

PANG ~ 198 Distribution Category UC-2 PUERTO RICO NUCLEAR CENTER ANNUAL REPORT \* JANUARY 1974 - JUNE 1975 OPERATED BY UNIVERSITY OF PUERTO RICO UNDER CONTRACT NO. B-(40-1)-1883 FOR US ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION. \* 'This Annual Report includes the activities of the Puerto Rico Nuclear Center from Calendar Year 1974 and the first six months of 1975. The reporting period was extended due to the transition period from an AEC to the ERDA, facility and the program reorientation activities involved, ---Page Break--- Medical Building ~ Rio Piedras ---Page Break--- 'TABLE OF CONTENTS Office of the Director A Organization Chart 1974... . 4 Organization Chart 1975 . . ) Senior Staff . . reer er 5 ce Publications. ©. 50 10 7 23 Papers Presented . Seminars... 'Training and Information 00 Seer 25 Radiation Oncology . eee eee re 35 Nuclear Medicine. 2... See err a7 Medical Physics Section ©... 2. ee ee eee 31 Biomedical Sciences - Human Ecology... so ve ee ee 63 Environmental Sciences Marine Ecology... 0 soe ee + 85 Marine Ecological and Pollution Studies... rrr rss) Oceanography and Limnology Studies. See 108 Analytical Methods. . Dee eee Fee 105 Bikini Atoll Project... 2... ses £106 Biological Availability of Pollutants to Marine Organisms |... |... 112 Mangrove Oyster Culture Project . errr see Mae Environmental Impact Studies 600000000 no ota) Environmental Sciences - Terrestrial Ecology... . « Pee e125 'Tropical Agro-Sciences . . - 2 eee eee eas) Nuclear Applications - Nuclear Science and Technology. . , Neutron Diffraction Project 2 2 ee ee 15S. Radiation Chemistry Project... 2 2 es 189 'Nuclear Applications - Nuclear Engineering... 2... 2... anna ics Health and Safety... 2. 2. 1s er + 6173 Joint Radiation Survey Project ©... 2... . see ee +. 176 Reactor Operations»... 1. ee eee 19 Applied Physical Sciences. 6... ee eee ee ee 5 Heterocyclic Molecules Project... . 2... ee 18M ---Page Break--- Edited By: Frederick Edward Rushford Ferne Louise Galantai Photographs By: Tom Smoyer ---Page Break--- OFFICE OF THE

DIRECTOR 'The role of the Puerto Rico Nuclear Center as a U.S. intermediary for international sharing of nuclear technology has virtually ended and its nuclear novelty faded under the impact of the comprehensive energy mandate of Congressional Public Law 93-438, which created the U.S. Energy Research and Development Administration. Programmatic reorientations are being made to meet an energy crisis, especially in relation to environmental impacts resulting from energy technologies and energy uses. Moreover, energy research and development is envisaged in relation to direct uses of solar energy and indirectly through ocean thermal energy conversion. More fundamental investigations are exemplified by studies on ferroelectric materials as pyroelectric energy converters. 'The PRNC program could be a major tropical research thrust by the U.S. Government. Other factors, as well as its tropical setting, make Puerto Rico a potentially important 'energy research center. It is unique for environmental impact studies, since in a small island area, it has "clean" air in certain areas due to prevailing tradewinds and very "dirty" air in adjacent parts. Moreover, there exists a series of ecosystems ranging from desert to rain forest, from deep-sea water to mountain lakes, and beaches of coral and mangrove with estuarine habitats linked with coastal plains and mountains. Thus in a small area of (100 by 30 miles) there are mini-regional replicas of large portions of the U.S., affording regional field trials. The fate of biota under the impact of heat and chemical pollution through air, soil, and water can be readily investigated. Correspondingly, studies on human health and well-being can be implemented. Divisions of terrestrial, marine, and human ecology, and tropical agro-sciences constitute an interdisciplinary group whose efforts can be integrated for a comprehensive study on the impact of oil-fuel pollution of air, land, and sea, and hydroelectric impoundments. Such a program could afford the opportunity to assist

African as well as South American countries. Contracts between PRNC and several African

countries now exist. The following paragraphs are a resume of significant project areas that might be integrated into a comprehensive environmental program. Agricultural productivity may be profoundly affected by pollution from oil fuels, with damage imposed directly on crop plants, or indirectly through soil, e.g., acid rain. Threatened losses in agro-power due to energy technology must be made known and equated against industrial benefits. Compensation may be possible through genetic selection of tolerant plants and protective measures. Hydroelectric power is deemed very important for initial energy requirements in developing countries. Environmental assessments have been made prior to impounding of water, but the actual environmental impacts therefrom have never been made. This appears possible in Puerto Rico where there are 25 lakes of varying ages and new ones planned. Evidence of hazards from hydroelectric reservoirs is emerging, so that lakes are a worldwide problem. PRNC has a plan and the expertise.

A unique study of the health effects of pollution from the refining and use of petroleum is possible in Puerto Rico, with areas of clean and dirty air embracing comparable populations in close proximity. Moreover, a modern Cancer Registry exists to facilitate epidemiological investigations. A comprehensive investigation of a relatively large Drainage Basin in tropical Puerto Rico will afford comparisons with the ongoing Walker Branch Watershed Study in a temperate climate (Oak Ridge, Tenn.). Conflict between man and the rest of nature is marked in Puerto Rico, due to one of the world's densest populations and industrial development. This study will provide information on the interactions of climate, hydrology, land areas, human needs, and management of all available resources including water, forests, soils, and manpower. Marine research will determine the transfer and distribution of

pollutants from the refining and industrial uses of petroleum into a well-defined estuarine environmental and ecological system. It will define basic mechanisms that control the movements of pollutants through water into sediments, shore substrates, and organisms, and determine physico-chemical changes in their state. Thermal pollution resulting from the generation of power is being evaluated against ecosystems. A photochemical degradation study has been recommended for funding. The natural fate of pollutants is indeed important and requires attention in different climates and under different light intensities. The environmental damages imposed by man may be 'more easily corrected through natural phenomena than currently anticipated. With the leadership anticipated, all environmental investigations will be integrated for a comprehensive, unified effort, including University-wide participation. A committee for developing an energy program for the University has been convened periodically for the past year by the President, and capabilities are apparent. Moreover, there is collaboration with Commonwealth Government agencies. From this cooperative endeavor, a proposal has been prepared for submission to ERDA for the location of its Solar Energy Research Institute in Puerto Rico, or, if not this, then there will be a proposal for a SERI subsidiary. Attention is also being given to Ocean Thermal Energy Conversion (OTEC) and bioconversion of energy. These are deemed significant developments for Puerto Rico because of favorable solar coverage, deep ocean thermal gradients near shore, and massive accumulations of cellulose refuse from sugar cane, all relating to renewable energy sources. Fundamental energy research, which is already in progress, includes the study of pyroelectrics as direct energy converters (thermal and solar). The significance of the work relates to the assessment of the potential of pyroelectric conversion through studies of its efficiency and specific power output, as well as practical feasibility for

energy production, storage, and reconversion under specific conditions. The Neutron Diffraction project (supported by NSF) is also concerned with the potentials of ferroelectric material for data

storage and transmission through associated optical and electric effects, and projected energy storage. A recent International Conference in Puerto Rico promoted by the University of Puerto Rico and PRNC staff members on "Low Lying Lattice Vibrational Modes and Their Relationships to Superconductivity and Ferroelectricity" attested to the importance of investigations on ferroelectrics. ---Page Break--- PRNC can serve as the focal point for all educational (research & training) activities of the university system in the energy field and energy-related areas. Such an approach would provide for the desired closer integration of the Nuclear Center with research groups and emerging academic programs of the University. The Medical Program has been disclosed as supportable by ERDA only through development of basic research. Its importance to the health problems of Puerto Rico is such that it will have to be maintained through the Commonwealth government and other federal agencies. Such support is already available, in part, through the Puerto Rico Department of Health and the National Cancer Institute. A joint basic research project between the Radiation Oncology and Nuclear Medicine Divisions involves the study of effects of radiation on normal tissues. Irradiation of the liver of dogs and subsequent studies are being conducted. Capabilities for the Nuclear Medicine Division are being sought through the use of the Whole Body Counter. A study on biological and effective half-lives of radionuclides in children is in the planning stage. Significant collaborative ongoing research in radiotherapy with several national research groups is in progress, to which the case input by PRNC exceeds that of any other cooperating agency. The following summaries are included as a supplement to this section to provide an appreciation.

of the educational backgrounds of the senior staff and the scientific productivity of the Puerto Rico Nuclear Center. a. Organization Chart, 1974. Publications b. Organization Chart, 1975 e. Papers Presented c. Senior Staff f. Seminars ---Page Break--- ---Page Break--- PUERTO RICO NUCLEAR CENTER 'vcantaion cuter 188,18 ---Page Break--- SENIOR STAFF 'race Quon: Sate LE Booty Fanta Mai, Pesto Vs Wandors Nika Barus de Gomes Tectia Servis Sites Tore, cronies Saton Honey L Beeline Ca J Lagu Ford R.Hutty iaubionng Seton Vier L Lequraue Neton Quitones Dovid Rockinver Maina Radiation Oneoony Vitor A, Morea Juan Reviche boat MTom Jeannie Vitor 'Antonio Bosch Zens Fries Nuclear Medicine 'Ald €, Lana René C. Dietrich 'Avitides H, Sarmiento Myr Cancel de Pain 'Carmen C de Vilodss 'ocate Octor and 'ne i Eneromenta Since 'ance. i.Mail Soeae race Aa to the Orector Techn Ault. Reproduction Genera Adminitrative OMe 'Admnitve Aso Scent | [computer 'imnatie eae 'adm Asoc | (Persone) Engieering Asoc Engineer npinering Assoc I Scletiie Glnblower Head Mayon) ead (Rio Pes) Hess Senor Scant Senor Sect | Sen Scent | 'Senor Seni Seantie Associate Hed Seine 'Sein I Scientific Aaacaet Research Associate | (Nursing) as es. mo. mo. mo. men mo, mo, mo. onthe Unnenity 'i of Whiner onars Unrty New York Unverity Toca AM Unity Univety of Peo Rico Univ of Porte Ris Syrcie Unrrity nies of Poet Reo nies of Po Rio niet of Port Rio Mas natu of Teehrlony niverty of Prt Rico Univesity of Porto Rico ImaetteConepion cad 'Arce Luge Baines College 1S. Neal Azadomy Santay de Componla Uni University of Puro Ro Perce Teche ti niesty of Put Ris University of Puro Rico Univeity of Porto Rico Word Univesity Harvard Univeity Univer of an Moeoe Univesity of Zaragoea Unit, Autonoma de Mexico Unirerty of tehnan LUnivrity of Buenos Aes Unit. Mayor de San Anis Univerity of Buenos Aires University of Puerto Rico iat School of Nuing Bosines Adminstration Engineering Pre Maia Since Etecronis Taxolony tet Eos echania Ersning Suveriea edition Thesey Radition Therapy

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Professor, Ohio State University; "Known Energy Resources Contrasted With Past, Present, and Projected Energy Uses in the U.S.A." (April 17, 1974-M), Dr. Frederick A. Valeriote, Washington University; "Cell Kinetics of Cancer" (May 8, 1974-RP). Dr. Mohyi Eldin M. Abu-Zeid, "Introduction and Fundamental Concepts in Energy Conversion" (May 14, 1974-M). Dr. Rupert A. Lee, "Fuel Cells" (May 23, 1974-RP). Dr. Rastko Maglic, "Radiation Cells: Energy Conversion of Light and Nuclear Radiation" (May 30, 1974-M). Mr. Byron L. Smith, "The Scientist and the Computer at PRNC" (June 14, 1974-M). Mr. James W. Patus and Mr. José A. Rivera, "Avifauna of Jobos Bay—Environmental Monitoring" Mr. Vance Vicente, "The Symbiont Zooxanthella in Relation to the Feeding of the Fish, *Chaetodon capistratus*" (August 2, 1974-M). Mr. Prudencio Martinez, Graduate Student, UPR Mayagüez; "Thermoluminescence and Vj, Centers in C,B,+C,I" (October 31, 1974-M). Dr. Julio A. Gonzalo, "A Comparison of the Ferroelectric Transitions for TGS and DTGS" (November 7, 1974-M). Dr. Raman S. Singh, "Raman Scattering by Molecules" (November 7, 1974-M). Dr. Victor A. Marcial, "Management of Cancer of the Esophagus" (November 22, 1974-RP). Dr. Julio A. Gonzalo, "Nuclear Energy" (November 25, 1974-M). Dr. Don T. Cromer, Los Alamos Scientific Laboratory, "Electron Density Studies on Nitrite" (January 8, 1975-M). 23 ---Page Break--- Dr. Mortimer, "Diffraction Work on Ferroelectric Transitions" Dr. P.F. William, "Resonance Raman Scattering and Resonant Fluorescence" (January 31, 1975-M). Dr. E. Theocist, "The Role of a Physicist in a Medical Institution" Dr. Richard, (Medical Center), "Electron Radiography" Dr. Richard, (Medical Center), "The Role of a Physicist in Chemotherapy" (April 14, 1975-RP). Kay,

Raymond Brown, and David Bruek discussing to be held at the University of Puerto ---Page Break--- TRAINING AND INFORMATION 'The Training and Information Division provides centralized direction and coordination for the training and information activities of the Puerto Rico Nuclear Center. The Division Head serves as Educational

Officer, Technical Information Officer, and Public Information Officer. 'Training responsibilities include registering students; maintaining centralized records on training activities; preparing reports for ERDA; scheduling the utilization of training facilities; providing audio visual equipment; assisting in the preparation of courses, symposia, and meetings; administering fellowship programs; and providing personal assistance to students in matters such as immigration and housing. The Division Head represents the Director on the Admissions Committee. Information responsibilities include preparation of manuscripts for ERDA patent clearance and publication release, maintenance of master files on all PRNC manuscripts and publications, preparation of Monthly Highlights and Annual Reports, providing editorial and translation assistance, operation of an ERDA Film Library, operation of a Technical Reference Room, operation of a Reproduction Shop, providing copying services, and assisting vi 'TRAINING ACTIVITIES Tables 1 and 2 provide information on student enrollment during FY 1974 and FY 1975. Although the overall enrollment diminished in FY 1975, the number of students doing thesis research increased to 51. This is a reflection of the greater emphasis on research at PRNC under the Biomedical and Environmental Research Division of ERDA. Table 3 provides a summary of thesis research activity during FY 1975 indicating a broad range of research topics. The geographical distribution of PRNC students from FY 1970 through FY 1975 is presented in Table 4. The total number of students trained at PRNC since its founding in FY 1958 through FY 1975 listed by country of origin is presented in Table 6. Fellowship Support. Financial support for PRNC students comes from many sources including the International Atomic Energy Agency, the Pan American Health Organization, the Organization of American States, and other government and private institutions. During FY 1974, the OAS did not provide funds for fellowship support under

the Regional Scientific and Technological Development Program in Nuclear Energy. During FY 1978, \$25,500 was assigned for fellowship support under this Program at PRNC. During 1975, 3 students started training in the Tropical Agro-Sciences Division: Héctor Enrique Flores, Peru; Julia Miryana Radosevich-Yrigoyen, Peru; and Hirore Ruter, Brazil. Another important source of fellowship support is the PRNC Student Economic Aid Program. Tables 6 and 7 provide information on the students supported under the auspices of this Program.

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Table 1: PRNC Student Enrollment ~ FY 1974 Enrollment Student Months Tabby Aawhy Maxima Darton These Research, Ph.D. Degree, Biology 2200 4800 These Research, MS. Degree, Biology 0.00 Graduate Research, Terrestrial Ecology 0.50 200 Undergraduate Research, Terrestrial Ecology 2.00 12.00 Summer Research, Terrestrial Ecology 2.00 6 12.00 Bate Cink! Radiotope Applications 200 200 Nuclear Medicine 22 Orientation, Radiotope Applications 0.80 2 9.50 Buse cir Main Technique, Hematology 1.00 400 Clinic Radiotope Applications Elective Course 1.00 i iis Spec ining Mace Medicine 100 470 Radon Therapy Residency Program 1200 22.00 Short Term Radiotherapy Training 200 30 Special Training - Radiotherapy 1 190 Special Training - Medical Physics 200 1 These Research, Ph.D. Degree, Medical Zoology 12:00 1 1200 These Research Ph.D. Degree, Microbiology 1200 2 2400 These Research MS, Dept, Microbiology 1200 3 29.50 These Research, MLS. Dept, Biology 1200 2 1880 Special Training, Virology 200 2 Special

Training, Schistosoma 200 8 Special Training, Pathology 800 MS. Degree Program, Radiological Health 12.00 These Research MS. Degree, Page 1100 1 Special Training Health Care 300 1 These Research, Ph.D. Degree, Chemistry 800 1 These Research MS Degree, Chemistry 1200 3 Radiotope Technique 100 84 Special Training Gamma Radiolysis 1200 7 Special Training - Organic Chemistry 1200 3 These Research, MS. Degree, Physics 300 These Research MS. Degree Chemistry 800 Introduction to Solid State Physics 080 a Radiation

Chemistry O80 3 Chemical Kinetics 880 6 'Theory of Electricity and Magnetism O80 6 Special Training Said State Payee '0 1 MS. Degree Program, Nuclear Engineering 3.00 B Introduction to Nuclear Engineering 080 ° Nuclear Measurement and Instrumentation 0.80 2 Summer Workshop letra Power Generation 98 58 'Thesis Research, MS. Degree, Biology 1100 3 Thesis Research, M.S. Degree, Chemistry 450 2 Thesis Research MS. Degree: Horticulture 00 i Nuclear Techniques in Agri 080 3 Cytogenetics 080 'Food Chemistry 0.80 2 Nuclear Chemistry 0.80 2 Radiochemistry 0.80 "Photophysiology and Crop Productivity O80 5 Special Problems in Horticulture 0.80 1 Growth Regulators 0.80 2 Special Training in Mutation Breeding and Radiobiology 9:80 i Grand Total 26

---Page Break--- — 'Table 2: PRNC Student Enrollment — FY 1975 a 'Training Activity 'Maximum Duration Enrollment Student Months mi eration \_Baraliment Student Morte 'Thesis Research, Ph.D, Biology 1200 A 8.00 'Thesis Research, Ph.D., Ecology 12.00 1 1100 'Thesis Research, Ph.D, Fisheries 1300 A ne) 'Thesis Research, Ph.D., Marine Sciences 1200 i '2.00 Research, Ph.D. Oceanography 1200 200 'Thesis Research, M.S., Oceanography 12.00 1 6.00 'Thesis Research, MS. Fisheries 1200 1 1200 'Thesis Research, M.S, Biology 1200 ' 200 [Special Training» Terrestrial Ecology \* 00 4 ran Special Training - Marine Ecology \*\* Elementary Nuclear Medicine Course 1.00 a 21.00 Nuclear Medicine Course 500 3 too . 6.00 8 23.00 2.00 @ 8.50 Short Term Radiotherapy Training oa 8 2800 'Special Training - Radiotherapy 600 3 yo00 Radiation Therapy Residency Program 1200 : i200 Medical Students Elective Case 100 2 200, Special Training "Medical Physics © ou 8 rd 'Thesis Research, Ph.D., Medical Zoology 1200 1 12.00 100 3 30.00 'Thesis Research, Ph.D. Biochemistry 1200 1 7.00 'Thesis Research, M.S, Microbiology 1200 4 16.00 'Thesis Research, M. 1200 3 26.00 'Thesis Research, M.S., Biology 12.00 3 13.00 Special Training, Fascioliasis 10.00 13 53.00 Special Training - Virology 6.00 4 20.00 Special Training - Schistosomiasis 5.00, 4

11.00 Special Training - Fossil Fuel Contaminants 6.00 1 3.00 Special Training Human Ecology \* 2.00, 1 2.00 MES. Degree Program = Radiological Health 12.00 16 115.00 Special Training - Health Physics 1.00 1 1.00, 'Thesis Research, M.S., Chemistry 12.00 3 29.00 Special Training - Gamma Radiolysis 12.00 4 15.00 'Special Training - Radiation Chemistry 10.00 2 11.00 'Special Training - Organic Chemistry 1.00 a 1.00 On-the-job Training, 4.90 1 4.00 'Thesis Research, M.S., Physics 12.00 a 26.00, Thesis Research, M.S., Chemistry 12.00 6 53.00 Postgraduate Research - Physics 11.00 1 11.00 'Chem. 608 - Radiation Chemistry 5.00 3 15.00 Special Training - Nuclear Sciences. \* 2.00 1 2.00 'Thesis Research, M.S., Nuclear Engineering 12.00 8 96.00 M.S. Degree Program: Nuclear Engineering 12.00 4 48.00 'Special Training - Nuclear Engineering@ 2.00 1 2.00 'Summer Workshop Electrical Power Generation 25 83 13.25 Thesis Research, M.S., Biology 12.00 2 16.00 12.00 1 4.00 'Thesis Research, M.S., Horticulture 12.00 1 2.00 'Thesis Research, M.S., Agronomy 12.00 1 12.00 Nuclear Techniques in Agriculture 4.00 3 12.00 Photophysiology and Crop Productivity 4.00 4 16.00 Special Studies - Biology 4.00 1 4.00 Growth Regulators 4.00 4 16.00 Special Training - Plant Physiology 6.00 4 20.00 Reactor Supervisor Course 6.00 1 2.00 Grand Total 259 98% 'One RDA Undergraduate Research Trainee 1@ ERDA Faculty Research Participant ---Page Break--- "Title 3 PRNG Thesis Research on July 11074 Although Done 90,1878. Test The State - Date Field - Urey Environmental Sciences Division. 1. "Ecology Survey of

Ture Gran, Tami etdinam Peter B. Schoeder PhD. Biology of Miami Dy. Fath. Lown, Koning a Thermally Affected Bay in Pero Rio Dr. Sepe Kale + Dunid Padgett - PhD. Biology: Ohio State U. Dr. RE Cwm 12. "Agaitie Hyphomyces Industry of Orne Fallston Metabolism and Recovery of Cort Ree Mer 28 Environmental Survey "ampipod Se Gr Der Interrelationships" "Grow and Weeding Merri osnbet (he Gant Fresh Water Pw 1. "Transfer of Heavy Metals From Sewanee Shade to Marine Ores" 1. "Change in Seawater Quality Parameters Inferred

by Lind Use Pater in the Expt Seno Waterbed" 8. "Dhapprine of Dcryoder eee Leal Liter 'Toca! Montane Rain Forest in Puerto Rico" 9. "Geogaphie Dstbtion, Intrptie Vary 'tnd Domestic Habitat of Caracol crac (Ganropodspuimonats) in Peta Rico" Biomedical Seeces Dron 1." "Sehitonoma manon! Studies on Functions! and 'Stactural Changes tthe Cecil to Scio 2 "ene Analy of Merosporum gypecum compls atthe Molar Level "The Effect of Gam Radiation on Vil nections Gamma Radiation and Syne of Macomobeul on Intec Cals 4 "Bifect of Radation on Dengue Vitus Infection in Mice and Tie Cute" 5. "The Bet of Gamma Radiation on Vir Growth In Sind IntecedL, Calle Monolayers" "Detection of Herpes Simplex Virus Type I and 2 im Human Extoitive Vaginal tet by 'Immuno Pluorscense Techniquis in Puerto ico" 17. "ntereron Production i Vi Induced Mutated LC" "Metalic Changes on Polymers Transformed Cell" 9. \*Multipcatio of Sindbis Viru a leCele Monolayers" 10, "Ioltion Punieation and Paral Characterization 'ofthe Mollusca Principe of Solanum mammowm" 11, "rotelytic Ensyms in Fescioe hepatic" 12, "The Btfects of Gam tradation on Diteent 'Stages of Facols hepatica" 13. "ology ofthe Predator Prey Relationship Between Fasciola hepatica Soil Vectors and Sepedn coerues Marsh Flies (DiptereSciomyeise)" 14. "lance of Water and Chlorine in Sobel melanoatigma"" 8. "The CrossReacting Antigens of Fatcols hepatic and 'S mansonii, Thee Characterization and Possible Role in Immunity' Carlyn Rodger PRD. Ecology = U.ef Florida Dr. Seppe Kelty Roger Zimmerman «PD. Maine Scene "UPR. Dr. RE Menton Vincent A rice" PRD. Faeries U.of Washiglon Dr. KW. Wat Mary Price <M, Pring Uf Washington Dr. KW: Wat tren P. Cues de Colom MS. Biology UPR. Dr. RB, Clemens 1 Fred Ca MS. Boony - UPR. De RE, Chments \* Carmen J Herhandes de ArroyoS.S. Brgy UPR Dr. Manoel Vee De. George Drewry be ard Bertin - PRD. Medi Zoology - UPR Dr Lt Raut Otero Jost A. Caraco Canales PAD. Micrbiclgly-UPR Dr. dull. Coie + ede Rios Oleaes PD, Micohislgly UPR ind Tomes B-PR.D. MirbiologyPR Dy dllo I.

Clin \* Ann Sst MS. Microbiology - UPR Dr. do 1 Clin Robert R. Sayhor-MS. Misobiology "UPR Dr, lot Clim Mercedes Rodriguez Nieves MS, Mirbiologs-UPR Dr. dulo 1 Clin 'Sendra M. Quidones ARPA. Biochomistn-UPR Dr. Julio. Colon Nitsa Map Davis Gomer MAS. Microbiology-UPR\_ Dr. dio. Colon (Gixmen . Vivero Mldomado-MS. Biochemistry UPR Dr. W. Godechalk Geno Oris Rivers = MS. Bochemisry- UPR Dr, Jone Cibo owt Luis Tomes MS, Biochemistry » UPR Dr. Jorge Chiiogs \* Eduardo Darin Sande - MLS. Bilogy - UPR. Dr. Gustevo Candela (Panam) \* Bdeimia Maya de Fala, Biology UP De. Gustavo Candela, (Parana) 'Ana del Lomo DiarMS. Biology-UPR De. Raymond Brom ---Page Break--- 'opt Ao Senee Onion 1 "Seyret Etec of Inn on Hamas Chromoomes" 2. "Rite of Colma onthe Patera Pca {bli Coop" 2 "Meramlas of Slurcontning Aino Aci ty btope ito of "Late Supt Dose" 4 Mata Sect ofS romodeonguane euton to Seahing Tine of Soybean Sec 1 "Ble of Planing Seats onthe Growth of 'prem Capsicum smu L. Conn, Yo monde Nc Sconce ad Tele Sation 1 Staemoturimacece and Vk Cee GB 2. "Rama Ssterg of Hydrogen Bonded Pome siecie Cea" 4 "Bucimene Proper of Carcnoeie Compounds" 4 "hades of Aguus Sohn af Satur {8 \*Raaalyos of Aquees Solution of Doro (cyinenine coal ll ie" 6 "FI Racon with Aromatic Compounds" 11. "Capa Induced Copotymeration of Metbacrye 'Ac With Methacyumie Under an ct Pit" 4 "Reda of Fete Ac 10, "Tipit Eected Sate™ 21. "Contam Clean of the Photonucer MectionCroseeicin ne" 'ee Eninirg Section 1. Statin) Ania of Mercury and Cadi In Fresh atk Ug

nstrmental Neutron Activation Analysis" 2 "Application of the Activity Ratio Technique in the Determination of Thermal Neutron Flux" 3. "Atmospheric Transport of Vias Casout 'active Effluent from the PRNC-THIOA Reactor" 4 "A.Cos-Berett Analysis of Condenser Cooling 'Station or Nucleus Power Plants in Puerto Rico" "Detention of Argon at the Puerto Rico Nucleus Center Boundary" 6 "Fett of Quaternary and Quaternary Base Seating States Using» 10000), American Source™ 1. "Acidic Analysis for the Determination of Total Uranium from » clear Power Plant Part History" |

"Population Exposed to Natural Radiation in 'Poverty Stricken Dion 1. Othoxanthone Derived Potential Agents Asn Chaps Daeue™ 2 "Luminescence Quantum Yields of Organic Compounds" 3 \*Radiation Induced Anions of Nitrogen Heterocycle" This is Completed  
---\*\*Discontinued Research PANG This Research amount 11974 Wmuph Dra 3,175 common  
'Soden Owe — Fed Uo Ac ni de Canbatons Boley UFR 'Carmen sono. Beles UFR From Cas "MS. Apooony- UPR 'Gonna Repti) (tea Ha Ale MS, Hons - UPR 1+ Prue Main MS. Pgs UPR no Mato B48. Phy UPR Joa Lig Sutin MS. Pays UPR sl Mar Gari de Rondo 3.5. Chemistry UPR Mar 8 Gadn elmo aS. Chery "UPR Mtoe Clan = MSC = UPR nega) Jost Hea MS, emi UPR 'itor Gomslen = MS Cem UPR Simon Helis MS. Chemie = UPR eco Suniags MLS. Chetry UPR Seamus 0, Chappe MS. Nae. Bge-UPR 'tnda) 'te Lopes Sivan <M. Nae, Bge-UPR Retando Piet Ori MS. Nac. age UPR, Jaan M, pom MS, Not ge. UPR (tn Ande Vibe MS, Nuc. UPR Dick Cameo Gant AUS, Nuc, Bar UPR la A, Reyes Modi - ML, Ne. Eng UF Antoni J GonalesRodigae MS. Nec. Bog-UPR Maul Rodsigves Romario MS, Chemistry UPR Bete Catia DS, Chmisy- UPR Meta Charén + MS. Chemistry - U Ded, A Pree Monge i 8.¥, Dnbpae BP > P PEP FP OFF z FR rs pee pyRPP PF i i i Dr. DS, Sacer De DS. Sacer be Bone eH Pan Dr. A.B Gia Dr JPA. Caen De JPA. Caton Dr Arce 'Compiled by Pedrick Rushford, Eavenonal Otic ---Page Break--- 'Table 4: Geographical Distribution of PRNC Students — FY 1970 — FY 1975 cal Yeara en oe 19701971 197219731974 1975. SOUTH AMERICA a CENTRAL AMERICA MEXICO 889712310 CARIBBEAN 8 6 6 8 ww 3 PUERTORICO(USA) 141.1055 164207189 CONTINENTAL (USA) 5 6 wm 5 18 om EUROPE, ASIA, AFRICA 5 2 4 4 4 'Total Students 190 1852282252659 PRNC Student Economic Aid Program — FY 1974 — \$10,000 Training Inclusive Dates Tables Name Country Roberto Cuenca Fajardo Colombia José Ortiz Montenegro Guatemala Angel Aguilar Ecuador Héctor Colman Paraguay Abraham Musalem Dominican Rep. Gentil Exteves Colombia Eddy 0. Rios Olivares Nicaragua LK. Lingappan India Jesis Michelen Dominican Rep. Eduardo Durin Panama Oscar H. Paiz Alfaro"

Guatemala. Chellappan India Enio Gomez de Freitas Virgilina Guimaraes M.S. Radiological Health 'Thesis Research M.S. Chemistry 'Thesis Research M.S. Chemistry 'Thesis Research M.S. Chemistry 'Thesis Research M.S, Nuc. Eng 'Thesis Research: M.S. Physics 'Thesis Research Ph.D. Microbiology 'Thesis Research-M.S, Nuc. Eng. 'Thesis Research-M.S, Nuc. Eng. 'Thesis Research M.S. Biology. 'Thesis Research MLS. Horticulture 'Thesis Research-M.S, Nuc, Eng Radioisotope Tech--Nue. Medi Radioisotope Tech--Nue. Medicine 'Aug-1-Nov.30, 1973, Sep.t-80, 1973 Sep.1-Dec.31, 1973 Oct.1-Dec.31, 1973, Nov.78-Jan.74, Mar-Apr.74 Dec.31, 1973 Jan-Jun, 30, 1974 Mar. 1-81, 1974 Mar.1-Apr.30, 1974 'Apr.-Aug. 31, 1974 Jun.1-Aug. 15, 1974 May 20-Aug.18, 1974 Jun.1-Aug. 31, 1974 'Jun.1-Aug. 31, 1974 ---Page Break--- 'Table 6: PRNC Students by Country — FY 1958—FY 1975 \* (A student is counted once each fiscal year he is in training) 24 6 6 - to 5 § 2 t 1 PH # A 2 4 4 4 19 2 i 7 7 i 1 a A p 2 1 1 1 18 eee sn 3 BR oh ee | rr | ea a | an a a ee os en: ee A — a ' tones - § 8 & 1 =. A 5 & 2 & \$ Fy 5 & 8 28 8 8 8 : Kenya 5 = 7 = = \* 5 as A @ & @ 8 2s i a ee ; Per R @eeø8e 3 es fe R = & : eee an + of 3 8 ee Se ; = ee ae e 5 lctllUctlt 2 i Fes 8 238 i United Arab Republic 1 - > ~ ~ ~ 1 Veni unum oh kkk "Total number of students trained at PRNC from its 31st year of operation FY-58 through FY-75 ---Page Break---



Table 7: PRNC Student Economic Aid Program — FY 1975 — \$10,000 Name Country 'Training Inclusive Dates Eduardo Duran Panama Thesis Research M.S. Biology Sep.A-Dec.31, 1974 Enio Gomez de Freitas Brazil 'Nuclear Medicine Course Sep.-Nov.30, 1974 Virginia Guimaraes Brasil [Nuclear Medicine Course Sep.1-Nov.30, 1974 Edelmira Mayta de Fanilla Panama 'Thesis Research-MS. Biology Jul. A-Jul31, 1974 Héctor Colman Paraguay Thesis Research M.S. Chemistry Sep.2, 1974-Jan.31, 1975, Rolando Mosquera Moreno Peru M.S. Radiological Health Sep.1, 1974-Jun.30, 1975 (César Pen Chiver Peru Reactor Supervisor Course Dec.21, 1974-Jan.31, 1975 Dick Carrero Guets

Puerto Rico Thesis Research M.S. Nuc. Eng. Feb. 1, 1976 - May 31, 1975, Alberto Espinoza Nam Chile Thesis Research, M.S. Biology Feb. 1, 1975 - Mar. 30, 1975, Angel Laracuente Puerto Rico Research - Biomedical Sciences Mar. 1, 1975 - Oct. 80, 1975 Yolanda Castro Jimenez Colombia Research - Tropical Agro-Sciences Jun. 1, 1975 - Aug. 15, 1975, Carlos A. Spada Argentina Radioisotopes Techniques - Nue. Med. Jun. 28, 1975 - Dec. 31, 1975 TECHNICAL REFERENCE ROOM The PRNC Technical Reference Room functions as an autonomous branch of the UPR Mayagüez Campus Library. Ms. Iraida Oliver de Padovani was transferred to the UPR Library and Ms. Grace Quiñones Seda replaced her as the librarian in charge. Table 8 information on contents of the PRNC Technical Reference Room Collection. Table 8: PRNC Technical Reference Room Collection - FY 1975 Books Theses Journals (Vols.) Periodicals Documents (AEC) Documents (Foreign Countries) Microcards (Units) Microfiche Movies (16mm) 4408 26 972 27,073 655 73,499 105,070 370 The utilization of the Technical Reference Room by scientists, professors, and students during FY 1975 is presented in Table 9. ---Page Break--- Table 9: PRNC Technical Reference Room Utilization During FY 1975. Consultations = Staff Students Circulation Staff Students Interlibrary Loans Intralibrary Loans Movies Loans Microfiche Util 31 Laboratory Tours 18 STAFF Mr. Frederick E. Rushford, Head of the Training and Information Division, served as a Councilman in the Executive Council of the Puerto Rico Chapter of the Health Physics Society during the 1974-75 Presidential Term. On May 1 and 2, 1974, Mr. Rushford met with officials of the OAS, PAHO, USAID, NRC, and USAEC in Washington, D.C. to discuss the PRNC training program and possibilities for fellowship support. He returned to Washington, D.C. on May 1-5, 1975 to meet with Dr. Rodolfo Monneret at the OAS, Dr. R. W. Kinney at the National Research Council, Mr. Harold Young at the Biomedical and Environmental Research Division of ERDA, Mr. J.

