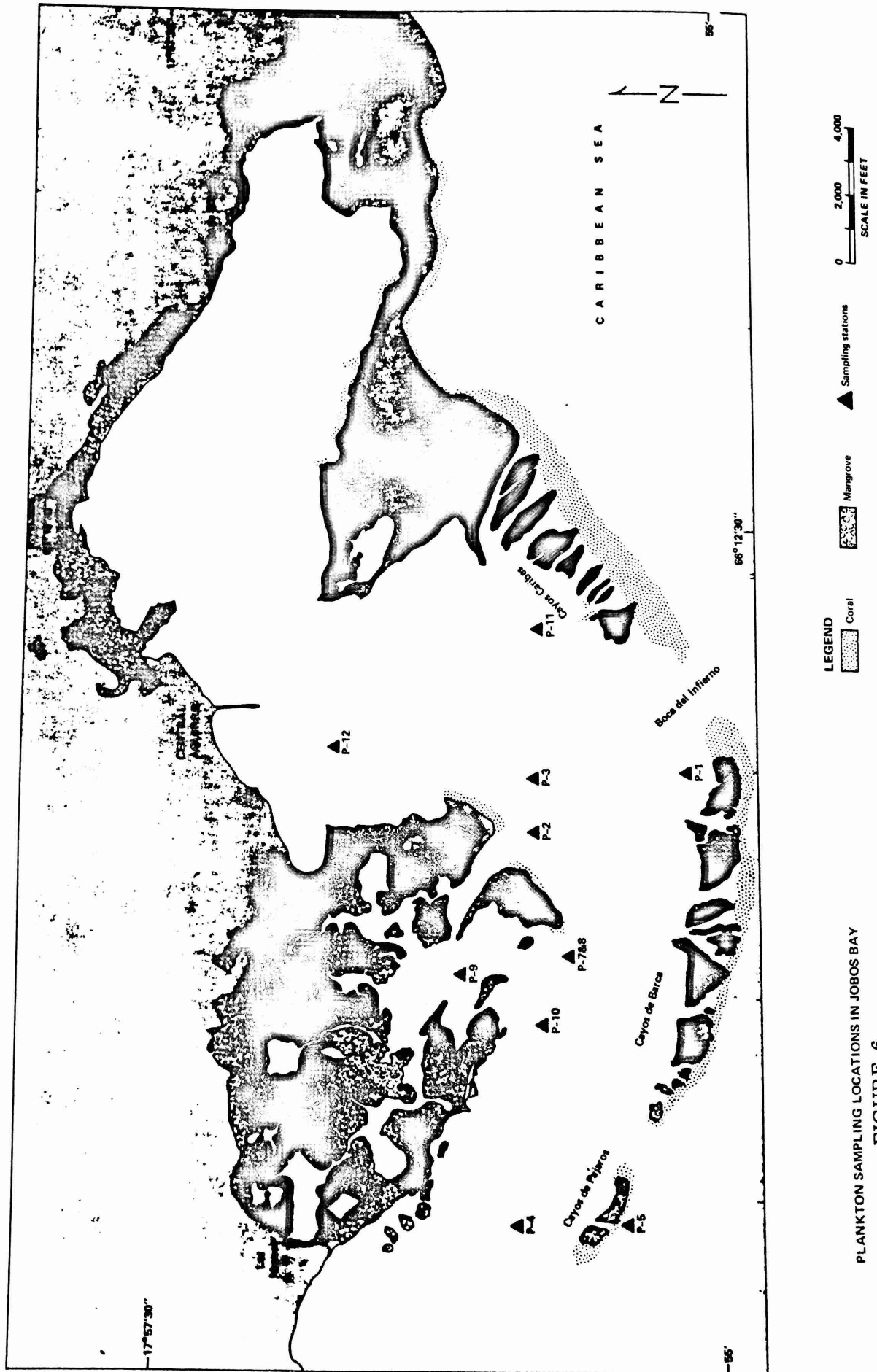
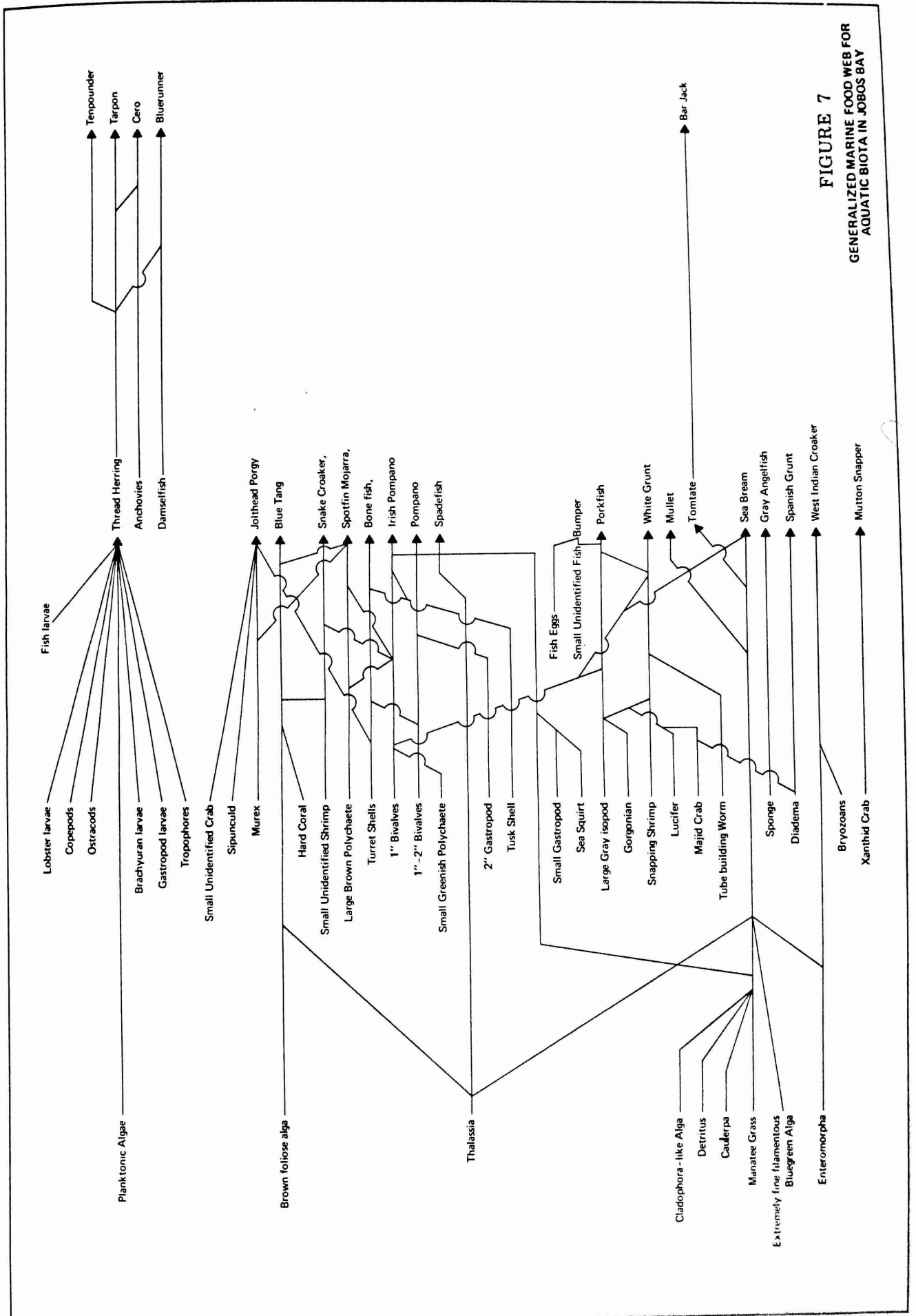


FIGURE 5. CROSS SECTION OF CORAL ZONATION AT JOBOS BAY



PLANKTON SAMPLING LOCATIONS IN JOBOS BAY  
**FIGURE 6**



**FIGURE 7**  
**GENERALIZED MARINE FOOD WEB FOR**  
**AQUATIC BIOTA IN JOBOS BAY**

**Fish.** Fishery research has provided a baseline of some 120 species common in the area. Species distribution and diversity is being worked out. The diagram of the food web for the fishes (Figure 7), already complex, is being revised and enlarged. 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.

**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 massive 750-lb constant temperature block has been constructed which is capable of maintaining a gradient over its 7-ft length of anywhere from 1.0° to 10.0°C with a maximum fluctuation of  $\pm 0.05^\circ\text{C}$ . A series of holes along the block allows for 60 sets of 5 replicates each to be maintained with a  $\Delta T$  between sets as low as 0.003°C. This block is designed for respiration and developmental studies of fish and brachyuran larvae, corals, and plankton.

**Other Studies.** These include the radiological monitoring program; working out an energy budget 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. Peter Willman has been making counts of bird species in the southwest region of Puerto Rico.

## THERMAL STUDIES IN GUAYANILLA BAY

Tropical marine organisms live at temperatures very close to the upper limit of their thermal tolerance, but 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 is 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. 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 have been started, under a one-year contract between PRNC and PRWRA, in Guayanilla Bay, where PRWRA has a fossil-fueled thermoelectric plant that discharges cooling water at a rate of 715 m<sup>3</sup>/min at 10°C above the ambient into a 14.3-hectare cove

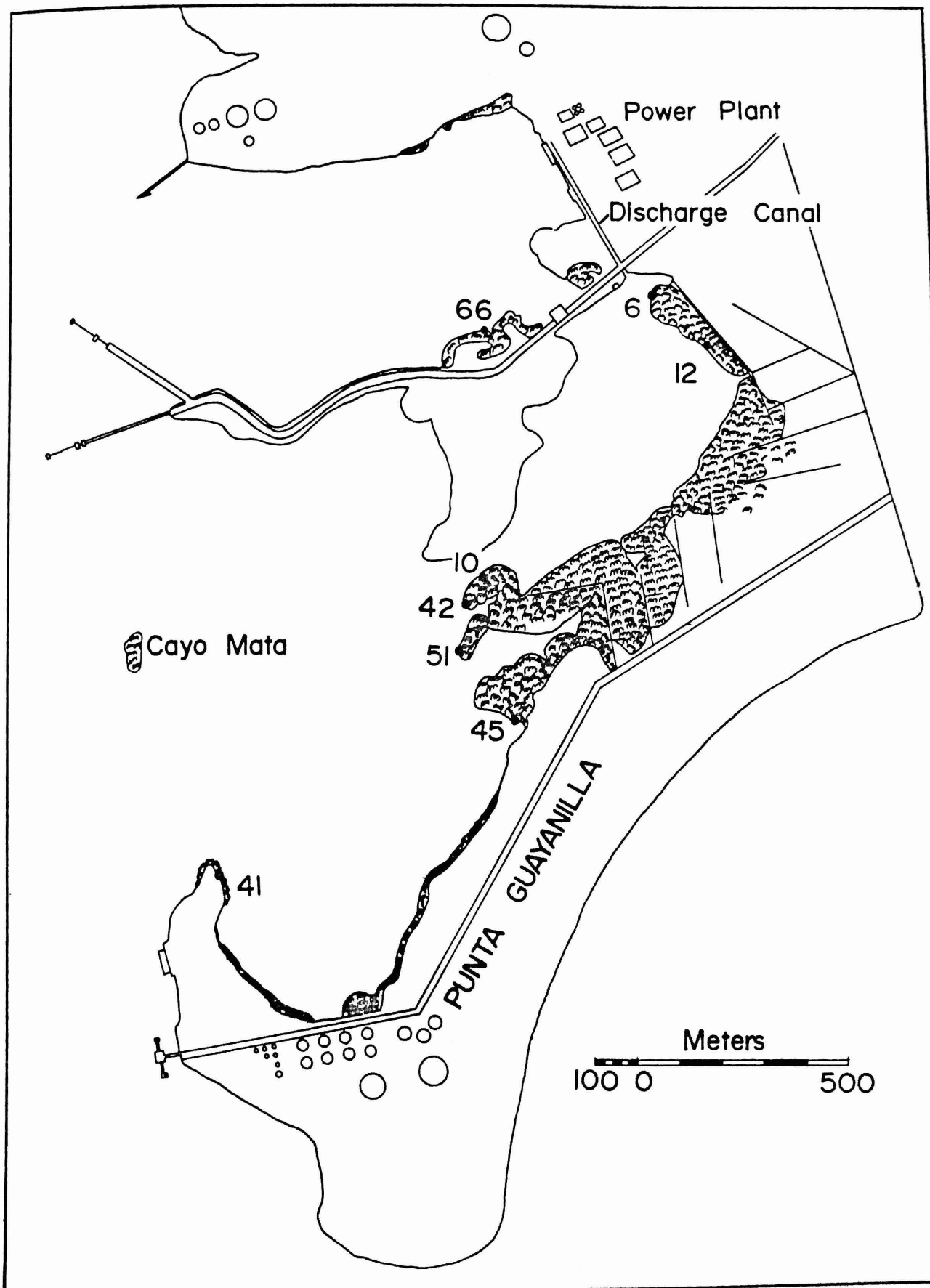


FIGURE 8. Numbers of species of organisms living on mangrove root around 'Guayanilla power plant.



that opens to the Bay (Figure 8). 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 twice, October 9, 1971, and January 13, 1972. The ambient temperatures were 30° and 25.7°C respectively. The horizontal distribution of surface temperatures is shown in Figure 9.

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. When the plant was discharging cooling water at 40°C on October 18, 1971, about 95% of the large copepods coming through the condensers and discharge canal were dead. About 75% of the small copepods were dead, but half the copepod and cirriped nauplii were alive. Large diatoms had suffered mechanical damage. In March 1972 PRWRA started testing a new large unit that puts out cooling water at 800 m<sup>3</sup>/min. During the testing this unit was pumping water at ambient temperature, and this lowered the water temperature in the discharge canal from 10°C above the ambient to 3.3°C above. During this period practically all zooplankters were alive after the trip through the condensers and the discharge canal. It seems that zooplankton is able to survive the trip through the condensers at 40°C but not the trip through the discharge canal. The former takes only a few seconds but the latter takes 8.5 ± 1 min.

Only one species of benthic organisms other than foraminifera has been found in the cove. Right at the mouth of the cove the number of species of benthic organisms is 15, and on turtle grass beds the number goes up to 25 in places where the temperature is 2° to 3°C above the ambient. Species diversity of organisms living on mangrove roots is not affected by water temperatures up to 34°C. Above this temperature the numbers of species of macroalgae, sponges, coelenterates, echinoderms, and tunicates decrease sharply. Red mangrove (*Rhizophora mangle*), black mangrove (*Laguncularia racemosa*), bluegreen algae, a cirripede (*Balanus eburneus*), and tree oyster (*Isognomon alatus*) were growing at temperatures up to 38°C. The numbers of species growing on mangrove roots at different locations are shown in Figure 8 and the biomasses, in Figure 9. The biomass was highest inside the cove, but it consisted mostly of one species, the tree oyster. The biomass was lowest where mangroves grow right in front of the discharge canal. At the mouth of the cove, where the temperature is 34° to 35°C in summer, the biomass was the same as in areas not affected by the heated discharge.

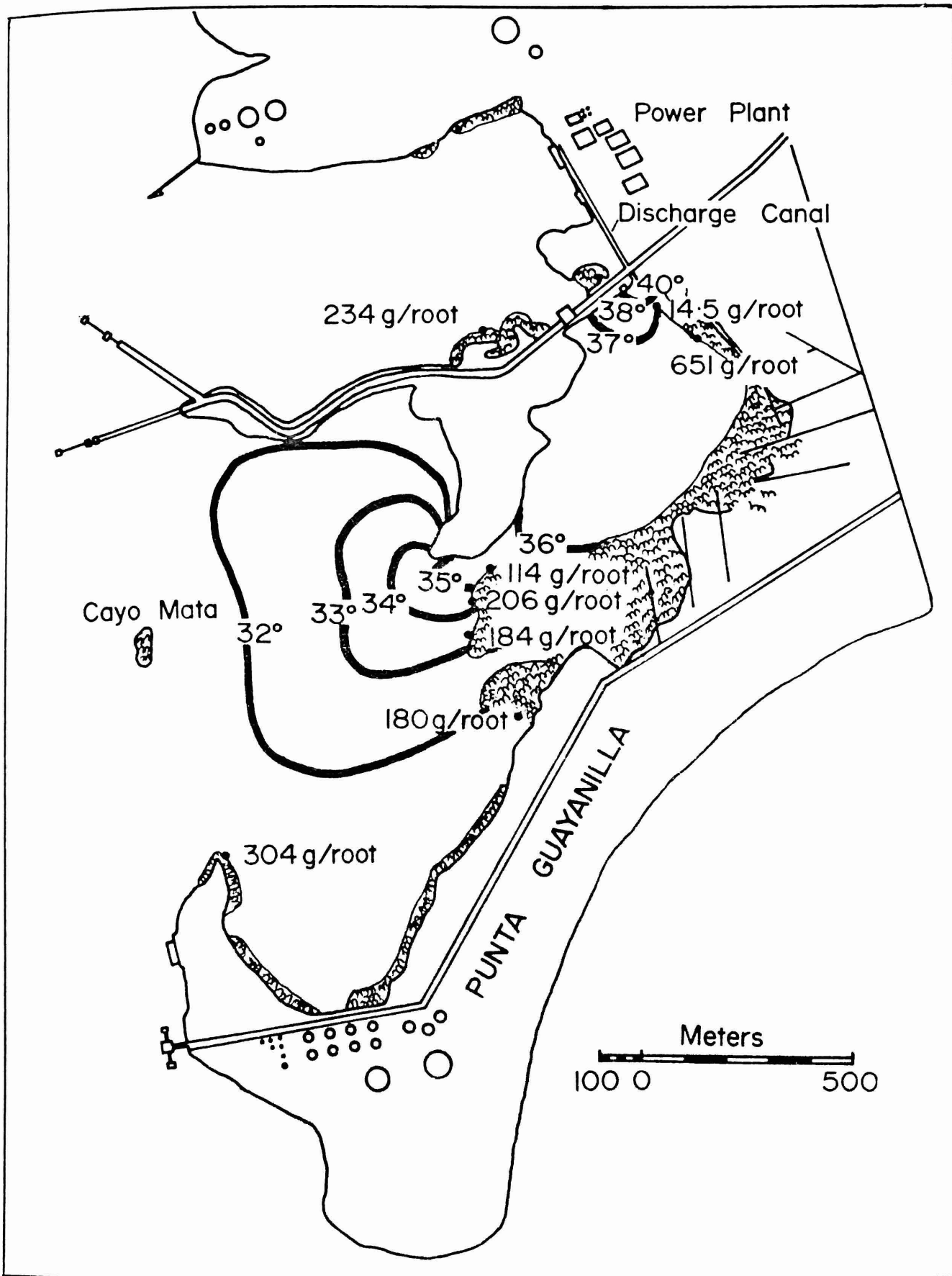


FIGURE 9. Biomass of organisms living on mangrove roots around Guayanilla power plant (g wet wt./root). Surface temperatures of water are also shown.