W. Kovach at the Agency for International Development, and Dr. G. Gémez Crespo at the Pan American Health Organization. Discussions centered on the PRNC training program and economic support for both training and research activities. Ms. Iraida Oliver de Padovani was transferred to the Reference Room of the UPR Mayagüez Campus Library in February 1975. Ms. Grace Quiñones Seda, a graduate librarian, was assigned to the PRNC Technical Reference Room in February 1975. Mr. Israel Ruiz and Ms. Vilma Flores, who had been assigned to the Reproduction Shop in Mayagüez, were terminated as PRNC employees in December 1974. Reproduction services were centralized in the Reproduction Shop in Río Piedras in an effort to reduce overhead costs. ---Page Break--- Dr. Gloria Arroyo Bosch and Dr. Alfredo Moseol, Radiatic ncer ease prior to initiating treatment ---Page Break--- RADIATION ONCOLOGY 'The Radiation Oncology Division conducts an advanced program of training and research in radiation therapy of cancer. The principal purpose had been to provide education and training for physicians and allied personnel in the use and application of ionizing radiation in cancer therapy. During fiscal year 1975 a change occurred which shifted the emphasis to research as the main purpose. The current policy is to expand the research programs and to carry on the training activities as a complement to the research effort. The purpose of the research effort is to improve present modalities of radiation

therapy of cancer. The PRNC Radiation Oncology Division operates as the Radiation Oncology Division of the Department of Radiological Sciences of the UPR School of Medicine. This division is responsible for providing radiation oncology support to the University Hospital and to the academic programs of the UPR Medical Sciences Campus. Patients from University Hospital have provided the base for educational and research projects of this division. The UPR School of Medicine, primarily through Federal Grants, has provided 60% of the financial

support and PRNC has provided 40% of the support for the activities of this division. Special interinstitutional relationships exist with the San Juan Veterans Administration Hospital and the Metropolitan Hospital in San Juan which permit the utilization of their cancer patients for the research projects of this division. The PRNC Medical Physics Program provides consultation services to the Radiotherapy Department of the Veterans Administration Hospital. RESEARCH ACTIVITIES A. Residents Tumor Regression in Carcinoma of the Esophagus — Dr. Gloria Arroyo. Evaluation of radiation-induced tumor regression in carcinoma of the esophagus is in progress. It is related to tumor control and survival and to treatment with and without carbogen. Twenty-five cases from the national carbogen study are being studied with radiographic techniques. Study of Intracranial Astrocytoma — Dr. Omar Salazar. A review of clinical cases diagnosed as intracranial astrocytoma seen at the affiliated hospitals of the University of Puerto Rico was made. A paper is ready for publication. Ependymomas of the Brain — Dr. Omar Salazar. A review of clinical cases diagnosed as ependymoma of the brain from affiliated hospitals of the University of Puerto Rico and the Strong Memorial Hospital in Rochester, New York was made. A paper has been accepted for publication in Cancer. 35 ---Page Break--- Salazar. A review of the characteristics of leukemia cases seen at University Hospital with emphasis on the characteristics was made. A paper is ready for publication. 5. Shift — intramural Poets of the Maun of Cotton of the eet sh were in 8a, aap The Director of the Comprehensive Cancer Center, Dr. Eniqua Pes Sentigs is working on an agreement with the Oncologic Hospital administration regarding the Once. Once an agreement has been reached, the project will be completed. Effect of Therapeutic Irradiation of the Lung by Pulmonary Function Test and Lung Scan Techniques. This project is carried out in

collaboration with the PRNC Nuclear Medicine Division (please see previous PRNC Annual Reports). Accession of cases provided by the Radiotherapy staff has continued. A total of 65 cases have been registered in this project through April 1975. Split-Course Radiation Therapy of Cancer. A total of 400 cases have now been included in this project (please see previous PRNC Annual Reports). This study became a national Project of the Radiation Therapy Oncology Group (RTOG) in 1972 under the direction of Dr. Victor A. Marcial, who serves as study chairman. A statistical report is prepared by RTOG every 6 months. The latest progress report available (June 1975) indicates that both techniques are giving equal initial tumor control and complications. In June 1974, a paper on this project was submitted for publication to the Revista Argentina de Radiología. Tumor Regression in a Mouse Chondrosarcoma. This is a pilot project conducted in collaboration with the PRNC Human Ecology Division. Evaluation of the factors that Liver Irradiation Project. A dog liver irradiation project is conducted in collaboration with PRNC Nuclear Medicine Division and the UPR School of Medicine Surgical Laboratory. The purpose is to identify factors in radiation hepatitis and how to prevent it. Lactic Dehydrogenase Levels and Prognosis in the Treatment of Cancer With Radiation. The relationship existing between the L.D.H. level in the serum of patients with the response to radiotherapy in carcinoma of the head and neck is under study, ---Page Break--- . Extramural Projects Carbogen Study. In 1974, a total of 272 cases were registered, 111 of which were contributed by the FRNG Radiation Oncology Division (Please see previous PRNC Annual Reports for project description). It is too early to evaluate the results in terms of tumor

control, curability, or complications, Treatment of Brain Metastases. This project is now in its second phase and the last data analysis showed that irradiation treatments of short duration may be equally effective in

terms of achieving palliation versus prolonged treatments (Please see PRNC 1973 Annu. Report) 'Treatment of Brain Gliomas. The best therapy for brain tumors is being evaluated. Two dose levels of radiation therapy, 6000 R vs. 7000 R, with and without chemotherapy (BCNU) are being tested. No patients have been registered to date, but the division is ready to begin case accession. Bone Metastases Study. The objective of this project is to determine the optimal palliative radiotherapy for bone metastases. Accession of patients will soon begin. Lung Carcinoma Study. The objective of this study is to determine the optimal therapy (radiotherapy with or without chemotherapy) for inoperable carcinoma of the lung. Clinical Study of Radiation Pneumonitis. The objective of this study is to determine the clinical factors contributing to symptomatic radiation pneumonitis and to develop means to prevent it. This study complements the study using pulmonary function tests and lung scans. D. Medical Students 'The following research projects were conducted by medical students on summer fellowships in the Radiation Oncology Division: Clinical Study of Patients With Carcinoma of the Breast at the Radiation Oncology Division — José E. Melendez; Clinical Study of Carcinoma of the Prostate at the University of Puerto Rico Affiliated Hospitals — Néstor C. Tirado; Clinical Study of Lymph Node Metastases From Carcinoma of the Breast at the University of Puerto Rico Affiliated Hospitals — Maria C. Cardona; Clinical Study of Patients With Carcinoma of the Base of the Tongue Registered in the National Split Course Study — Maria E. Vélez; Clinical Study of Patients With Carcinoma of the Endometrium Seen at the University of Puerto Rico Affiliated Hospitals — Noel Totti; Study of Eventual Prognosis of Patients With Brain Tumors Who Have Lived Five Years After Treatment — Carmen D. Zorilla; Study of Sarcoma of the Uterus — Nayda R. Figueroa; Study of Ovarian Tumors With Emphasis on Dysgerminoma — Sigfredo Acosta; 'Study of Carcinoma of the

Esophagus of the Radiation Oncology Division — Francisco J. Vizcarrondo. 37 ---Page Break--- 'TRAINING ACTIVITIES training for medical students in cancer and radiation therapy (summer fellows), in-service who participated in symposium conferences at the University of Puerto Rico, in-service of the Division, to be presented at the summary of Training Activities of the Radiation Oncology Division. a .\_, Table 1: 'Training Activities of the Radiation Oncology Division January 1974 through June 1975 Name Dates Present Pos A. RADIATION ONCOLOGY RESIDENTS De. Hernan Castro V Jan 1973 - Jun 1974 4th Year Resident, New York Dr. Gloria Aroxo Jul 1974 - Jun 1975, 2nd Year Resident, PRNC De-Rafael A. Saincher Mi 'Aug 1973 - May 1974 Private Practice Luis R. Gonzales Jun - Jul 1974 José E. Melendez Jun - Jul 1974 Luis A. Almodovar Jun - Jul 1974, Jun - Jul 1975, Maria S. Cardona Jun - Jul 1974, Jun - Jul 1978, Antonio G. Sotomayor Jun - Jul 1974, Jun - Jul 1978 Néstor C. Tirado Jun - Jul 1974, Jun - Jul 1975 Noel Totti Jun - Jul 1974, Jun - Jul 1975 Francisco J. Vizcarrondo Jun - Jul 1974, Jun - Jul 1973 Carmen D. Zorilla Jun - Jul 1974; Jun - Jul 1978 Iván E. Del Toro Sigfredo Acosta Jun - Jul 1975 Jun - Jul Maria E. Velez Jun - Jul 1973, Cayda Figueroa Jun - Jul 1975, Eduardo C. Castro Jun 1975 Gilberto Cotlazo Jun - Jul 1975, ©. SHORT TERM RADIOTHERAPY COURSE Dr. Gilberto E. Ocampo Dr. Josefina Garcia Dr. Maria E. Tavares Jan 1975 - Jun 1975 Jun 1974 - Jul 1974 Jun 1974 - Dec 1974 Returned to Colombia Intern, San Juan City Hosp. Radiotherapist, Bahia, Brazil Dr. Charles H. Kent Mar 1975 - Apr 1975 N.C.L, Bethesda: D. RADIOLOGICAL PHYSICS Dr. Maria E. Tavares Nov 1974 - Dec 1974 Radiotherapist, Bahia, Brazil Germin Ramirez Aug 1974 - Feb 1975 Medical Physicist, Colombia Roberto Cuenca Aug 1974 - Jan 1978 Radiation Techn 38 Program, Colombia ---Page Break--- MEDICAL SERVICES During fiscal year 1975 pure medical service activities were deemphasized.

The emphasis was placed on cases that would be of interest for research. The volume of pure service

Patients have been adjusted in accordance with this new policy. Interinstitutional relationships have been established with the San Juan Veterans Administration Hospital and the Metropolitan Hospital, which permit access to the case material seen in those institutions and allow them to contribute patients to the research projects of the Radiation Oncology Division. This arrangement enabled this Division to be the first in the nation in terms of contributed research cases to the Radiation Therapy Oncology Group (RTOG) in 1974. A sufficient volume of cases is necessary in order to conduct clinical, educational, and research activities in a radiation oncology department. Equipment available for conducting clinical therapeutic activities has been below the level considered adequate in the nation. The Division lacks proper tumor localization facilities, a simulator, and other items. Tables 2 and 3 summarize the case load in the Radiation Oncology Division from January 1974 through June 1975. Table 2: Case Load of the Radiation Oncology Division, 1974 site No. of Cases A. New Cases Treated Buccal Cavity and Pharynx Lip; Tongue Base of Tongue 6 Anterior Two-Thirds 6 Parotid 1 4 u 6 5 4 1 2 u 1 Nasopharynx A Hypopharynx fs Posterior Cricoid Region Posterior Wall 4 Pyriform Sinus 7 7 2 3 39 Continued ---Page Break--- Table 2: Cont, Site No. of Cases Laboratory System Maxillary Antrum Larynx Vocal Cords Epiglottis Larynx Soft Tissue, Skin and Breast Uterus Cervical Stump Pulmonary Vagina Prostate Testis Penis Bladder Wilms Tumor Kidney Other and Unspecified Sites Eye Brain a Craniopharyngioma Thymoma Pituitary Thyroid Primary Unknown Lymphatic and Hematopoietic System Reticulum Cell Sarcoma Hodgkin's Disease Malignant Lymphoma Mycosis Fungoides Eosinophilic Granuloma Multiple Myeloma Plasmacytoma Leukemia 2 (Be,) Cavernous Hemangioma B. Teletherapy Applications 13511. Intracavitary and Interstitial Therapy D. Follow-Up 1942 ---Page Break--- Table 9: New Cases in the Radiation Oncology Division - January

through June 1975. Senior Crestogy Division - January through June 1978. Bite — oct Duceavy and Pharynx up 'Tongue Base of Tongue Anterior two-thirds Parotid gland 'Submandibular gland Gum Floor of mouth Buccal mucosa Retromolar angle Oropharynx 'Tonsillar fossa Faucial arch [Nasopharynx Hypopharynx Pyriform Sinus Digestive Organs and Peritoneum Esophagus " Rectum 2 Respiratory System 'Maxillary antrum Larynx Vocal cords Epiglottis Lang Mediastinum Bone, Connective and Soft Tissue, Skin and Breast Bone 1 Rhabdomyosarcoma 1 Fibrosarcoma 3 Breast 7 Urinary and Genital Organs (Cervix uteri Cervical stump Endometrium Ovary Vagina Prostate ---Page Break--- 'Table 3 ~ Cont. Site No. of Cases Nf Cases Other and Unspecified Primary Unknown Lymphatic and Hematopoietic System Lymphosarcoma Hodgkin's Disease Mycosis Fungoides Eosinophilic granuloma Malignant Lymphoma 'Multiple Myeloma Leukemia Re'Treatments Base of tongue Gum Nasopharynx Pharyngeal wall Larynx Kaposi's Sarcoma Skin Breast Cervix uteri Prostate Brain Primary Unknown Reticulum cell Sarcoma Hodgkin's Disease Mycosis Fungoides 'Malignant lymphoma Multiple myeloma Benign Cases Glomus Tumor Hemangioma Total New Cases Total Re-treatments Total Applications Total Follow-up Patients absent in follow-up Appointment letter sent Follow-up letter sent Consultations 'Accepted Not Accepted 8,100 1,010 216 270 19 u0 a2 ---Page Break--- STAFF ACTIVITIES A. Scientific Meeting and Course Attendance Dr. Victor A. Marcial ~Semiannual Meetings of the Radiation Therapy Oncology Group: Denver, January 1974; Philadelphia, June 1974; Philadelphia, June 1975; Annual Meeting of the American Radium Society: Hawaii, April 1974; San Juan, May 1975; International Cancer Congress, Florence, Italy, October 1974; Clinical Cancer Education Committee of the National Cancer Institute, April 1975; Board of Governors of the American Federation of Clinical Oncologic Society: New York, May 1974, March 1975; Harvard Medical Alumni, Scientific Day,

Boston, May 1974; Inter-American Congress of Radiology, Bogotá,

Colombia, February 1975. Dr. José M. Tomé — Annual Meeting of the Puerto Rico Medical Association, November 1974; First and Second Postgraduate Cancer Courses sponsored by the Puerto Rico Division of the American Cancer Society, January 1974, Chairman, Scientific Committee, January 1975; 57th Annual Meeting of the American Radium Society, May 1975. Dr. Gloria Arroyo — Radiological Society of North America Meeting, December 1974; Annual Meeting of the Puerto Rico Medical Association, November 1974; First and Second Postgraduate Cancer Courses sponsored by the Puerto Rico Division of the American Cancer Society, January 1975; 57th Annual Meeting of the American Radium Society, May 1975. Dr. Juan Reusche — Second Postgraduate Cancer Course of the Puerto Rico Division of the American Cancer Society, January 1975; 57th Annual Meeting of the American Radium Society, May 1975. Dr. Jeanne Ubifias — 57th Annual Meeting of the American Radium Society, May 1975. Dr. Maria E. Tavaréz — Radiological Society of North America Meeting, December 1974. Mrs. Irene Lopez de Velázquez — Treatment Planning Course for Technicians, Memorial Hospital, New York. Mrs. Lourdes Maldonado de Walker — Radiation Therapy Oncology Group Meeting, June 1975. B. Appointments and Resignations: Dr. Antonio Bosch, Scientist II, left PRNC on a leave without pay to accept a position at the University of Wisconsin in April 1974. He has decided to remain in Wisconsin. Dr. Juan Reusche from Lima, Peru, joined the staff of the Radiation Oncology Division as a Scientific Associate II in May 1974. He has a joint appointment with the UPR School of Medicine where he is an Associate Professor of Radiation Oncology in the Department of Radiological Sciences. C. Comprehensive Cancer Center: The Comprehensive Cancer Center of the University of Puerto Rico Medical Sciences Campus received final approval for funding from the National Cancer Institute in June 1975. Activities will officially begin on July 1, 1975. Funding has been received for core

activities related to education and research programs. Both the Radiation Oncology and the Nuclear Medicine Divisions of the Puerto Rico Nuclear Center interact with the Comprehensive Cancer Center. Dr. Victor A. Marcial, Head of the Radiation Oncology Division, serves as Associate Director for Clinical Programs and Chairman of the Steering Committee for the Comprehensive Cancer Center. It is anticipated that the activities of the Cancer Center will complement and enhance the research and training programs of the Puerto Rico Nuclear Center. VISITORS The Radiation Oncology Division received the following visitors: Dr. George R. Prout Jr. Professor and Chairman, Department of Urology/Biology, Massachusetts General Hospital, Boston; Dr. Hans H. Baruch, New York Medical Center; Dr. William Hanson, Radiological Physics Center, Houston; Dr. Fred Valeriote, Chief of Tumor Biology Program, Department of Radiation Oncology, Washington University, St. Louis; Dr. Victor Brito, Venezuelan Consul in Puerto Rico and Radiation Oncologist; Dr. Haydee Kimmick, Orthopedic Surgeon, Alabama; Dr. Homer Kimmick, Head and Neck Surgeon, Alabama; Dr. Tranquilino Elicafio Jr., Chief of Cancer Control, Department of Health, Manila, Philippines; Dr. Austin Colén, Dominican Republic; Dr. Ursol Vianco, Rockefeller University; Dr. James Marks, Washington University; Dr. Victor Swanson, American Cancer Society; Mr. Bruce Jameson, American Cancer Society; Dr. Lucas Di Rienzo, Radiotherapist, Cordoba, Argentina; Dr. Glenn Sheline, National Cancer Institute. ---Page Break--- ---Page Break--- ---Page Break---

NUCLEAR MEDICINE The Nuclear Medicine Division conducts clinical research in nuclear medicine and offers training in the medical applications of radioisotopes for physicians and technicians principally from Latin America and Puerto Rico (USA). Diagnostic and therapeutic services are offered for patients from University Hospital and other community hospitals not equipped with clinical radioisotope facilities in order to ensure an adequate

patient load for research and training. RESEARCH ACTIVITIES 'A. Completed Daily Ingestion of Iodine With Habitual Diet in Inhabitants of Puerto Rico — A. E. Lanaro and L. Haddock. Knowing the influence of regular iodine ingestion on the healthy population and on the results of normal thyroid function tests, a group of 181 individuals from Puerto Rico was studied in order to establish their habitual iodine ingestion. The values obtained were then related to the results of our normal values in thyroid tests. Table 1 summarizes the average iodine ingestion in Puerto Rico by interior rural and urban areas and coastal rural and urban areas. The results were published in the Bulletin of the Puerto Rico Medical Association. OO 'Table 1: Daily Ingestion of Iodine in Puerto Rico ( $\mu\text{g}/24$  hrs) Grand \_\_\_Interior Coast 'Totals 'Total Rural\_\_City Rural City Interior Coast Men 00 230 +60 40 170 290 20 270 23.0 'Average Intake 3824 481.4 909.7 414.8 266.6 445.9 294.8 471.5 2177.8 sD. 272.3 399.7 195.8 288.1 136.4 920.2 175.8 3284 160.4 Women 1310 21.0 180 28.0 63.0 99.0 920 500 81.0 'Average Intake 293.9 285.7 387.8 310.4 270.8 319.0 283.8 300.0 290.1 sD. 169.1 199.1 153.0 181.6 154.9 190.7 163.8 187.6 156.8 Total 110 440 «24.0 88.0 80.0 680-1330 77.0 104.0 Average Intake \$18.4 988.0 945.8 923.1 269.9 373.1 285.4 360.2 287.4 8, 207.7 295.4 161.5 194.5 190.3 255.7 1654 2576 155.5 47 ---Page Break---

Differences in the Normal Survival Values of \*Cr Labeled Red Blood Cells A. E. Lanaro, A. Bosch, and Z. Frias. The results of \*#Cr labeled red blood cell survival studies at PRNC gave normal values larger than most values reported in the literature. This could lead to a misinterpretation of results in diagnosing several diseases. An average RBC survival of 36.1 days  $\pm$  3.5 was obtained from studying 20 volunteers, who were hematologically normal. Table 2 presents RBC survival values taken from the literature and the value obtained at PRNC. This study was published in the Journal of the Latin American Association of Societies of

Biology and Nuclear Medicine. 'Table 2: RBC Survival in Normals — Literature Review Number of RBC Survival (Davey Author Date "Patients Range 'Average 3D. Necheles et al 1983 6 30-33 31.2 16 Read et al 1954 5 23-30 26 Read 1954 5 28 Sutherland et al 1954 5 21-38 32.5 Donohue et al 1955 5 24-26 26 2 Mollison et al 1955 n 26 2 Oske et al 1956 5 4 16 Freyman et al 1958 5 215-385 316 42 Giannopoulos et al 1959 8 30.9 39 Desforges et al 1960 2 2 Lanaro et al (PRNC) 1973 20 285-420 36. 35 'Lung Scanning in Children With Congenital Cardiac Malformations — As a consequence of the good results obtained in this study, the pediatric cardiologists made this test a routine part of their evaluation of patients. Two papers were prepared: 4. Lung Scanning Alterations in Congenital Heart Disease — R. Dietrich, J. Sanchez, A. Munoz, A. E. Lanaro, and A. Martinez Pico. Results were classified in 8 groups: Group I with symmetrical diminution of activity, Group II with unilateral diminution of activity, and Group III with segmental diminution of activity. Different types of cardiac malformations were included in each of the 3 groups. The study was published in the Bulletin of the Puerto Rico Medical Association, b. Lung Scanning in Congenital Heart Disease — A. E. Lanaro, R. Dietrich, A. Munoz, J. Sanchez, and A. Martinez Pied. The image findings in different typical cases studied at PRNC were analyzed. The results were submitted for publication to the Journal of the Latin American Association of Societies of Biology and Nuclear Medicine, Evaluation of Soft Tissue Calcifications in Dermatomyositis With  $^{99\text{m}}\text{Tc}$  Labeled Phosphate Compounds — A. H. Sarmiento, J. Alba, A. E. Lanaro, and R. Dietrich, 'One case of dermatomyositis studied with a whole body scanner using  $^{99\text{m}}\text{Tc}$ -Pyrophosphate and  $^{123\text{I}}$  Se Nitrate showed positive areas of calcinosis in the subcutaneous and muscular calcium accumulation in soft tissue. The results were published in the Journal of Nuclear Medicine. ---Page Break---

Figure 1. The scanning showing calcium accumulation in

sft teres Sensitivity of the Thyroid Cell to External 2. Frias. This study deals with the last of 'were

irradiated 6 years ago and the chat Early and 1 year late effects were pi hypothyroid and changes in the submitted for publication to the ---Page Break--- Evaluation of Liver Detoxification With <sup>14</sup>C-Phenobarbital — Experimental work done with dogs on this new test for the evaluation of the detoxification function of the liver gave very good results. Dose elimination in the urine of normal dogs amounted to 84.65% (± 10 S.D.). A needle biopsy of the liver for histologic examination was done on each dog. After administration of 250 mg of Thioacetamide, elimination of the radiopharmaceutical was only 50% (± 7.5 S.D.) and the liver biopsies of these dogs showed different degrees of liver necrosis. Dr. A. Rodriguez Ollerros presented a paper based on this study at the Inter American Congress of Gastroenterology in Mexico in October 1974. Experimental work will be completed carrying out the same test on humans using <sup>14</sup>C-Lallyl barbituric acid. Vitamin B12 Absorption in Pregnancy Utilizing the Whole Body Counter — In order to evaluate anemia during pregnancy, a <sup>57</sup>Co-labeled vitamin B12 absorption test was made using the Whole Body Counter on 63 women who were in the first trimester of pregnancy. Only 1 case gave an abnormal value (14%) out of a total of 81 tests given. Clinical and hematological examinations were done at the same time on these patients at the Clinical Research Center by Dr. J. J. Coreino. Data obtained is now being analyzed. Radiation Injury to the Liver — Evaluation of hepatic function variations in dogs is carried out. Only a few studies were performed during the year because of difficulties in handling the dogs. Quantification of Radiocolloid Uptake by Liver and Spleen — The purpose of this study is to quantify the relative uptake in liver and spleen of different radiocolloids in order to establish normal values for each colloid and to compare results using different colloids and observe their

clinical correlation. The Anger Camera was used to study 188 patients. The ratio between the activity in liver and in spleen using the whole organ and equal areas of each was established. The total number of patients studied included: 71 cases studied with sulfocolloids from New England, 65 cases studied with sulfocolloids from Mallinckrodt, 5 cases studied with sulfocolloids from Squibb, and 47 cases studied with Phytate from New England. Preliminary observations showed a lower ratio for Technetium-99m than for the New England Nuclear Kit, with Phytate in third place showing a significantly higher ratio. Pathological studies are being made to correlate the results. Evaluation of Salivary Gland Function - The Anger Camera is used to evaluate salivary gland function by external measurement. Uptake and excretion under stimulus are quantified. Results with the Anger Camera in counts and results obtained by salivary catheterization by the Stensen ducts will be compared. Eight patients have been studied and the techniques developed. No conclusions have been made to date. Use of <sup>99m</sup>Tc-MDSA for the Diagnosis of Myocardial Infarction - In collaboration with the Experimental Surgery Section, 6 dogs were studied to determine the concentration of <sup>99m</sup>Tc-MDSA in the necrotic heart tissue after surgical myocardial infarction. The study entails scanning the dog during different periods after surgery and different periods after the injection of the radioactive material. The dog is sacrificed after the study to measure the ratio of the activity of healthy heart tissue to necrotic tissue and the activity of heart tissue to other organs. Data is still being collected. 50 ---Page Break--- Leotopic Angiocardiology in Congenital Cardiovascular Diseases - Radioangiocardiology is very valuable as a diagnostic tool in congenital heart disease and in the detection of intracardiac shunts. This method is now used as a routine test in cardiology practice. A paper was sent for publication to the Journal of the Latin American Association of

Societies of Biology and Nuclear Medicine. Dynamic Studies of Esophageal Transit — This simple test is utilized in evaluating esophageal disorders. A total of 800 patients with different diagnoses were studied, and very good results were obtained. A paper has been prepared for publication. B.

In Progress Use and Usefulness of  $^{67}\text{Ga}$  in Tumor Localization — Data was collected on approximately 100 patients with different malignant and inflammatory diseases. Evaluation of the data is now in progress. Effects of External Irradiation on the Normal Thyroid and Pituitary Glands — This study is an extension of the evaluation of thyroid uptake done at PRNC several years ago. The purpose was to study the variation of thyroid function after irradiation by different laboratory methods. Only a few patients were studied during this period due to budget restrictions. A total of 22 new cases, plus a few cases from the previous year, were given  $^{67}\text{Ga}$  uptakes and T3 and T4 determinations. TSH, Ca, P, and thyroid antibody tests are being done in the Endocrinology Laboratory of San Juan City Hospital. Seven patients were lost: 2 died and 5 failed to keep their appointments. No conclusions have been made to date. Follow-up on Patients Treated With Iodine-131 — Once again (see PRNC 1973 Annual Report), hyperthyroid patients treated with I-131 at PRNC were requested to come for their annual check-up. Clinical examinations and thyroid uptakes were given to 120 patients. At the present time, the condition of these patients is as follows: 72 are euthyroid, 80 are hypothyroid, and 16 are hyperthyroid. Patients who were treated for thyroid carcinoma were also requested to come for a check-up. Seventeen cases were seen with 9 positives and 8 negatives. The positive cases will continue to receive treatment. 81 ---Page Break---

TRAINING ACTIVITIES a Table 3: Nuclear Medicine Activities January 1974 to June 1975, MS wh 1. Basic Nuclear Medicine Course Name Country Duration Sponsor 7 =29 Nov 1974 PANG Vilna Guimaraes vs Pyne Gomes Broa Bo Novisrs re Mion

Barnes Pi Sha Nov ore Spe — Topic 2. Special Training Rafael J. Rodeguer, M.D. Carlos E. Lopez, M.D. (Cynthia Cotto Cuba dose Alba, M.D. Felix Lesa, M.D. Antonio Rosich, M.D. Tis A. Maren, ND, Maria E. del Rosario, M.D. Zais Bora Blas, M.D. Fernando L. Catinchi, M.D. Oat M. Rivers, M.D. 7 Mar - 18 Mar 1974 Lung Studies May 1974 Lung Studies 1 Jun - 31 Jul 1974 Nuclear Medicine 2 Jul - 30 Aug 1974 Nuc. Med. Radiology Sep 1974 Lung Studies Oct 1974 Nuc. Med. Neurology Oct 1974 Nuc. Med. - Radiology Dec 1974 Nuc. Med. - Radiology Nov 1974 Nuc. Med. - Neurology Jan 1975 Lung Studies 3 Feb - 31 Mar 1975 Nuc. Med. Radiology (Carlos A. Melendez, M.D. Apr 1975 Nuc. Med. - Neurology Frank Kolodgie, M.D. May 1975 Nuc. Med. - Neurology. 3. Nuclear Medicine Residency Frieda Silva, M.D. PR, Oct - Nov 1974 Carmen C. Caballero, M.D. PR Feb - Mar 1975 BRSPREP PES Pee 4. Elementary Course in Nuclear Medicine for Technicians 22 lectures for 27 students PRNC 5. M. S. Degree Program in Radiological Health 4 Lectures and 9 demonstrations for 7 students 24 Jun - 28 Jun 1974 UPR School of Public Health 4 Lectures and 8 demonstrations for 8 students 9 Jun - 13 Jun 1975 UPR School of Public Health 6. Oak Ridge Undergraduate Research Training 1 Student 10 weeks 7. Nuclear Medicine for Radiology Residents 12 Conferences for 22 Residents 8. Nuclear Medicine Course for Endocrinology Fellows 2 Conferences, 7 Demonstrations to 5 students UPR School of Medicine 9. Lectures for Medical Students in Pathology 2 Lectures UPR School of Medicine ---Page Break---

In addition, the following seminars were presented: "Radioisotopes in the Diagnosis of Cancer", A. E. Lanaro — first postgraduate course in Cancer, Puerto Rico Chapter, American Cancer Society. "Thyroid Function Studies", A. E. Lanaro — Human Biology Course, UPR School of Medicine. "Diagnosis and Treatment of Thyroid Diseases," A. E. Lanaro — Symposium on Clinical Applications in Nuclear Medicine, Mayaguez Medical Center. "Clinical Application of Radioisotopes," A. E. Lanaro — Basic Radioisotope Techniques.