Fish samples have been collected with a set of gill nets. Fish are abundant in the cove and have a somewhat higher biomass there than outside: 16 species, including tarpon, mullet, thread herring, anchovy, moharras, jacks, and mangrove snapper have been caught. At the control area 23 different species have been found. In general, species in Guayanilla Bay have been found living at higher temperatures than in temperate or subtropical climate. 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.



Aerial view of Jobos Bay Project site.

# 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.

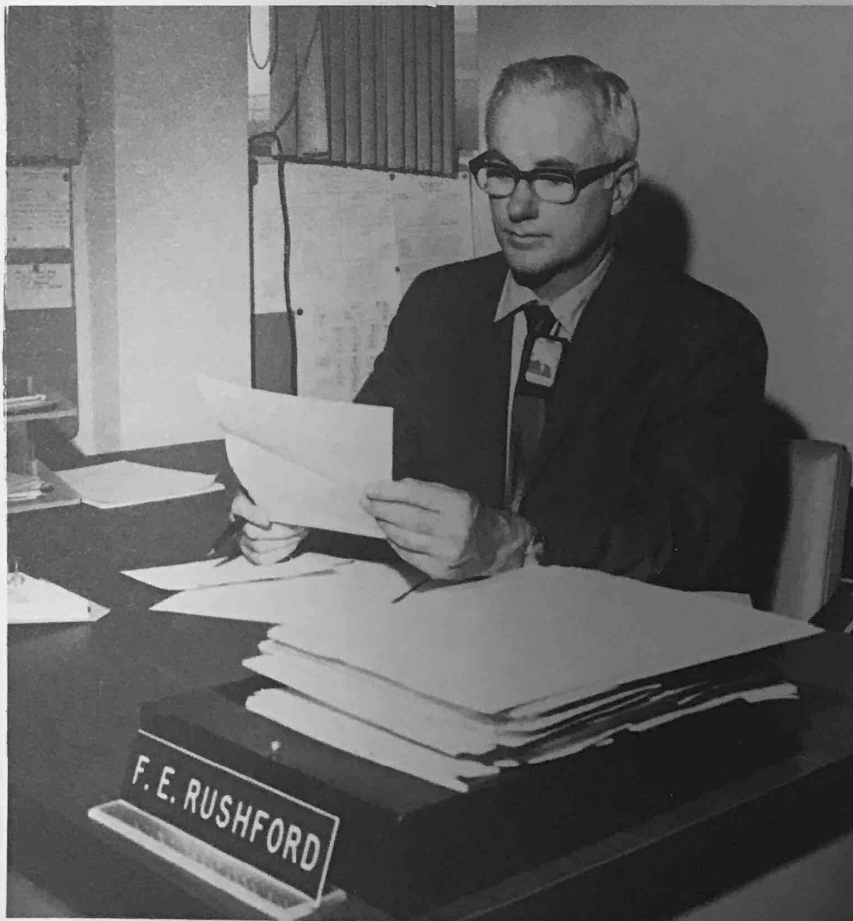
## STAFF

Mr. Frederick E. Rushford, Head of the Division, met with officials of the Organization of American States in Washington, D.C., on August 12 and 13, 1971, to review the PRNC participation in the OAS Regional Scientific and Technological Development Program in Nuclear Energy. He also met with Mr. Nazario C. de Baca at the Agency for International Development of the U.S. State Department and with Mrs. Marvelle Toney, Training Officer, Fellowships Section of the Department of Human Resources Development of the Pan American Health Organization to discuss fellowship opportunities for Latin American students interested in studying at PRNC.

Mrs. Iraida Oliver de Padovani, a UPR librarian assigned to the PRNC Reading Room in Mayagüez, attended a meeting of the Association of Caribbean University and Research Libraries held in Caracas, Venezuela, on November 7-12, 1971. Mrs. Padovani represented the PRNC Technical Reading Room, which is an autonomous branch of the UPR Library at Mayagüez.



Miss Ivette Minguela, at work in PRNC technical reading room in Mayagüez.



Mr. Frederick E. Rushford, Head of the Information and Education Services Division.

Table 1  
PRNC Student Economic Aid Program - Fiscal Year 1972 - \$10,000.00

Name	Country	Training	Inclusive Dates	Grant
1. Célica Barboza	Uruguay	Clinical Radioisotope Applications	6 Jul 71-27 Aug 71	\$ 453.00
2. Ingrid Mai Pinkes	Bolivia	Clinical Radioisotope Applications	6 Jul 71- 1 Oct 71	678.00
3. Elvira Giambartolomei	Argentina	Clinical Radioisotope Applications	6 Jul 71-30 Jun 72	453.00
4. Gerardo Valverde Aguilar	Costa Rica	Clinical Radioisotope Applications	6 Jul 71-27 Aug 71	116.00
5. Isabel Bulla	Colombia	Thesis Research, M.S. in Biology	1 Jul 71-30 Dec 71	200.00
6. Mercedes Vargas	Dominican Republic	Schistosomiasis and Fascioliasis	1 Jul 71- 20 Aug 71	400.00
7. Freddy R. Medina	Dominican Republic	Thesis Research, M.S. in Biology	1 Jul 71-30 Jun 72	1,650.00
8. Ingrid Erdelyi	Brazil	M.S. in Radiological Health	16 Aug 71- 30 Jun 72	250.00
9. Elaine Montague	Jamaica	Radiobiology	12 Aug 71-10 Sep 71	300.00
10. Gilberto Arenas Rosillo	Colombia	M.S. in Nuclear Engineering	16 Aug 71-30 Jun 72	1,500.00
11. René C. Dietrich	Bolivia	Nuclear Medicine	1 Jul 71-30 Jun 72	550.00
12. Alfredo Velarde Ponce	Peru	Fascioliasis	1 Jul 71- 30 Jun 72	25.00
13. Plinio Costa Gomes	Brazil	Fascioliasis	1 Jul 71-30 Jun 72	25.00
14. Alberto J. Moreno	Colombia	Thesis Research, M.S. in Physics	17 Aug 71-12 May 72	1,200.00
15. Rubén Restrepo	Colombia	Thesis Research, M.S. in Biology	1 May 72-30 Jun 72	300.00
16. Luisa Nélica Elba Pérez	Argentina	Radioisotope Tech., Clinical Appl.	1 Jun 72-30 Sep 72	900.00
17. Percy C. Naranjo Williams	Peru	Radioisotope Tech., Clinical Appl.	1 Jun 72-30 Aug 72	450.00
18. Jorge D. Caputto Escudero	Argentina	Radioisotope Tech., Clinical Appl.	1 Jun 72- 30 Sep 72	225.00
19. Ricardo G. Decillis Caló	Argentina	Radioisotope Tech., Clinical Appl.	1 Jun 72- 31 Aug 72	325.00

Table 2  
OAS Regional Scientific and Technological Development Program - Nuclear Energy - Fiscal Year 1972<sup>☆</sup>

Name	Country	Training	Inclusive Dates
1. Massoyoshi Yoshida	Brazil	Radiation Chemistry	1 Dec 70 - 31 Aug 71
2. Eleuterio Molinas Villasanti	Paraguay	M.S. in Radiological Health	1 Aug 71 - 31 Aug 72
3. Anibal Jorge Camnasio Simoni	Argentina	Special Training in Nuclear Physics	1 Jan 72 - 30 Sep 72
4. Gentil A. Esteves Gómez	Colombia	Special Training in Nuclear Physics	10 Jan 72 - 10 Oct 72
5. Angel Benigno Reyes Vega	Ecuador	Special Training in Reactor Control	10 Jan 72 - 10 Oct 72
6. José Mireles Sahagun	Mexico	Special Training in Nuclear Engineering	10 Jan 72 - 10 Oct 72
7. Santiago Gómez Figueroa	Colombia	Special Training in Agricultural and Biological Sciences	12 Jan 72 - 10 Oct 72
8. Ariel Alonso Oroz	Uruguay	Special Training in Nuclear Reactors	1 Feb 72 - 31 Oct 72

☆ Fellows assigned to PRNC as of May 12, 1972

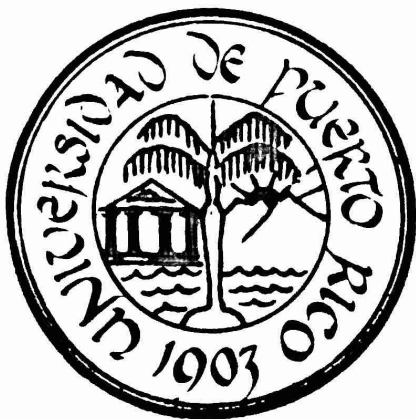
LA UNIVERSIDAD  
DE PUERTO RICO  
y el  
CENTRO NUCLEAR  
OTORGAN POR ESTE MEDIO AL  
DR. SHIELDS WARREN M.D.

el presente

DIPLOMA DE HONOR

POR HABER INAUGURADO EL CICLO ANUAL DE CONFERENCIAS  
EN MEMORIA DEL DR. JOHN C. BUCHER, CON SU DISERTACIÓN  
SOBRE "LA ENERGÍA NUCLEAR Y LA MEDICINA," OFRECIDA EN  
EL ANFITEATRO DE LA ESCUELA DE MEDICINA DEL RECINTO  
DE CIENCIAS MÉDICAS EN SAN JUAN, EL 16 DE FEBRERO DE  
1971.

Y PARA QUE ASÍ CONSTE, DAMOS DE ELLO FE HOY DÍA 2 DE  
ABRIL DEL AÑO 1971.



*Jaime Benítez*  
Presidente de la Universidad de Puerto Rico

*Henry J. Lombreg*  
Director del Centro Nuclear de Puerto Rico

## 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 participate in the teaching and research activities of several PRNC divisions.

### JOHN C. BUGHER MEMORIAL LECTURE

The John C. Bugher Annual Lecture Series was inaugurated on February 16, 1971, by UPR President Jaime Benítez. Dr. Shields Warren, Professor Emeritus of Pathology, Harvard Medical School, and a close friend of Dr. Bugher, lectured on "The Impact in Medicine of Nuclear Energy." Mrs. John C. Bugher attended the inaugural lecture.

This series of annual lectures in the sciences is dedicated to the memory of Dr. John C. Bugher. The lectures are given in recognition of the contributions he made to the advancement of the sciences and their applications on a global basis, and of the special contribution he made to the advancement of science in Puerto Rico. His life work was expressed mainly through contributions to four great institutions: the University of Michigan, where he spent a decade and one-half, first as an advanced student, and then as an instructor and assistant professor of pathology; the Rockefeller Foundation, where he spent nearly three decades in major research assignments in Colombia and Nigeria, and in major policy positions within the Foundation itself; the Atomic Energy Commission, while on leave from the Foundation, where he served as deputy Director and Director of the Division of Biology and Medicine; the University of Puerto Rico, where he culminated his service to both the Foundation and the AEC as Director of the Puerto Rico Nuclear Center, until his retirement in 1966. Concurrently he served the nation as a Presidential appointee to the General Advisory Committee to the AEC. Following retirement he continued to serve until his death in September 1970. His honors include: Award of the Cruz de Boycaya from the President of Colombia; Life and Honorary Membership, Academy of Medicine, Bogotá, Colombia; Commander of the Order of the British Empire; US AEC Citation Award; The Howard Taylor Ticketts' Award, University of Chicago; Order of the Phoenix from the Government of Greece; honorary degrees from Taylor University, University of Michigan, and the University of Puerto Rico.





Dr. Shields Warren



Dr. John Wolfe, Deputy Assistant to the Director, US AEC Division of Biomedical and Environmental Research, speaking at the dedication ceremony for the research vessel *R. F. Palumbo* in Mayagüez. The widow of Dr. Palumbo, Mrs. Doris Palumbo Ashe (front row), presented her husband's service flag for the ship.

## MEETINGS

On January 27, 1971, the Nuclear Medicine Society of Puerto Rico was founded during a constitutional assembly held at the PRNC Bio-Medical Building in Río Piedras by 14 physicians specializing in nuclear medicine. The by-laws were approved, and a provisional Executive Committee for organizing the Society was designated with Dr. Aldo E. Lanaro as President, Dr. Mario Rosa as Secretary, and Dr. Julio V. Rivera as Treasurer.

The Advisory Committee to the University President on the Puerto Rico Nuclear Center met on February 15 and 16 in Mayagüez, the dates having been selected to coincide with the inauguration of the J.C. Bugher Lecture Series. In addition to the members of the Committee, the meeting was attended by Dr. John Totter, Director of the US AEC Division of Biology and Medicine, Dr. Shields Warren, Professor Emeritus of Pathology at the Harvard Medical School, and Dr. Jaime Benítez, President of the University of Puerto Rico. Operations in Mayagüez were reviewed, and reports were made on programs in agriculture, radioecology, nuclear engineering, and nuclear sciences and on the progress of the installation of the new TRIGA reactor.

The Tenth Inter-American Congress of Radiology was held in San Juan, May 16-22. Approximately 1200 registrants attended the meeting, representing the majority of the countries in this hemisphere. In addition, there were observers from Japan as well as several European countries. The meeting was organized by the Radiological Society of Puerto Rico, the UPR School of Medicine, and the Puerto Rico Nuclear Center. Dr. Víctor Marcial, Associate Director for Medical Programs at PRNC, served as President of the Executive Committee of the Congress.

A panel discussion on agricultural research coordination and cooperation with the objective of producing more and better food was held at the Bio-Medical building in Río Piedras on October 22. The meeting was attended by scientists from the University's College of Agricultural Sciences and the Puerto Rico Nuclear Center. Dr. Francis K.S. Koo, Head of the Tropical Agro-Sciences Division, served as coordinator for the meeting.

## NEW OCEANOGRAPHIC RESEARCH VESSEL

On January 23, 1971, christening ceremonies were held at the Tatco Ship Building Corporation in San Diego, California, for the launching of a new research vessel to be used by the Atomic Energy Commission in marine research programs in Puerto Rico. The ship was christened the *R. F. Palumbo* in honor of the late AEC scientist, who was a radioecologist for 16 years prior to his death in 1965. Dr. Frank Lowman, Director of the PRNC Radioecology Division, will utilize the ship in two major programs. One involves a long-term marine biology program dealing with the measurement of trace elements and their movement from the Island into the sea, and the second is a cooperative environmental-ecological study by the AEC and the Puerto Rico Water Resources Authority.

A dedication ceremony was held on June 4 in Mayagüez when the *R. F. Palumbo* was officially turned over to President Jaime Benítez on behalf of the University of Puerto Rico. The ceremony was attended by seventeen members of the Palumbo family, including the widow of Dr. Palumbo and his sole surviving son. Among the guests was Dr. John N Wolfe, Head of the Environmental Sciences Branch of the Division of Biology and Medicine, the AEC official most instrumental in assisting the Puerto Rico Nuclear Center in the acquisition of the research vessel.

## VISITORS

During the week of January 10-14, the following group of distinguished visitors inspected the Arecibo Ionospheric Observatory and other scientific facilities in Puerto Rico including the Puerto Rico Nuclear Center: Honorable Charles A. Mosher, Congressman, Ohio, Member, House Committee on Science and Astronautics, and ranking minority member, Subcommittee on Science, Research, and Development; Mrs. Charles A. Mosher; Dr. William D. McElroy, Director, National Science Foundation; Mr. Clarence Ohlke, Office of Government and Public Programs, National Science Foundation.

Congressman Howard W. Robinson from New York, a member of the Appropriations Committee, visited PRNC on April 15.

## STAFF

Dr. Henry J. Gomberg, who served as Deputy Director of the Puerto Rico Nuclear Center from 1961 to 1966 and as Director since 1966, resigned on April 20, 1971, to accept the position of President of KMS Fusion, Inc., in Ann Arbor, Michigan.

Dr. Amador Cobas, former Deputy Director of PRNC and currently Head of the Physical Sciences Division, was appointed Acting President of the University of Puerto Rico by the Superior Education Council on October 7, 1971.

Dr. Edwin Roig, Deputy Director of PRNC, was appointed Acting Director.

Dr. Roig attended the Bio-Medical Program Directors' Fall Meeting held in Los Alamos, New Mexico, on October 4-5. On October 28-29, he attended the Annual Meeting of University Consortia and National Laboratory Educational Directors held in Oak Ridge, Tennessee.

At the invitation of the International Atomic Energy Agency, Dr. Roig participated as a professor in an IAEA Regional Training Course on the Application of Nuclear Techniques in Plant Biochemistry With Reference to Protein, held at the Instituto de Asuntos Nucleares in Bogotá, Colombia, from October 30 through November 12. Following this course he visited various South American countries where he met with local AEC officials, OAS personnel, and representatives of PAHO.

# APPENDIX

## Publications

1. *Aguirre Power Project Environmental Studies, 1971 Annual Report*, Submitted to Puerto Rico Water Resources Authority, Dec. 31, 1971.
2. *Annual Report 1970*, PRNC-144.
3. Barrett, R. F. (Inst. Theor. Physik) and Delsanto, P. P., Continuum Shell Model Calculation for  $^{208}\text{Pb}$ , *Phys. Lett.* **34B**, 110-12 (1971).
4. Block, A. McB., Use of a 6,328-Å Secondary Source in Differential Refractometry, *Appl. Opt.* **10**, 231 (1971).  
Block, A. McB. - See also Mehta, K.  
Bosch, A. - See Lanaro, A. E.; Picó, J.  
Brown, J - See Chiriboga, J.  
Casanova de Bras, I. - See Wheeler, O. H.
5. Castrillón, J., The Resolving Time of a Counter by the Method of Paired Sources, *Radiochem. Radioanal. Lett.* **6**, 249-56 (1971).  
Castrillón, J. - See also Gómez, E.; Szmant, H. H.
6. Chiriboga, J., Ritchie, L. S., Oliver-González, J., Brown, J., Martínez-Silva, R., Colón, J. I., and López, V. A., Bacteria in the "Curative" Effect of Hemolymph of *Biomphalaria glabrata* on *Schistosoma mansoni*-Infected Mice, *Amer. J. Trop. Med. Hyg.* **20**, 672-8 (1971).  
Chiriboga, J. - See also de León, D.
7. Clements, R., Drewry, G. E., and Lavigne, R. J., *The Rain Forest Annual Report, June 1970*, PRNC-147.  
Cobas, A. - See Weisz, S. Z.  
Colón, J. I. - See Chiriboga, J.; Szmant, H. H.
8. de León, D. (UPR Agr. Exp. Sta.), Ritchie, L. S., and Chiriboga, J., *Fasciola hepatica in Puerto Rico, Jan. 1970 - Apr. 1971* (in Spanish), PRNC-148
9. de León, D. (UPR Agr. Exp. Sta.), Ritchie, L., and Chiriboga, J., Refractiveness of *Physa cubensis* (Pfeiffer) and *Aplexa marmorata* (Guilding) to *Fasciola hepatica* (L.), *J. Agr. Univ. P.R.* **55**, 267-70 (1971).  
Delsanto, P. P. - See Barrett, R. F.  
Drewry, G. E. - See Clements, R.
10. Fiala, W. and Wheeler, C. V., A Simple Total-Reflecting Low-Energy Neutron Spectrometer, *Nucl. Technol.* **10**, 215-20 (1971).
11. Forcher, H. M. (Endocrinol. & Metab. Clin., Buenos Aires), Lanaro, A. E., Enriori, C. L. (Ibid.), and Reforzo-Membrives, J. (Ibid.), Adaptation of Thyroid Function to Iodine Intake in Buenos Aires, *J. Clin. Endocrinol. Metab.* **32**, 254-9 (1971).  
Freer, J. - See Gómez, E.