'Course, PRNC. "Radioisotopes in Cancer," A. E. Lanaro ~ Summer Course for Medical Students, Radiation Oncology Division, PRNC. "Radioesophagogram," R. Dietrich — Society of Nuclear Medicine, Puerto Rico. "Medical Applications of Radioisotopes," A. H. Sarmiento — Vila Mayo High School Group. "Liver-Spleen Uptake Ratio Significance in Radiocolloid Scanning," A. H. Sarmiento



— Society of Nuclear Medicine, Puerto Rico. A workshop on Quality Control of Scintillation Cameras was offered during the afternoons of February 13 and 14, 1975. Dr. Peter Paraskevoudakis, former Associate Director of PRNC for Mayagüez operations and now Director of Radioisotopes and Nuclear Medicine, Bureau of Radiological Health, DHEW, Rockville, Maryland; and Dr. Richard Riley, Head, Division of Radiological Science, University of Kansas Medical Center, served as visiting lecturers. MEDICAL SERVICES From January 1974 through June 1975, a total of 9,209 diagnostic and therapeutic procedures were carried out in the Nuclear Medicine Division. Services were limited to University Hospital patients only beginning in February 1975 because of an overload in work and budget limitations. Table 4 presents a summary of the services rendered: Table 4. Number of Teaching and Service Procedures Carried out during Jan 74-Jun 75. = incl Teaching Teaching Tired Sain 01 as 9 Gacoimesina To ' Hematology is 5 6 Uber Ste : Q Creation Studia D 2 : Renal Studies 3 u | Organ and Tumor Localization 2341 304 fz Se Coen 2582 38 2 tl Body Water et a 08s Tae 0 Total = 9,209 53 ---Page Break---

STAFF ACTIVITIES [A Scientific Meeting Attendance. Aldo E. Lanaro attended the Twenty-first Annual Meeting, Society of Nuclear Medicine, Philadelphia, Pennsylvania. Puerto Rico Chapter, American Cancer Society; Symposium on Clinical Applications in Nuclear Medicine, Mayagüez Medical Center; Second Meeting, Puerto Rico Chapter, Health Physics Society; Symposium on Clinical Aspects of Nuclear Medicine, Roosevelt Roads Naval Station; Preconvention Seminar and Third Annual Convention, Hermanos Meléndez Hospital, Dorado. Dr. René Dietrich attended the Annual Meeting of the Asociación Puertorriqueña del Corazón; 72nd Annual Meeting of the Puerto Rico Medical Association; Pre-convention of the Hermanos Meléndez Hospital, Bayamón; Echocardiography Course, Hermanos Meléndez Hospital, Bayamón. Dr. A. H. Sarmiento attended the 72nd Annual Meeting of the Puerto Rico Medical Association and the Symposium on Clinical Aspects of Nuclear Medicine, Roosevelt Roads. B. Appointments, Resignations, Ad Honorem Appointees Appointments: Aristides H. Sarmiento, M.D. - Scientist I - April 22, 1974 Linda Rodriguez Quiñones - Technician - May 6, 1974 Carlos Jimenez Ferrer - Technician - July-August, 1974 Alberto Martinez - Technician - August 14 - September 14, 1974 Francisca Narvaez - Nurse - September 1974 Vilma E. Pérez - Technician - September 1974 Pascual Tirado - Technician - February 3, 1975 Héctor Luis Ramírez - Technician - June 1, 1975 Resignations: Mirva Conde de Miraldi - Technician - April 8, 1974 Nydza Bajandas - Technician - June 30, 1974 Jeanette Rivera de Elías - Technician - July 5, 1974 Irma Rodriguez Comulada - Technician - July 5, 1974 Alejandro Trigo Chívez - Technician - October 30, 1974 Dorotea Escalera - Assistant in Nursing Services - October 30, 1974 Inés Rivera Acevedo - Secretary - December 31, 1974 Pascual Tirado - Technician - May 2, 1975 René Dietrich, M.D. - Scientist II - June 30, 1975 Linda Rodriguez Quiñones - Technician - June 30, 1975 54 ---Page Break---

Ad Honorem Appointees: Dr. Pedro Juan Santiago Dr. J. J. Corcino Dr. Mario Rosa

Nuclear Medicine, Philadelphia, Pennsylvania. Puerto Rico Chapter, American Cancer Society; Symposium on Clinical Applications in Nuclear Medicine, Mayagüez Medical Center; Second Meeting, Puerto Rico Chapter, Health Physics Society; Symposium on Clinical Aspects of Nuclear Medicine, Roosevelt Roads Naval Station; Preconvention Seminar and Third Annual Convention, Hermanos Meléndez Hospital, Dorado. Dr. René Dietrich attended the Annual Meeting of the Asociación Puertorriqueña del Corazón; 72nd Annual Meeting of the Puerto Rico Medical Association; Pre-convention of the Hermanos Meléndez Hospital, Bayamón; Echocardiography Course, Hermanos Meléndez Hospital, Bayamón. Dr. A. H. Sarmiento attended the 72nd Annual Meeting of the Puerto Rico Medical Association and the Symposium on Clinical Aspects of Nuclear Medicine, Roosevelt Roads. B. Appointments, Resignations, Ad Honorem Appointees Appointments: Aristides H. Sarmiento, M.D. - Scientist I - April 22, 1974 Linda Rodriguez Quiñones - Technician - May 6, 1974 Carlos Jimenez Ferrer - Technician - July-August, 1974 Alberto Martinez - Technician - August 14 - September 14, 1974 Francisca Narvaez - Nurse - September 1974 Vilma E. Pérez - Technician - September 1974 Pascual Tirado - Technician - February 3, 1975 Héctor Luis Ramírez - Technician - June 1, 1975 Resignations: Mirva Conde de Miraldi - Technician - April 8, 1974 Nydza Bajandas - Technician - June 30, 1974 Jeanette Rivera de Elías - Technician - July 5, 1974 Irma Rodriguez Comulada - Technician - July 5, 1974 Alejandro Trigo Chívez - Technician - October 30, 1974 Dorotea Escalera - Assistant in Nursing Services - October 30, 1974 Inés Rivera Acevedo - Secretary - December 31, 1974 Pascual Tirado - Technician - May 2, 1975 René Dietrich, M.D. - Scientist II - June 30, 1975 Linda Rodriguez Quiñones - Technician - June 30, 1975 54 ---Page Break---

Ad Honorem Appointees: Dr. Pedro Juan Santiago Dr. J. J. Corcino Dr. Mario Rosa

Garcia Dr. Jorge Sánchez Miss G. Coll Canales Dr. Angel A. Cintrón Rivera Dr. Angel L. Rodríguez Rosado Dr. Francisco Aguilé Dr. Lillian Conde Dr. A. Rodríguez Olleros in Association of Societies of Biology and Nuclear Medicine on October 31, 1974. He will hold this position for 2 years and his responsibilities will include a Work Group on Health Physics and a Work Group concerned with the teaching of Nuclear Medicine in Latin America. He was designated Representative of the Association in the Planning Committee of the World Federation of Biology and Nuclear Medicine by

Dr. Luis F. Barragán, President. The committee met in Philadelphia on June 17, 1975. The Nuclear Medicine Division staff participate in the Journal Club with the Veterans Administration Nuclear Medicine Laboratory and with the San Juan City Hospital Nuclear Medicine staff. The Medical Staff meet with the V.A. Hospital Nuclear Medicine Medical Staff weekly. VISITORS Dr. Enrique Strajman, Professor of Biological Physics, University of Buenos Aires, Argentina, accompanied by his wife, visited the Nuclear Medicine Division and Dr. Raúl Vera from Venezuela. ---Page Break---  
---Page Break--- Medical Physics Section The Medical Physics Section provides radiation dosimetry and treatment planning support to the Ra conducts scientific programs and supervises the operation of the whole body counter facility and the cobalt-60 irradiator facility. In addition, it conducts an educational program in the area of radiological physics for radiation oncology residents, medical physics students from Latin America, and other participants in graduate and post-graduate programs. Consultation services are provided to some local hospitals. RESEARCH ACTIVITIES TLD Measurements of Radiation Exposures to Newborn Babies With Two Different Types of X-Ray Machines — H. Pabén and E. T. Agard. A paper was presented at the Annual Meeting of the American Association of Physicists in Medicine in July 1974. Dosimetry for Isocentric Techniques With 8 MV X-Rays — J. C.

Pacheco and E. T. Agard The currently accepted protocols for calibrating high energy radiation beams require the use of detectors in a phantom rather than in air. Hence the use of tissue-air ratios at these energies. Where computer facilities do not exist, tumor doses can be readily calculated by the use of TMRs and field-dependence ratios. When clearly understood, the procedure is essentially the same as that involved in the use of depth dose data and back-scatter factors, except that treatments are based on dose settings rather than time. A paper based on this research was presented at the XI Inter American Congress of Radiology held in Bogota, Colombia during February 1975. A manuscript is almost ready for publication, Electron Dosimetry at 3, 7, and 11 MeV. A paper is in preparation for presentation at the Congress on the Medical Uses of Linear Accelerators to be held in Bello Horizonte, Brazil in July 1975. A Nomogram for the Estimation of an Average Tissue-Air Ratio for Rotation Therapy Planning, Calculations of tumor dose in full rotation therapy are generally based on the determination of an average tissue-air ratio (TAR) or tissue-maximum ratio (TMR) using 12 or more radii from a contour of the patient taken in the central plane of rotation. The time taken to obtain this mean TAR (or TMR) can be considerably reduced by the use of a nomogram obtained by regression analysis of already existing data. Only 3 parameters are required for use of this nomogram: (1) AP dimensions of the patient, (2) lateral dimensions of the patient, and (3) field size of the irradiation beam. A nomogram so obtained from analysis of 56 pelvic rotations is presented and its use explained. The TARs obtained from this nomogram are all within 2% of the calculated values. A paper based on this research has been accepted for publication in Physics in Medicine and Biology. 87 ---Page Break--- A summary of the training activities of the Medical Physics Section from January 1974 through June 1975 is presented in Table 1. Table 1:

#### Training Activities — Medical Physics Section

##### In-Service Training in Medical Physics

Mr. Vietor M1, Velizquez, Teacher, Humacao

Dr. Gloria Arroyo, Resident in Radiology

Mr. German Ramírez Contreras, LA.E.A. Fellow, Colombia

Mr. Roberto Cuencas Fajardo, P.A.H.O. Fellow, Colombia

Mr. Antonio G. Sotomayor, Fourth Year Medical Student, UPR

Ms. Maria E. Velez, Fourth Year Medical Student, UPR  
Mr. Sitfredo Acosta, Fourth Year Medical Student, UPR  
Ms. Jammie B. Pernel, ERDA Undergraduate Research Participant  
Mr. Drew Remignanti, Tucker Fellow, Dartmouth College

## B. Master of Science Degree Program in Radiological Health, UPR

### 1. Orientation in Medical Physics

César Picén Chavez, LA.E.A. Fellow, Peru  
Germán Ramírez Contreras, LA.E.A. Fellow, Colombia  
Roberto Cuencas Fajardo, P.A.H.O. Fellow, Colombia  
Rosalinda González Taull, Puerto Rico (USA)  
Brenda Manich Morales, Puerto Rico (USA)  
Haydee Pérez Kraft, Puerto Rico (USA)  
Cruz María Nazario, Puerto Rico (USA)  
Carmen Zorila Maldonado, First Year Medical Student, UPR

### 2. Summer Training in Medical Physics

Eloy Gibbs, P.A.H.O. Fellow, Panama  
Anucena Garzón Quiroz, O.A.S. Fellow, Ecuador  
Rolando Mosquera Pecú  
Karl Prado, P.H.L.S. Fellow, Puerto Rico (USA)  
Luz Emilda Cabén, P.H.S. Fellow, Puerto Rico (USA)  
Edgardo Hernández, P.A.H.S. Fellow, Puerto Rico (USA)  
Armando Torres, Puerto Rico (USA)  
Jammie B. Pernel, ERDA Undergraduate Research Trainee

3. PRNC-626, Radiation Dosimetry, Dr. E.T. Agard
4. PRNC-530, Radiation Protection Hazards, Dr. E.T. Agard
5. PRNC-535, X-Ray Protection, Me. J. Pacheco
6. PRNC-501, Radiation Physics, Dr. E.T. Agard

## C. Lectures in Radiological Physics

Offered in collaboration with the Dept. of Radiological Sciences of the UPR School of Medicine  
Sep — Nov, 1974

## D. Lecture Series for University Hospital Nurses

Offered with the assistance of the Health and Safety Division on Safe Handling of Patients  
Lecturers:

Pacheco, Porfirio Toledo Soe C: Pacheco; Sentingo Gomez José C Pacheco, Santiago Gomer May 15-21, 1974 Nov 4-8, 1974 Feb 3-7, 1974 1. 1974 through June 1975. 1974 1974 1975 1975 1975 1975 1975, 1975, 1974 1975 ---Page Break--- In Feb, 1975, Dr. Peter Paraskevoudakis, former Associate Director of PRNC now Director of the Division of Radioactive Materials and Nuclear Medicine of the Bureau of Radiological Health, presented lectures for the students in the M.S. Degree Program in Radiological Health on MIRD Calculations for Dosimetry of Radioisotopes Deposited Internally. He also participated as a lecturer in a workshop on "Quality Control of Scintillation Cameras" organized jointly by the Medical Physics Section and the Nuclear Medicine Division. Dr. Richard Riley, Associate Professor in Medical Physics at the University of Kansas

Medical Center and an Ad Honorem Member of the Radiological Health Program staff at the UPR School of Public Health, presented a series of 12 lectures on X-Ray Protection as part of the course PRNC-535 of this program during February 1975. He also made a very valuable contribution to the workshop on "Quality Control of Scintillation Cameras." On February 12 and 19, he presented 2 seminars: "Electronic Radiography" and "The Role of a Medical Physicist in Diagnostic Radiology." Seminars offered by the Medical Physics Section as part of the training activities: "The Role of a Medical Physicist," Dr. E. T. Agard, June 7, 1974 at the Weekly Radiotherapy Conference; "Physics Aspects of the Mevatron XII Linear Accelerator," Mr. J. C. Pacheco, at the Weekly Radiotherapy Conference; "Factors Which Affect the Discrimination and Sensitivity of Scintillation Scanners and Cameras," Dr. E. T. Agard, August 20, 1974, for the Basic Course in Nuclear Medicine. "The Role of a Physicist in a Medical Institution," Dr. E. T. Agard, January 30, 1975 for the Society of Physics Students, UPR Mayagüez. STAFF ACTIVITIES Dr. E. Theodore Agard, Head of the Medical Physics Section, was appointed PRNC.

Representative to Committee N44 of the American National Standards Institute, a position vacated by the resignation of Dr. P. Paraskevoudakis. He had served as an Alternate Representative previously. He attended a meeting at the Bureau of Radiological Health in June 1974 and another meeting in Chicago on December 3, 1974, during the joint meeting of the American Association of Physicists in Medicine (AAPM) and the Radiological Society of North America (RSNA). In January 1974, Dr. Agard was appointed Director of the Master of Science Degree Program in Radiological Health, offered by the UPR School of Public Health with the collaboration of PRNC. In September 1974, Dr. Agard was appointed a member of the International Affairs Committee of the American Association of Physicists in Medicine. The Committee met during the joint meeting of the AAPM and RSNA in December 1974. He accepted an invitation to serve as a member of the Physics Advisory Group to the Memorial Hospital Cancer Control Program, Northeast Radiological Physics Center. This Center monitors the physical aspects of radiation treatment and diagnosis for Cancer Control Program Demonstration Projects in the Northeastern United States and Puerto Rico. He attended meetings of the Radiation Control Program Directors in San Antonio, Texas, on April 28-May 2, 1974, and in Hyannis, Massachusetts, on April 26-May 9, 1975. His chief interest was to meet with directors of other Radiological Health Programs to investigate other sources of financial support. One important acquisition by the Radiation Oncology Division having important implications for the Medical Physics Section is a computer utilized for radiotherapy treatment planning. While investigating the commercial systems available in order to determine the most appropriate system for PRNC with due consideration to budget limitations, Dr. Agard visited the Artronix World Trade Factory on May 3, 1974, and the Malinkrodt Institute of Radiology in St. Louis, Missouri, where the Artronix PC12.

System was demonstrated. On November 14, 1974, he visited Tampa, Florida for a demonstration of the SHM Rad 8 and then went to the George Washington University Medical Center on November 15 to recheck certain features of the Artronix PC12 System. These efforts culminated in the installation of an SHM Rad 8 System in June 1975. While in Washington, D.C., Dr. Agard met with Drs. Gomez-Crespo and Gerry Hanson at the Pan American Health Organization to discuss training programs in radiological sciences offered at the Puerto Rico Nuclear Center and at the Medical Sciences Campus of the University of Puerto Rico. They expressed special interest in Spanish-language education for technologists from Latin America, where the need is great. Dr. Gomez-Crespo paid a subsequent visit to the Puerto Rico Nuclear Center to inspect the facilities and training programs locally on December 18-20, 1974. Dr. Agard was appointed President-elect of the Puerto Rico Chapter of the Health Physics Society for the 1975-76 Presidential Term during

the Annual Meeting of the Chapter at Mayagüez on February 9, 1975. On February 16-21, 1975, he attended the XI Inter American Congress of Radiology in Bogotá, Colombia, where he presented a paper on "8MeV Photon Dosimetry for Isocentric Techniques." Several inquiries were made about the training programs in Radiological Health and Medical Physics at PRNC. Mr. José C. Pacheco, Research Associate III, attended a workshop on "Mould Room Technology" at the Sloan Kettering Cancer Center in New York on September 23-24, 1974. He also attended the Annual Meeting of the American Association of Therapeutic Radiologists in Key Biscayne, Florida on October 30—November 3, 1974. He participated in a number of workshops on the applications of simulators, computers, linear accelerators, and other treatment devices in radiation oncology. Mr. Alfredo Vargas-Linares worked in the Medical Physics Section from February 4 through June 30, 1974, on a part-time basis operating the cobalt-60 irradiation facility. He

had replaced Mr. Néstor Rodríguez. 60 ---Page Break--- Dr. William F. Hanson, Assistant Physicist in the Radiological Physics Center of the M.D. Anderson Tumor Institute, visited the Medical Physics Section during the week of May 7-10, 1974. His mission was to inspect dosimetry procedures to ensure compliance with protocols established for participants in national clinical studies. Dr. G. Gomez-Crespo, Regional Advisor in Radiological Health of the Pan American Health Organization, visited PRNC on December 18-20, 1974. He was interested in investigating the local training programs and facilities for training x-ray technicians in the hope that through the combined facilities of PRNC and the UPR Medical Sciences Campus, the quality and quantity of trained personnel in this field may be improved throughout Latin America. The importance of Spanish-language education was stressed. He also discussed the possibilities of financial assistance in research projects of interest to PAHO. Since Dr. Agard had previous conversations and correspondence with Dr. Gomez-Crespo, he was asked to coordinate arrangements for his visit. Dr. Gomez-Crespo was notably impressed with what he saw, and he expressed hope that PRNC would serve a useful role in supplying the dire need for trained personnel for the peaceful applications of atomic energy in Latin America. Mr. Paul Pfalzner, Senior Medical Physicist at the Ontario Cancer Foundation in Ottawa, Canada, and a former member of the International Atomic Energy Agency staff in Vienna, visited the Medical Physics Section on February 27, 1975. Ecuadorian student Azucena Garzón is at the operating console of the MEY, which she is using in a study of electron dosimetry at 61 ---Page Break ---

BIOMEDICAL SCIENCES — HUMAN ECOLOGY 'The Biomedical Sciences Division has been committed to the study of tropical diseases, particularly those due to viral and parasitic infections. Radiobiological techniques are used where feasible to resolve problems related to the ecology and host-parasite relationships.

and to provide a rational approach to control. Other disciplines utilized include biochemistry, immunology, electron microscopy, and tissue culture. The diseases currently under study are those due to viral infections, helminthic infections caused by *Schistosoma mansoni* and *Fasciola hepatica*. The program is structured not only to gain and apply knowledge, but to afford training opportunities for candidate scientists from Latin America. Close liaison is maintained with the UPR Medical Sciences Campus, especially in relation to the research training of advanced degree candidates. Effective July 1, 1975, the Biomedical Sciences Division will be replaced by the Human Ecology Division. The new division will focus on the effects of energy production on human ecology. RESEARCH ACTIVITIES *Schistosoma mansoni* Project — R. A. Brown, W. R. Jobin, F. F. Ferguson, L. B. Ritchie, F. Liard and V. Lopez. This research was terminated on June 30, 1975, as part of the reorientation of the research effort towards the effects of energy production on human ecology. Reports on individual sub-projects follow: The Hydrogen Ion as an Attractant for *Schistosoma* Miracidia — R. A. Brown. A simple substance capable of attracting the miracidia of

*Schistosoma mansoni* might be used to prevent infection of the vector snail, and thus reduce transmission of the disease known in Puerto Rico as bilharzia. The idea is to provide artificial baiting more alluring to the miracidia than is the snail's integument. An element common to all substances shown to be active as attractants is the hydrogen ion. Since the diffusion constant of this substance is anomalously large, it might serve as an attractant over reasonably large distances. An assay comparing the number of miracidia congregating about 2 agar blocks has been used to show that 0.005 M HCl is more attractive than 0.005 M NaCl and that ion exchange resin in the hydrogen form is more attractive than the sodium form. The latter experiment was made in dechlorinated tap water where one would obtain

release of the sodium or hydrogen ion by an exchange with the cations present in the water. These and other experiments demonstrated that the hydrogen ion is capable of attracting the miracidia. Significantly, high concentrations of hydrogen ion both attract and kill miracidia. Pellets of phthalic anhydride hydrolyze and dissolve slowly to release phthalic acid. They have been used as decoys in an attempt to reduce the infection rate of snails in several laboratory experiments. The results are summarized in Table 1. There was marked and significant reduction in the infection rate of the snails in the presence of decoys. Phthalic anhydride is an inexpensive industrial chemical. It might serve as an effective attractant and trap for field use. 63 ---Page Break--- Table 1: Infection Rates of Snails Exposed in the Presence or Absence of Decoys is / Total Snails Probability Experiment Number Decoys Taffected Si + ons 1 , oor - ss + ane 0 0.01 - sas + ana os <sup>TM</sup> - ans. + 346 00 tent 1 mem - 21143 Release of TBTO and Other Toxicants Measured by Cercarial Bioassay — V. Lopez. Since freshly-shed *Schistosoma mansoni* cercariae reacted quite uniformly to the action of ultra-low concentrations of tributyl tin oxide (TBTO), tributyl tin fluoride (TBTF) and Niclosamide, a bioassay was designed based on their immobilization after a 30 minute exposure to these chemicals. Measured quantities of the toxicant-containing rubber pieces were placed in dechlorinated tap water and water samples removed at predetermined intervals. Dilutions of the samples, together with standard solutions of each of the chemicals were mixed with freshly-shed cercariae and observed microscopically after a 30 minute exposure. The end point of each titration was determined as the lowest concentration. producing total immobilization of the larvae. By this method a 60-day release curve for TBTO was obtained, Which is shown in Figure 1. Figure 1: TBTO Released From Elastomer Into Water as Measured by Bioassay PPM PER cu? s+ DAYS IN WATER 64 ---Page Break--- A

Comparison of the Biological Half-Life in Mice of an Organotin With Inorganic Tin — R. A. Brown, C. M. Nazario, J. A. Castrillón, R. S. de Tirado, and E. T. Agard. Although data obtained in this laboratory have demonstrated that rubber formulations which slowly and continuously release tributyl tin oxide (TBTO) into the environment may be very effective in controlling several phases of the *Schistosoma mansoni* life cycle (life stages of the snail vector, *Biomphalaria*, as well as *Schistosoma* larvae), there is the question of the ecological impact of prolonged application of this toxicant. Knowing of the serious problem of methyl mercury, one is concerned about the turnover rate of TBTO in biological systems. The Physical Sciences group has prepared Sn<sup>113m</sup> labeled TBTO and its biological half-life has been compared with inorganic Sn<sup>113m</sup> using the whole body counter in collaboration with Medical Physics. The observed radioactivity of the two substances in the whole body counter is shown in Figure 2. The TBTO is cleared from the body more rapidly than inorganic tin. The curve appears to become asymptotic to that of the inorganic tin after 10 days. This suggests, but does not prove, that the TBTO is slowly converted to less toxic inorganic tin in the body of the mouse. It would appear that TBTO may turn over rapidly in biological systems. Figure 2: Total body counts as a function of time in mice injected with Sn<sup>113m</sup> tin and SI labeled TBTO.

Average Total Body Counts over 90 minutes are 1080. ---Page Break--- Antigens Isolated from the Sera of Hodgkin Patients — R. A. Brown. It has been possible to demonstrate antigens similar to the exoantigens of eggs and cercariae circulating in the sera of *Schistosoma mansoni* infected mice, and using similar technology, it has been possible to isolate antigens from the sera of Hodgkin patients with active disease. The elution pattern for the labeled and purified antigens after molecular sieve chromatography is highly reproducible using different samples isolated from sera. This is

shown in Figure 3. The chemistry appears similar to the parasite antigen except that they carry a net positive charge and the tumor a net negative charge. The similarity in the chemistry of these two different systems suggests that one is working with a general phenomenon. Figure 3: Elution pattern and specific binding of labeled antigen recovered from serum of 50 active Hodgkin's disease patients. COUNTS PER MINUTE (10% TUBE NUMBER) *Fasciola Hepatica* Project — J. Chiriboga, D. de León, and P. Bendezu. The fascioliasis research project at the Puerto Rico Nuclear Center was originated as a cooperative effort of the Department of Agriculture, the UPR Agriculture Experiment Station, and the Pan American Health Organization, which has sent scientists from different countries to be trained in this bovine-ovine disease problem. The program was terminated in June 1975, because of difficulties in obtaining local funds and because of reorientation of the research program. However, in 1974 several significant problems were attacked and the data will soon be published. 66 ---Page Break--- Epidemiological Studies — J. Chiriboga. Epidemiological studies continued in two distinct subtropical ecological zones of Puerto Rico. In the high altitudes near Jayuya, a study was conducted identifying different transmission sites in the Jauca River valley. Each site had two observation points: one in the river and the other on the shore. Every 16 days for 6 months the numbers of 4 species of snail were recorded in each place: *Lymnaea cubensis*, *Lymnaea columella*, *Biomphalaria glabrata*, vector of schistosomiasis, and *Physa cubensis*. *Lymnaea* snails were tested for *Fasciola* infection. This study was very useful for the understanding of the biology of the snails concerned. *B. glabrata* is an aquatic snail in this area, *L. columella* is amphibious with a tendency to be more aquatic than *L. cubensis* and somewhat similar to *B. glabrata*. *L. cubensis* is practically an amphibian but prefers mud as a habitat, whereas *Physa* is aquatic.

Snails infected with *Fasciola* were found mainly in one muddy field close to the river. *Lymnaea cubensis* were present in great numbers and always with a high degree of infection: the place was contaminated with cow feces and was an obligatory pathway for the animals. It was discovered that after the river received the water of an oxidation pond, *Physa* became markedly dominant, and the rainy season erased test snails from almost all the areas surrounding the river. Isolation, Purification and Immunological Studies of *Fasciola hepatica* — J. Chiriboga, J. L. Torres. It was found that *Fasciola hepatica* has a protease activity of the Chymotrypsin type. Tyrosyl ester at pH 7.2 was split by a homogenate of adult *Fasciola*. A similar enzyme was found in the exoproteins produced in vitro by *Fasciola*. Further purification is underway and some of the immunologic parameters are being investigated prior to termination of this project. Biological Control of *Fasciola hepatica* — J. Chiriboga and P. Bendezu. Preliminary studies of the annelidan, *Chaetogaster*, and its biocontrol effects on *Lymnaea*, *Fasciola* vector in Puerto Rico. Comparisons are being made of the ecological requirements of two strains of the annelids (about 5 mm long) that commonly affect the snail intermediate hosts of *Fasciola* and *Schistosoma* (species of *Lymnaea* and *Biomphalaria*, respectively) both as internal and external parasites. Thus they may possibly provide control of bovine liver fluke and bilharzia transmission. A strain of *Chaetogaster* collected at an elevation of 10,000 feet in Peru and parasitic on *L. viator* has proven to have a faster rate of reproduction and is

significantly more lethal to Puerto Rican *L. eubensis* than is the local ectoparasite. Biological Control of *Fasciola hepatica* — J. Chiriboga and B. Duran. Sciomyzidae (Marsh Fly) Predation of Lymnaeid Vectors of *Fasciola*. A graduate student from Panama, in cooperation with our group, finished his thesis on the predator-prey relationship of *Sepedon caerulea* in the field and in the

laboratory. *L. columella* and *L. cubensis* were used as prey in aquatic and amphibious conditions. Every 15 days, the population of the fly and the different types of snails in the two ecological niches were measured. A numerical correlation existed between the fly and the snails; however, the ratio of the number of flies to the snails was very low. In the 67 ---Page Break --- ---Page Break --- the larva of the fly was a very inefficient predator. A field trial of this method of biocontrol was not indicated. 'Survey of *Fasciola hepatica* Infection in the Slaughterhouses of Puerto Rico — 4. Chiriboga, Delfin D. de Leon, P. Bendezu. In 1952, Rivera Anaya made the only published survey of *Fasciola hepatica* infected animals in the slaughterhouses of Puerto Rico. This year, we started a second survey which we were not able to finish. The data showed a marked increase in prevalence in the localities formerly analyzed: Caguas, Naguabo, and Carolina. Virology Project 'The purpose of this project is to study the potential impact of gamma irradiation on virus infections in wild arthropods and vertebrates. ERDA financial support for this research is being terminated. The isolation of Coxsackie type A10 virus from the blood of sick wild rats caught in a small irradiated portion of the El Yunque rain forest and from organs of one rat found dead led to studies of the changes induced by radiation in the virus-host relationship. We hoped to answer some fundamental questions of virology and immunology, especially those related to long-lasting viral immunity, and the synthesis of neutralizing antibodies and interferon. Latency (i.e., infection of an organism by a virus with no apparent ill effects) is a commonly seen and noteworthy phenomenon. Gamma radiation is being used to elucidate the mechanism by which latent infections are established and activated. Synthesis of Macromolecules on Irradiated and Infected Cells. Previous experiments in our laboratory have shown that certain doses of gamma radiation given at different times before

or after virus infection alter the virus-host relationship in various ways, i.e., enhancement of virus growth, inhibition of viral growth, and production of virus in immune animals that showed no viral activity prior to radiation treatment. We have reported that doses of radiation of less than 1,000 rads inhibited viral production and that this inhibition was mediated by an increased production of interferon by the irradiated cells. The interferon enhancement diminished with radiation doses greater than 1,000 rads, and the total production of interferon was inhibited with doses of 10,000 rads. The experiments to be described here were designed to study the effects of gamma radiation (1,000 and 10,000 rads) on the synthesis of macromolecules in chick fibroblast monolayers infected with Sindbis virus. The effect of different doses of gamma radiation on the multiplication of Sindbis virus in chick embryo monolayers is shown in Figure 4. Monolayers irradiated with 1,000 rads produced less virus during the first 6 hours of infection, while more virus was produced in monolayers irradiated with 10,000 rads during the same period of the growth cycle. Monolayers irradiated with higher doses showed low viral yield early in the cycle, but after 8 hours the cells apparently recovered from the damage produced by the radiation and were able to produce virus with the same efficiency as did unirradiated cells. ---Page Break--- In order to determine the difference observed in the virus titers as a result of abortive adsorption of the virus by a damaged cell membrane, a comparison was made of the cell-associated virus found in monolayers irradiated with 1,000 and 10,000 rads. Figure 5 shows that the amount of cell-associated virus in the irradiated monolayers was the same for 1 1/2 hours and was higher when compared with the unirradiated control. This indicates that both doses of radiation favor virus adsorption. The same amount of virus penetrated the cells independently of the irradiation dose, but the intracellular



damage done by the

10,000 rads favors the virus growth while that done by 1,000 rads inhibits its multiplication. This is clearly shown in Figure 5 where the amount of cell-associated virus increased immediately with 10,000 rads. In monolayers irradiated with 1,000 rads, the cell-associated virus continued to decrease for 1/2 hour more. In control monolayers, the cell-associated virus decreased for 1 1/2 hours and then increased. The synthesis of RNA and protein was studied using uridine and <sup>3</sup>C-protein hydrolysate incorporation, respectively. There is an identical steady increase in uridine incorporation that lasted for 3 hours in monolayers irradiated with 1,000 or 10,000 rads (Figure 6). The incorporation shown in monolayers irradiated with 10,000 rads is viral, since it was not inhibited by actinomycin D, while the incorporation shown at 1,000 rads seems to be cellular since it was inhibited by actinomycin D. After 8 hours, the uridine incorporation in monolayers irradiated with 1,000 rads decreased while that irradiated with 10,000 rads significantly increased; part of this increase could be inhibited by actinomycin D. The incorporation of <sup>3</sup>C-protein hydrolysate is shown in Figure 7. There is a large activity of incorporation in the cells irradiated with 1,000 rads, while in those monolayers irradiated with 10,000 rads the activity is significantly less. The <sup>3</sup>C incorporation activity shown in monolayers irradiated with 1,000 rads does not seem to be viral since practically no viral titer is shown at this time. The small activity shown in the monolayers irradiated with 10,000 rads is viral as shown by the infectivity titer and by the fact that it is not inhibited by actinomycin D. The results to date indicate that a protein, which inhibits viral multiplication, was synthesized by the cells that were irradiated with 1,000 rads and infected. In cells irradiated with 10,000 rads this protein is not synthesized; consequently, more virus is produced. If this protein is a product of the cell genome (interferon-like protein).

the transcription of these genes should be inhibited by actinomycin D. Therefore, actinomycin D should enhance the virus production just as irradiation with 10,000 rads. The results shown in Figure 8 demonstrate a significantly higher amount of virus in the monolayer treated with this drug as was predicted. The relative effect of radiation and actinomycin D on the uridine incorporation in chick embryo monolayers infected with Sindbis virus is shown in Figure 9, which clearly shows a higher viral activity in monolayers irradiated with 10,000 rads and treated with actinomycin D. Timing experiments in which radiation was given at different times before and after infection demonstrated that the production of this inhibitory protein is dependent on the time radiation is given in relation to infection with the virus. Radiation could be given from 2 hours before to 1/2 hour before to 1/2 hour after the infection in order to either stimulate (1000 rads) or inhibit (10,000 rads) protein synthesis. 70 ---Page Break---

‘Taking into consideration what is known in the literature and the results obtained in the timing experiments and those obtained when adding exogenous interferon to cells prior to or after irradiation and infection with virus (not shown for sake of space) an elaborate model for the interferon-regulating mechanism is proposed. (Figures 10 and 11). ‘The supporting data for the model proposed is the following: Gamma radiation (1,000 and 10,000 rads) and actinomycin D given 1-2 hours before 0.5, 1, 1.5, and 3 hours after infection induced different responses by the cells to the infecting virus. It was particularly remarkable that there was a revision from a refractory state to a more susceptible one when the chick embryo cells were treated with actinomycin D for two hours and immediately irradiated with 1,000 rads prior to infection. A similar phenomenon was also observed when the cells were irradiated with 1,000 rads 0.5 hours after infection. The results of these experiments indicate that the action of the

The interferon system can be induced or repressed effectively depending on whether the drug or a specific radiation dose was administered at a specific time before or after infection. In other words,

these agents are effective if given at a particular time when a specific gene involved in the mechanism of transcription of the messengers for the interferon system is being transcribed. Additional relevant information was obtained from monolayers treated with interferon for 2 or 18 hours and then irradiated immediately with 1,000 or 10,000 rads. When monolayers were irradiated with 1,000 or 10,000 rads 18 hours after interferon treatment, there was a reduction in the number of plaques indicating that the external interferon was active in these irradiated monolayers as well as in the controls; presumably because the genes involved in the interferon system were already transcribed. When the monolayers were irradiated with 1,000 or 10,000 rads 2 hours after treatment with interferon, the exogenous interferon was only active in the monolayers treated with 1,000 rads. These results indicate that there are genetic areas, transcribed 2 hours after treating monolayers with exogenous interferon, which are more radioresistant than those transcribed earlier after induction of the system. Physical distance or separation between genes would account for such differences. On the other hand, when cells were irradiated 2 hours prior to interferon treatment, the interferon activity was similar to that shown by the control monolayers regardless of the radiation dose, indicating that the interferon activity was carried out by the exogenous interferon, since according to the original working model, the only genes that could be affected when the system is repressed (normal condition of a negatively regulated system) are those involved in regulation and interferon mRNA transcription. The timing experiments with radiation (10,000 and 1,000 rads) and actinomycin D pointed very clearly to the existence of a critical period in the early

growth cycle of Sindbis virus multiplication in chick embryo monolayers, in which radiation can effectively influence viral replication. In other words, there seems to be a sequential series of events at the molecular level (probably at transcription) that follow immediately after radiation or viral infection, which differ in the degree of radiosensitivity. Therefore, it can be concluded that the decision of the cells to synthesize viral inhibiting substances can be effectively affected by transcription repressing agents only before or immediately after infection. There is no question that we are dealing with interferon or an interferon-like substance. The evidence obtained in the experiments with the exogenous interferon clearly indicates that a regular interferon is the one responsible for the phenomena observed in the present study. The results observed with the exogenous interferon and those obtained from the timing experiments suggest that: (a) A system identical or similar to that known as interferon is definitely involved in the increased or decreased susceptibility shown by irradiated chick cells to Sindbis virus infection, (b) The mechanism responsible for the control of the antiviral state of the cells is radiosensitive, varying in sensitivity at various stages before and after virus infection, (c) The reading of the portion of the genome that codes for the interferon-like system postulated is done stepwise in a sequential series of chronological events. (d) Apparently, the portions of the genome or set of genes being transcribed at the moment when radiation is applied seem to be more radiosensitive than genes that are not active (not being transcribed). The results obtained in the set of experiments described in this work, coupled with what is known in the literature, suggested a model that consists of a combined negative and positive regulating mechanism (Figure 10). Normally, gene I (REG) produces a repressor that does not allow the transcription of gene II.