- Frías, Z. - See Lanaro, A. E.; Picó, J.
12. Gileadi, M., *Joint Radiation Survey: Evaluation of Health Hazards Due to Unintentional Irradiation of the Gonads During Routine Abdominal X-Ray Examination of Male and Female Patients in Puerto Rico, Report No. 3*, May 1971.
  13. Gileadi, M., A Joint X-Ray Radiation Survey in Puerto Rico, 1968, *Radiol. Health Data Rep.* **12**, 495-9 (1971).
  - Gomberg, H. J. - See Muñoz-Ribadeneira, F.
  14. Gómez, E., Freer, J., and Castrillón, J., Nitriles as Scintillation Solvents: Benzo- and Acetonitrile, *Int. J. Appl. Radiat. Isotop.* **22**, 243-50 (1971).
  15. Gonzalo, J. A. and Rivera, J. M., Ferroelectric Free Energy Expansion Coefficient from Double Hysteresis Loops, *Ferroelectrics* **2**, 31-5 (1971).
  16. Grimison, A., *Gamma Radiolysis of Heterocyclic Molecules, Progress Report No. 5*, PRNC-150, July 1971.
  17. Grimison, A., The Radiation Chemistry of Organic Glasses, in *Proc. 2nd Inter-Amer. Conf. Radiochemistry, Mexico, D.F., Apr. 1968*, pp. 69-74, Organization of American States, Washington, D.C., 1971.
  18. Grimison, A., Theoretical Treatment of Overcrowding in Phenanthrene, *Theor. Chim. Acta* **20**, 263-72 (1971).
  - Grimison, A. - See also Mehta, K.
  - Infante, G. A. - See Wheeler, O. H.
  - Julián, D. A. - See Wheeler, O. H.
  19. Kay, M. I. and Kleinberg, R., *Neutron Diffraction Program Progress Summary Report No. 9*, Apr. 1971.
  20. Kay, M. I., Okaya, Y. (SUNY), and Cox, D. E. (BNL), A Refinement of the Structure of the Room Temperature Phase of Phenanthrene,  $C_{14}H_{10}$ , from X-Ray and Neutron Diffraction Data, *Acta Cryst.* **B27**, 26-33 (1971).
  - Kay, M. I. - See also Moyer, R. O. Jr.
  21. Kleinberg, R., *Crystal Structure of  $CoBr_2 \cdot 6H_2O$  at Room Temperature by Neutron Diffraction*, PRNC-146, 1971.
  22. Kleinberg, R., *A Least-Square Refinement of the X-Ray Data on Azurite,  $Cu_3(OH)_2(CO_3)_2$* , PRNC-145, 1971.
  - Kleinberg, R. - See also Kay, M. I.; Moyer, R. O. Jr.
  23. Kline, J. R. (ANL), Martin, J. R. (LRL), Jordan, C. F. (ANL), and Koranda, J. J. (LRL), Transpiration in Tropical Trees Measured Using Tritiated Water, *Ecology* **51**, 1068-73 (1970). (Work done at PRNC.)
  24. Koo, F. K. S., Mutation Breeding in Soybeans, in *Induced Mutations and Plant Improvement (Proc. FAO/IAEA Study Group Meet., Buenos Aires, Nov. 1970)*, pp. 285-92, IAEA, Vienna, 1972.
  - Koo, F. K. S. - See also Liu, L. C.
  25. Lanaro, A. E., Bosch, A., and Frías, Z., Red Blood Cell Survival in Patients with Hodgkin's Disease, *Cancer* **28**, 658-61 (1971).

- Lanaro, A. E. - See also Forcher, H. M.  
 Lavigne, R. J. - See Clements, R.
26. Lee, R. A., *Radiation and Hot Atom Chemistry Program, Progress Summary Report No. 6, Nov. 1970 - Apr. 1971.*  
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 Levinson, J. - See Weisz, S. Z.
27. Liu, L. C., Cibés-Viadé, H. (UPR Agr. Exp. Sta.), and Koo, F. K. S.,  
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 451-60 (1971).  
 López, V. A. - see Chiriboga, J.
28. Lowman, F. G. et al., *Bioenvironmental and Radiological-Safety Feasibility Studies, Atlantic-Pacific Interoceanic Canal, Estuarine and Marine Ecology, Final Report*, BMI-171-32, 1970.
29. Lowman, F. G., Rice, T. R. (Bur. Com. Fish.), and Richards, F. A. (U. of Wash.),  
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*Radioactivity in the Marine Environment*, pp. 161-99, NAS-NRC, Washington,  
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30. Marcial, V. A., Radiotherapy of Cancer of the Stomach and Esophagus (in Spanish),  
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 Martínez-Silva, R. - See Chiriboga, J.
31. Mehta, K. (UPR), Grimison, A., and Block, A. McB., Effect of Dispersing Agents  
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32. Mejía-Avilés, B. and Pedersen, K. B., *Activation Analysis as a Method for Tracing  
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33. Moyer, R. O. Jr. (U. of Conn.), Stanitski, C. (U. of Conn.), Tanaka, J. (U. of  
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 Function of the Apparent Particle Radius, Leaching Time, and Solvent Con-  
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35. Muñoz-Ribadeneira, F. J., Roasting of Chalcopyrite: Rate of Copper Sulfate  
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37. Picó, J. (I. González Martínez Hosp.), Frías, Z., and Bosch, A., Cervical Lymph  
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- Quintana-Muñiz, V. - See Walker, D. W.  
Ritchie, L. S. - See Chiriboga, J.; de León, D.  
Rivera, J. M. - See Gonzalo, J. A.
38. Rodríguez, R. and Lee, R. A., Gamma Ray Induced Copolymerization of Vinyl Acetate and Crotonic Acid, *Rev. Latinoamer. Quim.* **2**, 50-53 (1971).
39. Szmant, H. H., Colón, J., and Castrillón, J., Isotopic Evidence for a Rearrangement During Chromic Acid Oxidation of 1,1-Di(*p*-iodophenyl)ethane *J. Org. Chem.* **36**, 573-5 (1971).
- Torres, J. - See Walker, D. W.
40. Walker, D. W., *Insect Sterility Program Technical Report No. 5*, PRNC-143, Feb. 1971.
41. Walker, D. W., Quintana-Muñiz, V., and Padovani, F., Effect of Gamma Irradiation on Immature Sugarcane Borers, in *Sterility Principle for Insect Control or Eradication (Proc. IAEA/FAO Symp., Athens, Sept. 1970)*, pp. 513-24, IAEA, Vienna, 1971.
42. Walker, D. W., Quintana, V., and Torres, J., Genetic Collapse of Insect Populations. 1. Extinction of Inbred and Outbred Lines in Laboratory Populations of the Sugarcane Borer, *J. Econ. Entomol.* **64**, 660-7 (1971).
43. Weisz, S. Z., Levinson, J., and Cobas, A., A Method for Obtaining Microsecond Risetime Step Function High Intensity Light Pulse, *Rev. Sci. Instrum.* **42**, 261-2 (1971).
- Wheeler, C. V. - See Fiala, W.
44. Wheeler, O. H. and Casanova de Bras, I., Labeling of Iodocytosine and Iodouracil, *Int. J. Appl. Radiat. Isotop.* **22**, 667-70 (1971).
45. Wheeler, O. H., Julián, D. A., and Infante, G. A., Radiolysis of Glycylglycine and Glycine Anhydride, *Rev. Latinoamer. Quim.* **2**, 112-16 (1971).
46. Willman, P. A., Birding in Southwest Puerto Rico, *Birding* **3**, No. 1 (Jan.-Feb. 1971).