(IF) which codes for interferon. This repressing activity of gene I maintained the complete interferon regulatory system from expression (negative control). When an exogenous inducer acts on the control region (C) of gene II, interferon is produced stimulating the transcription of gene II (TIP). When TIP is derepressed, it synthesizes the mRNA of the translation inhibitory protein, creating the viral refractory state of the cell. When a sufficient amount of TIP has been produced, the system is

stopped. The termination of transcription of genes II and III is caused by the action of a blocking protein coded by gene IV (TERM), which could act as a superrepressor on the IF repressor (gene I) or at the level of translation of IF mRNA. The existence of the TERM gene (IV) has been deduced from experiments of superinduction utilizing cycloheximide-actinomycin D treatment (Billiau et al., 1973 and Mozes et al., 1974) and from preliminary results obtained in our laboratory in which 10,000 rads applied 3 hours after infection diminished the viral yield as compared to unirradiated controls. Apparently, there's a specific repressing effect upon the interferon blocking gene (TERM) which is being transcribed approximately 3 hours after infection. (See chronology of transcriptional events in the model of Figure 10). With regard to the most probable action of radiation on the chronology of transcriptional events of the interferon system proposed in the model (Figure 11), it can be postulated that: (a) 1,000 rads given 1-2 hours before infection only destroy or inactivate gene I (regulator), which is transcribed normally by the cell constitutively. Consequently, the interferon system will be depressed. (b) 1,000 rads administered 0.5 hours after infection destroy or inactivate gene II (interferon), which is the one being transcribed. As a result, interferon will not be synthesized and there will be a reversion from the refractory state induced by 1,000 rads when applied before infection. 72 ---Page Break---

(c) 10,000 rads given 1-2 hours before infection or 0.5 hours after enhanced Sindbis virus infection, the gene II that codes for interferon is shut off completely, thus shutting down the interferon system. (a) 10,000 rads given immediately before treating the monolayers with exogenous interferon for 2 hours and then infecting with Sindbis virus did not destroy or inactivate gene III, since added interferon was active in the irradiated monolayers. (e) 10,000 rads administered 2 hours after treatment with exogenous interferon destroyed or inactivated the gene that codes for the mRNA of the translation inhibitory protein (TIP) that blocks the translation of viral protein, since the added interferon was not active. (8) 10,000 rads administered 3 hours after infection destroyed or inactivated gene IV (TERM). Therefore, a state of superinduction is established; more interferon is produced, and the refractory activity of the cell to the virus will be greater. (G) Gene III is more radioresistant than genes I and II since even when 1,000 rads are given at the time it (Gene III) is being transcribed, it is not affected. (h) Actinomycin D applied 2 hours before or 0.5 hours after infection represses the interferon action, allowing more viral multiplication. Actinomycin D reverses the enhancing effect of 1,000 rads on interferon synthesis. However, when given 3 hours after infection, it can create a superinduced state, but this state was not observed in our system since IF is not active in the presence of Actinomycin D. As mentioned above, genes I and II, which appear in the left arm of the DNA molecule illustrated in the model (Figure 11), seem to be more radiosensitive than genes III and IV, gene III being the most radioresistant. Moreover, the whole genome that codes for the interferon system seems to be radiosensitive at the moment when the genes are being actively transcribed. This change in radiosensitivity could be caused by: (a) loss of the histone protective layer, (b) more exposure when the DNA molecule is uncoiled, since it has been suggested that the DNA molecule changes.

from a condensed, coiled structure to a stretched uncoiled one during transcription (Clever 1968), (c) rich areas of A:T nucleotide pair, (d) smaller size of the more radioresistant genes, and (e) physical distance or separation between genes. For example, it appears that genes III and IV belong to a different battery of structural genes, that is, if we assume that the Britten and Davidson (1973) model is correct. In general, it can be stated that the model proposed in the present work to explain the experimental data is a composite of the operon-lac described originally by Jacob and Monod (1961), the regulatory mechanism described for fungi (see text), and the model more recently postulated by Davidson and Britten (1973 and 1974) for eukaryotic cells. 3 ---Page

Break--- Figure 4. Effect of different doses of radiation (1,000; 10,000; 25,000; 50,000 and 100,000 rads) on the multiplication of Sindbis virus in chick embryo monolayers: Twenty-four-hour-old chick embryo fibroblast monolayers seeded with  $4 \times 10^6$  cells per ml were irradiated with 1,000; 10,000; 25,000; 50,000 and 100,000 rads 1-2 hours before infection with Sindbis virus at a multiplicity of infection of 0.1. The monolayers were washed 3 times before and after infection and lact-calf serum added before incubation at 37°C in a CO2 incubator. The extracellular virus was titered at the indicated times.

---Page Break--- Figure 6. Adsorption and multiplication of Sindbis virus in chick embryo cell monolayers irradiated with 1,000 and 10,000 rads. Twenty-four-hour-old monolayers were irradiated with 10,000 and 1,000 rads 1-2 hours before infection with Sindbis virus at a multiplicity of infection of 50. Immediately after adsorption, the monolayers were washed 8 times with Saline A and growth medium added before cultures were incubated. Samples were taken at the indicated times, the monolayers washed 3 times with PBS and the cell-associated titer was determined,

z = « ° c w ° © 10,000 RADS + SINDBIS VIRUS > ". IS 1,000 RADS + < " 5 SOT © RADS + . A IH 4 POG ' 2 3 4 HOURS AFTER INFECTION 75

---Page Break--- Figure 6. Comparative effect on <sup>3</sup>H-uridine incorporation in chick embryo monolayers irradiated (1,000 and 10,000 rads) and infected with Sindbis virus: This figure presents the results from figures IX and XII for comparison purposes. In both irradiated groups, the irradiation was done 1-2 hours before infection, and the radioisotope was added 1 hour after infection. The amount of incorporation is expressed in percentage from the non-infected group which was taken as 100%. PERCENT OF <sup>3</sup>H-URIDINE INCORPORATION 100 % (NON-INFECTED CELLS T i ° . / N\ ROL / '4 4 100 | /\ A 60 R 4 "LE 4o-----\* INFECTED CELLS 4 OO -« L " + 1,000 RADS o——o . " + 10,000 RADS C 3H-URIDINE ADDED HOURS AFTER INFECTION 76

---Page Break--- Figure 7. Comparative effect on the "C-protein hydrolysate incorporation in chick embryo monolayers irradiated (1,000 and 10,000 rads) and infected with Sindbis virus: This figure presents the results from figures X and XIII. In both irradiated groups, the irradiation was done 1-2 hours before infection and the radioisotope was added 1 hour after infection. The amount of incorporation is expressed in percentage from the non-infected unirradiated group, which was taken as 100% —T oT oO ooo r - 5 = Hen 7 INFECTED CELLS s ° . e i «+ 1,000 RADS S\$ WL O\_O . «+ 10,000 RADS B & A . ~ XZ 8 OL 1 EG A 53 A4 3D 28 > 100 7 S100 | = Ww zo g OP CE 52 ZZ 80 71 AST É I. 5 OOL 1 Z 14, Z ERAN J 8

HYDROLYSATE & PEW 4 SL FOM HOURS AFTER INFECTION 7 ---Page Break--- Figure 8. Effect of actinomycin D on the multiplication of Sindbis virus in chick embryo cells:

Twenty-four-hour old chick embryo monolayers were treated with actinomycin D for 2 hours (2 µg/culture). The monolayers were washed 3 times with PBS and infected with Sindbis virus at a multiplicity of infection of 50. Untreated monolayers were inoculated at the same time as control. After an adsorption period of 30

minutes, the virus inoculum was removed and the monolayers washed 3 times with PBS. To the actinomycin D treated group, fresh amino acid-deprived medium containing 2 µg/ml of the drug was added and maintained throughout the entire sampling period. Amino acid-deprived medium without the drug was added to the control group. Cell-associated virus was titrated at the indicated times.

Infected Cells PLAQUE FORMING UNITS PER µL Infected Cells + Actinomycin D HOURS AFTER INFECTION 78 ---Page Break--- Figure 9. The effect of actinomycin D and 10,000 rads on <sup>3</sup>H-uridine incorporation in chick embryo monolayers infected with Sindbis virus: Twenty-four-hour old monolayers were treated with actinomycin D (2 µg/culture) for two hours and immediately irradiated with 10,000 rads. Two hours after the irradiation, half of the monolayers were infected

with Sindbis virus at a multiplicity of infection of 50. The remainder half served as uninfected control. After an adsorption period of 30 minutes, all the monolayers were washed 3 times with PBS, amino acid-deprived medium containing 2 µg of actinomycin D per ml plus 0.25 Ci of <sup>3</sup>H-uridine was added and incubated at 37°C. Monolayers not treated with any agent were also included. The amount of incorporation is expressed as a percentage of the non-infected, unirradiated cells, which was taken as 100%. Infected Cells + Actinomycin D + 10,000 Rads Non-infected cells + Actinomycin D + 10,000 Rads

PERCENT OF <sup>3</sup>H URIDINE INCORPORATION (UNINFECTED CELLS 100%) HOURS AFTER INFECTION

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Figure 10. Normal function of the proposed interferon regulatory genetic system: Gene I (REG) produces a repressor (r©) constitutively, that does not allow the transcription of gene II (IF) which codes for interferon. This repressing activity of gene I maintained the complete interferon regulatory system from expression (negative control). When an exogenous inducer acts on the control region (C; ) of gene II, interferon is produced stimulating the

transcription of gene III (TIP). When TIP is derepressed, it synthesizes the message of the translation inhibiting protein, creating the viral refractory state of the cell. When a sufficient amount of TIP has been produced, the system is stopped. The termination of transcription of gene II and III is caused by the action of a blocking protein coded by gene IV (TERM), which could act as a superrepressor on the IF repressor (gene I) or at the level of translation of IF mRNA. ---Page Break---

Figure 11. Effect of radiation on the proposed interferon regulatory genetic system. Probable action of radiation on the chronology of transcriptional events of the interferon system: (a) 1,000 rads given 1-2 hours before infection only destroy or inactivate gene I (regulator), which is transcribed normally by the cell constitutively; (b) 1,000 rads administered 0.5 hours after infection destroy or inactivate gene II (interferon), which is the one being transcribed; (c) 10,000 rads given 1-2 hours before infection or 0.5 hours after, destroy or inactivate gene I (regulator) and gene II (interferon), shutting off completely the interferon system; (d) 10,000 rads administered 2 hours after treatment with exogenous interferon destroy or inactivate gene III, since it was being transcribed at the moment of irradiation; (e) 10,000 rads given immediately before treating the monolayers with exogenous interferon for 2 hours and then infecting with Sindbis virus did not destroy or inactivate gene II. Gene III was more radioresistant since it was not being transcribed at the moment of irradiation; (f) 10,000 rads administered 3 hours after infection destroy or inactivate gene IV (TERM), and a state of superinduction is established; (g) Gene I is more radioresistant than gene II and III since when 1,000 rads are given at the time it is being transcribed, it is not affected.

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Education and 'Training of Graduate Students. Master Thesis Completed: 1. Detection of Herpes Simplex Virus Type 1 and 2 in Human Extoli

Epithelium by Virus Isolation and Immunofluorescence Techniques — Robert Saylor. re Vaginal 1974. 2. The Effect of Gamma Radiation on the Multiplication of Sindbis Virus in Packed L-Cells Monolayers — Ann Sukri-1974. Master Thesis in Progress: 1. Interferon Production in Viral Induced Mutated L-Cells — Mercedes Rodrigues, Sindbis Virus in Chronically Infected L-Cells — Nitza M. Davila, 2. Multiplication of 3. Metabolic Changes on Polyoma Transformed Cells — Sandra M. Ph.D. Thesis 1. The Effect of Radiation on Infected with Sindbis Virus — Eddy Rios Olivares 2. Effect of Radiation on Dengue Virus-Host Relationships — Luis Torres Baus 3. Genetic Studies of the Microsporium Gypseum Complex at the Molecular Level — José A. Carrasco. on the Synthesis of Macromolecules on Chick Fibroblast TRAINING ACTIVITIES Research activities in Schistosomiasis, Fascioliasis, and Virology served as the basis for the training activities of the Biomedical Sciences Division. A summary of these activities during the period of January 1974 through June 1975 is presented in Table 2 STAFF ACTIVITIES Retirement of Dr. Frederick F.

Ferguson: After several years with the Biomedical Sciences Division as Consultant and part-time Director, Dr. Ferguson passed the role of Division Head to Dr. William R. Jobin in February 1975. Dr. Ferguson continues to serve as informal advisor to the Nuclear Center and pursues various subjects of interest as time allows. He has considerable influence in encouraging students and young scientists in the study of biological methods for pest control and it is hoped that this informal relation with the Nuclear Center will continue for many years. In March, Dr. Jobin attended a conference in St. Lucia, Eastern Caribbean, on developing a plan for research activities by the Edna McConnell Clark Foundation as part of their schistosomiasis program. 82 ---Page Break---  
'Table 2: 'Training Activities of the Biomedical Sciences Division, January 1, 1974 through June 20, 1975. 'Subject 'Thesis Rear: PRD. Medical Zoology.

PRD. Microbiology PRD. Biochemistry MS. Microbiology M.S. Biochemistry MS. Anatomy MS. Biology Training Facilities Fuel Contaminants Meme Félix Lard Bertin ost Carano Canales Edie Rios Otraree ais. Torres Bas Robert R. Saylor Mercedes Rodrigues Carmen €. Vivero Genaro Ortiz, Sout Lae Tones Coe Eduardo Darin Sone Edeimira Maya 'Ana del Lan Gace de Sse Zavala out A Ator Ores {ie Pier Dr. Néstor Cordon Vici M. Vetnguee agar M. Maldonado Angel Laracuenta Yolends Mendoss Santiago ML Quibones Shin Barc Hast A Ri Laila Mitagros Veter Ruben Die aan D. Miranda De. deine A. Rodrigues Hector L Rodriguer Wands R. Ramee Dr. Francisco L- Fuch Soares Dr. Gilbert Sincher Liane Poss. Freddy Medi owe M. Die tein Vidal Cabrera, Justo O. Ramer 'ida Livia Enid Acosta 'Ange Laracuenta Socorro Rivers dorge L, Meténder 'Ana L. Rodrigues Lynnette Oliver Nita M. Diva Mercedes Redriquer Lie Tors aes ames Roig Michael Urvin 83 dy 197 — June 30, 1973 Saly 1973 — June 30, 1975 4 = June 30, 1978 Sy 1978 hog. 41974 ly 1823 Aug 1974 am. 1978 ~ June 20, 1925 'apa 19% 1 ~ June 39, 1955 June 30, 1935 ane Sepb. 1971 © Dec. 81, 197 'Aug. 19. — Aug. 28,1 Shoe, 1874 — June 39,195 = My 18, 1974 dupe 1.1974 Stay 3, 1974 Mey 3, 1074 1978 shine 30, 195 July 1971 Avg. 16,1975 'hn. 1925 May 30, 1978 July 1974 - Sept., 1974 'Aug 1974 Sept." 1924 thn 1974 June 30, 1974 Jan. 1974 ~ June 30, 1924 in 1974 ~ June 20, 1 Shin 1974 — May 81, ton Shin. 1074 ~ June 30, 19 Sin. 1974 — June 30, 1978 Feb, 1974 — May 21, 1974 Apr. 1978 ~ June 20,1978 Shine 1974 = Aug. 18,1924 'Rog. 1974 ~ Dec. 20. 1974, 'Rog. 1874 ~ Dec. 20, 1974 'hog 1874 — Dec. 80, 1974 June 12, — June 30, 19 'June 9,7 — June 20,1978 ---Page Break--- The A-frame and winch apparatus aboard the R. F. Palumbo used in marine ecology studies. ED. Wood, assisted by technicians, readies a water sampling bottle which will be lowered into the sea off the west coast of Puerto Rico. ---Page Break---  
ENVIRONMENTAL SCIENCES MARINE ECOLOGY In July, 1975, the name of the Division was changed from Radioecology to Marine

Ecology. 'The Division provides centralized administrative and logistic support to its programs and projects, including the research vessels R. F. Palumbo and the Sultana. The Sultana, used in environmental impact studies, belongs to the Puerto Rico Water Resources Authority. 'There have been eleven research programs and projects in progress. These are: the Marine Biology Section Projects, Bikini Atoll, Terrestrial Ecology, Mariculture, Fish and Oyster Culture, Shrimp Culture, and the Jobos Bay, Islote and Site Selection environmental impact studies. The Guayanilla Bay and La Chalupa Mission No. 12 projects, sponsored by the Puerto Rico Water Resources Authority, have been completed. The other PRWRA-sponsored projects on Jobos Bay and Islote, and the Site Selection Survey, terminated on June 30, 1975. RESEARCH COMPLETED Guayanilla Bay Project — F. D. Martin and Staff. In 1971, research was begun to obtain baseline data applicable to thermal tolerance studies in Jobos Bay. The effects of high temperatures on zooplankton, benthic organisms, mangrove root communities, algae, and fish were investigated. The results are published in "PRNC-179, Puerto Rico Nuclear Center Guayanilla Bay Environmental Report,

1971-1974." La Chalupa Mission No. 12 — R. Castro, P. H. Davis, J. J. Kimmel, T. W. Purcell and J. A. Rivera. In June 1974, a research mission utilizing the underwater habitat, La Chalupa, was completed. The study site was located 900 meters off the north coast of Puerto Rico in 22 meters of water. A team of two invertebrate zoologists, one ichthyologist, and one phytoplanktologist observed the area and collected samples for 16 days. The results of the mission, and an evaluation of an underwater habitat as a survey tool, are published in "PRNC-178, La Chalupa Mission No. 12 Final Report (March 1975)." Mariculture Fisheries Development Project — K. Watters. The project was undertaken as a joint study of the University of Rhode Island's International Center of Marine Resource Development and the Radioecology Division.

of the Puerto Rico Nuclear Center, and was carried out at Mayagüez, Puerto Rico. The work was funded by the National Science Foundation, and the following objectives were fulfilled: (1) The existing harvest fishery and mariculture potential of Puerto Rico was reviewed, (2) Ways were identified to fully exploit this potential, (3) The technology available for fulfilling the potential was identified, as well as problems in applying the technology, and (4) Methods were suggested for the optimum development of fisheries and mariculture in Puerto Rico. 85 ---Page Break--- 'Studies on the Commercial Rearing of the Giant Prawn, *Macrobrachium rosenbergii* (de Man) in Puerto Rico — Vincent Price, (Stocking densities in earthen ponds and nutritional studies of the Giant Freshwater Prawn, *Macrobrachium rosenbergii* — July 1, 1974 to June 30, 1975). A comparison between two stocking densities of *Macrobrachium rosenbergii* in earthen quarter acre ponds (supplied with well water), showed that after six months of growth the two ponds stocked at a density of two juveniles per square foot produced 11 and 26 pounds each, weighing around 10 per pound (whole weight). The two ponds stocked with one juvenile per square foot produced 31 and 43 pounds each, weighing 8 per pound. In these single stocked ponds, however, production declined rapidly and after five months were producing 14 and 27 pounds at 6-8 per pound. The double stocked ponds increased their production and were producing around 40 pounds at 6-8 per pound. A predominant submerged aquatic plant, *Najas guadalupensis*, was consumed by prawns in a two and a half month nutritional experiment in 500-gallon tanks. Prawns which consumed it solely had a 16% survival rate. Those fed *Najas* plus "Broiler Starter" had a survival rate of 80%, but those fed "Broiler Starter" alone had a survival rate of 96%. A statistical analysis indicated that either carapace length or total length could be used as accurately as the other. Toxic Metals in the Atmosphere — F. Muñoz Ribadeneira, T. Mo,

and M. J. Canoy. 'Three studies were made. The first was concerned with the metallic elements Ni, V, Mn, Sb, Se, Hg, Pb, Cd, and Cr. The instrumental neutron activation analysis (INAA) methods being adopted and developed in the PRNC laboratory are described. 'The second study focused on the determination of concentrations of Cr, Mn, Co, Ni, Cu, Zn, and Pb by Atomic Absorption Spectrophotometry (AAS). Methodology was developed for the preparation of air filter paper tape samples for AAS and an inventory of metal concentrations in the aerosols retained by filter paper tapes at different sampling stations. The third study investigated the actual concentration of toxic metals in the atmosphere at six selected sites throughout southwestern Puerto Rico. 'The results of the first study, and summaries of the latter two studies, previously reported in full, are published in "PRNC-186, Toxic Metals in the Atmosphere (May 1975)." RESEARCH IN PROGRESS This program has been directed primarily toward the cycling of radionuclides and trace metals in the marine environment and coastal watersheds. In July 1975, the aims of the program will be expanded to include studies of the impact of oil refining and electrical power generation on the water quality and ecology of tropical marine communities. Studies on the impacts of pollution upon marine communities are a natural outgrowth of past environmental assessment studies done by the

Environmental Sciences Division for power plant siting in Puerto Rico. 86 ---Page Break--- MARINE ECOLOGICAL AND POLLUTION STUDIES Zonation of Organisms in Red Mangrove Swamps of Puerto Rico — S. B. Kolehmainen, W. Hildner, and M. D. Banus. On the south and west coasts of Puerto Rico, red mangroves, *Rhizophora mangle*, constitute over 90% of the trees. Black mangroves, *Avicennia nitida*, and white mangroves, *Laguncularia racemosa*, comprise the other 10%. The swamps have little fresh-water run-off and salinities range normally from 35 ‰ to 40 ‰. In spite of the small range of tides (20-30 cm), there is

a definite zonation, both vertical and horizontal, of organisms in the mangrove swamp. On the water's edge, prop roots have a diverse community of sessile organisms with up to 100 species belonging to 11 phyla. Several species of fish feed in this zone, including *Lutjanus*, *Haemulon*, and *Anisotremus*. This zone is about 2 meters wide. Behind this zone, there is a zone which contains an intertidal alga "Bostrychietum" which often ranges all the way to land. This zone is characterized by subdued light. "Bostrychietum" cannot survive direct sunlight and resulting dehydration. However, this alga is sometimes absent if there is insufficient light. This zone has a few species of mollusks (*Littorina*, *Murex*), crabs crawling on the roots (*Aratus*, *Goniopsus*, *Clibanarius*), and burrowing crabs (*Eurytium*, *Ocides*, *Sesarma*). Many fish species use this zone for hiding and feeding. On sandy beaches, red mangroves extend all the way to the supralittoral zone, but in these areas, the swamp is usually less than 20 m wide. In areas where the swamps are extensive, there is an intertidal mudflat behind the red mangroves. This mudflat zone has scattered red, white, and black mangrove trees. In the tidal pools and salterns, fiddler crabs (*Uca*), brine shrimp (*Artemia*), and insect larvae (*Ephydra*) are found. Behind the intertidal mudflat zone, there is a transitional zone characterized by occasional mangrove trees and halophytes. Animals here include crustaceans (*Uca*, *Cardisoma*, *Sesarma*) and mollusks (*Melampus*). Species diversity and biomass of macro-organisms have been studied in these zones in several mangrove swamps in Puerto Rico. The zonation of sub-communities has been related to environmental parameters. Mangrove Root Communities in Thermally Stressed Areas — E. Kolehmainen, T. Morgan, and R. Castro. Studies were conducted on zooplankton, micro and macro-benthos, turtle grass (*Thalassia testudinum*) beds, mangrove communities, and fish fauna in the vicinity of a 310-MW fossil fuel power-generating plant that has been operating for two

decades near Guayanilla Bay. The temperatures in the heated effluent vary from 35°C in the winter to 40°C in summer. This is about 10°C above ambient water temperature. In addition to elevated temperatures, organisms in Guayanilla Bay are exposed to hydrocarbons and heavy metals discharged by nearby petrochemical and chemical plants. The additional effects of elevated temperature on organisms were determined by comparing communities in the thermal plume to those near the cooling water intake area. These were surveyed in all of the environmental impact studies projects, which have the same chemical pollutants as the plume but do not have elevated temperatures. Results indicate that about 95% of zooplankters were killed in the condensers and in the discharge canal. Further mortality occurs in the plume 100 m from the mouth of the discharge canal. At this point, temperatures are still 8°C above ambient. At temperatures between +1°C and +6°C, species diversity and biomass were higher than at ambient temperatures. This was assumed to be a result of increased nutrient content of water due to decomposition of the killed plankton. During a period when large volumes of water at ambient temperatures were pumped through a new power generating unit, it was observed that most of the mortality was due to the relatively long exposure (14 minutes) to the elevated temperatures in the discharge canal rather than the short (4 s) exposure in the condensers, or mechanical damage in the water pumps. Among the meiofauna, the species diversity of foraminifers was lower in the thermal plume than in control areas. Benthic



nematodes were nearly non-existent in the bay. It appears that nematodes are very sensitive to chemical pollutants while benthic foraminifers seem to be protected against chemicals by their shells. Benthic macroorganisms were not found on the bottom in areas where water temperature was 5°C above ambient. Species diversity and biomass of sessile organisms living on the prop roots of mangroves.

were not affected below 34°C. 'Table 1: Number of Species and Water Temperatures at Eight Mangrove Root Sampling Stations in Guayanilla Bay Station Control Water Temp. °C 30 31 31 34 35.5 36.7 Algae Species 6 3 5 8 7 4 5 58 Invertebrate Species 9 4 7 6 5 2 10 'Total (all species) 96 48.75 Biomass of this community was highest between 36°C and 37°C and the number of species was inversely related to the temperature above 35°C. Despite the chemical pollutants, there were more species living on the prop roots in Guayanilla Bay at the control area than in Jobos Bay which is without high levels of pollution. Species diversity of fish in the heated area of Guayanilla Bay was similar to that of the inner, turbid part of Jobos Bay. The number of fish species in the heated areas was 28 compared with 53 in the control area. 'The species most tolerant to elevated temperature were blue-green algae, mangrove trees, certain molluscs, crabs and fish, all of which had populations living at 37°C or higher. 'The most sensitive organisms were red and brown algae, coelenterates, and echinoderms. 'Thermal maxima of individual species were 1 to 2°C higher than reported for the same species in the subtropics. 89 ---Page Break--- 'Table 2: Biomass of Organisms on Mangrove Roots at 8 Sampling Stations in Guayanilla Bay Biomass (wet) Control 1 28 5 6 7 Algae 16 15 23.4 9.3 0.8 0.6 1.2 Porifera 55.6 4.6 14.7 5.0 Coelenterata 2.2 7.0 27.2 18.1 3.4 0.5 0.2 Mollusca 98.1 15.4 9.0 7.0 1.3 6.3 62.6 Cirripedia 5.09 3.34 1.18 3.77 0.75 8.0 2.2 1.81 Other Crustacea 6.9 0.6 2.9 9.4 7.0 0 Bryozoa 5.16 0.4 0.3 0.5 0 Echinodermata 0.3 1.0 0.08 Chordata Ascidiacea 48.0 28.3 40.7 26.8 6 36.7 'Total biomass (wet weight) per root 240.0 90.41 179.6 184.0 205.7 114.1 651.1 14.4 One standard deviation 13.0 12.01 4.85 4.16 5.4 3.24 10.86 2.81 Biomass (wet weight) per root, 38.7 6.76 26.4 27.0 3.74 25.4 7.98 0.41 One standard deviation 1.15 2.67 0.64 0.61 1.00 0.72 1.27 0.08 'Mangrove Roots Communities in a Polluted and an Unpolluted Bay — S. E. Kolehmainen, W.

Hildner, J. Rivera, Jobos Bay, on the south coast of Puerto Rico, had been receiving sugar mill effluents until 1972 and some domestic sewage but, for the most part, the bay is unpolluted. In 1973, a 900 MW(e) fossil fuel plant was put into operation. A mangrove swamp along the shores covers an area of 820 hectares and this is one of the largest mangrove swamps in Puerto Rico. Guayanilla Bay, also on the south coast, once was similar to Jobos Bay ecologically, but industrial development has significantly changed the topography and marine communities. On the eastern shore of the bay, there is a 1100 MW(e) fossil fuel plant that discharges heated effluents at 40°C. In addition to the heated water, Guayanilla Bay receives inorganic chemical and petroleum pollutants from nearby oil refineries and chemical plants. Mangroves now cover only about 20 hectares in the eastern part of this bay. The number of species on the mangrove roots at different stations in Jobos Bay varied from 27 to 86. The total number collected at all stations was 161. Distribution among the different phyla is shown in Table 3.

Table 3: Number of Species of Mangrove Roots in Jobos Bay and Guayanilla Bay

Common Species  
 Pecopteris 6  
 Coelenterata 5  
 Beroe 8  
 Platyhelminthes 7

Mangrove root communities in Guayanilla Bay reflect long-term effects of elevated temperatures and water currents. The number of species has decreased with increased temperatures and currents. The distribution of species between the different phyla is given in Table 3. During the winter months when the temperatures in the heated plume drop below 35°C, many heat-sensitive organisms establish colonies on the roots. As the water temperatures rise towards the summer, these species die in Thermal Cove. The total number of species was slightly higher in Guayanilla Bay (172) than in Jobos Bay (161). Jobos Bay had more than double the number of macroalgae as.

Guayanilla Bay, but the latter bay had twice the number of molluscs and bryozoans. The numbers of species in other phyla were similar in both bays (Table 3). The biomass of organisms living on mangrove roots in Guayanilla Bay was affected by the temperature and water currents. The lowest biomass, 14 grams per root, in summer 1971, was in the area of the mangroves subjected to the highest temperatures. In this area the water currents came from the discharge canal directly into the mangroves at a high velocity. All the stations outside the cove had a biomass between 200 and 300 grams per root. Organisms living on the mangrove roots had a distinct zonation both in species distribution and biomass caused by the light, tidal range, and competition. A majority of the organisms were 20 - 50 cm below the mean water level. The Effect of Thermal Stress on Mangrove Seedlings — M. D. Banus and S. E. Kolehmainen, At Guayanilla Bay, on the south coast of Puerto Rico, a fossil fuel electric generating station of about 1100 MW(e) has a “once-through” cooling system which uses coastal sea water. The discharge canal enters a nearly enclosed lagoon of about 900 m length. The major portion of the shoreline of this lagoon and adjacent shore is a mangrove swamp of about 20 hectares dominated by red mangroves *Rhizophora mangle* L. with a minor population of black mangroves *Avicennia nitida* Jacq. and white mangroves *Laguncularia racemosa* Gaertn. The waters from this lagoon exit via a channel approximately 40 m wide and 5 m deep (Fig. 1). Figure 1: Plan of Guayanilla Bay thermal cove, site locations are underlined numbers. Water temperatures for April 1974 are compared with temperatures for October 1971 (in parentheses). The topography of the lagoon and the behavior of the thermal plume in 1971-72 have been described. At that time the power plant had a capacity of 710 MW(e). The increased thermal load has been handled by increasing the cooling water flow so that the temperature at the

discharge has not risen above the 40°C observed in 1972. However, the increased volume of heated water has altered temperature gradients in the lagoon, water currents, and stress on mangroves. In 1972, only mangroves near the discharge canal were subject to water temperatures as high as 38°C and showed evidence of serious stress. The major portion of the surface waters in the cove were 4 to 5°C below the discharge temperature. Early in 1974 the red mangroves along most of the shoreline of the lagoon were under serious stress and many were dying. Signs of stress included larval numbers of aerial roots, loss of leaves so that only the terminal leaves remained, smaller leaves, leaves with greyish-green coloration instead of clear, dark green, and small, scarce seedlings. Red mangroves expand and replace themselves by dropping viviparous seedlings into the water. It is important to know if the seedlings from these thermally stressed trees would float, rotate, form roots, and grow in a manner which would permit replanting and regeneration of the mangroves. When mangroves are stressed to the point of dying, there are two possibilities for seedlings to replace the dying trees: (1) seedlings from stressed trees may remain in the stressed area and grow; and/or (2) seedlings from non-stressed trees may enter the stressed area and grow. Since the water entering the “thermal” lagoon enters either through the power plant cooling system or as a deep countercurrent through the mouth of the lagoon, unstressed seedlings cannot enter

the lagoon. Furthermore, the prevailing northeast and southeast winds blow seedlings out of rather than into the lagoon against the current. If the stressed mangrove swamp is to survive, replacement trees must grow from seedlings from the stressed trees. When the seedlings fall, they land in relatively deep (0.5-1.0 m) water of the outer Prop Root zone or between the roots in shallow water. Here they may plant themselves, but the low light level discourages growth of new trees. Those that

Land in water deep enough to float are carried deeper into the mangrove swamp or out of the area, depending on tidal currents. A baseline study on the behavior of mangrove seedlings was made using seedlings from an unpolluted, unstressed area, Pta. Ostiones, and observing them in a series of experiments in the lagoon and in the laboratory in order to obtain detailed information on the rate at which mangrove seedlings rotate from horizontal to vertical floating positions, the rate of root formation, the rate of early growth and leaf formation, and the effect of sunlight or shade on these rates. Most of the work was carried out in cages in the Pta. Ostiones lagoon. Similar experiments were made in laboratory tanks to see if the same data could be obtained under laboratory conditions. Large groups of representative ripe seedlings were collected from the trees at Pta. Ostiones, at Boqueron Bay, and later at several places in Guayanilla Bay. The seedlings were weighed, measured, and batches of 100 observed in net cages 4' x 4" x 4' suspended in lagoon water. They were observed daily at first, then bi-weekly, and finally weekly to determine floating angle, buoyancy, root and leaf formation. The data were recorded as percent of batch with the given attitude as the number of days from the start of the experiment. The temperature and salinity of the seawater were also recorded along with water depth. The results of the baseline experiments showed that newly fallen seedlings almost always floated horizontally in seawater. In sunlight in the control lagoon, they all assumed vertical floating positions (Fig. 2) in 10 to 30 days, although many rotated on the first day. Fig. 2: Position of mangrove seedlings in water with increased time for release from the trees, MANGROVE SEEDLINGS LAGOON BEHIND PTA. OSTIONES. BATCH 3 BATCH BATCH 0. Horizontal, + x Vertical. The amount and intensity of sunlight affected this behavior. In the shade, about one-half of the seedlings remained floating.

horizontally for several months. Seedlings formed roots when floating both horizontally and vertically. Initial root development was more rapid for seedlings that floated in the sun. The percentage that had roots versus time in seawater was reproducible from batch to batch (See Fig. 3.) After several months of floating, secondary roots formed, and the root system accumulated algae and sediments. The formation of the first leaf pair occurred after 40-50 days, and the percentage with leaves versus time was also reproducible from batch to batch. Apparently, the initial leaf pair growth was not dependent upon the rooted seedlings being planted in mud. Seedlings floating with their tips 10-20 cm below the surface still formed leaves, but the leaves remained small. In the shade, leaf formation was delayed, and no leaves appeared for 3 months.

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Fig-S: Root development in mangrove seedlings with increased time after release from the a 3 8 % 4 a @ x4 0 | ° ° o \_ ga ° ee avs. The present data on seedlings in the sun agree with the rotation, rooting, and growth behavior of Florida mangrove seedlings reported by other authors. The present data do agree with reports of other authors that contact with a substrate is important for the formation of roots. To the contrary, both in laboratory tanks and in cages in the lagoon, substantial root growth was observed on seedlings that had no contact with a substrate. Light intensity does, however, appear to be a factor. Horizontal floating seedlings rooted faster when in the shade, while vertical floating seedlings rooted first in the sun. Thus, there appears to be an optimum light intensity for root formation.

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zone of mangrove development in an area of Puerto Rico as discussed in the study of the rotation, rooting, and growth of red

mangrove seedlings. The important features include: turtle grass bed in shallow water; young seedlings with 2-4 pairs of leaves; small trees 9-5 years old with initial prop roots; a large bushlike tree about 1.3 m tall; and the coastal

mangrove at left which supplies the seedlings ---Page Break--- ‘Mangrove seedlings grow well in laboratory trays in sea water of 30-87‰ salinity. ‘The seedlings grew until they had 6-10 leaves and some had 2-4 branches. They were later transplanted to the thermal and control lagoon. However, there was 100% loss of leaves in both locations so that transplant stress appears to be at least as large as thermal stress. ‘The temperatures at various times in Guayanilla Bay are listed in Table 4. The 1971 and 1972 readings were taken before the recent power units were in operation. Table 5 lists average monthly temperatures in the experimental cages at Pta. Ostiones lagoon. The salinities at the cages varied from 26‰ to 20‰ in the fall (rainy) season to 34‰ to 36‰ in the late spring (dry) season. The salinities in Guayanilla Bay are 34‰ to 36‰ all year because the bay is not affected by large freshwater inputs. SSO ‘Table 4: Daytime Water Temperatures in Guayanilla Study Areas, °C ————\$ arrival Study zones, °C Date Intake Discharge Site 1 Site 2 Site 3 Site 4 Site 5 Site 6 oO a » » = BS van 285 2 2 ez Rx cc) ere “ 35 me wo 2» 2 oct. 428 2s BS SS van 75 26 6 » aS HO a fe har. 758 Ea ” uM» a # + Refer to Figure 1. One large unit of plant not operating Table 5: Average Monthly Water Temperatures, °C, at Experimental Cages at Pta. Ostiones Month Feb June July Aug Oct. Nov-Dec 7 3% M 2 Mw BB (Max. in afternoon) Nighttime (Hine near midnight) 26 27,29 8225s ‘of daytime high temperatures and nighttime low temperatures which were constant for several hours. For the initial evaluation of thermal stress, seedlings from thermally stressed trees from two locations in Guayanilla Bay and from a non-stressed area in the west of the bay were collected and measured. Their floating angles, buoyancy, rooting and leafing rates were observed in the cages at Pta. Ostiones and compared with new control batches. ‘The mean lengths and weights of seedlings collected in the thermal lagoon and from other areas are listed in

Table 6. These data show that the seedlings from the heated lagoon were significantly smaller. Collections “Guay.t1” and “Guay.H2” had many small seedlings, 18 to 19 cm, a maximum number between 20 to 25 cm, and few above 30 cm. Seedlings from non-heated areas had few lengths below 20 cm, most lengths were between 25 and 32 cm, and some lengths were up to 45 cm. Batch “Guay.S5” from site 5, with temperatures about 3°C above ambient, showed a more even size distribution with few seedlings below 17 cm or above 30 cm.

Table 6: Description of Seedling Batches used in Cage Experiments, seedling length, and eight, and water source:

Batch Name	Source	EC (dS/m)	Length (cm)
Guay.mS	Heated Lagoon	5-7	1a?
GuayML	Heated Lagoon	5-7	BRA
GuaySne-S	Heated Lagoon	5-7	102024
GuayHeL	Heated Lagoon	5-7	0832S
Guayantanwest	4S	7284	89a
PLO.Control 1	Pea, Questions 6-8	100A	
PeOucontrol 2	Pea, Questions 6-8	OT	EBA 5.0
MOcontrol 3	Pa: Questions 6	12D	S824
Lak fq.control 15			

Collections Guay.Mt and Guay.t2 were split into large (L) and small (S) batches at 21 cm. The size of the seedlings may be related to the size of the trees which produce them; larger trees may produce larger seedlings. Size of trees, estimated using a 4 m pole, are included in Table 6. The seedlings of the two large samples from the trees between site 2 and 3, which were 5 to 7 m tall, were significantly smaller (mean lengths 21.8 and 20.6 cm) than those from somewhat shorter trees (5 to 6 m) of site 6 (mean length 27.7 cm) but which did not show stress. Similarly, the seedlings from the mouth of Rio Yauco, which came from trees that were as much as 15 m tall (some of the tallest and best appearing mangroves in southern Puerto Rico), had about the same mean length as seedlings from Boquerón Bay and Pta.

Ostiones were the trees were substantially shorter. Therefore, thermal stress appears to be the principal cause of the smaller size of seedlings. Initially, most seedlings from all samples floated horizontally as had been found in the baseline studies. They rotated normally and over 90% were vertical in 10 to 20 days, depending on the month. However, from stressed trees a larger percentage developed negative buoyancy than from control trees. The length of seedlings did not affect this behavior. The data could not be used after about 50 days because of the larger quantities of firmly attached epiphytes on the seedlings. Control batch "Guay. Amb" had a substantially lower percentage of negative buoyant seedlings than any other batch. The relationship between root development and time is shown in Figure 4 for seedlings from Guayanilla. The new batches from Pta, Ostiones, and Boquerón Bay had no seedlings with roots until after 10 days, consistent with baseline observations. The seedlings from the two collections in the heated lagoon initially formed roots more quickly than the "Guay. Amb." or the "Guay. S5" batches. However, about 10% of the seedlings from each group did not root until 60 to 75 days. For the second collection "Guay. H2," both large and small seedlings rooted at the same rate.

Figure 4: Development of roots in mangrove seedlings with time after release from the trees.

The rate of initial leaf formation for the first sampling of stressed seedlings was much slower than was previously observed for unstressed seedlings (See Fig. 5). The stressed seedlings are compared with this earlier data because "Guay. H1S" was in the same experimental cage that held batch 3, and "Guay. H1L" was in the cage which held batch 7. The second sampling of the stressed seedlings ("Guay. H2S" and "Guay. H2L") developed leaves at the same rate for the first 120 days.

70 80 90 100 110 120 130 140 150 160 Days Figure 5: Time of formation of the first pair of leaves after release of seedlings from the trees. A second series of experiments is currently being followed. Sub-batches of 100 seedlings from the Guayanilla heated lagoon (Sites 2-3) and from Pta. Ostiones are in cages at Site No. 2 (Fig. 1) and at Pta. Ostiones. In addition, sub-batches of 100 seedlings from site 3A (~2°C cooler than Site 2) are at Site 3A (along with 100 seedlings from Pta. Ostiones) and at Pta. Ostiones. Thus, a simultaneous comparison of the seedlings from stressed trees (at two temperatures) and non-stressed trees is being made both at the temperatures of stress and at a control site. Preliminary data show that seedlings from both stressed areas root rapidly in the control area (as found earlier) and slower in the stressed areas. Unstressed seedlings do not form appreciable roots either at temperatures of 36-39°C (Site 2) or at temperatures of 34-37°C (Site 3A). There is also evidence of deterioration of the seedlings from Pta. Ostiones but not for the seedlings from stressed trees at these temperatures. The data so far show that seedlings from non-stressed trees cannot enter the thermal lagoon, root, and grow. Seedlings from the stressed trees (particularly between Sites 2 and 4 where most seedlings are

grown) are too short, ~ 20 cm, to find suitable water depth to root and grow. Mangrove seedlings establish themselves in mud bottom and turtle-grass areas where the water is the right depth so that vertically-floating seedlings can make contact with the bottom and take root. The normal tidal range for the south coast of Puerto Rico is ~ 20 cm. Therefore, seedlings of this length or smaller have little chance to establish themselves, because they would be completely exposed at low tide if the rooting tips were just in contact with the bottom. No seedlings of 20 cm length have been found growing naturally in the shallow areas of the thermal lagoon or at other mangrove areas.

Thus, the smaller seedlings have a low probability of survival. There is a small area in the thermal lagoon where small trees judged to be 3 to 5 years old are living. However, no seedlings in their first year of growth have been found. The small trees started growing before the temperature at this site became 38°C during part of the year. In locations outside the thermal lagoon, where there are similar young mangrove trees, many seedlings in their first year of development are also present. Therefore, seedlings may not be able to survive, root, and grow in water at 98°C. The absence of growing seedlings is additional evidence of the stress to which this mangrove is subjected. For many batches, approximately 30 seedlings were frozen at 10°C and later the top and bottom 3 cm were cut off and analyzed for trace metals. Trace metal analyses on the tops and bottoms of five batches of seedlings show that Ni, Cd, and Pb are below detection limits (4 ppm, 0.0 ppm, and 5 ppm) in all samples. The values for Cu, Mn, and Fe are given in Table 7. The amount of copper in seedlings from "buoyH1S" and "HLL" was significantly higher than "Guay. Amb." and "Bog. Cont." which were significantly higher than "Pta. Ostiones Cont." All seedlings exhibited nearly a 4-fold increase in Mn between bottoms and tops. "Batch Guay," "HIS," and "HIL" were not significantly different from each other but are significantly larger than Bog. Cont. The variation between seedlings for Fe is so large that there is no statistical significance between samples of 30 seedlings. The same metals are being determined in the seawater at these locations to see if there is a correlation.

Table 7: Trace Metal Analyses Results

Cu			Mn			Fe		
Tops	Bottoms		Tops	Bottoms		Tops	Bottoms	
19221	20.8	2217	5.3	16234	210.8	13.1286		
Guay	MIS	5.232	2.35	5.22	+ 2.01	Guy		
5.062	168	5.002	147	Guy.me	42	eh	AL	LO
9.05	19TH	Ge	6	162285	poq.ceT	4.6	20.8	45   20.8
RTL	WHELB	le	711	10.7246	Ptovecont	3.5	210	25   20.9
M2622	12225	15.52	5.6	12.0832	101			

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The data and observations so far

have related stress on the mangroves to elevated water temperatures and not to chemical pollution. The critical temperature appears to be between 37° and 38°C. Natural water temperatures as high as 32°C are found around flourishing mangroves. At sites "3A" and "5", the mangroves showed no stress even though a water temperature of 37°C was recorded at site "BA." The major deterioration of the trees was between sites "1" and "4" where the summer water temperatures had increased up to 38-39°C from 36-36°C. Additional studies over the next several years will be needed to confirm

the lethal temperature for mangrove seedlings and trees as well as the effects of hydrocarbons and toxic metals introduced in the water. Effect of Thermal and Petrochemical Stress on the Detrital Pathway and Productivity of Red Mangroves — W. Hildner and M. Banus. The productivity and content of nutrients in the leaf litter of *R. mangle* are being studied at Guayanilla Bay to determine the effect of thermal and chemical stress thereon. Leaf litter from *Rhizophora mangle* L. supplies a substantial portion of the nutrients for a mangrove ecosystem. Increased industrialization along the shoreline of Puerto Rico has had a marked impact on these mangroves. *R. mangle* contributes about three tons (dry weight) of leaves per acre annually to the benthos. Each leaf represents a nutritional surface for bacteria, fungi, scavengers, and detritivores. The bacteria and fungi receive nutrients directly from the leaf while scavengers and detritivores gain nutrients mainly from associated bacteria and fungi. Bacterial and fungal development is indicated by an approximate increase in protein of 18% in the leaf particles after a period of twelve months. At Guayanilla Bay the water temperatures average 35.9°C minimum to 37.2°C maximum for Station No. "2-3" and 33.3°C at Station No. "8A." A control station has been established at Punta Ostiones. The water temperature mean minimum and maximum near that transect is 27-29.29°C. Productivity is being measured.

using two parameters: metabolism and biomass. In conjunction with the biomass studies, measurements of photosynthesis and respiration are being made. Studies thus far suggest that stress may be indicated by a repletion of structure. The nutritional contribution of *R. mangle* is being studied by litter bag experiments. Results of the analyses in conjunction with the productivity studies are compared to determine the effect of chemical and thermal pollutants on *R. mangle* as a nutrient source for the mangrove system. Distribution of Foraminifers close to the sewage outfall of Mayaguez Bay —G. Seiglie. Living foraminiferal faunas at eight stations in Mayaguez Bay and their relation to the sewage outfall were studied. The number of foraminifers per sediment sample (10 cm<sup>2</sup> per 1 cm of depth) and per species were determined. The number and specific composition did not differ from determinations made previously. (See PRNC Annual Report 1973) The distribution of living foraminifers in sediments was patchy and therefore these determinations were not significant to this study. 102 ---Page Break--- Seiglie had previously determined that *Fursenkoina punctata* (d'Orbigny) (= *F. pontont* {Cushman}) was the most significant of the living foraminifers in its sensitivity to pollution and that its increase in number in Mayaguez Bay was caused by pollutants of human origin. Seiglie also determined that the ratio length-width in populations of *F. punctata* was related to pollution. The preliminary results of the present study show that the mean diameters of the first chamber (proloculus) of *F. punctata* are related to the degree of pollution. The diameter of the proloculus was found to decrease in size from the surface to 83 cm in the core. The size was approximately constant from a depth of 33 cm to the bottom of the core (160 cm). The proloculus also decreased in diameter with distance away from the sewage outfalls to the entrance of the bay. The mean diameter of the proloculus increased when the number of megalospheric.

Specimens increased in the population. The distribution percentages of megalospheric specimens followed the same pattern as the diameter of the proloculus. The high number of megalospheric specimens has a biological significance. The megalospheric generations represent the sexual reproduction by gametes in the life cycle of foraminifers. An abundance of megalospheric specimens and sexual reproduction indicates a trend toward developing a faster adaptation to the changing environment. The present results will be correlated with the study of invertebrates and heavy metals in the sediments in future studies.

Trace metal concentrations in coral reefs and sediments of the west coast of Puerto Rico — J. Montgomery, Z. Padilla, A. Ramirez, and S. de la Rosa. The concentration of six trace metals, Zn, Cu, Ni, Mn, Fe, and Co, was determined for three reefs and near reefs located six miles west of Punta Ostiones off the west coast of Puerto Rico. The object of the experiment was to determine the baseline levels for the six metals in the sediment at the face of the reef, in the “Halophila,” and algal/sponge-flat zones. The concentrations of the metals were determined in the upper and lower composite 10 cm sections of a 20 cm core. They were compared statistically to detect any difference between the three zones and within the core levels. The results for the acid extractable metals are shown in Table 8. There was no significant difference in the upper and lower 10 cm core segments except for Fe in the algal zone. The results were pooled for all the metals except iron. When the mean pooled concentration of each metal for each zone was compared, the following was found: 1. There was a significant increase in the Fe concentration between the upper and lower 10 cm segments of the reef and algal zones. 2. The concentration of Fe in the lower 10 cm levels between the reef and “Halophila” zones and between the algal and “Halophila” zones shows a significant increase in Fe concentration.

following the order algal > “Halophila” > reef, 103 ---Page Break--- ‘Table 8: Pooled Mean Concentration, in g/g. Dry weight, of Acid Extractable Cu, Ni, Mn, Zn, Fe and Co in Reef, Halophila, and Algal Zone Sediments off the West Coast of Puerto Rico. wae = \* a btm FD = a a a er oj tn sa Hata wigan 8 tn Ya ma et Mi ek eee : we kom us ter oS wea eae www a yw ma meres i we mem \* seeks amy vs Upper 10 ex Lower 10 om ‘The concentration of metals extracted by 5% EDTA show that the absorbed trace metals, expressed as a percentage of the acid extractable fraction, are in an easily released form in the following amounts: 5% of the Fe, 33% of the Mn, 12% of the Co, 11% of the Ni, and 11% of the Zn. The distilled water extraction released 0.2% of the Fe and 11% of the Zn as compared to the acid extraction. When the mean atomic ratios of Ni, Mn, and Zn to Fe for the present study (off Punta Ostiones) are compared to those found off the Afiasco River by other researchers at PRNC (see PRNC 1973 Annual Report), they are found to be greater by a factor of 3 for the atomic ratio Ni/Fe; greater by a factor of 2 for the atomic ratio Mn/Fe; and lower by a factor of 5 for the atomic ratio Zn/Fe. This difference in atomic ratios is primarily due to the lower Fe concentration found in this study (a factor of approximately 17). ‘The Zn and Ni concentrations detected in the sediments for this study are also lower than those found in sediments off the Afiasco River, Western Puerto Rico, by factors of 40 and 8 respectively. The sediments in the present study do not appear to be greatly influenced by the river systems of the west coast. The closest river is the Rio Guanajibo at Mayagüez 104 ---Page Break--- which drains a predominantly serpentine watershed. Serpentine is higher in nickel than the volcanic/limestone minerals which comprise the Afiasco River watershed, and therefore the Ni concentration should be higher in these sediments compared to the Afiasco sediment. However, the Ni concentration in the reef sediments is lower in Ni than the

sediments off the mouth of the Afiasco River by a factor of three. It appears that the trace metal regime of this area is influenced more by inputs from deep water than by the land. The percentage of total metals, which can be easily released by 5% EDTA, was quite high for Mn (mean 337) and much lower for Co, Ni, and Zn (approx. 11%) and lowest for Fe at 5%. This easily released fraction of adsorbed metal has a greater ecological impact than the trace metal fraction which requires strong acid leaching for release. Individual Variations of Trace Metal Contents in Fish — J. Montgomery, M. Banus, and S. Kolehmainen. Fifty herring *Opisthonema oglinum* (Le Sueur) were collected from Boquerón Bay, Puerto Rico, in one gill net haul. Each whole fish was wet-digested and analyzed as a separate sample in triplicate for iron, zinc, lead, cadmium, copper, and



manganese using atomic absorption spectrophotometry. Results were correlated to the size of the fish. The concentrations of iron, zinc, cadmium, and copper were significantly higher in the pooled small fish as compared to the pooled large fish. Lead concentration showed no detectable difference between the size classes. However, the manganese concentration was significantly higher in the pooled large fish as compared to the pooled small fish. The mean concentration of these metals was statistically compared to the results of 4 pooled samples of fish collected and analyzed identically and to a pooled sample of thread herring collected in another location at a different time. No significant difference was found between these two pooled samples of medium-sized fish or between the trace metal values for the individual medium-sized fish. A determination of the sample size necessary to detect a 15%, 20%, and 25% difference between two significantly different means showed that a minimum sample size to detect that magnitude of difference would be 124, 70, or 50 fish, respectively. ANALYTICAL METHODS Monitoring of an Atomic Absorption Spectrophotometer Using Cumulative Sum Statistics.

Statistical Control Charts — J. Montgomery and J. Echevarria. A method has been devised to monitor the reproducibility of an atomic absorption spectrophotometer utilizing statistical control charts. Standard curves for five elements, copper, lead, zinc, manganese, and cadmium, have been monitored to determine if the cumulative sum type control charts with "V" mask can detect incipient changes in sensitivity of the atomic absorption spectrophotometer caused by alterations in lamp output, fuel, air mixtures, and electronic gear. The cumulative sum chart is easily computed and allows the operator to quickly detect significant changes in the sensitivity of the machine.

BIKINI ATOLL PROJECT — F. G. Lowman, Fausto J. Muñoz, and R. J. Santiago. During October-November 1974, samples of marine water, sediments, algae, plankton, marine vertebrates, marine invertebrates, and birds were collected at Bikini Atoll for analysis of transuranium elements. Tide gauges were installed at Bikini and Bigren Islands, and water currents were measured near the surface, middle, and bottom of the water columns at stations in the south, west, and northwest areas of the lagoon. Forty-seven samples of metered plankton were collected at 38 stations with paired nets of mesh size 202. Settled volumes and wet weights were measured. Other organisms were dissected, wet weighed, and dried for return to Puerto Rico. Plastic plates were placed in the water to collect epiphyton at the edge of the Zuni Crater. Bottom sediments were taken at 42 stations throughout the lagoon with a pipe dredge. The sediments were wet sieved to separate particles smaller than 0.59 mm from the others. Both fractions were analyzed for <sup>239</sup>Pu and <sup>241</sup>Am. Ten water samples were collected from near the bottom of the western half of the lagoon. The samples were filtered through membrane filters with a 0.45 μm pore size, and the filtrate was acidified to pH 2 before shipment to Puerto Rico. Preliminary analysis of the data from the water current meters indicates that the winds.

and oceanic waters breaking over the outer reef exert the major influence upon the water currents inside the lagoon and that tidal fluctuations cause minor changes in the currents. Contrary to earlier reports, significant amounts of water in the lagoon do not flow westward over the west reef of the lagoon. Rather, the oceanic waves breaking over this reef produce a hydrostatic head that causes a variable but continuing flow of water eastward across the west reef, even during periods of high tide that were measured during the survey. The water current data have been transferred to punch cards and subjected to computer analysis. Current directions and velocities show positive correlation with observed wind directions and velocities. Plots of the preliminary visual examinations of the bottom sediments showed a distinct distribution pattern of size of bottom sediments (Fig. 6). Coarse sediments of Halimeda rubble occurred in the northeast part of the

lagoon and in the central lagoon with an extension of the distribution of coarse sediments westward from the center of the lagoon to a position due north of Bokoroyuru Pass. Fine silt occurred in the north and northwest parts of the lagoon as well as in the west cul-de-sac of the lagoon and in the area from Bokoroyuru Pass northeast by east for a distance of about 8 kilometers. The remainder of the bottom sediments in the lagoon were intermediate in size between that of the coarse Halimeda rubble and the silt, being mainly sand with some rubble. The sediments are being analyzed for  $^{13}\text{Co}$ ,  $^{101}\text{Rh}$ ,  $^{111}\text{Sb}$ ,  $^{137}\text{Cs}$ ,  $^{152}\text{Eu}$ ,  $^{210}\text{Bi}$ ,  $^{210}\text{Po}$ ,  $^{210}\text{Pb}$  and  $^{241}\text{Am}$ . In the sediment fines the concentrations of  $^{152}\text{Eu}$  were two to four times those for  $^{241}\text{Am}$ . In the coarse fractions of the same sediments the ratio of  $^{152}\text{Eu}$  to  $^{241}\text{Am}$  was one or less. 106 ---Page Break---

Settled volumes of plankton were compared with the total volume of water strained as determined from the metered samples. The amounts of plankton inside the lagoon per unit volume of water are known to exceed greatly those in the open sea near the atolls. Because of this, the distribution patterns of the ratio, plankton volume/water volume, may be used to determine those areas of the lagoon where upwelling occurs and where open-sea water is swept into the lagoon. In Figure 7, the parts of plankton per million parts of water are shown. The open sea water in the Marshall Islands contains 0.01 to 0.03 parts of plankton per million parts of water. The concentrations of plankton inside the lagoon are as high as 1 part per million. High ratios of plankton/water ( $>0.7/10^6$ ) were observed in the north and east areas of the lagoon—sites where upwelling of deeper lagoon water is known to occur. Upwelling also occurred in the Ingoon at area "A" (see Fig. 7) inside the north reef, but the upwelled waters, rich in plankton, were diluted by open-sea waters, low in plankton, coming across the north reef west of Bikini Island. The low values of plankton to water ( $<0.16/10^6$ ) in the south and west areas of the lagoon occurred in areas into which water from the open sea was introduced into non-upwelling areas of the lagoon. During the past year, additional chemical separations for  $^{239}\text{Pu}$ ,  $^{240}\text{Pu}$  and  $^{241}\text{Am}$  have been done on the 1972 samples of water, sediments, plankton, and other organisms. The distribution pattern of  $^{239}\text{Pu}$  in the sediments collected in 1972 is shown in Figure 8. The highest concentration of these radionuclides, mostly  $^{239}\text{Pu}$ , occurred in the sediments approximately 3,000 meters southwest from the Bravo Crater inside of the lagoon. Both Tewa and Bravo Crater probably constitute the major source of these radionuclides. Of the 3 major weapons craters in the lagoon, Zuni Crater had the lowest amounts of the  $^{239,240}\text{Pu}$ . The distribution pattern of  $^{241}\text{Pu}$  in the 1972 sediments is shown in Figure 9. In contrast to the distribution pattern for  $^{239}\text{Pu}$ , the highest concentration of the radionuclide occurred in the sediments of the Zuni Crater. The next highest amount was measured in samples from the Bravo Crater. Zuni Crater is the major source of

$^{241}\text{Pu}$  in Bikini Lagoon, the distribution pattern of  $^{241}\text{Am}$  approximated that of  $^{241}\text{Pu}$ , with the greatest amounts of americium occurring 3,000 meters southwest of the Bravo Crater (Fig. 10). The amounts of  $^{241}\text{Am}$  in these sediments were 2 1/2 times the concentration observed in sediments from the Bravo Crater and 3 times those in the Tewa samples. The Bravo and Tewa Craters constitute the major source of  $^{241}\text{Am}$  in Bikini Lagoon.

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Figure 6. Simplified characteristics of bottom sediments based on sediment collection made October 21 — November 2, 1974 on NTU PASS:

Figure 7. Parts of plankton per million parts of water filtered through paired plankton nets with 202.1 mesh openings. The high values of plankton to water ratios ( $\sim 0.1/10^6$ ) in the north and east areas

of the lagoon occur in areas of upwelling. Upwelling also occurs in the lagoon at an area on the north shore, but the upwelled waters, rich in plankton, are diluted with open-sea waters, low in plankton, coming across the reef west of Bikini Island. The low values of plankton to water ( $>0.16/10^*$ ) in the south and west areas of the lagoon occur in areas into which water from the open sea is introduced into the lagoon.

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Figure 10. A review of the ratio of  $^{239}\text{Pu}/^{240}\text{Pu}$  between the sediments, water, and marine organisms indicates differences in the movement of the two plutonium nuclides from the lagoon to the organisms. Significant discrepancies were found in plankton and fish taken at Bikini Atoll as follows: the uptake of  $^{239}\text{Pu}$  over  $^{240}\text{Pu}$  by a factor of about 1.6. In contrast, this discrimination in favor of the uptake of  $^{239}\text{Pu}$  over  $^{240}\text{Pu}$  is observed in plankton.

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Figure 8. Plutonium-239,240 in sediments (d/n/).

Figure 9. Plutonium-238 in sediments (d/mie).

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Samples from the Bikini Atoll Project.

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## BIOLOGICAL AVAILABILITY OF POLLUTANTS TO

MARINE ORGANISMS J. Montgomery, P. Price, J. Thurston and G. Laite—A program supported by the Environmental Protection Agency was begun in September 1974 to study the leaching by sea water of trace metals and hydrocarbons from secondary treated sewage sludge. The release of these pollutants into a tropical marine ecosystem was studied. Two running sea water tanks containing sediments and organisms from a turtle grass/mangrove ecosystem were used. One tank initially was stressed with an addition of secondary sewage sludge; the other tank was used as a control. Samples have been taken of water, sediments, and organisms beginning on 12 March 1975, and continuing at 1, 5, 22, and 50 day intervals thereafter. The final samples (120 day) will be taken on July 15, 1975. Analysis will continue throughout 1975-1976. MANGROVE OYSTER CULTURE PROJECT K. Watters, T. Prinslow and P. Acosta—For the past year, this project has concentrated on developing culture methods for the mangrove oyster, *Crassostrea rhizophorae*. The work has been sponsored jointly by the National Marine Fisheries Service and the P.R. Dept of Agriculture since December 1972. It has been carried out primarily at the artisan level. Research has concentrated on several areas: (a) Developing culture methods suitable for native fishermen, (b) Experimenting with cultch types and designs aimed to optimize cost effectiveness, simplicity, durability and deployment strategy, (c) Evaluating potential culture areas, (d) Monitoring growth, mortality and spatfall, as well as water quality (coliform contamination), (e) Monitoring growth and survivorship of Pacific oysters, *Crassostrea gigas* (Thunberg), and American oysters, *Crassostrea virginica* Gmelin, imported May 1973 as cultchless spat. A floating sea water laboratory was constructed at Rincón Lagoon, Boquerón to serve as a base of operations. In five consecutive

experiments, cultch of various materials and designs were employed for the production of *C. rhizophorae*. These were: 1-String-tire cultch consisting of

sections of automobile tires strung on 2 m long No. 12 gauge wire; 2-Rubber sheets stretched in 46 X 71 cm wooden frames fixed inertially; 3-Cement-coated wood (41 X 61 cm), commercial grade ~24 cultch plates per raft; 4-Repeat of Exp. 3 re-using same cultch; 5. Cultch material preference test using frames with rubber sheet-plastic sheet-tar-coated wood-cement coated wood-bare wood. In all experiments except number 2, cultch were suspended from 3 X 4 meter rafts in Rincén Lagoon. Stocking of oysters was by natural spatfall. In experiment number 8, the oysters were harvested by removing the cement layer attached to oysters. The cultch were dried and a fresh cement layer was applied in preparation for experiment number 4. Cultch were evaluated in terms of costs of materials; labor necessary for construction, maintenance, and harvesting; attractiveness to oyster spat; and growth of oysters. Several areas on the South and West coasts of Puerto Rico (Figure 1) which have produced commercial mangrove oysters were evaluated for present culture potential. Experiments in Rincén Lagoon, Jobos Bay, Guanica, and Phosphorescent Bay began on October 12 ---Page Break --- ATLANTIC PUERTO RICO Ponce 'cuoyarita Bay 2 CARIBBEAN Fig. 1. Sites evaluated for oyster culture potential. 1974. Those in Puerto Real began in February 1975. Cement-coated cultch positioned subtidally were checked monthly for spatfall, growth, and mortality. Biweekly coliform checks were initiated in April 1975 by the P.R. Department of Health at Puerto Real, Rincén Lagoon, and Phosphorescent Bay. In addition to monitoring spatfall on cultch for purposes of area evaluation, spatfall on Butler collectors, rainfall, water temperature, and salinity have been monitored since February 1974 to determine how these environmental variables affect spatfall. Collectors consisting of two 10 X 10 cm asbestos plates were hung from rafts in Rincén Lagoon at a depth of 30 cm. Plates were inspected, cleaned, and rehung weekly. At the same time, temperature, salinity, and rainfall

(accumulated between sampling periods) were recorded. In May 1973, cultchless spat of *C. gigas* and *C. virginica* were imported to Puerto Rico. Growth and survivorship were monitored in three consecutive experiments at Rincon Lagoon. The string and rubber sheet-frame cultch experiments were conducted during the previous project segment. Detailed results were reported in PRNC-176 - Annual Report, 1973 (Project 2-184-R). Briefly, these tests demonstrated that *C. rhizophorae* would set and grow on artificial substrates suspended from rafts. The string-tire cultch was cumbersome. Construction and harvesting of one raft took about 15 and 8 man hours, respectively. Labor alone cost \$57.50 (at \$2.50/hr.). Therefore, a simpler flat frame design was created. The frames showed reasonable set (40-50 oysters) and growth (about 1 mm/day, umbral height). However, expensive rubber sheeting (about \$0.35/ft, in 1973) would constitute a large investment for a native fisherman. Thus, for experiment number 3, a variety of less costly materials were adapted to the frames.

After two months in Rincon Lagoon, cement-coated cultch had 8-10 times the set of other materials (Fig. 2). The larger oysters ranged from 40 to 50 mm in umbral height, a growth rate of about 1 mm/day.

To determine if setting density and growth on cement cultch would hold true on full-scale deployment, a raft was set with 24 cultch frames. The design was simplified to use 4 single pieces of 3/4 inch (1.9 cm) plywood per cultch instead of the plywood and wood frame combination used previously. The size was changed to 41 x 61 cm to minimize available plywood. The cultch were harvested after 3 months (Table 1).