# Papers Presented

1. Blum, L., Vargas, L., Cobas, A., and Weisz, S. Z., A Time Dependent Calculation of Exciton Diffusion in an Isotropic Crystal, presented (by L.B.) at Amer. Phys. Soc. Meet., Cleveland, Mar. 29-Apr. 1, 1971. Abstract, *Bull. Amer. Phys. Soc.* 16, 374 (1971).
2. Bosch, A., Complications in the Treatment of Carcinoma of the Cervix Uteri, presented at Hospital General de Asturias, Asturias, Spain, Apr. 1971.
3. Bosch, A., Treatment of Carcinoma of the Uterine Cervix with Irradiation, presented at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
- Brown, R. - See Chiriboga, J.
4. Carrera, J. (P.R. Dept. of Health), Gileadi, A. E., and Gileadi, M., Genetically Significant Radiation Doses Associated with Various X-Ray Diagnostic Procedures in Puerto Rico, presented (by J.C.) at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
- Castrillón, J. P. - See Dubey, A.
5. Chiriboga, J., Interferon and Interferon Inducers in Parasitic Diseases, presented at Amer. Chem. Soc. Metrochem.'71 Meet., San Juan, Apr. 30-May 3, 1971.
6. Chiriboga, J., Oliver-González, J. (UPR Med. School), Ritchie, L. S., Brown, R., Martínez-Silva, R., Colón, J. I., and López, V. A., The Role of Bacteria in the "Curative" Effect of Hemolymph of *Biomphalaria glabrata* in *Schistosoma mansoni* Infected Mice, presented (by L.S.R.) at 18th Annu. Meet. Amer. Soc. Trop. Med. Hyg., San Francisco, Nov. 1970.
7. Chiriboga, J. and Ramos-Aliaga, R., Poly IC Stabilized with Different Metals: Structural and Functional Differences, presented (by J.C.) at Joint Meet. 2nd Pan-Amer. Meet. Biochem. Soc. and Argentinian Congr. Biochemistry, Bariloche, Argentina, Nov. 1971.
- Chiriboga, J. - See also Ritchie, L. S.
- Cobas, A. - See Blum, L.; Weisz, S. Z.
- Colón, J. I. - See Chiriboga, J.
- Dellonte, S. - See Weisz, S. Z.
8. Delsanto, P. P., Barrett, R. (Inst. Theor. Physik), and Fraser, R. F. (U. of Toronto), Continuum Structure of Mass-15 Nuclei, presented (by P.D.) at Amer. Phys. Soc. Meet., Tucson, Ariz., Nov. 1971. Abstract, *Bull. Amer. Phys. Soc.* 16, 1158 (1971).
9. Delsanto, P. P., Barrett, R. (Inst. Theor. Physik), and Wahsweiler, H. G. (Ibid.), Effects of the Introduction of  $\alpha$ -Channels on the Continuum Structure of  $^{16}\text{O}$ , presented (by P.D.) at Amer. Phys. Soc. Meet., Washington, D.C., Apr. 1971. Abstract, *Bull. Amer. Phys. Soc.* 16, 650 (1971).

10. Dubey, A. and Castrillón, J. A., Tritium Recoil Labeling of Phenylacetic Acid, presented (by J. A. C.) at Amer. Chem. Soc. Metrochem. '71 Meet., San Juan, Apr. 30-May 3, 1971.
11. Eberhardt, M. K., Radiation-Induced Homolytic Aromatic Substitution, presented at Amer. Chem. Soc. Metrochem.'71 Meet., San Juan, Apr. 30-May 3, 1971.
12. Fiala, W. and Foote, H. L. Jr. (BNL), Production and Analysis of Monochromatic Cold Neutron Beams Using Neutron Total Reflection, presented (by W.F.) at Amer. Phys. Soc. Meet., Washington, D.C., Apr. 1971. Abstract, *Bull. Amer. Phys. Soc.* 16, 518 (1971).
13. Forster, W. O., Wolfe, D. A., Lowman, F. G., and McClin, R., Trace Element Interactions between River Water and Sea Water, presented (by W.O.F.) at 3rd Nat. Symp. Radioecology, Oak Ridge, May 1971.  
Forster, W. O. - See also Lowman, F. G.  
Gileadi, A. E. - See Carrera, J.; Pedersen, K.  
Gileadi, M. - See Carrera, J.
14. Gonzalo, J. A., Critical Behavior of Ferroelectrics, presented at Midwinter Solid State Research Conf., Univ. of California, Irvine, Jan. 1970.  
Gonzalo, J. - See also Kay, M. I.
15. Hamilton, W. C. (BNL), Kay, M., and Lassier, B. (BNL), Phonon Dispersion Curves in Trigonal Selenium, presented (by W.C.H.) at Amer. Cryst. Ass. Meet., Ames, Iowa, Aug. 1971.
16. Jordan, C. F. (ANL), Kline, J. R. (ANL), and Sasscer, D. S., Tritium Movement in an Old-Field Ecosystem Determined Experimentally, presented (by C.F.J.) at 3rd Nat. Symp. Radioecology, Oak Ridge, May 1971.
17. Kay, M. and Gonzalo, J., The Structure of Ferroelectric  $\text{NaNO}_2$  at  $150^\circ\text{C}$ , and Paraelectric  $\text{NaNO}_2$  at  $185^\circ\text{C}$  and  $225^\circ\text{C}$ , presented (by M.K.) at Amer. Cryst. Ass. Meet., Columbia, S.C., Feb. 1971.
18. Kay, M. and Kleinberg, R., Deuterium Positions in Strontium Iridium Deuteride and Strontium Ruthenium Deuteride by Neutron Diffraction, presented (by M.K.) at Amer. Chem. Soc. Metrochem.'71 Meet., San Juan, Apr. 30-May 3, 1971.  
Kay, M. - See also Hamilton, W. C.  
Kleinberg, R. - See Kay, M.
19. Lanaro, A. E., Effects of Habitual Ingestion of Iodine in the Interpretation of Some Tests of Thyroid Function, presented at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
20. Lanaro, A. E., Gammagraphy in the Diagnosis of Congenital Cardiovascular Diseases, presented at 1st Argentine-Paraguayan Workshops in Radiology, Asunción, Paraguay, Sept. 1971.
21. Lanaro, A. E., Pulmonary Gammagraphy, presented at 1st Argentine-Paraguayan Workshops in Radiology, Asunción, Paraguay, Sept. 1971.
22. Lee, R. A., The Effects of Scavengers on Methyl Fluoride Radiolysis, presented at 6th Caribbean Chemical Conf., Trinidad, Jan. 1971.

- Levinson, J. - See Weisz, S. Z.
- López, V. A. - See Chiriboga, J.; Martínez-Silva, R.
23. Lowman, F. G. and Forster, W. O., Trace Elements in the Marine Waters of Puerto Rico, presented (by W.O.F.) at Amer. Chem. Soc. Metrochem.'71 Meet., San Juan, Apr. 30-May 3, 1971.
- Lowman, F. G. - See also Forster, W. O.
24. Marcial, V. A., Cancer of the Floor of the Mouth, presented at 19th Argentine-Paraguayan Workshops in Radiology, Corrientes, Argentina, Sept. 1971.
25. Marcial, V. A., Carcinoma of the Cervix in a Latin American Community, presented at Annu. Meet. Amer. Radium Soc., Mexico, D.F., Mar. 1971.
26. Marcial, V. A., Carcinoma of the Cervix in Puerto Rico, presented at Annu. Meet. P.R. Med. Ass., San Juan, Nov. 1971.
27. Marcial, V. A., Clinical Results of Cobalt Therapy and Radium Treatment of Cancer of the Uterine Cervix, presented at 19th Argentine-Paraguayan Workshops in Radiology, Corrientes, Argentina, Sept. 1971.
28. Marcial, V. A., Split-Course National Collaborative Study, presented at Annu. Meet. Amer. Soc. Therapeutic Radiologists, Phoenix, Oct. 1971.
29. Marcial, V. A., Split-Course Radiation Therapy of Cancer, presented at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
30. Martínez-Silva, R., López, V. A., and Ugarte, G., Alteration of Immunity to *Trypanosoma cruzi* in Mice Subjected to Sublethal Doses of Gamma Radiation (in Spanish), presented (by R.M.-S.) at 3rd Central-Amer. Congr. and 1st Nat. Congr. Microbiology, Guatemala City, July 1971.
31. Martínez-Silva, R., López, V. A., and Ugarte, G., Isolation of *T. cruzi* in Primary Culture from Tissues of Mice with Experimental Chronic Infection (in Spanish), presented (by R.M.-S.) at 3rd Central-Amer. Congr. and 1st Nat. Congr. Microbiology, Guatemala City, July 1971.
32. Martínez-Silva, R., López, V. A., and Ugarte, G., Multiplication of Virulent Strains of *Trypanosoma cruzi* in Immunized Mice (in Spanish), presented (by R.M.-S.) at 3rd Central-Amer. Congr. and 1st Nat. Congr. Microbiology, Guatemala City, July 1971.
- Martínez-Silva, R. - See also Chiriboga, J.
- McClin, R. - See Forster W. O.
33. Ortiz, E., The Zero Momentum Frame Versus the Laboratory Frame in a Relativistic Collision Between Two Particles, presented at Amer. Assoc. Phys. Teachers Meet., New York, Jan. 1971.
34. Pedersen, K. and Gileadi, A., Activation Analysis as Used in the Study of Sedimentation, presented (by K.P.) at Amer. Nucl. Soc. Topical Meet. Nucl. Methods in Environmental Research, Columbia, Mo., Aug. 1971.
- Pereira, L. - See Weisz, S. Z.
- Ramos-Aliaga, R. - See Chiriboga, J.

35. Ritchie, L. S., de León-Dancel, D. (UPR Agr. Exp. Sta.), and Chiriboga, J., Growth, Reproduction, and Life Span of *Lymnaea (Fossaria) cubensis*, a Vector of *Fasciola hepatica* in Puerto Rico, presented (by L.S.R.) at Annu. Meet. Amer. Soc. Parasitologists, Los Angeles, Aug. 1971.  
Ritchie, L. S. - See also Chiriboga, J.
36. Sasscer, D. S., Jordan, C. F. (ANL), and Kline, J. R. (ANL), Dynamic Model of Water Movement in Soil Under Various Climatological Conditions, presented (by D.S.S.) at EPA Tritium Symp., Las Vegas, Nev., Sept. 1971.
37. Sasscer, D. S., Jordan, C. F. (ANL), and Kline, J. R. (ANL), A Mathematical Model of Tritiated and Stable Water Movement in an Old-Field Ecosystem, presented (by D.S.S.) at 3rd Nat. Symp. Radioecology, Oak Ridge, May 1971.  
Sasscer, D. S. - See also Jordan, C. F.  
Sequeira, J. E. - See Wheeler, O. H.
38. Stark, Nellie (Desert Res. Inst., U. of Nevada), Radiotracer Studies of Nutrient Cycling Pathways, presented at 3rd Int. Symp. Radioecology, Oak Ridge, May 1971.
39. Tomé, J., Bilateral Wilm's Tumor - Our Experience and Review of the Literature, presented at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.  
Ugarte, G. - See Martínez-Silva, R.  
Vargas, L. - See Blum, L.
40. Villafaña, T., The Modulation Transfer Function in Radiology, presented at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
41. Villafaña, T. and Bates, L. M. (Johns Hopkins), The Modulation Function of a Misaligned Microdensitometer Scanning Slit, presented (by T.V.), at 10th Inter-Amer. Congr. Radiology, San Juan, May 1971.
42. Weisz, S. Z., Transient Photoinjection Currents in Anthracene, presented at Conf. Electrical Insulation and Dielectric Phenomena, Williamsburg, Va., Nov. 1971.
43. Weisz, S. Z., Cobas, A., and Pereira, L., Surface Radiation Damage in Anthracene Crystals, presented (by S.Z.W.) at Miller Conf. Radiation Chemistry, Porto Conte, Sardinia, Apr. 1971.
44. Weisz, S. Z., Dellonte, S., Cobas, A., and Pereira, L., Carrier Trapping Measurement by Continuous Photoinjection, presented (by S.Z.W.) at Amer. Phys. Soc. Meet., Cleveland, Mar. 29-Apr. 1, 1971. Abstract, *Bull. Amer. Phys. Soc.* 16, 374 (1971).
45. Weisz, S. Z., Dellonte, S., Levinson, J., Cobas, A., and Pereira, L., Surface Trapping in Anthracene Crystals, presented (by S.Z.W.) at Int. Conf. Conduction in Low Mobility Materials, Eilat, Israel, Apr. 1971.  
Weisz, S. Z. - See also Blum, L.
46. Wheeler, O. H. and Sequeira, J. E., The Radiolysis of Succinimide, presented (by O.H.W.) at Amer. Chem. Soc. Metrochem'71 Meet., San Juan, Apr. 30-May 3, 1971.  
Wolfe, D. A. - See Forster, W. O.

## Seminars

### RIO PIEDRAS

- Dr. Néstor Azziz, Universidad de Uruguay, Montevideo, "Multiple Scattering and a Few-Body Formalism" (January 13).
- Dr. Martin Pope, New York University, "Carrier Diffusion Currents in Organic Insulators" (January 14).
- Dr. Norman Maldonado, UPR School of Medicine, "Immunologic Concepts in Malignant Disease" (January 15).
- Dr. H. L. Frisch, State University of New York at Albany, "Aspects of the Theory of Fluids" (January 19); "Chemical Hydrodynamics" (January 21).
- Dr. Clodoaldo Pavan, University of São Paulo, Brazil, "Virus-Chromosome Relationships in Different Types of Cells" (January 20).
- Dr. Marvin Silver, University of North Carolina, Chapel Hill, "Hot Electron Injection Into Insulators" (January 25; January 26).
- Dr. G. J. Dienes, Brookhaven National Laboratory, "Cyclic Straining of Order-Disorder Alloys" (January 27); "Some Recent Work in Organic Crystals" (January 28).
- Dr. John Felcher, Argonne National Laboratory, "Neutron Diffraction as an Experimental Tool in Solid State Physics" (February 9).
- Dr. P. M. Tannenbaum, Bell Telephone Laboratories, "An Introduction to Color Theory and Color Vision" (February 11); "A New Physics for Color Vision" (February 12).
- Dr. I. Balberg, RCA Laboratories, "Amorphous Semiconductors and the Switching Phenomena" (February 16); "Transition Metal Oxides and New Types of Switching in These Materials" (February 16).
- Dr. Flavio Padovani, UPR Mayagüez, "The Sex Ratio Modifying Factor in *Estigmene acrea*" (February 17).
- Dr. Herbert R. Morgan, University of Rochester School of Medicine and Dentistry, "The Function of DNA in the Transformation of Cells by RNA Viruses" (February 24).
- Dr. B. Berne, Columbia University, "How Molecular Fluids Make Noise" (February 25); "Light Scattering From Molecular Fluids" (February 26).
- Dr. Juan E. Rizek, San Juan City Hospital, "Hot Thyroid Nodules" (March 3).
- Dr. Antonio Bosch, "Biological Effects of Radiation" (March 24); "A Study of the Incidence of Leukemia in Patients Treated for Cancer of the Uterine Cervix" (April 21).
- Dr. Thomas S. Matney, University of Texas, "The Possible Role of Radiation-Sensitive Mutations of *Escherichia coli* on Gene Conversion" (April 25).

- Dr. George Drewry, "The Amphibians of Puerto Rico" (May 5).
- Dr. Héctor M. Forcher, Clínica de Endocrinología y Metabolismo, Buenos Aires, Argentina, "In Vitro Tests in the Diagnosis of Thyroid Dysfunction" (May 12).
- Mr. Richard Brown Campos, "The TRIGA Reactor" (October 7).
- Dr. Raymond A. Brown, "Attempts to Obtain Meaningful Data on Immunity to *S. mansoni* in Mice" (December 1).
- Dr. Julio A. Gonzalo, "A Review of the Critical Behavior of Ferroelectrics" (December 2).

## MAYAGUEZ

- Dr. Mortimer I. Kay, "Thermal Vibrations in Sodium Nitrite" (January 29).
- Dr. Julio A. Gonzalo, "Radiation Effects in Ferroelectrics" (February 4).
- Dr. Milton B. Yatvin, University of Wisconsin Medical Center, "Physiological Considerations When Interpreting Biochemical Data in Studies Employing Radiation and Metabolic Inhibitors" (February 19).
- Dr. Henry L. Stadler, Ford Scientific Laboratory, "Research on Phosphors and Its Application in Television and Computer Technology" (February 26).
- Dr. Mortimer I. Kay, "Solution of Some Chemical Problems by Means of Neutron Diffraction" (March 4).
- Dr. L. Vargas Viñas, UPR Mayagüez, "Mesonic Molecules" (March 12).
- Dr. Julio A. Gonzalo, "Research in Ferroelectrics" (March 30).
- Mr. Rafael A. Ríos, UPR graduate student, "A Time-of-Flight Experiment To Measure the Speed of Gamma Radiation" (April 1).
- Dr. F. Douglas Martin, University of Indiana, "Some Effects of Dieldrin on Reproduction, Development, and Behavior of the Guppy, *Paecilia reticulata*" (April 5).
- Mr. Rafael H. Sardina, UPR graduate student, "Activity Ratio Technique for Measuring Thermal Neutron Flux Using Activation Detectors" (April 20).
- Mr. Vincen A. Alvarez, UPR graduate student, "A Technique for Measuring the Photoelectric Mass Absorption Coefficient Using the Fluorescent Radiation From Various Elements" (April 20).
- Dr. R. W. Gammon, Catholic University of America, Washington, "Brillouin Scattering From Ferroelectrics" (May 20).
- Mr. Julio Ortíz Torres, UPR graduate student, "Possibilities of Recovering Copper From Chalcopyrite by Leaching With Sea Water-Sulfuric Acid Solutions" (July 23).
- Dr. William Whittemore, Gulf Energy and Environmental Systems, San Diego, "Technical Discussion on the TRIGA Flip Core" (August 12).
- Dr. Chester Kylstra, University of Florida (Visiting Scientist, Jobos Bay Project), "Understanding Data" (September 7).

# Staff

\*Henry J. Gomberg, Director  
Edwin Roig, Acting Director  
Peter Paraskevoudakis, Associate Director  
Víctor A. Marcial, Associate Director for Medical Programs  
Luis E. Boothby, General Administrative Officer  
Marie Barton, Executive Assistant to Director

Abu-Zeid, Mohyi E. M., Scientist  
Acosta Servera, Ileana, Adm. Assoc.  
Alemañy, Juan Carlos, Reactor Operator  
Alfaro Méndez, Aura N., Adm. Assoc.  
Arce Blanco, Rafael, Scientist  
Arce Quintero, Rafael, Scientist  
Bailey, Carroll Edward, Scientist  
Banuchi de Gómez, Nérida, Adm. Officer  
Beck, Barry F., Scientist  
Besselievre, Henry L., Engineer  
Bosch, Antonio, Sen. Scientist  
Boyko, Alberta, Adm. Assoc.  
Bravo, Anibal, Tech. Assoc.  
Brown, Raymond A., Sen. Scientist  
Brown Campos, Richard, Head,  
Reactor Division  
Brunet Brunet, David, Sen. Assoc.  
Canoy, Michael, Scientist  
\*Cantarell, Ignacio, Scientist  
Carmona Trutten, Alfredo, Eng. Assoc.  
Carrión Bonano, René, Eng. Assoc.  
Castrillón, José P. A., Scientist  
Cesani, Fernando, Scientist  
Chiriboga, Jorge M., Sen. Scientist  
Clements, Richard G., Sen. Scientist  
\*Cobas, Amador, Head,  
Physical Sciences Division  
Colón, José Antonio, Res. Assoc.  
Colón de Villodas, Carmen, Res. Assoc.  
Correa López, Sylvia, Adm. Assoc.  
Crespo de García, Leila, Scientific Assoc.