Table 1: Raft Harvest Data. (Oct. '74 to Jan. '75)

No. cultch:

Total no. oysters set: 1589

Mean no. per cultch: 66

No. market size oysters (over 4 cm): 237

Only 237 market size oysters (over 4 cm) were taken from the 24 cultch. This

represented no net density increase over the initial set. Conditions of unusually low salinity which persisted throughout the 2nd and 3rd months reduced growth and spatfall. Just prior to harvesting, these conditions dissipated, resulting in a heavy spatfall which raised the final density to 66 oysters/cultch. Construction of the 24 cultch cost about \$40 for materials (Table 2) plus \$20 (8 man hours at \$2.50/hr for labor). 14 ---Page Break--- ee 'Table 2: Materials and costs of cultch for one 3x4 m raft. (6) 1/4 in x 20 ft steel rods (6 mm x 6 mm) 7.50 (2) 3/4 in x 40 x 8 ft plywood 29.00 (1) bonding agents 3.00 (20) cement Total \$40.00 Harvesting took 2 hours. Preparation of used cultch for experiment number 5 again took about 8 hours, but only cement and bonding agent were needed. Rincón Lagoon (Boquerón) presently produces the majority of commercial *C. rhizophorae* in Puerto Rico. Because of this, it was chosen as the base of operations and as the standard of comparison for alternate areas. In the first experiment (Oct. '74 - Jan. '75) oyster set and growth were inhibited by unusual weather conditions. After 3 months, the set of market size oysters was about 10 oysters/cultch. Total set was 66 oysters/cultch. Growth was about 0.3-0.4 mm/day. In the second experiment begun Jan. 1975 the total set after 3 months was 104 oysters/cultch of which only 1% will be harvested in July 1975 to take the largest number of m experiments was less than 2%, ---Page Break--- 'At Guanica, root populations of *C. rhizophorae* were dense and the oysters were uniformly small (around 20 mm). Cultch placed near these roots disappeared on three separate occasions. No additional set of root oysters was apparent during 5 months. Therefore, experiments were terminated in May 1975. 'At Phosphorescent Bay, 40 oysters per cultch set within the first month (Oct.-Nov. '74). During the period from January to June 1975, set was only 3-4 oysters/cultch. Two previously-set plates from Rincon Lagoon were installed in February 1975. These oysters grew about

0.4 mm/day. Predation by drills (*Murex* sp.) resulted in 100% mortality of oysters over 20 mm. Again, cultch was fixed on the bottom where drills could reach them. Growth of juveniles was about 0.7 mm/day. Lack of accessibility to Jobos Bay has limited experiments in this area. Available data suggest that spatfall is very light and predation heavy. Due to low standing populations and lack of set on experimental plates, no growth data were obtained. Coliform contamination in Puerto Real and the northeast end of Rincon Lagoon was greater than the "unrestricted" shellfish sanitation standard of 70 colonies/100 ml suggested by the U.S. Public Health Service. They were less than the upper limit of 700 col./100 ml for this classification at most sampling sites. However, some areas showed dangerous levels of sewage contamination. Samples from the southwest end of Rincon Lagoon and from Phosphorescent Bay were less than 70 col./100 ml. The degree of contamination is affected by the proximity of sewage input and by rainfall. Rains appear to flush the surrounding watershed of accumulated sewage which then flows into the culture areas. Spatfall, salinity, and temperature at Rincon Lagoon were monitored for 15 months. The data suggest that periods of spawning are associated with changes in salinity and temperature. These changes are induced by rainfall (Fig. 3). The relationships are complex, and accurate prediction of spatfall timing and intensity is still elusive. Probably some of this uncertainty results from the Butler plates. Spatfall on both cement cultch and Butler plates has been monitored simultaneously since November 1974.

In 8 out of 29 checks, spat were observed on the cultch but not on the plates. A collector using cement cultch of reduced size will be utilized for further spatfall monitoring. Culturally spat of both species reached commercial size (6 cm) in 6-9 months. Survival was low (10-40%), due primarily to thermal stress. Some *C. gigas* reached sexual maturity, as evidenced by successful induction of spawning.

and formation of larvae. In the evolution of cultch design, the cement plates so far best meet the criteria of cost, effectiveness, durability, and ease of handling. Furthermore, materials are readily available, and the plates are simple to construct. To test the commercial feasibility of cement cultch, the Project is presently assisting two oyster fishermen in a pilot commercial study. Two 6 x 8 m rafts (double the experimental size) and 96 cement cultch have been constructed and are anchored in Rincon Lagoon. The Project will monitor operations and provide technical assistance. In return, the study should yield usable data on the application and acceptance of raft culture oyster production in Puerto Rico. 116 ---Page Break--- Figure 3: Records of spatfall, temperature, salinity, and rainfall in Rincon Lagoon. mak™ 40. 30) md 2: aiz00) 100 No ot 99! same" 50 28) \* 0 1 22880 Production figures from the first experimental harvest were low (Table 1). However, the total density of 66 oysters/cultch at harvest time indicates that a better strategy for the commercial oysterman would have been to delay harvesting until the majority were marketable (about 2 months). The cultch in the next experiment, which held 104 oysters/plate after 3-1/2 months, will be harvested after a total of 5 months (in July 1975). Of the five areas investigated, Rincon Lagoon, Phosphorescent Bay, and Puerto Real show the greatest potential. Growth in all three areas was favorable, yielding marketable oysters within 6 months from immersion of cultch. Extremely heavy predation at Puerto Real and Phosphorescent Bay would be eliminated with raft culture. Rafts would also facilitate the depuration necessary due to coliform contamination. Rafts could be easily towed prior to harvesting to the western ends of Rincon Lagoon and Puerto Rico where contamination is low. The main problem in all areas is spatfall. Continued high levels of spatfall at Puerto Real will cause crowding, poor shape, and growth. Surplus oysters would have to be culled by hand. Venezuelan

Oyster culturists presently face this problem. On the 17th, where other ---Page Break--- Barco Islote study site for the proposed North Coast Nuclear Plant No. 1. This site was studied intensively by PRNC scientists under contract to the Puerto Rico Water Resources Authority ---Page Break--- scorpion fish (*Neomerinthe*) searched for environmental 19 ---Page Break--- hand, spatfall at Phosphorescent Bay is very light. Oysters grow well, but in order to obtain more than one harvest per year, previously-set cultch (e.g., from Puerto Real) would be necessary. In Rincon Lagoon, spatfall intensity varies with local weather conditions. Optimum production would require monitoring of these conditions and frequent inspection of cultch to prevent crowding. Thus all three areas could support raft culture, but each would require different methods of setting cultch. The pilot commercial study should help to quantify this. From the above discussion, it appears that a knowledge of timing and intensity of spatfall is critical to the culturist. Even if accurate prediction were possible, the culturist would still be constrained by natural cycles. In temperate culture of *C. gigas* and *C. virginica*, artificial production of spat is now routine. Similar manipulation of *C. rhizophorae* could produce spat on demand. To form the basis of future hatchery work, a preliminary study of larval development time of *C. rhizophorae* was carried out by a local high school student (Charles H. Fastigg, CROEM, Mayagüez, P.R.) under Project guidance. ENVIRONMENTAL IMPACT STUDIES Aguirre Environmental Studies, Jobos Bay — M. J. Canoy and Staff. In 1970, an impact study was planned for a proposed nuclear power plant to be located at Aguirre, Jobos Bay (on the south coast of Puerto Rico). A cooperative effort of the U.S. Atomic

Energy Commission, the Puerto Rico Nuclear Center, and the Puerto Rico Water Resources Authority was initiated. As the study progressed, the Puerto Rico Water Resources Authority and the Puerto Rico Nuclear Center continued the

research. The project culminated on June 30, 1975. The first two years emphasized the assembling of a research team and library, gathering of baseline data, and monitoring of the area. Basic background data was reported (see PRNC Annual Reports, 1972, 1973, and PRNC-162), and the main environmental study began. The research investigations over the five years of this study have resulted in a wealth of scientific information on an area where little or no scientific investigation had been done before. The research results are discussed in the Jobos Bay Annual Environmental Report 1974 issued in March 1975, and in the Aguirre Environmental Studies, Jobos Bay, Puerto Rico, Final Report June 1975 (PRNC-196). Environmental Studies of the Proposed North Coast Nuclear Plant Unit No. 1 (NORCO-NP-1) Site. — J. D. Parrish, R. E. Munson, and Staff. The Puerto Rico Nuclear Center was under contract to the Puerto Rico Water Resources Authority from September 1973 to June 30, 1975, to conduct environmental studies of the proposed NORCO-NP-1 plant site. Studies to acquire knowledge about oceanographic, terrestrial, and aquatic in 1978 have been completed. In addition to the Final Report of this project issued in July 1975 as PRNC-197, the research is published in the Puerto Rico Water Resources Authority Environmental Report of North Coast Nuclear Plant Unit No. 1, Chapters 2 and 6. See also the section on Terrestrial Ecology in this report and the PRNC Annual Report, 1973. Site Selection Survey — E. D. Wood and Staff. As part of the contract between the Puerto Rico Water Resources Authority and the Puerto Rico Nuclear Center, site selection surveys and environmental research studies of seven coastal sites were initiated in 1972 and terminated on June 30, 1975. Useful data to aid in the assessment of the desirability and practicability of locating power generating plants on one or more of these sites, and additions to the knowledge about these areas, was obtained. Physical, chemical, and

geological parameters of the sites, and ecological parameters of zooplankton, benthic invertebrate, and fish communities were studied. For all but one offshore site, plant associations were included. The results of the survey are published in a series of environmental studies for each of the seven sites. These are: Tortuguero Bay (PRNC-181), Punta Manati (PRNC-182), Punta Higuero (PRNC-183 and 183-A), Cabo Rojo Platform (PRNC-189), Punta Verraco (PRNC-187), and Cabo Mala Pascua (PRNC-188). (See Fig. 11). The seventh site, Barrio Islote, was studied and reported under a separate contract. (See NORCO NP-1 Environmental Studies). In addition to the environmental studies that have been published, this project has also compiled three hydrographic data reports from 1973-74 data, one each for the North Coast, the West Coast, and the South Coast of Puerto Rico, published as PRNC-177, 184, and 185, respectively. ATLANTIC OCEAN Puerto Rico CARIBBEAN SEA Figure 11: Site Selection Survey Study Sites. Tortuguero Bay (TB); Punta Manati (PM); Punta Higuero (PH); Cabo Rojo Platform (CRP); Punta Verraco (PV); Cabo Mala Pascua (CMP). Barrio Islote is not shown. Winds for Puerto Rico with Summaries ~ D. Wood. Four years of wind data were collected at the International Airports of San Juan and Ponce covering the period January 1, 1971, through December 31, 1974. Data contain wind direction to the nearest 10° for the direction the wind is blowing from, and velocity in knots. The data were taken hourly, 24-hours per day. The raw data were supplied by the National Oceanographic and Atmospheric Administration, Dept. of Commerce, San Juan. The computer programs and analysis of the data were performed at the Puerto Rico Nuclear Center in Mayagüez. The data reports are contained in "Winds for Puerto Rico with Summaries San Juan 1971-1974 (PRNC-192, Volume 1), and "Winds for Puerto Rico with Summaries Ponce 1971-1974" (PRNC-192, Volume 2). Manual for

Hydrographic Cruises — E. D. Wood. This handbook is intended to serve

as a guide to persons planning and executing hydrographic cruises and those who interpret and evaluate the resulting data. Written and compiled by Dr. Wood in 1974-75, "A Manual for Hydrographic Cruises" is published as PRNC-190. 'TRAINING ACTIVITIES Drs. Frank G. Lowman, E. D. Wood, and M. J. Caney collaborated in offering a course to graduate students in the Department of Geology of the University of Puerto Rico Mayagüez Campus during the Spring Semester, 1975. Steven Curtis, ORAU Fellow, conducted research under the supervision of Dr. M. Banus at the Cornelia Hill Laboratory and on the R. F. Palumbo during the summer of 1975. STAFF ACTIVITIES For a listing of the staff who participated in symposia and conferences during this period, see the sections on Papers Presented and Seminars. Dr. Seppo Kolehmainen, Head of the Marine Biology Program, resigned from the Puerto Rico Nuclear Center in April 1975. Dr. Kinkar P. Kharkar, Head of the Bikini Atoll Project, resigned in 1974 to accept a position at the University of California, Berkeley. Dr. Frank G. Lowman assumed the leadership of the project at this time. Dr. F. Douglas Martin, Head of the Guayanilla Bay Project, resigned in October 1974. Dr. Tin Mo resigned in February 1975 to accept a position as Associate Scientist with the Lovelace Foundation for Medical Education in Albuquerque, New Mexico. Dr. James D. Parrish resigned in February 1975 to accept a position as Assistant Unit Leader of the Massachusetts Cooperative Fishery Unit. 122 ---Page Break--- Research vessel R.P. Palumbo. This ship has laboratories for on-ship analysis: data gathered during cruises. Research in 1 included studies on the impact of nuclear fuel power plants on water quality and tropical marine communities; chemical and unpolluted areas; hydrographic analysis of particulate and trace metals associated with marine organisms. The nekton, mangrove, turtle grass, and the impact of thermal and electrical changes on these systems were investigated. 123 ---Page Break--- ---Page Break--- ENVIRONMENTAL SCIENCES

TERRESTRIAL ECOLOGY In January 1976 confirmation was received on Program re-orientation for a five-year Integrated Drainage Basin Study. Planning began in February with the identification of eight research areas: (1) land use, (2) climatology, (3) hydrology, (4) soils, (5) plant ecology, (6) animal ecology, (7) limnology, and (8) chemistry. For the planning identification and ordering of research priorities over the next five years, project staff began a literature review and preparation of position papers on each of the research areas. These papers have been and are being reviewed internally and, when completed, will be subjected to one external review. The preparation of conceptual models of the system has been completed and is being used as a planning tool for the final document. When completed in late 1975, this document will become the master research plan for the 'Terrestrial Ecology Program. Construction of the new laboratory facility at the El Verde Field Station is still pending. It is anticipated that construction will begin in late 1975. The purpose of the Espiritu Santo Drainage Basin Program is twofold: (1) to provide baseline ecological data for future environmental assessment studies at the local and regional level, and (2) to determine through an ecosystem approach management alternatives for the wise utilization of energy, water, and land resources. The study will describe the interrelationships among climate, vegetation, animals, soils, and man and their combined influence upon the hydrologic cycle of the drainage basin at both the local and regional level. The entire drainage basin is considered regional in size since it encompasses the river from its origin in the mountains to the final discharge into the Atlantic Ocean. Environmental management involves planning and decision making, and both of these require data. At present, little is known about the interworkings of a complete, integrated system such as the drainage basin. While many isolated, ecologically oriented studies have been conducted:



4 tropical environments, few, if any, have provided the database required for environmental management. In view of rapidly changing socioeconomic conditions and natural resource limitations, management urgently requires input data from three systems: (1) physical (Geological-meteorological), (2) biological, and (3) cultural. This integrated study has been designed to provide these data. The scope of the program will deal with the hydrologic cycle as it is affected by the interactions of the physical, biological, and cultural systems. It will be multidisciplinary and utilize the team approach that has been developed within the Terrestrial Ecology Program to conduct integrated studies of climate, soils, vegetation, animals, and man. It will begin first with an intensive study of the forest segment of the drainage basin and then incorporate the agricultural lands and urban areas, and finally the estuarine system. 125 ---Page Break--- RESEARCH ACTIVITIES Activities these past year have focused on the completion of ongoing research and planning and reorientation of the Program toward a Drainage Basin Study. Two theses for Master of Science degrees in Biology were completed, fieldwork for another Master of Science degree, and fieldwork for a Ph.D. dissertation (see Training Activities) were finished. Disappearance of *Dacryodes excelsa* Leaf Litter in a Tropical Montane Rain Forest in Puerto Rico — Fred LaCaro. Rate of leaf disappearance was measured on Tabonuco leaf litter in the Luquillo National Forest near El Verde Station located in the northeastern part of Puerto Rico at 385 meters of elevation. The string non-confined method was used to determine leaf disappearance. Disappearance rate was found not to be significantly affected by temperature and amount of rainfall in the area during the time studied. Regression equation analysis yielded a predictive equation of the form  $y = a + bx$ , where  $y$  is the percent leaf remaining and  $x$  is time. The equation  $y = 88.92P - 248x$  was found to best describe the leaf disappearance.

rate of Tabonuco leaves under the conditions studied. Based on this equation, the average disappearance rate was 1.77 g/100g/wk. It was also determined that for 95% of the leaf material to disappear, it would require approximately 68 weeks. On the basis that a slow rate of leaf disappearance occurs in the forest and that leaves do not appear to accumulate, it is proposed that usable plant materials are constantly being released from available litter in the forest floor in a steady and perpetual manner to meet the demands for growth, production, and maintenance. The Rainfall Interception Process and Mineral Cycling ~ R. Clements and J. Colon. A comprehensive interception study was carried out in a Montane Rain Forest in Eastern Puerto Rico. Results indicate that the factors of intensity, duration, and overall distribution of storms by storm size must be taken into consideration when determining the fate of isotopes that reach the forest via rainfall. The relationships rainfall-throughfall and rainfall: stemflow are best described by linear equations. However, neither is a constant percentage of rainfall but varies with storm size. The predictive equation for throughfall is  $Y = 0.954P - 0.028$  while for stemflow it is  $Y = 0.088P - 0.037$ . Although small storms contribute very little to the total annual rainfall, the impact of these storms on the chemical inputs to this tropical ecosystem is major. Input budgets for Ca, Mg, Na, and K are estimated at 115.2, 79.1, 415.8, and 98.7 Kg/ha/yr. Throughfall is the major contributor of Mg, Na, and K to the soil system, accounting for 60, 60, and 80 percent, respectively, of the estimated inputs of these elements. Leaf fall provides 71 percent of the Ca input while throughfall accounts for 22 percent. Changes in Selected Water Quality Parameters as Influenced by Land Use Patterns in the Espiritu Santo Watershed — Elvira Cuevas. This study was started in October 1973 and completed in April 1974. The objectives were: 1) to evaluate the changes in selected water quality parameters as

influenced by the land use patterns of the area, and 2) to evaluate the gradation of these variables from higher elevations to near sea level. Ten stations were selected to represent areas under

forest, pasture, mixed farming, human impact, and tidal influence at the lower reaches of the drainage basin. Bi-monthly collections and measurements were made for the variables of dissolved oxygen (DO), temperature, free carbon dioxide (CO<sub>2</sub>), salinity, sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), and chloride (Cl). The average values for the variables measured at selected stations of the Espiritu Santo watershed are presented in Table 1. The summary of the results according to vegetation types are presented in Table 2. \* ns 'Table 1: Average Values for the Variables Measured at Selected Stations of the Espiritu Santo Drainage Basin \_Average Concentration m Vegetation Temp. Free Sain River 'Type © pO co<sub>2</sub> ity, Na K Mg Quebrada Forest Sonadora east branch 19.5 85 2.06 23.85 4.98 0.28 0.90 181 14.484 Quebrada Forest Sonadora west branch 19.2 87 2.04 22.57 4.63 0.26 0.86 1.54 19.680 Quebrada Grande. Forest 22.0 85 2.34 38.82 7.0 0.2 1.28 3.1 19.89 Quebrada Grande Grassland 28.0 86 3.52 98.84 8.91 0.43 2.21 5.05 21.780 Quebrada Siménez Forest 20.0 85 2.02 27.8 5.76 0.28 1.18 225 16.86 Quebrada Gireree Grassland 23.62 8.90 2.626 40.052 9.00 0.41 2.184 4.800 24.278 Esp Seis forest 29.13 8.82 0.88 14 14.014 Espiritu Santo boundary 22.4 8.51 2.20 26.60 6.19 0.92 11 16.12 Espiritu Santo Grassland 28.00 8.62 2.44 28.98 6.560 0.85 1.91 28.90 17 Grand Mean 85 24.1 90.98 64.9 0.33 19.3 26.2 17.98 x 06 00 015 218 083 002 017 04d 1. Values followed by a common letter designation do not significantly differ at the 0.05 probability level according to Duncan's New Multiple Range Tests. SSF Summary of Results for the Variables Measured According to

Vegetation Type 'Table Vegetation Temp. DO CO<sub>2</sub>; Salinity Na KM ee '© emgit mgt magi gil mg gl mg 030 118 210 15.84 Forest 23 86 219 26.13 5.65 23.2 85 2.86 3409 816 040 1.90 4.25 21.07 240 82 3.44 565.08 8814 3.29 2.94 14.86 34.27 'The results show a general increase in the values of all the parameters measured from higher to lower elevations with the exception of DO which decreased slightly. DO values were found to be near saturation at all times. Free CO<sub>2</sub>; concentrations ranged within the normal values for natural surface waters as did the pH values, which ranged from 6.5 to 8.2 with a modal value of 7.0. The values for Na, K, Ca, Mg, and Cl were found to be below or near those accepted for drinking water standards. Each river or tributary differed significantly from others in the concentration of the elements. These differences were maintained throughout time. No marked seasonal variabilities were observed except for water temperatures which reflected the lowering of air temperatures during the winter months. Mechanisms of Activity and Biodegradation of Lindane — Arthur McB. Block. This program is being carried out jointly with Dr. Leo W. Newland, Director, Environmental Studies Program, Texas Christian University, Ft. Worth, Texas. It was begun in the summer of 1973 when Dr. Newland participated in the AEC summer research program for senior investigators. Experimental evidence for the anaerobic isomerization of lindane (gamma isomer of benzene hexachloride (BHC)) to less toxic alpha, beta and delta isomers before subsequent reduction and degradation has been published by Newland. A theoretical basis for interpretation of the activity of the gamma isomer compared with the alpha, beta and delta forms was sought. Also, a molecular basis for the apparent inability of aerobic organisms to degrade lindane or the other isomers was considered. SCF-MO calculations using complete neglect of differential overlap (CNDO/2) were performed for the alpha, beta, gamma and delta isomers of hexachlorocyclohexane. Assuming

standard geometries, the total energy (heat of formation), total electron density of chloro-substituents, dipole moment, energy of the lowest unoccupied molecular orbital (LUMO), energy of the highest occupied molecular orbital (HOMO), and LUMO d-orbital coefficients for the axial chloro-substituents were obtained for each of the isomers. The temperature coefficients of the equilibrium constants with respect to the conversion of the gamma isomer (lindane) into each of the other isomers were also calculated. The LUMO calculations indicate the gamma isomer is the best

electron acceptor, which suggests electron transport disruption in cells can be accomplished easily. The large dipole moment obtained for the gamma isomer would facilitate good long-range dispersion force attraction to hydrophobic portions of the cell. Therefore, the axial chlorine with good d-orbital extension could indirectly disrupt charge transfer (e- transfers) associated with metabolic pathways in mitochondria which depend on hydrophobic parts of ATP, NADPH, acetylcholine, and coenzyme A. Single electron reduction potential oxidation potentials. Subsequent studies dealt with the ability of the various isomers to exist in nature in the classically quoted "chair" and "boat" conformations characteristic of the substituted cyclohexanes. Experimental dipole moments and polarizability measurements have been obtained, and the dipole moments of chair and boat configurations of the alpha, beta, gamma, and delta isomers of 1,2,3,4,5,6-hexachlorocyclohexane were calculated using an enlarged, 84 orbital, all valence electron, self-consistent field (SCF) molecular orbital (MO) calculation with complete neglect of differential overlap (CNDO/2). The dipole moments, so calculated, were consistent with dipole moment and polarizability measurements for the beta isomers and also for the alpha isomers, provided that possible mixtures of chair and twisted boat conformations were considered. No mixtures of conformations gave

calculated results consistent with both the experimental values of dipole moment and the experimental values of polarizability for the gamma and delta isomers, though there was good agreement between the calculated and measured dipole moments for the gamma isomer chair forms. Ongoing studies of the lindane problem include the study of the alteration (if any) of the single electron oxidation and single electron reduction values when the possible twisted tials were calculated to be less than half the corresponding boat forms are taken into account. Plant Growth Regulation in Succession Mechanisms — Arthur Mc.B. Block and Richard Clements. Microbial decomposition of leaf litter to form allelochemical compounds has not been investigated for semi-deciduous canopy species in humid tropical forests. The mechanism of allelochemical plant growth inhibition is not well understood but appears to be related to the stimulation or control of auxins or plant growth regulators naturally present in plants. Electron characteristic types are probably important in deciding whether a molecular type is likely to be a plant growth inhibitor or regulator. Experiments on substituted indole-3-acetic acid and halogenated indoles have led to the suggestion that fractional positive charge development on the -NH group of the indole ring at a fortuitous distance (5.5 Å) from the carboxylic acid function is requisite for plant auxin activity exhibited by indoleacetic acids (W.L. Porter and K.V. Thimann, 1965). Calculations using self-consistent field (SCF) molecular orbital (MO) theory with complete neglect of differential overlap (CNDO) were carried out on a series of halo-substituted phenoxyacetic and indoleacetic acids. No net positive charge development calculated for the N-H group in the substituted indole-acetic acids gave the observed order of auxin activity. No development of positive charge in the  $\pi$  system calculated for N was in any way comparable to the observed auxin activity increase. However, the energies of the lowest

Unoccupied molecular orbitals (LUMOs) decreased nearly linearly with increasing auxin 'y. Twelve substituted phenoxyacetic acids, also treated, showed a correlation between the LUMO energies and the square of the LUMO coefficients at the ortho position, respectively, and plant auxin activity when the lipophilicity of the molecules in the series was taken into account. The correlation coefficient of the activity as a function of LUMO energy was virtually identical to that calculated from the data of Hansch et al., 1963, using ring substituent Hammett sigma values for the ortho position instead of the LUMO energies. Identification of phenolic residues (aglycons) from leaf litter decomposition is now underway for tree species: *Dacryodes excelsa* (tabonuco) and *Tabebuia*

*pallida* (roble). In preliminary experiments, layers of forest soil at the bottom of 2000 ml flasks were covered with a layer of leaf fragments from known forest species, and fresh seeds of *Tabebuia pallida* were placed on the surface of the litter. Germination in the cotton-plugged flasks was ultra-rapid in some of the flasks when compared with control flasks of pin soils with no leaf fragments covering. There appeared to be inhibition of seed germination in two of the flasks. Confirmatory experiments are underway. References: Porter, W.L. and K.V. Thimann, 1965. *Phytochem.* 4, 229. Hansch et al., 1963, *J. Amer. Chem. Soc.* 85, 2817. Geographic distribution, intraspecific variability, and home range of *Caracolus caracolla* (Gastropoda: Pulmonata) in Puerto Rico — Carmen Hernandez. *Caracolus caracolla* is widely distributed in Puerto Rico. It was originally described under the name *Pleurodonte caracolla*, Linnaeus. Bartsch (1918) described a new species, *Pleurodonte debooyi*, based on fossil findings in Santa Cruz. In 1966, Aguayo established these two species as subspecies of *Caracolus caracolla*, *Caracolus caracolla caracolla* and *Caracolus caracolla debooyi*. In order to determine the existence of two distinct species, two

Subspecies, or the effect of an intraspecific variation in *Caracolus caracolla*, different aspects of the animal were studied. Data obtained on the geographic distribution of *Caracolus caracolla* in Puerto Rico indicate that the height and diameter of this species vary independently of geographic elevation and other related factors of temperature, humidity, and rainfall. In contrast to previous findings by Bartsch (19), it appears that the height and diameter of *Caracolus caracolla* are an intraspecific variation having no relationship to any other aspect of the geographic distribution. The population studies at El Verde demonstrate that an intraspecific variation occurs in regard to height and diameter that is similar to the rest of the island. A sexual preference study indicates that *Caracolus caracolla* at El Verde do not show mate preference in relation to size, diameter, or height. And, these snails are mating randomly; we are mitigating against the process of subspeciation. That is, in this case, different breeds of subspecies do not exist. According to the data obtained in the population study made at El Verde, the average home range of *Caracolus caracolla* is 7 sq. meters. It appears that the home range of this ubiquitous species of decapod crustacean in the Espiritu Santo River system. *Caracolus caracolla* is apparently determined by the availability of food, mates, and favorable environmental conditions. Preliminary observations also indicate that this snail moves about as much at night as it does during the daytime. A random sample taken of *Caracolus caracolla* from El Verde showed that the coelotestis cells of each snail had 18 chromosomes. References: Bartsch, P. 1918. A New West Indian Fossil Land Shell, *Proc. U.S. Nat. Mus.* 54 (2254) 605-606. Aguayo, C.G., 1966. Lista de los Moluscos Terrestres y Fluviales de Puerto Rico. *Stahlia* 5:1-17. Environmental Studies for Siting of a Nuclear Reactor — Staff. (a) Terrestrial Ecology. Beginning in October 1973,

Members of the Terrestrial Ecology Program undertook a one-year study to provide data on the terrestrial ecology of an area proposed for a nuclear reactor site. The study also provided radiological background data. Species lists were prepared for the vegetation and fauna of the area. A complete mapping of vegetation in the one-square-mile exclusion zone was completed and reported along with a special detailed survey of a 36-acre tract. Eighteen 1 sq. meter quadrats were mapped every three months to provide information on seasonal changes in species composition. The final survey was completed in late January 1975. Final data reduction and reporting were completed by June 1975. The report has been submitted to the P.R. Water Resources Authority, and a detailed report on the project will be published as a P.R.N.C. numbered report.

(b) Background Radioactivity in Northwestern Puerto Rico. Studies were initiated in October 1978 for the Puerto Rico Water Resources Authority for inclusion in the Environmental Report to support

the PRWRA's petition for licensing the construction of a nuclear power plant in Barrio Islote. The radiological background studies were of widely varying scope. A complete review of literature on former radiological background studies in Puerto Rico and a collection of data taken by U.S.GS., PRNC, U.S.P.ILS., and the P.R. Public Health Service were carried out. The results appear in Chapter 2.8, Environmental Report, North Coast Nuclear Plant No. 1, 1974-1975. A pre-operational radiological monitoring program consonant with local conditions and customs was then designed, and logistics of milk sample collection were specified and successfully field tested. Milk monitoring is perhaps the most important and detailed of all the monitoring programs, especially with respect to scheduling and field operations. It was demonstrated that such monitoring can be undertaken in local laboratories with the necessary precision and accuracy. Details of the pre-operational monitoring program are contained in

Chapter 6.3 of the Environmental Report. In addition, thermoluminescent (integral) dosimetry was carried out at 10 land-side stations, seven lying in the direction of the principal wind sectors relative to the Islote nuclear plant exclusion zone, one at the zone and two off the principal wind vectors. The stations were located at Barceloneta, Florida Adentro, Islote, Arecibo Airport, Arecibo, Charco Hondo, Dos Bocas, Lares, San Sebastián, Quebradillas, and Mayagüez. Dosimeter calibration was accomplished using a C187 source with an estimated stopping ability for the CaP dosimeters, giving a rating of 1.5 mr/mR. The study's scheduled termination date was May 1975. Experiments comparing low-energy cut-off shielding values with results for normal (i.e., unclad) dosimeters are also in progress. Temperature effects are also considered important, and shielded lead brick stations have been installed at critical stations for determination of these effects. Air monitors operating continuously and collecting samples of dust on filter paper tape were established at all stations except Mayagüez. Four days' worth of samples per month were analyzed for total gamma activity using a NaI crystal detector and a single channel analyzer with a wide window (0.15 MeV to 1.85 MeV). The experiments are still ongoing. Arecibo Airport and Quebradillas seem to be the only locations showing air-borne radioactivity substantially in excess of background. These observations will be checked against TLD dosimeter data. In Barrio Islote, five transects were laid out, and soil samples were collected along them. Gamma spectral qualitative analysis using Ge:Li detection shows clearly defined Cs-137, K-40, and Co-60 peaks, among others, in several of the samples. Ongoing work includes the estimation of total gamma activity for these samples. Water from deep wells, from artesian upwelling from small spring and marsh areas, and from the sea in the region around the exclusion zone was collected. Gamma activity of the samples collected is under

study. Measurements of gamma activity of sediments from fresh, brackish, and salt water from points around the exclusion zone were carried out with a targeted termination date of May 30, 1975. References: Puerto Rico Water Resources Authority, 1974 and 1975. Environmental Report North Coast Nuclear Plant No. 1, Vol. 1, Chapter 2.8 and Vol. 2, Chapter 6, PRWRA, San Juan. TRAINING ACTIVITIES 'Two theses for Master of Science degrees in Biology were completed. Research investigations were completed for an additional Master of Science degree and one for a Ph.D. dissertation, Name Title of Thesis Major Professor Carmen Heeninder Geographic Distribution, Intraspecific Variability and M. Vélez Home Range of *Caracolus caracolla* (Gastropoda; Pl: 'monato) in Puerto Rico. M.S. degree completed. F. La Caro Disappearance of *Ducryodes excelsa* Leaf Litter in a R. Clements 'Tropical Montane Rain Forest in Puerto Rico, MS. degree completed. E. Cuevas Changes in Water Quality as Influenced by Land Use. Clements Patterns. M.S. Degree D. Padgett 'The Contribution of Aquatic Hyphomycetes in the R. Clements Decomposition of Submerged Leaf Litter. Ph.D. dissertation. 134 ---Page Break--- Rolando Mosquera Moreno; Graduate (Master) Research. "Rejection Criteria for Pairs of Environmental

Dose Values Inferred from Thermoluminescence Dosimetry," M. Publ Health Prog. Research work completed, May 1975. Supervision by Dr. A. McB. Block. Karl P. Prado; Graduate (Master) Research. "A Computer Program for Calculation of Field Dose Received by Thermoluminescence Dosimeters (TLD CALC in FORTRAN-G.); M, Publ. Health Prog. Research work completed May 1975, Supervision by Dr. A. McB. Block Daniel Lebrén-Pitre, Graduate (Master) Experimental Research, "Natural Radiation Exposure in Puerto Rico," M. Nucl. Eng., Research work completed April 1974, Degree awarded June 1974. Supervision by Dr. A. McB. Block and Dr. R. G. Clements. Antonio Gonzalez, Graduate (Master) Experimental Research on TLD Measurements of Natural Radiation Background in Puerto Rico,

M. Nucl. Eng., Research work completed May 1975. Supervision by Dr. A. McB. Block and Dr. R. G. Clements. Edgardo Hernandez; Graduate (Master) Research. "Laboratory Investigation of Statistics of Thermoluminescence Dosimetry using CaF<sub>2</sub> Dosimeters," M. Publ. Health Prog. Research work completed, May 1975, Supervision by Dr. A. McB. Block. PRNC-550 (Environmental Radioactivity) course offered for M.S. Degree in Radiological Health was taught by Dr. A. McB. Block, Spring semester, 1975. A total of 8 graduate students completed the course. STAFF ACTIVITIES Dr. R. Clements was appointed to the U.S. National Committee for Man and the Biosphere, Project 1. This project deals with the Ecological Effects of Increasing Human Activities on Tropical and Sub-tropical Forest Ecosystems. The program continued its cooperative efforts with various agencies and individuals. Dr. A. McB. Block participated with University of Puerto Rico scientists in two projects and provided theoretical, interpretational, and computational support in the field of chemistry. Dr. Block carried out cooperative work with scientists from the Industrial and Economic Development Laboratory of the Commonwealth of Puerto Rico and with Dr. Leo Newland, Director of the Environmental Studies Program, Texas Christian University. 135  
---Page Break--- ---Page Break--- TROPICAL AGRO-SCIENCES The Tropical Sciences Division conducts research on problems of major importance in tropical agriculture, in particular, food production and quality improvement. It also provides training through teaching and thesis supervision for University of Puerto Rico students majoring in agriculture, biology, or chemistry, and special training in selected disciplines for postgraduate students and visiting scientists. Nuclear science and its applications are emphasized in research, teaching, and training. The Division's research and training activities represent a major ERDA program directed toward the application of nuclear energy to tropical agriculture. The need for agricultural research in the

Tropics has never been so imperative because of the population explosion and the need for alleviating hunger in the world. The utilization of nuclear techniques is expected to facilitate and expedite the research toward positive results.