Cruz González, Pedro, Reactor Operator  
Cruz Vidal, Baltazar, Scientist  
Cuebas Ruiz, José, Sen. Assoc.  
Davis, Russel W., Res. Assoc.  
Delsanto, Pier Paolo, Scientist  
Deshpande, Shreekant N., Scientist  
Dietsch, Jean M., Adm. Assoc.  
Dirk, William, Eng. Assoc.  
Dodds, James E., Res. Assoc.  
Drewry, George, Scientist  
Eberhardt, Manfred, Scientist  
\*Fernández Aguayo, Domingo, Eng. Assoc.  
Ferrer Monge, José, Sen. Scientist  
\*Fiala, Werner, Scientist  
Forster, William O., Sen. Scientist  
Frías Monserrate, Zenaida, Scientific Assoc.  
Galantai, Ferne Louise, Adm. Assoc.  
Gaztambide, Germán, Tech. Assoc.  
Gileadi, Aviva E., Sen. Scientist  
Gileadi, Michael, Sen. Assoc.  
Gómez, Manuel, Scientist  
González Pérez, Alberto, Tech. Assoc.  
Gonzalo González, Julio A., Head,  
Nuclear Science Division  
Grimison, Alec, Acting Head,  
Physical Sciences Division  
Hernández, Cayetano, Tech. Assoc.  
Hernández de Rivera, Norma, Adm. Assoc.  
Hufty, Richard Renwood, Eng. Assoc.  
\*Irizarry, Sergio, Sen. Scientist  
Jusino Laboy, Edwin, Tech. Assoc.

\*Terminated before December 31, 1971

\* Julian, Dolores, Res. Assoc.  
 Kay, Mortimer I., Sen. Scientist  
 \* Kleinberg, Robert, Scientist  
 Kolehmainen, Seppo E., Scientist  
 Koo, Francis K. S., Head,  
     Tropical-Agro Sciences Division  
 Laguer, Carlos J., Eng. Assoc.  
 Lanaro, Aldo Ernesto, Head,  
     Clinical Radioisotope Applications Div.  
 Lee, Rupert, Scientist  
 Lequerique, Víctor, Scientific Assoc.  
 Liard Bertin, Felix, Res. Assoc.  
 López, Leonardo, Reactor Operator  
 López de Velázquez, Irene, Res. Assoc.  
 López Santiago, Víctor A., Adm. Assoc.  
 Lowman, Frank G., Head,  
     Radioecology Division  
 Marrero Sullivan, Gloria M., Res. Assoc.  
 Martin, Floyd Douglas, Scientist  
 \* Martínez, Prudencio, Res. Assoc.  
 Martínez Silva, Ramiro, Sen. Scientist  
 \* Mercado Ferrer, Braulio F., Eng. Assoc.  
 Muñoz, Ramón Jr., Adm. Officer  
 Muñoz Ribadeneira, Fausto, Sen. Assoc.  
 Mackay, Kenneth P., Res. Assoc.  
 \* McClin Escalera, Raúl, 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.  
 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 Radiobiology Div.

Rivera, Efigenio, Scientific Assoc.  
 Rivera Castrolópez, Roberto, Adm. Assoc.  
 \* Rivera de Campos, Carmen, Res. Assoc.  
 Rivera Guzmán, José E., Reactor Supervisor  
 \* Robles de Irizarry, Edith, Res. Assoc.  
 Rodríguez, Miguel 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 Div.  
 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.  
 Soto Santana, Luis A., Tech. Assoc.  
 Suárez Castro, José A., Scientist  
 Szmant, Alina M., Res. Assoc.  
 Ting, Robert Y., Scientist  
 Tomé, José M., Sen. Scientist  
 Toro González, Mirta, Res. Assoc.  
 Torres, Sigfredo, Eng. Assoc.  
 Torres Carmona, Guillermo, Eng. Assoc.  
 Torres Castro, Heriberto, Scientific Assoc.  
 \* Trujillo Sánchez, Mirta, Scientist  
 Ubiñas Villeneuve, Jeanne, Sen. Scientist  
 Vallecillo, Fernando, Scientific Assoc.  
 Vázquez Martínez, Florencio, Scientist  
 Vélez Martínez, Elba M., Adm. Assoc.  
 Vélez Méndez, 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  
 \* Zapata Silvestry, Edwin, Tech. Assoc.



PRNC STUDENT ENROLLMENT  
Fiscal Year 1971

Training Activity	Duration (Months)	× Enrollment =	Student Months
<u>Río Piedras</u>			
Radioisotope Techniques Course	1	15	15
PRNC Portion - M.S. degree Chemistry - UPR Río Piedras	12	8	96
PRNC Portion - Ph.D. degree Chemistry - UPR Río Piedras	12	1	12
PRNC Portion - M.S. degree Physics - UPR Río Piedras	12	3	26*
Special Training - Radiation Chemistry	9	1	9
Special Training - Hot Atom Chemistry	0.5	1	0.5
Clinical Radioisotope Applications Course	2	8	16
Special Training - Clinical Radioisotope Applications	1-12	8	14.5
Orientation Course - Clinical Radioisotope Applications	0.5	49	25
Special Training - Metabolism, Endocrinology, Nephrology	1	1	1
Special Training - Lung Scanning	0.25	9	2
Radiotherapy and Cancer Residency Program	12	5	45
Radiotherapy Training Course - Short Term	1-12	4	19
Radiotherapy Training Course - One Month	1	8	8
Special Training - Autoradiographic Techniques	3	1	3
Special Training - Autoradiography, Electron Microscopy	5	1	5
Special Training - Radioimmunology	2	1	2
Special Training - Radiation Biology	3	2	3.5
PRNC Portion - M.S. degree Biology - UPR Río Piedras	12	3	36
Special Training - Schistosomiasis and Fascioliasis	5	1	5
Special Training - Tissue Culture	1	1	1
Special Training - Virology	1	2	2
Special Training - Intermediary Metabolism	0.25	1	0.25
PRNC Portion - M.S. degree Radiological Health - UPR Med. Sci.	12	9	59
Dosimetry in Radiotherapy Course	2	11	21
Special Training - Radiation Protection and Dosimetry	6	1	6
Special Training - Health Physics	2	1	2
Total		156	435
<u>Mayagüez</u>			
PRNC Portion - M.S. degree Physics - UPR Mayagüez	12	15	90
PRNC Portion - M.S. degree Chemistry - UPR Mayagüez	12	12	85
PRNC Portion - M.S. degree Nuclear Engineering - UPR Mayagüez	12	18	112
Nuclear Reactor Operator Training	3	5	15
Special Training - Reactor Instrumentation and Control	10	1	10
Special Training - Applied Health Physics	4	1	4
PRNC Portion - M.S. degree Health Physics - UPR Mayagüez	12	2	10
PRNC Portion - M.S. degree Biology - UPR Mayagüez	12	2	12
Special Training - Cytogenetics, Physical and Chemical Mutagenesis	2	1	2
Total		57	340
Grand Total		213	775

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

PRNC STUDENTS BY COUNTRY

(Tabulated September 30, 1971; a student is counted once each fiscal year he is in training)

	1958-66*	1967	1968	1969	1970	1971	Total
Argentina	15	1	1	3	4	6	30
Bolivia	7	1	1	-	1	5	15
Brazil	-	1	1	1	-	2	5
Canada	-	-	-	-	-	1	1
Chile	10	4	4	3	1	1	23
Colombia	39	5	4	8	10	12	78
Costa Rica	3	2	1	1	1	5	13
Cuba	9	-	-	2	2	1	14
Dominican Republic	19	2	5	6	6	3	41
Ecuador	8	2	1	3	5	4	23
El Salvador	6	2	1	-	-	-	9
Formosa	4	2	6	-	-	1	13
Germany	1	1	-	-	-	-	2
Great Britain	3	1	1	-	-	-	5
Greece	-	-	-	-	2	1	3
Guatemala	4	-	2	2	1	-	9
Haiti	1	-	-	-	-	1	2
Honduras	-	-	-	-	-	1	1
Hungary	-	-	1	-	-	-	1
India	2	3	4	-	1	-	10
Israel	-	-	1	1	1	-	3
Jamaica	-	-	-	-	-	1	1
Japan	1	-	-	-	-	-	1
Korea	-	-	-	2	-	-	2
Lebanon	-	1	1	-	-	-	2
Liberia	-	1	1	1	-	-	3
Mexico	15	1	2	1	2	3	24
Nicaragua	2	1	2	2	3	2	12
Panama	2	-	-	1	-	2	5
Paraguay	6	-	-	3	2	2	13
Peru	6	-	-	3	2	1	12
Philippine Islands	3	1	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	6	1	-	1	1	3	12
Venezuela	15	3	3	2	1	14	38
Total Non-U.S. Citizens	214	37	46	50	45	72	464
Total U.S. Citizens	1024	199	167	142	146	115	1793
Total Students	1238	236	213	192	191	187	2257

\* Total number of students trained at PRNC from its first year of operation (FY-58) through FY-66.