## RESEARCH ACTIVITIES

Soybean Mutation Breeding — F. K. S. Koo and J. Cuevas. The "day-neutral" selections from the gamma-irradiated Hill and Lee varieties have been subjected to yield trials since the winter of 1972. Based on their yielding capacity through the years, four Hill lines and five Lee lines were finally selected and again entered in the yield trials at Isabela Station during the winter of 1974. These lines are about two to eight days later in maturity than the parental varieties, and a few of them have shown consistently higher yielding capacity (up to 50 bushels per acre). Also, one selection each from these Hill and Lee lines has been entered in the Regional Trials in Central American countries which are sponsored by the Organization of American States.

In the summer of 1974, seeds of four varieties, Hardee, Dortchsoy, N.T.U. Kaohsiung No. 5, and Palmetto, were irradiated with 15,000 rads of gamma rays, and the M1 and M2 generations were advanced in the field. The individual plants within each of the M1 lines have been harvested and are being screened for high methionine content. In the past, the Division devoted much time to developing a mass-screening method for methionine based solely on isotopic dilution and neutron activation principles. However, these techniques proved to be extremely time-consuming in practice. In the past few months, a simple method with a good degree of accuracy has been worked out. The basic procedures of this method follow Horn's method closely but with several modifications and improvements. Sample size and the amount of reagents used have been optimized in this method. Improvements include cutting down hydrolysis time by autoclaving, filtrating hydrolyzate without dilution, using 2-mercaptoethanol for eliminating destruction of

Methionine during hydrolysis, and using repipets for delivering various reagents. Most of these improvements have been made for the sake of simplifying the procedures. The method is fairly reliable for detecting small differences in methionine quantity for a mass-screening program.

Plant Tissue Culture — F. K., 8, Koo, J. A. Ferrer and Milagros Beauchamp. Over 40 young flower buds of *Arabidopsis* were cultured in Nitsch medium in vials. Nine seedlings appeared four to seven weeks later. These seedlings were transferred to either Murashige and Skoog medium or Nitsch medium without NAA, and three plants matured with seeds. Four others were sterile. The sterile plants could have developed from immature pollen. The development of these plants could not be determined because of the difficulty of using the root tip squash technique for this material.

Mutagenic Specificity of 5-bromodeoxyuridine in Germinating Soybean (*Glycine max* (L.) Merrill) Seeds — F. E. Cuevas and F. K. S. Koo. Since the mutagen 5-bromodeoxyuridine (BUDR) can be incorporated into genetic material during DNA synthesis, and the genes of a genome follow a definite time sequence for replication, it is possible to incorporate this mutagen into a specific gene or genes by treating the material at a specific stage during the DNA synthetic period. Consequently, any particular mutation may be "selectively" induced according to the time of BUDR treatment during the specific seed soaking period. In this study, soaked soybean seeds in the second cell cycle during germination were treated with 5-bromodeoxyuridine at the concentration of 150 µg/ml for one hour at 6, 7.5, 10, 12.5, and 15 hours of soaking at 25°C following 20 hours of first soaking (25°C) plus 6 hours of cold treatment at 4°C which was employed to synchronize the cell generation. The treated materials were grown in the field, and the progenies were screened for mutations at the seedling stage. It was found that BUDR was an effective mutagen for inducing genetic alterations.

in soybean seeds. The highest overall mutation frequency was reached at the peak of the S-period. Four types of mutations were recovered, with the unidirectionally-oriented first leaf pair type being the most frequent, the twisted first leaf pair type next, the twisted central leaflet type third, and the twisted lateral leaflet type the least. The latter two types, which affected the first trifoliate leaves, were found most abundant in the treatment where the seeds were treated for 15 hours in the post-cold treatment soaking, indicating clearly the dependence of the induction of specific types of mutations by BUDR on the treatment period. On the other hand, the former two types were induced most readily when the seeds were treated for 12.5 hours in the post-cold treatment soaking, but these two types also tended to spread over other treatment periods. The DNA synthetic period was determined by the H-thymidine labeling study in soaked soybean seeds. The S-period of the first cell cycle in the germinating seeds was found to be at 16 hours of seed soaking at 25°C and that of

the second cell cycle at 12.5 hours plus 6 hours of cold treatment at 4°C. The peak occurred after 20 hours of soaking at room temperature (25°C). Studies on the Mechanisms of Cadmium Toxicity in Isolated Chloroplasts — A. Cedeno Maldonado and Carmen Asencio. Cadmium is one of the trace metals whose concentration in the environment is increasing as a result of continuous expansion in the production and consumption of this metal in the industrialized world. Although not known as an essential element in plant nutrition, its accumulation in different plant tissues is well documented. High concentrations of cadmium are known to be deleterious to plants by decreasing their growth and productivity. At the cellular level, damage appears as a decrease in the activities of such organelles as mitochondria and chloroplasts. The mechanism of damage to these organelles is not fully understood, but present knowledge indicates that energy generation is

affected. In this study, chloroplasts were isolated in aqueous media by standard procedures and the following reactions were studied: (a) electron transport in photosystems I and II using natural and artificial electron donors and acceptors, (b) CO<sub>2</sub> fixation using NaH<sup>14</sup>CO<sub>3</sub>, (c) ATP synthesis using <sup>32</sup>P-labeled phosphate, and (d) carbonic anhydrase activity. The results (Tables 1-4) obtained so far indicate that cadmium inhibition of photosynthetic electron transport, CO<sub>2</sub> fixation, and ATP synthesis occurred at relatively high concentrations of this metal, suggesting that electron transport dependent reactions are not the primary site of action. However, cadmium is a potent inhibitor of carbonic anhydrase. In all experiments, concentrations of CdCl<sub>2</sub> exceeding 50 μM caused considerable inhibition of this enzyme. Since carbonic anhydrase appears to be one of the key enzymes involved in regulating the levels of free CO<sub>2</sub> inside the chloroplast, our results are indicative that CO<sub>2</sub> depletion of the chloroplast is one of the primary mechanisms of Cd toxicity.

Table 1: Effect of Cd on O<sub>2</sub> evolution by isolated chloroplasts using K<sub>3</sub>Fe(CN)<sub>6</sub> as electron acceptor (Photosystem II activity) [Ca] (μM) O<sub>2</sub> evolved % inhibition

0	50	100	50	200	43	13	250	35
30	350	20	39	500	2	52	650	2
58								

(O<sub>2</sub> evolution is given in micromoles per milligram) Table 2: Effect of Cd on O<sub>2</sub> uptake with DCIP-ascorbate as electron donor and anthraquinone as electron acceptor (Photosystem I activity) [Ca] (μM) O<sub>2</sub> uptake % inhibition

0	186	150	154	1	350	25	500	106	32	700
64	59									

(O<sub>2</sub> uptake is given in micromoles per milligram of chlorophyll per hour.) ---Page Break---

Table 3: Effect of Cd on O<sub>2</sub> evolution by intact chloroplasts using CO<sub>2</sub> as electron acceptor [Ca] (μM) O<sub>2</sub> evolved % inhibition

0	1	25	5	33	46	38	100	42	44	200	42	44	350	39	82	450	17
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(O<sub>2</sub> evolution is given in micromoles per milligram of chlorophyll per hour.) Table 4: Effect of Cd on the carbonic anhydrase activity of isolated chloroplasts. [Ca] (μM) Enzyme Activity % inhibition

0	20	35
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40 2% a 80 5 89 100 2 95 150 1s 9 Enzyme activity is given as units of activity per milligram of chlorophyll! Effect of Herbicides on the "In Vivo" Activity of Nitrate Reductase in Lemna major L. (Spirodela polyrrhiza) — Lilia Delgado and A. Cedefio. Some of the most common chemicals used in Puerto Rico for weed control belong to two of the major classes of herbicides, namely the substituted ureas and the S-triazines. These compounds are well-known photosynthetic inhibitors, deleterious to the growth of both target and non-target species. Recently, Klepper reported that these photosynthetic inhibitors are also harmful to plants by blocking some of the steps involved in the reduction and assimilation of nitrate-nitrogen. However, the extent and mechanism of damage to the nitrate reduction processes have not been fully clarified. Since nitrate is one of the most important sources of nitrogen for plants under most environments, it is expected that any chemical which impairs nitrate reduction constitutes a threat to the life activities of plant communities. One of the key enzymes involved in the pathway of nitrate reduction in plants is nitrate reductase. Present in the cytoplasm, this enzyme catalyzes the reduction of nitrate to nitrite through redox reactions involving the reducing power of the cell. Due to its key role, any inhibition of the function of this enzyme by chemicals present in the environment, such as herbicides, could produce detrimental



effects on the ecosystem. The present investigation was conducted for the purpose of determining the effects of some widely used and relatively persistent herbicides on the activity of nitrate reductase in *Lemna major* L., a representative non-target species. The material was grown under autotrophic conditions. The herbicides tested were:

2-(ethylamino)-4-(isopropylamino)-4-ethylthio)triazine (Ametryne),  
2,4-bis(isopropylamino)-4-ethylthio)triazine (prometryne), 3-(3,4-dichlorophenyl)-1,1-dimethylurea (Diuron), and 1,1-dimethyl-3-(2,4,6-trifluoro-m-tolyl) urea (Fluometuron).

The treatment consisted of inoculating *Lemna* plants in nutrient solution containing different concentrations of the herbicides. Each herbicide concentration was replicated 4 times. Two days after inoculation, a sample of 20 fronds (leaves) was removed from the herbicide solution and assayed. Nitrate reductase activity was assayed "in vivo" using a combination of the methods of Harper and Sma, and Shen. The assay solution contained 10 mM potassium phosphate buffer, pH 7.5, and 0.2 M KNO<sub>3</sub>. Five ml of this solution in 15 ml test tubes were used for each sample. The *Lemna* fronds, after being punctured three or four times with a syringe needle to facilitate infiltration, were submerged in test tubes containing the assay solution and infiltrated under vacuum. The infiltrated samples were incubated in a water bath with shaking at 30°C for 1 hour in darkness. The reaction was terminated by adding 1 ml of 1% sulphanilamide in 1.5 N HCl. Five minutes later, 1 ml of 0.02% N-(L-naphthyl)-ethylenediamine-dihydrochloride in water was added to each sample. The samples were immediately shaken, and after allowing color development for 10 minutes, the optical density of the samples at 540 nm was recorded. Results obtained are summarized in Table 5. Effect of Herbicides on Nitrate Reductase Activity in *Lemna major* L. 'Activity as percent of control rate Ametryne Diuron Fluometuron Prometryne Concentration ° 300 100 100 100 1x10<sup>-1</sup> 101 98 102 100 1x10<sup>-1</sup> 143 133 149 181 5x10<sup>-2</sup> 87 216 98 18x 107 100 90 8 105 1x10<sup>-3</sup> 88 82 102 25x 10<sup>-4</sup> 65 81 133 75 5x10<sup>-5</sup> 62 40 10 15 12108 36 83 92 68 Control Rate: 60.25 x 10 micromoles of nitrate reduced per sample of 20 leaves. Each of the herbicides tested had a dual effect on nitrate reductase activity. At low concentrations, enzymatic activity was increased, but with increasing concentrations, enzyme activity was inhibited. Fluometuron and prometryne, the herbicides producing the highest increases in enzymatic activity, were the least inhibitory at high concentrations.

concentrations. Ametryne, causing 65% inhibition of enzyme activity at 10% M, was the strongest inhibitor tested. Although the effects of the herbicides were not related to the chemical nature of the compounds, the concentrations at which effects were observed were at 10% M, whereas the ureas were most effective at 5 x 10<sup>-6</sup> M. Since the concentrations of these herbicides causing significant inhibition in nitrate reduction are much higher than those causing similar inhibition of growth and photosynthesis, it is unlikely that inhibition of nitrate reduction is the primary mechanism of toxicity of these compounds. However, the great increase in nitrate reductase activity produced at very low concentrations could have serious ecological implications. In earlier studies, similar concentrations of these chemicals brought about significant increases in the growth and photosynthesis of *Lemna major* and similar species. The possibility exists that a similar situation occurring in a natural environment would bring about excessive growth of some species to the detriment of ecology. This could happen particularly in water habitats, where herbicides are most likely to accumulate and where species that multiply profusely, such as algae and duckweeds, exist.

## TRAINING ACTIVITIES

The Division continues to provide instruction and training to students and scientists at graduate and

postgraduate levels in the fields of agriculture, biology, and chemistry. These undertakings, especially training, are frequently related to the Division's basic research activities.

Graduate Courses. During 1974-1975, Division staff members holding joint or ad-honorem appointments in various science departments of the U.P.-R. taught the following courses:

- Course No. of Students Professor First Semester, 1974-75
- Agro 552 Radioisotopes Techniques in Agriculture 1 J. Cuevas Ruiz
- Agro 699 Research 1 BLKS. Koo
- Hort 605 Nuclear Techniques in Agricultural Research 2 J. Cuevas Ruiz
- GGF 648 Photophysiology and Crop Productivity 4 A.

Cedefo-Maldonado Biol 660 1 BLK. Koo Biol 699 1A. Cedefo-Maldonado Biol 699 Research 1 LA. Ferrer-Monge Chem 699. Chemistry Research 1 8. N. Deshpande Second Semester, 1974-75 Agro 699. Research 1 Hort 668 Growth Regulators in Horticulture 4 Biol 660 Special Studies in Biology 1 1 Biol 699 Research Research. During 1974-1975 four graduate students were active in M.S. thesis research under the supervision of the Division staff members: Student Department Thess Tite [Major Professor Federico Cuevas Pérez (Dom. Rep.) Agro. Mutagenic specificity of Sbromo: F. K. S. Koo. deoxyuridine in relation to soaking time of soybean seeds. Maria Arzol (PR) Chem, Microanalysis of sulfur-containing 8. N. Deshpande amino acids by isotopic dilutions of IClabeled silyl derivatives. Alice Ort (PR) Biol, Cytogenetic effect of insulin on human chromosomes. Carmen Asencio (P.R) Biol. Effects of cadmium on the photosynthetic process in isolated chloroplasts. 142 ---Page Break--- Special Training. The Division is active in technical and scientific training programs. During the second half of FY-1975, four trainees under the sponsorship of OAS and the Gran Mariscal de Ayacucho Fellowships of Venezuela program received special training in the fields of plant physiology and application of nuclear techniques to agriculture. Trainee Country Sponsorship Trolog Period Jesus N. Garcia Villalobos Venezuela Gran Mariscal de Ayacucho Fellowship Lilia Delgado Martes Venezuela Héctor B. Flores Merino Peru OAS Julia M. Radosevich-Yrigoyen In addition, these trainees were engaged in research training in the following topics: Trainee Research Jesus N. Garcia Villalobos Protection of crop plants against SO<sub>2</sub> by organic acids. Lilia R. Delgado Martes Physiological effect of herbicides on Lemna, Héctor E. Flores Merino Plant Tissue culture. Julia M. Radosevich Yrigoyen Role of endogenous hormones on cornelization in tanier. STAFF ACTIVITIES Drs. Francis K. S. Koo, Arturo Cedefo and Mr. José Cuevas

participated in the Workshop on Grain Legume Diseases on June 24, 1974, in Rio Piedras. The Workshop was sponsored by the UPR Agricultural Experiment Station and the U.S. Agency for International Development. On May 11-16, 1975, Dr. Francis K.S. Koo attended the First International Symposium on Acid Precipitation and Forest Ecosystems in Columbus, Ohio. Dr. Koo served as an IAEA Expert at the Centro de Energia Nuclear na Agricultura (CENA) in Piracicaba, Brazil, during the period of September 9 to December 8, 1974, under the auspices of the United Nations Development Program. His principal duty was to help strengthen a research program at CENA on the improvement of *Phaseolus vulgaris* and to train counterpart staff at CENA and post-graduate students at the College of Agriculture (SALQ), University of Sao Paulo. Dr. José Ferrer was on leave during FY-1975. During this period, he traveled extensively in Europe. Among the places he visited were the Academia de Ciencias e Historia Natural in Madrid, Spain; the British Museum of Natural History in London; the University of Brussels; Antwerp Museum of Natural History and Zoo; and the Congo Museum in Belgium. 143 ---Page Break--- "The He-Ne lasers used

primarily by scientists in the Nuclear Science and Technology Division. This laser emits a coherent monochromatic light of wavelength 6528 Å with 50 mW power and R. Purcell to test irradiation direction as the transition. The crystal was 144 ---Page Break---

NUCLEAR APPLICATIONS  
NUCLEAR SCIENCE AND TECHNOLOGY 'The Nuclear Science and Technology Section is engaged in research on physical properties of materials and the effects of radiation upon them. This involves solid state materials undergoing phase transitions, energy storing materials, and temperature dependent effects in bio-materials. 'The Section also offers research facilities for M.S. and Ph.D. degree thesis work in the fields of physics, chemistry, materials, and radiation sciences in cooperation with the various colleges and departments of the University of Puerto

Rico Mayagüez Campus. It is anticipated that if present support is expanded moderately, our group can serve as a catalyst to start energy-related research programs involving solar energy in cooperation with the faculty of the science departments and the College of Engineering of the UPR Mayagüez Campus. To encourage and promote cooperative efforts, the section maintains contact with former graduate students and visiting scientists who hold academic positions of responsibility in Latin American research institutions. Effective July 1, 1975, this Section will be known as the Material Sciences Division.

## RESEARCH ACTIVITIES

Research Completed Dipolar Theory of Ferroelectrics Revisited — J. A. Gonzalo. An analysis of experimental data has been done for various ferroelectrics within the framework of the dipolar theory, along the same lines of the recent work on triglycine sulfate (TGS) and triglycine fluoroberyllate (TGEB). A simple method is applied which, using solely dielectric data near  $T_g$ , leads to the determination of the main parameters of the theory. The resulting numbers,  $N$ , of elementary dipoles per unit volume appear to be close to the numbers of unit cells per unit volume as determined from crystallographic data. The elementary dipole moments are reasonably consistent with observations of low-temperature spontaneous polarization. The mean-field coefficients appear to be consistent with an independent evaluation of the "reaction" field in cases for which quasi-point-dipoles in the lattice can be assumed. The relative contribution of the dipolar polarization to the total (dipolar plus atomic) appears to be larger in the more ionic ferroelectrics. The transition entropy polarization due to the order-disorder process can account for the observed values in most (but not all) cases. No adjustable parameters have been used.

Departure From Mean Field Critical Behavior in Ferroelectric DTGS — A. Carnas- sio and J. A. Gonzalo. Dielectric constant and hysteresis loop measurements have been performed in

single crystals of deuterated triglycine sulfate (DTGS) in the vicinity of the 145 ---Page Break --- transition temperature. In the range  $0.02^\circ\text{C} < AT < 0.60^\circ\text{C}$  deviations from mean field behavior were observed. In the range  $1^\circ\text{C} < AT < 10^\circ\text{C}$  the dielectric constant data fitted mean-field predictions fairly well. Using the experimental (non-mean-field) values for the critical exponents in the temperature range closer to  $T$ , the "scaling" equation of state  $h(x) = (x_0 + x)^{-1}$  was seen to be fulfilled in a wide range of  $x$  ( $AT/T$ ,  $IP/P_0$ )<sup>1/8</sup> below and above  $T$ . The same is true for TGS data, using classical values for the exponents. Fig 1 See a log-log plot for 165 of (a) inverse dielectric constant. The polarization rts Tele 146 ---Page Break --- Equation of State for the Heisenberg Model Near  $T$ , — J. A. Gonzalo. Recently, Milosevic and Stanley have done numerical calculations on the Heisenberg model for various lattices (s.c., fcc, and b.c.c.) and various spins ( $S=1/2$ ,  $S=1$ ) which show that the equation of state is rather independent of lattice type and spin. In this

communication, it is shown that a simple expression  $(x_9 + x) / h(x) = (x^4 + x) / x^2 - 2$  can be obtained rigorously for the “scaling function.” A further detailed comparison is given between experimental data for Ni and CrBr, and this simple equation of state using the (6-1) value which fits best the Heisenberg model numerical results of Milosevic and Stanley. The normalization values for magnetization (M) and field (H) were determined from data near T (critical isotherm, coexistence curve, and  $kT = H g Syug$ ). The resultant  $x_0$ 's from both sets of data ( $x_9 = 0.243$  for Ni, and  $x_q = 0.230$  for CrBr) are in good agreement with each other and suggest a possible relationship  $x_9 V^{1/5}$  similar to the mean field case. Comparative Study of the Ferroelectric Specific Heat in TGS and DTGS — A. Camnasio and J. A. Gonzalo. A comparative study has been made of the specific heat in single crystals of triglycine sulfate (TGS) and

deuterated triglycine sulfate (DTGS). Measurements were performed (a) in the temperature interval 100-400°K, and (b) around the respective critical regions (at small temperature intervals  $\leq 0.02^\circ\text{C}$ ). In the low temperature region, both experimental curves were almost coincident, and they showed a temperature dependence indicative of strong anomalous anharmonicity. The heats of transition ( $4Q1.90 + 0.10$  joule/g) and entropy change ( $\Delta S = (6.21 + 0.80) \times 10^3$  joule/g°C) were almost the same for both crystals. The specific heat discontinuity was substantially different in both cases,  $\Delta C_p = 0.24 + 0.03$  joule/g°C for DTGS. Calculations based on both the thermodynamic theory and the statistical theory of ferroelectrics show fair agreement with the data. The Phase Transition in Sodium Nitrite — M. I. Kay, J. A. Gonzalo, and R. Maglic. Neutron diffraction data were collected on Sodium Nitrite at room temperature to provide a complete set of amplitudes of motion of individual atoms. Diffraction experiments were also performed at  $162 \pm 1^\circ\text{C}$  just below the transition and at 145 and  $150^\circ\text{C}$ . It was found that the quasi-mirror plane that relates the two unevenly occupied possible nitrite (and sodium) sites is about  $0.03 \text{ \AA}$  closer to the oxygen y parameter than is the center of mass. The amplitudes of motion correlated satisfactorily with dynamical, spectroscopic, and elastic compliance data up to the transition. Above the transition, lack of elastic data that could be correlated with transverse acoustic sound velocities prevented fitting. The lack of agreement may be interpreted to indicate that longitudinal frequencies decrease relatively faster with temperature than transverse. The amplitude data is in agreement with mechanical data that the a direction is “softer” than the b or c direction. Evidence of rotational motion about the c axis is also presented. Elastic and Elasto-optic Constants of Ammonium Perchlorate — F. Vazquez, R. S. Singh, and J. A. Gonzalo. Using Brillouin scattering, the elastic and elasto-optic constants of Ammonium

Perchlorate has been measured at room temperature. The polarized Brillouin scattering spectra yielded the nine elastic constants (in the units of  $10^{11}$  dynes/cm<sup>2</sup>) 147 ---Page Break --- 51,  $C_{xx} = 2.46$ ,  $C_{yy} = 3.15$ ,  $C_{xy} = 0.66$ ,  $C_{xz} = 0.47$ ,  $C_{zx} = 1.03$ ,  $C_{zz} = 1.63$ ,  $C_{xy} = 1.15$ ,  $C_{yy} = 0.76$ ; as well as twelve elasto-optic constants. In light of these results, some thermodynamic properties of the crystal are discussed. RESEARCH IN PROGRESS Pyro-ferroelectric Materials as Energy Converters ~ J. A. Gonzalo. The performance of pyro-ferroelectric materials as converters of thermal into electrical energy has been analyzed in terms of their fundamental dielectric and thermal properties. The time-dependent operation of a single-stage pyro-ferroelectric converter performing a spontaneous cyclic process has been evaluated, leading to expressions for the specific power, current, and voltage outputs in terms of the relevant static and transport parameters. It is concluded that ideal efficiencies of the order of 10-15% could be attained if proper materials with relatively large performance factors are developed to be used in multistage converters operating under large OTs. deuaus R ' Clemoasemad RRAN28 | gai, Ta 4 Cima RR. Thiet aa 2 Heat out Tele Te Fig. 2. Pyro-ferroelectric converter (single stage spontaneous process).

Charge AQ flows upon heating from ( $T_c$ - $A_{To}$ ) to  $T_e$  through load  $R_e$  ( $=R_j$ , internal resistance), and back, upon cooling front, to  $(T_e - a_{To})$ . 'Charge, 4G-Peos resistance.  $R_e = R; \rho = \rho_e A/K$ ; capacitance  $c = c(T)R/4nd =$  Palaver bay. 148 ---Page Break --- 'able 2: Feroeacrtegramamters (these ante) and perarmeefatareln i) tar srios paectrcntctet omen cots BBY tn GP? (BD pape pen tle me LasSrg, Bag, N20, Ms oon 7 5.30 a % 0 - " mari0y Sad 0.03125, a 0.67 0 0 om a) wan or oe 268 26 0 5 6 060 (4) a} os - ase oe - rc) atiog 168 (5.6) (77) ore (0.7) 100 6) von oe rn) titIncens vtues tn the col wnaer C3E°Q/C pes {then veperinlts for the performance Factor' emperatore intervals tn each RODSTe}» ane Oe Thermoluminescence and Vy Centers in Cal and CsBr

— Prudencio Martinez and J.-A. Gonzalo, A comprehensive study of recent research on the thermoluminescence of alkali halide crystals has been made together with a brief historical review of the subject. Experimentally, emphasis was placed on the thermoluminescence of CsBr and CsI, which, as suggested by previous work of the author of this thesis and other researchers, is due to self-trapped holes, better known as  $V_j$  centers. The relationship between the two low-temperature TL peaks in CsBr and CsI has been studied, and an analysis of the others suggests that the observed interdependence between the two glow curves can take place only in body-centered cubic crystals of the CsCl type. It is further suggested that the 93°K peak in CsI and the 160°K peak in CsBr are due to  $V_1$  centers oriented in the (1,1,0) direction, and that the 165°K peak in CsI and the 280°K peak in CsBr are due to a similar center aligned in the (1,1,0) direction. The orientation model appears to satisfy the observed phenomena. A computer analysis of monomolecular decay, of first-order kinetics, appears to apply quite well to the experimental results. 149 ---Page Break--- Brillouin Scattering of DTGS around the Transition Temperature — F. Vázquez. The elastic constants are known for the TGS and we are obtaining them for the DTGS. They allow us to compare the effect of the hydrogen bonds on the elastic properties. Studying the scattering through the transition temperature will give us insight into the dynamics of the second-order phase transition and relate it to the results obtained with TGS. Data have already been taken for the elastic constants and we are computing them. Uniaxial Pressure Dependence of the Elastic Constants Around the Transition Temperature — F. Vázquez and J. A. Gonzalo. Uniaxial pressure in the direction of the ferroelectric axis is going to be applied to observe the dependence and coupling of the acoustic modes. Uniaxial pressure may give important results because it breaks some of the symmetry-selected properties of the

crystal. Phonon-Raman Spectra of Hydrogen Bonded Ferroelectric in its Para and Ferroelectric Phases — R. B. Singh and J. A. Gonzalo. Phonon Raman spectra of TGSe, DTGSe and TGEB are being studied both in its para- and ferroelectric phases. These crystals are iso- 'morphic in structure with TGS which has been studied recently. A further study on these may help in assigning their lattice modes unambiguously and also may shed further light on the mechanism of phase transition. Phonon-Raman Spectra of Crystals Under High Pressure — R. B. Singh. A high pressure pump to generate hydrostatic pressure (10KBar) has been procured. The pressure cell is currently being built. The system will be tested soon. A few selected crystals will be studied under hydrostatic pressure. Phonon-Raman Spectra of Triglycine Sulfate (TGS) and Deuterated TGS in Ferro- and Paraelectric Phases — R. B. Singh, O. Matos, A. Camnasio and J. A. Gonzalo. Both TGS and Deuterated TGS are ferroelectric at room temperature and belong to  $C_{1P}$  space group with two formula units distributed as:  $11A(T) + 12A(R) + 10B(T) + 12B(R)$ , which are all IR as well as Raman active. In the paraelectric phase, both belong to  $C_{1v}$ - $P_63$  space group with two formula units per cell, and the zone center optical phonons are distributed as:  $GA_g(T) + GA_g(R) + EB_g(C) + OB_g(R) + 5Ag,(T) + 6Ay,(R) + 4B_1(T) + 6B_1(R)$ . Only g-types are active in Raman while u-types are active in IR. Polarized phonon Raman spectra of single crystal TGS and DTGS have been measured in the

ferroelectric phase and nearly all the zone center optical phonons have been identified. Measurements in the para-electric phase are in progress. Temperature dependence of those observable modes in ferro- and para-electric phases will be presented. Nature of the interatomic forces, mechanism of phase transition and thermodynamic properties were investigated. Scaling Breakdown Near a Critical Point — J. A. Gonzalo. It is shown that at least for the case of the mean field model, the scaling function  $h(x) = H/M^\beta$  is not uniquely

defined in a certain region around the coexistence curve ( $x < 0, H = 0$ ), and in another region around the critical isotherm ( $x = 0, H > 0$ ). At least for the same model, the function  $h(x)$  for  $H/M = \text{const}$ , tends asymptotically to a constant in the neighborhood of the critical point. ---Page Break---

‘TRAINING ACTIVITIES ble 2mm the Section of the Nuclear Applications Division. Neclar Se a recnoleey ‘Table 2. ‘Training Activities of the Nuclear Science and Tech Nuclear Science and Technology Section, January 1, 1974 — June 30, 1975 ~ ~ — — oo. so ‘Name Country ‘Advisor Tactaive Daten A. Thesis Research, M.S. Degree, Physics Gentit Esteves Colombia 3.A.Gonzalo Avg. 1973 Jun 1974 Prudencio Martinez Puerto Rico. ZA.Gonmslo Sul 1974—Feb 1975 Anibal Camnasio Argentina ‘Avg 1973—Jun 1974 Héctor Santiago Puerto Rico P. Paolodel Santo Aug. 1973—Mar 1975 Onvaldo Matos Puerto Rico B.S. Singh 1974 — Dee 1974 José Léper Santiago Puerto Rico 1974 — Jun 1975 B, Thesis Research, M.S. Degree, Chemistry Héctor D. Colman Rolén Paraguay RALee Jan 1974—Feb 1975 Maria B. Colén de Olmo Puerto Rico RA Lee Yul 1974 Jun 1975, sosé Escabi Pies Puerto Rico RA Lee an 1974—Now 1974 Luz del Mar Garcia de Rosado Puerto Rico RA Lee ul 1974—dun 1975, Maria Garcia Puerto Rico RALee Gel 1974—Dec 1974 Vietor Gonsslez Puerto Rico R.A Lee Gul 1974—Jun 1975 Semuel Hernsndes Puerto Rico FF Herero and RA.Lee Jul 1974—Jun\_ 1975 ©. Post-Graduate Research, Physics Genaro Coronel Paraguay 4. A.Gonaalo and ML. Kay ‘Aug 1974—Jun 1975 ‘Anbat Camnasio Argentina 3.A. Gonzalo D, Graduate Courses Course Enrollment Chem 587 Introduction to Solid State Physics 3 students Chem 608 Radiation Chemistry 8m Chem 673 Chemical Kinetics un Chem 571 Nuclear Chemistry 6 Chem 691 Graduate Seminar on lee Eng 625 Solid State Electronics 4 EE, Special Research Training in Nuclear Sciences Robert M, Purcell, ORAU Undergraduate Research Trainee Jun 1975 ‘A series of special seminars on “Direct Energy Conversion” were presented at the Physics Department of the UPR Mayagüez Campus

with the collaboration of the Nuclear Science and Technology Section. 151 ---Page Break---

‘The following seminars were presented at the Colegio de Ingenieros de Quimicos (Chemical Engineers Association) Headquarters in San Juan. Topic ‘Speaker Department Date 1. Fundamental Concepts in Energy Conversion Dr. Physics -PRNC May 14 2. Electrochemical Effects and Fuel Cells Dr. Chemistry -PRNC May 16 3. Magnetic Systems Dr. Physics May 21 4. Heating and Cooling With Solar Energy Dr. Mechanical Engineer May 23 5. Geothermal Sources of Energy Dr. PRNC May 28 6. Energy Conversion of Light and Nuclear Radiation Dr. Physics -PRNC May 30 7. The Politics of Energy: Domestic and International Dr. Political Science June 4 8. The Economics of Electric Energy in General in Puerto Rico Prof. Economics June 6 9. Electrostatic Systems Dr. Physics -PRNC June 11 10. Energy Storage Dr. PRNC June 18 11. Energy from the Ocean Prof. Physics - Arecibo Obs. June 20 12. Risks and Benefits of Breeder Reactor Dr. D. Nuclear Eng. - PRNC June 25 13. Solar Energy Dr. J. Comella Physics June 27 14. Energy Crises and their Solutions Dr. M. Tiarte - PRWRA July 2 STAFF ACTIVITIES Dr. Julio A. Gonzalo, Dr. Florencio Vézquez, and Dr. Ramn Shankar Singh attended and presented papers at the American Physical Society Meeting held in Washington, D.C. from April 21-26, 1974. Dr. R. S. Singh attended the Fourth International Conference on Raman Scattering held at Bowdoin College, Maine from August 25-Sept. 1, 1974. Dr. Julio A. Gonzalo presented a paper at the Midwinter Solid State Research

Conference, Laguna Beach, Cal. He discussed "Pyroelectric Energy Converters" with participants from Brookhaven N.L., Honeywell Co., and Bell Labs. Dr. J. A. Gonzalo presented a 30-minute talk on "Pyroelectric Converters" at the University of Puerto Rico President's Committee on Energy on February 15, 1975. VISITORS Dr. K. Shimaoka (U. of Ritsumeikan, Japan) discussed current work in ferroelectrics with Drs. F. Vazquez, R. Singh, M. Kay, and J. A. Gonzalo. Dr. W. Daniel (U. of Delaware)

visited our Brillouin Scattering laboratory and discussed experimental techniques with Dr. F. Vazquez. He also discussed, at length, ferroelectric phase transitions with Drs. Singh, Kay, and Gonzalo. 152 ---Page Break--- Neutron Diffraction Project 'The Neutron Diffraction Program is a National Science Foundation funded (Grant DMI-71-01745-A02) investigation into the structural changes that occur in materials undergoing ferroelectric and antiferroelectric transitions. The microscopic molecular structure of crystals defines their lattice vibrational and molecular spectra, which determine the response of the materials to impressed fields. Thus, the crystal structure and its changes through phase transitions is the basic information needed to predict and interpret transition mechanisms via their dynamics. Ferroelectric, antiferroelectrics or more generally ferroic materials have been used as optical gates, infrared detectors, transducers, and optical memory devices. The application of these materials, via the pyroelectric effect, as possible (solar) energy converters is dealt with earlier in this report. One might point out that the study of most materials and their interactions with various force fields leads, in one form or another, to "energy conversion." While some solids have more short-term possibilities such as superconductors, superionic conductors, and possibly ferroelectrics, almost all materials will react and respond to electromagnetic and mechanical inputs. As data accumulate on these properties and interactions, it is hoped that theories will become more predictive, permitting an arsenal of devices and "effects" to convert, store, and transmit energy in its desired form. RESEARCH COMPLETED A Refinement of the Paraelectric Phases of Copper Formate 4H; 0 from Three-Dimensional Neutron Diffraction Data — M. I. Kay. In 1954, Kiriyaama, Ibamoto, and Matsuo published an X-ray determination of the structure of copper formate tetrahydrate. They described a structure consisting of alternate layers of copper

formate and water. Okada, in 1965, determined the antiferroelectric nature of the transition discovered by Kiriyaama. A neutron diffraction study based on projection data, by Okada, Kay, Cromer, and Almodovar described the nature of the disorder in the paraelectric phase. The antiferroelectric transition mechanism has been studied by Soda and Chiba and Kay and Kleinberg. Cell doubling was noted by Turberfield. Lately, Okada and Allen have given theoretical statistical descriptions of the transition which seem to call for a better experimental structural base than was possible to determine from the projection data. It was thus decided to undertake a three-dimensional study of first the paraelectric phase and then the antiferroelectric in order to better elucidate hydrogen positions, occupancies, thermal parameters and their changes through the transition. As noted in previous work, the structure consists of alternate layers of copper formate (Fig. 1) and water (Fig. 2).

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Figure 2. Schematic representation of four possible fully hydrogen bonded water layers. The structures in Fig. 1a and 1b (and their centric pairs) in a 2 to 1 ratio probably make up the master layer in the paraelectric phase, although the same occupancies may be derived from 1c and 1d. (a) and (b) contain 2; orca les denote oxygen.

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A three-dimensional Fourier map showed that the hydrogen positions from the neutron projection data were approximately correct. Since no new hydrogen sites appeared and none could be dismissed, a set of equations may be written limiting and relating the occupancy of sets. The occupancy of hydrogen site (i) is denoted by  $f_i$ . The electroneutrality condition of the water molecules gives rise to  $f + 12 + 03 - 2 + 4 + 05 + 06 + 7 - 2 = 0$ . No hydrogen bond can be filled by more than one hydrogen atom, thus:  $f + f_6 < 1$ ,  $Q_{eIT} < 1$ ,  $203 < 1$ ,  $f_4 < 1$ ,  $25 < 1$ . The sum of the two equations (1) proves that all  $<$  signs in equations (2) may be changed to equal signs. Thus:  $f = 0.5$ ,  $a = 1.0$ ,  $f_2 = 1.5 - f_1$ .

$f_6 - 1 - A = n - 0.5$  Since equation 3.

describes the occupancy in terms of a single variable,  $f_1$ , it was decided that it would be faster to fit that variable by trial and error by refining all other parameters with a given  $f_1$  held fixed. The maximum possible range of acceptable values for  $f_1$  was from 1.0, where  $\{6 = 0.0$ , to 0.75 where  $\{1 = £2.75$ . The Fourier maps definitely indicated that  $£1 > 12$ . The value for  $f_1$  finally accepted from the limits set by the above refinement for all atoms was  $f_1 = 0.85 (+0.5, -0.1)$ . If  $f_1 = 0.833$ , then the water layer may be regarded as being made up of a 2:1 ratio of structures a and b as given in Fig. 1. There does not, at this time, seem to be any good reason to regard the structures as being present in the ratio of small integers. Bond distances and angles are listed in Table 1. The copper ion at the center of symmetry is surrounded, as noted in previous work, by 4 distorted octahedral oxygen environments of four formate oxygens and two water oxygens. The formate ions link copper ions. The formate hydrogen atom which is connected to the carbon atom has a very large major principal axis of vibration. The rms amplitude of 0.35 Å is very nearly perpendicular to the plane of the formate group and thus probably associated with a wagging motion. The other two principal axes are more normal values of (0.16 and 0.18 Å). From the angles listed in Table 1, it is seen that the surroundings of the water oxygen atoms are distorted from the tetrahedral, with oxygen(2) surrounded at all times by four hydrogen atoms (two of them tightly bound) and oxygen(1) surrounded by three hydrogen atoms and copper ion.

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Table 1. Bond Distance and Angles "Riding correction" is given in brackets for O-H distances. Standard deviations are in parentheses.

Wa-owi—H7 Owls" we--ow1— 7 Na~-- ows — 7 W4—ow2—H2  
Ha—ow2—Hi Ha—ow2—H6 wa—owa—ma Hs—ow2—n2 wa-owa—Ht  
He-ow2— He W1-owa— Ha! 7~0wa— Hh owa—or2 Ha-ora owi—owa Ha—owl  
ow2—ow2 ona som owas ~ow2 Hi-ows He-owa Ow —ow2 H2-ow2 I-OWa Distance 1970) rou) 240)  
1.2803) 1.28903) 109314 f.a4al 0.96a){ 98), 100(2) (1.03) 0.9841) {1.00) 0.964) [0.96), 0960) l097),  
110346) (105), 0943) (0.96), 282808) 1.886¢7) 250108) 1.828(6) 22390) 17790) 27048) Laz)  
1.781160) 27610) 170818) Laan) 'Bond Ani OF Cu owi or Gu—om Wa—ows—n2 Ha—owi—H3  
i4—owe—ns ia—ow2— He Ha-ow2—H7 ow2—H4-oF. ows —H9— ows ow2—Hs-owe ows Ha  
—owe OW1—H6—ows ows -H2-ow2 wi — 17 owe stay 8320) 85.82) sans) 19.82) ors) 107.16)  
96.98) 104.49) 138) 99.508) nro.ae) 09.108) 108.210), 226) ory 91065) 106 99) '870 105.408)



101.54) 114618) 11168) 306.37) ini6116) mise) 108.417) prrerny 168.313) 178.80 a77200) 11590) 15720) 167.6) yrasany 120.10) 104544) anno) 113.9) 119.5) 100.716) een 156 ---Page Break--- Hydrogen bond data given in Table 1 further indicates that the hydrogen bonds are of medium strength." The principal amplitudes of motion of the hydrogen atoms are reported in Table 2, together with the angles of the axes from their respective O-O hydrogen bond directions. It is seen that the largest amplitudes of motion are more perpendicular than parallel to the bonds. 'Table 2: Root mean square amplitudes of motion of hydrogen atoms along principal axes and angle of the axis with O-O hydrogen bond. — Atom Amplitude Anas wa oar29) 14.40) 0.206 (6) san 0.223 (6) 79.02) na 0.204 48) 1 0.213 (8) 0 (30) 0248.04) 103) Ha 0.149 25) 20) 0.225 (8) a7) 0.256 (1) oo) Ha 0.206 6) 208) 0218 4) nas) 0.280 (8) 89 (6) 8 0.186 (28) 37 a2) (0.208 (0) 58 (0) 0.382 (0) 75.25) He 0.182 (80) 14 0) 0224 (3) 5 (41) 0.288 (38) m3) a 0.148 (29) 19:05) 281 G4) 79.05) 0.288 16) 7.05) Summary. A structure of copper formate tetrahydrate has been refined from three-dimensional neutron diffraction data. 'The disordered structure has been placed on a firmer, more certain and precise basis than the earlier two-dimensional work. The occupancies due to about a 2:1 ratio of structures a to b in Fig. 2 have been refined and limits of probable errors assigned. A set of anisotropic thermal parameters are presented that show higher thermal motions for water.

than for copper formate. Most hydrogen motion is perpendicular to the hydrogen bonds as would be expected for moderate strength bonds exhibiting single minima close to one of the oxygen atoms. The nature of the disorder and geometry of the water is very "ice" like. Both water oxygen atoms are tetrahedrally coordinated. 157 ---Page Break--- RESEARCH IN PROGRESS Crystal Structures — M. I. Kay. A full set of 1500 reflections has been collected on 4 copper formate crystals at 77K in collaboration with Dr. E. T. Prince of the National Bureau of Standards. These data should reveal the ordering scheme of the very complex superstructure and the detailed molecular geometry of the antiferroelectric phase without the very gross ambiguities of our earlier projection data. An attempt will be made to follow the transition as a function of temperature via the superstructure intensities at PRNC. TGS —M. I. Kay. A complete set of data has been collected and almost refined in the paraelectric phase for triglycine sulfate. These data should supplement the X-ray results of Mitsui and Itoh. We have at this time already noted disorder in the hydrogen bond between Glycine II and III. Differences in the hydrogen bonding scheme of the amine group in Glycine I have also been found, revealing bond breakage in the transition. Further refinement and analysis of these data is in progress. Special Project — R. Magli. A polarized neutron spectrometer was completed. The spectrometer was calibrated and the neutron resonance established. A beam polarization of 92% was obtained. This corresponds to a "bare" flipping ratio measured as 20. Further improvements are expected to improve this value to 100. Training Activities. Mr. M. Echeandia from Peru and Mr. L. Arroyo, Mayaguez Campus engineering students, are the technical personnel employed on the project. It is assumed that working on the project will give them experience in various useful techniques not encountered in the normal engineering school curriculum. STAFF ACTIVITIES Dr. M. I. Kay

attended A.C.A. meetings in August 1974 and April 1975. He presented 4 papers on the  $\text{NaNO}_3$  phase transition in the former. He also spent a week in April at the National Bureau of Standards setting up data collection for the copper formate problem. Dr. R. Maglic spent the month of July 1974 at the Argonne National Laboratory as a principal user of one neutron spectrometer. In collaboration with Drs. Lander and Mueller, he carried out a study of spin density in an alpha Uranium crystal in the field of 20 Kgs. VISITORS Scientific Laboratory visited the project in June 1975. 158 ---Page Break--- Radiation Chemistry Project on the date of this program. Therefore, a

brief summary of its accomplishments from its inception to the present time is presented. In December 1970, upon the resignation of Dr. Owen Wheeler from the Puerto Rico Nuclear Center, the then Hot Atom Chemistry program was placed under the direction of Dr. Rupert A. Lee, a radiation chemist. Immediately, with the consent of Dr. R. J. Kandel of the Division of Physical Research, Atomic Energy Commission, the aim of the program was changed from Hot Atom to Radiation Chemistry. Over the years the program has provided Master of Science thesis research opportunities for ten students from Puerto Rico and Latin America. The list of completed theses supervised by Dr. Lee, provided below, is most indicative of the scope of the program. 'THESES COMPLETED 1970-1975 Radiolysis of aqueous solutions Manuel Lagunas Chile of organic sulfur compounds Gamma induced copolymerization Bernabe Zuluaga Colombia of crotonic acid with styrene Gamma induced copolymerization of Raul Marco Puerto Rico crotonic acid and methacrylate Radiolysis of fluoroform Roberto F. Amaris, Colombia Electron-impact studies of Josefina Rodriguez Puerto Rico fluorotoluenes Radiolysis of pectinic acid José Escabi Pérez Puerto Rico Gamma induced copolymerization Héctor D. Colman Paraguay of methacrylic acid with methacrylamide under an electric field In addition,

There are three theses which will be completed during the first semester of the academic year 1975-1976. Radiolysis of gaseous solutions of Marfa Colén de Olmo Puerto Rico Coomer compound Bind sat of some spe get Sav Heminder to Rio. During the last two years, we attempted to expand the scope of the research with the collaboration of Drs. Federico A. Herrero and Pier Paolo Delsanto of the Physics Department of the University of Puerto Rico Mayagüez Campus at no additional cost to the program. However, before definitive results could be obtained, all funding for the program was terminated. 159 ---Page Break--- Dr. Herrero had been working on excited states produced from substances such as CO, CO<sub>2</sub>, NO, NO<sub>2</sub>, etc., and Dr. Delsanto was leading calculations related to impacts on work involving theoretical possible Gion and Gex values in complex gases. The support of the program by the former AEC and ERDA is acknowledged with appreciation and thanks. STAFF ACTIVITIES Dr. Lee is in Ann Arbor, Michigan, carrying out research under the general direction of Dr. Henry J. Gomberg, former Director of PRNC and now President of KMS Fusion, Inc. Dr. Lee will join the staff of the organization in January 1976. He spent the summer of 1975 at KMS Fusion. De. Rupert A. Lee, Head of the Chemistry Program. 160 ---Page Break--- ---Page Break--- D. S. Sasscer discusses the use of the gamma spectro analyzer with graduate students. ---Page Break--- NUCLEAR APPLICATIONS — NUCLEAR ENGINEERING The Nuclear Engineering Section is engaged in research and teaching. Staff members teach both graduate and undergraduate courses at the University of Puerto Rico, Mayagüez Campus and direct the thesis work of nuclear engineering students. They conduct research on their own projects and assist the staff of other PRNC divisions as the need arises. RESEARCH COMPLETED A Cost Benefit Analysis of Condenser-Cooling Systems for Nuclear Power Plants in Puerto Rico — K. B. Pedersen, H. Plaza and J. M. Cajigas. A computer program

was used to find the most economical method of cooling a nuclear power plant from among five different types of cooling systems. It also studied the environmental impact of the various systems and finally recommended once-through cooling as the optimum. Accident and Cost Analysis for the Transportation of Irradiated Fuel from a Nuclear Power Plant in Puerto Rico — H. Plaza, K. B. Pedersen and L. Reyes Medina. The exposure dose from irradiated nuclear fuel to persons along the shipping route under normal conditions was determined, and also the probabilities of various types of accidents occurring during shipment. The higher dose value was found to be for a person 20 feet from the centerline of the shipping route. This dose was conservatively calculated to be

$7 \times 10^{-1}$  mrem. Statistical Analysis of Mercury and Cadmium in Fresh Milk Using Instrumental Neutron Activation Analysis — K. B. Pedersen and S. Chellappan. The concentration of Hg in milk in Puerto Rico was found to be only slightly higher than the safe range set by the World Health Organization on food (0.05 parts per million), but high compared with other countries. The Cd concentrations were also found to be high when compared with other countries. Low Concentration Measurements of Argon-41 — D. S. Sasscer and C. Andreu. The Draft Standard for “Restrictions on Radioactive Effluents from Research Reactors” of June 1974 recommends that the allowable concentration of argon-41 be reduced by a factor of 50, to a value of  $8 \times 10^{-1}$  uCi/cc. The object of this investigation was to develop a simple and accurate procedure for measuring argon-41 when it exists in concentrations significantly below the Draft Standard’s recommended value. The system developed consisted of: (a) connecting a 4X4" and 3"X3" sodium iodide detectors in parallel; (b) measuring concentrated samples of air in scuba tanks filled to 2,200 psi; and (c) obtaining low background by locating the detector on a separate air sample tank in a lead cave with 6"-thick walls. The system was able to measure

argon-tl at concentrations of  $8 \times 10^{-1}$  which is less than 10% of the allowable concentration recommended by the Draft Standard. 163 ---Page Break--- ‘The experimental values were used to validate the application of Sutton’s model to determine the yearly average maximum concentration of argon-41 in unrestricted areas surrounding the PRNC reactor. The yearly average maximum concentration occurred 125 meters from the reactor off-gas stack and was approximately one-third of the allowable value. The location of the maximum concentrations for the dry season and the rainy season are shown in Figure 1, or . JO00y Mg - Well Locations Figure 1: PRNC reactor site showing location of yearly average maximum concentration of Argon. 164 ---Page Break---

Evaluation of Population Exposure to Natural Radiation Background in Puerto Rico — A. E. Gileadi and D. Lebrén. External exposure to natural radiation background of the population in Puerto Rico has been estimated using published data concerning terrestrial and cosmic radiation, and demographic data on population distribution with respect to elevation and geographic location. Estimates of the annual dose equivalent rate due to exposure to external natural radiation background for each municipality of Puerto Rico and the insular average value were derived by means of a computer program written for that purpose. Inputs included measured and calculated values of terrestrial and cosmic ray components of the natural radiation background in Puerto Rico, fallout corrections, and relevant demographic data. In order to assess the degree of validity of the above estimates, background measurements using CaF:Dy TL dosimeters were performed in 16 municipalities. Comparisons of measured and estimated values show reasonable agreement in most cases as shown in Table 1. Table 1: Comparison of Measured Values With Estimates.

Municipality	Sen Juan	Caguas	Camuy	Carolina	Guayanilla	Guaynabo	Humacao	Lares	Mayaguez	Moca	Naguabo
Population	39	104	6	10	6	10	4	10	4	10	4
Weighted Average Value	38	50	38	38	38	38	38	38	38	38	38

Alto a1 38 Vega Baja 50 38 Population Weighted Average Value “ ~ Population Exposure Measurements in Puerto Rico — A. E. Gileadi and J. A. Gonzalez — ‘Thermoluminescent dosimetry has been used to determine the whole-body dose equivalent rates in 85 municipalities of the Island, covering 61% of the population. The population ‘weighted average value obtained in these measurements was  $53 \pm 8$  mrem/year/person. Following the proposition of Ms. Gail Burke of HASL, the above values were checked against exposures measured by means of “personal dosimeters,” that is, identical TLDs worn by volunteers for a given period of time. The average value of four personal dosimeters was determined to be  $54 \pm 8$  mrem/year/person. 165 ---Page Break---

Computerized Fission Product Inventory System — A. E. Gileadi and A. Musalem, ‘A computer code has been developed to calculate data required for the assessment of ‘environmental

impact and safety of nuclear reactors. The basic option of the code uses the build-up equations to determine number densities of individual fission products present in irradiated fuel. Besides the operating history and certain relevant reactor parameters, the input data file includes: (a) fission yield tables; (b) detailed decay characteristics of all precursor chains considered; and (c) relevant neutron cross sections. The output of the basic option contains operating history, dependent number densities of all fission products along with energies, and intensities of the beta and gamma radiation emitted by each. The cumulative spectral composition of beta resp. gamma radiation emitted by the total fission product inventory present is calculated by first subdividing the maximal energy range in consecutive channels of suitable widths and then totaling the beta particles resp. gamma photons. Computed results serve as basic input data for a variety of problems, e.g. of an upper limit to the release of radioactive gases or water-soluble radioactive materials in case of cladding failure, establishing a maximal gamma source.

For shielding calculations, obtaining a conservative estimate for radiation-induced heat generation, associated meltdown problems (see Figure 2), and many others. Establishment, Figure 2. Fission Product Decay Energy Vs. Time After Shutdown 1,000 Hrs. Operation — 100 Hrs. Operation & — 10 Hrs. Operation & — 1 Hr. Operation. Treatment of Centrifugal Elastic Stresses in Nuclear Rotation — N. Azziz, J. C. Palathingal, and R. Méndez Plicido. A treatment of elastic stresses in nuclear rotation with the nucleus considered as an incompressible elastic body with a stationary spherical core surrounded by a circulating mass is presented. Centrifugal stresses acting in directions perpendicular to the axis of rotation introduce variations in the moment of inertia. The Variable Moment of Inertia (MVI) Model, so successful in predicting the rotational spectrum of even-even nuclei, is explained. High-energy Behavior of the Vibrational Excitation Cross Section  $\sigma$ , for H<sup>\*</sup>-H, — N. Azziz, F. A. Herrero, and R. Méndez Plicido. We present calculations of the cross section  $\sigma$ , for the vibrational excitation of H by proton impact with several interaction potentials. The calculation with a long-range anisotropic potential shows features very similar to the calculation with the H' potential surface, but both calculations fail to account for the observed persistence of the cross section at high velocities (proton energy range from 200 to 1000 eV). A trajectory-dependent potential is introduced semiempirically, and it is found that the main features of the observed cross section can be explained by its short-range parts ( $r \approx 2$  A). Energies and Quadrupole Moments of Rotational Levels in Even-Even Nuclei — N. Azziz. Theoretical values for the excitation energies and rotational levels are presented for even-even nuclei. The method is based on the elastic solid-body model proposed by N. Azziz in 1971. A non-rotating core is introduced in order to account for the quadrupole moments. Harmonic and anharmonic terms are

incorporated in the stretching potential, Atmospheric Transport of Gaseous and Volatile Radioactive Effluents From the PRNC TRIGA Reactor — A. E. Gileadi and Rolando Pérez Ortiz. A computer code has been developed to evaluate certain radiological hazards associated with the discharge of gaseous and volatile radioactive effluents from the PRNC-TRIGA.FLIP research reactor, using actual operating parameters and local meteorological data for the evaluation. The code is written in FORTRAN IV and executed on the PDP-10 computer at the University of Puerto Rico Mayagüez Campus. Based on the mathematical model of the generalized Gaussian plume, the code calculates the concentration of any isotope of interest at any given position with respect to the source, using such input parameters as position coordinates and source intensity as well as climatological data describing the prevailing weather conditions. Allowance is made for effective stack height, reflection at the ground surface, and depletion by ground deposition and radioactive decay. The model is tested for accuracy by comparing estimated concentrations with available diffusion data. RESEARCH IN PROGRESS Feasibility of Qualitative and Quantitative Elastic

Scattering Studies Using a 100 Ci Am Source — B. Ortiz and D. Carrero. The purpose of this project was to develop, construct, and test a simple device that will allow qualitative and quantitative determination of target nuclei mass from elastic scattered alphas emitted from a 100  $\mu$ Ci Am source. To test the equipment, thin foils were mounted and irradiated by a collimated beam of 5.47 MeV alphas. The alphas scattered at a certain angle were counted and energy analyzed. Theoretically, from a set of curves obtained from the computer and from the energy of the scattered particle and the angle, one could measure the mass of the target. Unfortunately, a reasonable number of alphas were scattered only at small angles and at these positions, there was no measurable change in energy. It is hoped

that with the 300 Kev, H\* beam from the neutron generator positive results can be obtained. With a 1 ma beam current only about  $10^6$  particles/sec are produced compared with  $10^8$  particles/sec from the radioactive source. Probabilistic Techniques Used in Evaluation of Reactor Safety — A. E. Gileadi, Based upon the premise that no activity is free of hazards, the risk associated with operating a nuclear reactor or any nuclear installation may be quantized by means of a diagram representing the probability of a given release of radioactive material of the value of the release for example, in terms of I-131 equivalent. To compile such a diagram with a reasonable accuracy all pathways of accident propagation must be considered. An attempt is being made to generalize the approach so as to include probability distribution of events instead of a given value of probability and computing what is termed by K. Ott an "accident propagation spectrum." A detailed study of existing European and U.S. literature on the subject indicates that such a generalization is feasible and desirable from the point of view of better quantification of risks. Various collections of data on component failures will be made part of the input of the code to be developed. TRAINING ACTIVITIES Scientists on the staff of the Nuclear Engineering Section hold joint appointments at PRNC and UPR and compose the faculty of the Nuclear Engineering Department of the College of Engineering of the University of Puerto Rico Mayagüez Campus. The Head of the PRNC Nuclear Engineering Section is also the Chairman of the University's Nuclear Engineering Department. The Section provides classrooms, offices, laboratories, equipment and most of the administrative personnel required for the education and training of graduate students of the Nuclear Engineering Department of the College of Engineering. Special Courses. Short courses varying in length from one week to three months covering a variety of topics related to nuclear engineering are offered.

approximately once a year for scientists, engineers and others who have an interest in or need for knowledge in the nuclear field. During the first week in June 1975, a Summer Workshop on "The Risks and Benefits of Electrical Power Generation in Puerto Rico" was offered for high school science teachers. This one-week workshop was jointly sponsored by the United States Energy Research and Development Administration, the Puerto Rico Nuclear Center, the University of Puerto Rico, Mayagüez Campus, and the Puerto Rico Water Resources Authority. The purpose of the workshop was to provide secondary science teachers with sufficient background to enable them to guide their students and communities towards a more factual and less emotional consideration of the risks and the benefits of electrical power generation in Puerto Rico. Fifty-two participants from several cities and towns throughout Puerto Rico attended the workshop. Master of Science Degree Program. The University of Puerto Rico, in close cooperation with the PRNC Nuclear Engineering Section, offers a Master of Science in Nuclear Engineering degree. 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, thesis, and a final oral examination. Sixteen graduate students were enrolled in the Master of Science in Nuclear Engineering degree program. As is shown in Table 2, six of these students graduated with M.S.

degrees in Nuclear Engineering in May 1974 and six students were primarily engaged in thesis research. The rest were taking full loads of academic course work. Table 2: Summary of Student Progress in the Master of Science Degree Program in Nuclear Engineering from January 1, 1974 to June 30, 1975 Name Citizenship Awarded M.S. Degree Chellappan, S. India Lebrén, D. U.S. Lingappan, K. India Léper Sullivan, P. U.S. Michelen, J. Dominican Republic Musalem, A. Dominican Republic Primarily Engaged in

Research 'Andeeu, C. us. us. us. us. us. US. Primari us. us. us. us. 169 ---Page Break--- 'The twelve thesis project topics in which Nuclear Engineering students were conducting research during 1974 are listed in Table 3. Six of these projects were completed by the six students who graduated in 1974. 'Table 3: Student Thesis Research Projects Student Title of Thesis Major Professor Andres, C. Determination of Argon-41 Dose at the Puerto Rico D. 8, Sasscer Nuclear Center Site Boundary Caiigas, J 'A Cost-Benefit Analysis of Condenser-Cooling System KB. Pedersen for Nuclear Power Plants in Puerto Rico Carrero, Dick Feasibility of Qualitative and Quantitative Elastic Seat E. Ortiz Filtering Studies Using a 100 uCi Americium Source Chellapan, B. \* Statistical Analysis of Mercury and Cadmium in Fresh K. B. Pedersen 'Milk Using Instrumental Neutron Activation Analysis Gonzites, A. Population Exposure to Natural Radiation in Puerto Rico E. Ortiz Lebeén, D. + Natural Radiation Exposure in Puerto Rico A. Gilead Lingappan, K. \* Determination of the Concentration of Trace Elements Plaza in Some Foods in Puerto Rico Using Instrumental Lopes Sullivan, P. D.S. Sasscer Determination of Various Nuclear Parameters Michelen, J. \* A Technique for Measuring Gas Stopping Power E. Ortiz of Alpha Particles Using Two Solid State Detectors Musslem, A. \* Computation of Operating History and Cooling Time A.E. Gilead Dependent Fission Product Inventories and Related Quantities Perea, R. Atmospheric Transport of Volatile and Gaseous Radio- E. Ortiz active Effluents From The PRNC-TRIGA Reactor Reyes L. 'Accident Analysis for the Transportation of Irradiated KB. Pedersen Fuel From a Nuclear Power Plant Located in Puerto Rico \* Completed 170 ---Page Break--- Graduate Courses. The staff of the Section taught 10 regular graduate courses in Nuclear Engineering and one undergraduate course, in addition to the Summer Workshop previously reported under "Special Courses." The course titles and the professors are shown in Table 4. 'Table 4: Courses Taught by Nuclear

Engineering Faculty/Scientists Course Professor Elements of Nuclear Engineering K. Pedersen Mathematics of Modern Science 1 ALE, Gilead Reactor Theory 4 H. Plaza [Nuclear Measurements & Instrumentation D.S. Sasser "Advanced Reactor Theory H. Plaza Mathematics of Modern Science II ALE. Gileadi Nuclear Reactor Technology I K. Pedersen. Reactor Laboratory D.S. Sasser Special Problems ALE. Gilead Gilead, Ortiz, Pedersen, Plaza, Sasser Gileadi, Pedersen, Plaza, Sasser Generation in Puerto Rico Ortiz, Pedersen, Plaza, Sasser STAFF ACTIVITIES During the reporting period Dr. Knud Pedersen returned from assignment with the Environmental Statement group at the Oak Ridge National Laboratory. Dr. Heriberto Plaza attended the NASA-ASEE Summer Faculty Systems Engineering Design Program at Marshall Space Flight Center during the summer of 1975. During this same time, Dr. Aviva B. Gileadi was a Visiting Scientist with the Reactor Analysis and Safety Division at the Argonne National Laboratory. 1m" ---Page Break--- ---Page Break--- HEALTH AND SAFETY 'The Health and Safety Division provides the following services primarily for the Puerto Rico Nuclear Center: personnel and area monitoring, calibration of instruments, handling of radioactive materials, environmental surveillance, decontamination, waste disposal, and industrial and fire safety. Lectures on industrial and radiological safety are given to new PRNC personnel. Potential hazards which may develop with new research activities are identified and procedures are established to protect the health and safety of personnel. Attention is drawn to safety-related problems through the issuance of monthly

“Safety Tips” and by displaying safety posters in the laboratories. Unscheduled fire drills and radiation evaluation drills are executed several times a year. Films are shown from time to time. Members of the Division participate in seminars and give lectures on health and safety to high school students and other groups as a service to the community. RESEARCH COMPLETED  
Emission

Studies of Pyrene Solutions — Mohyi-Eldin M. Abu-Zeid, R. Lopez, J.C. Acevedo, and R. Groff. Emission spectra of pyrene in hexane have been obtained over a temperature range from 130°K to 260°K and concentrations that range from  $10^{-6}$  mole/l to  $2 \times 10^{-7}$  mole/l. The data have been analyzed, and values of intersystem crossing activation energy,  $W_{id}$ , and the corresponding temperature independent rate parameter,  $A_p$ , and frequency factor,  $k$ , evaluated. They were found to be 0.066 eV, zero  $\text{sec}^{-1}$ , and  $4.7 \times 10^7 \text{ sec}^{-1}$  respectively. These values are identical to those obtained in a decay time measurement experiment by Birks et al. for pyrene single crystal. Two different approximations were used to calculate excimer association energy,  $W_y$ , from the same set of data used in calculating  $W_{xy}$ . At all concentrations used in this experiment, the value of  $W_y$  agrees quite satisfactorily with the values reported in the literature. However, when attempts were made to evaluate some rate parameters employing these two approximations, only for concentrations  $< 10^{-6}$  mole/l was excellent agreement between our values and the values of other authors obtained. In addition, there were no differences in the ratio of excimer ( $I_p$ ) to monomer ( $I_m$ ) quantum yields when an intense laser beam was used as a source of excitation rather than a super-pressure Hg lamp. This suggests that the concentrations used might not be large enough to render a high density of excited molecules that could affect the ratio of  $I_p/I_m$ .

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## RESEARCH IN PROGRESS

Emission Spectra and Thermodynamic Properties of 1- and 2-Amino-anthracene and 3, 4, 9, 10-Dibenzo pyrene — M. E. Abu-Zeid, R. Lopez, P. Martinez, J.C. Acevedo, and P. Clemente.

Excimer and Monomer Emissions from 2- and 3-Methyl Chloranthrene Carcinogens — M. E. Abu-Zeid, R. Lopez, P. Martinez, and J.C. Acevedo.

Emission from Second Electronic Excited States of Polyatomic Molecules — M. E. Abu-Zeid, R. Lopez, P. Martinez, and J.C. Acevedo.

## SERVICES PROVIDED

Personnel monitoring devices are

provided to PRNC staff and other institutions and persons in Puerto Rico. Environmental samples are analyzed monthly in order to determine if the reactor effluents are contributing to any contamination in the area surrounding PRNC-Mayagüez. To date, no radiation levels above background have been found. PRNC has a long-standing surveillance program for the now-closed BONUS Reactor plant in Rincón, Puerto Rico. An annual survey is made to detect promptly any unexpected radiation emitting from this plant. All services offered to PRNC and other institutions or individuals are listed below: Film Badge Services Neutron Beta-Gamma Puerto Rico Nuclear Center 720 5,148, Oncologie Hospital 1,644 Mayagüez Regional Medical Center 890 Mayagüez

Civil Defense Unit 84 Lajas Agricultural Experiment Station 2 Metropolitan Hospital 144 Adjuntas Health Center 48 Dixon Ramirez, M.D. 24 University of Puerto Rico, Mayagüez 84 Campus Medical Services Center Ponce District Hospital 625 Rafael Mercado, M.D. 96 48 Ramón Acosta, M.D. School of Medicine, Clinical Investigations 96 Tropical Mal Absorption Unit oD Cardiovascular Unit 252 University Hospital 128 Totals 720 71 174 ---Page Break--- Dispensary. The Mayagüez Laboratory maintains a Dispensary staffed with a full-time nurse and a doctor who visits the laboratory thrice weekly and is "on call." Services provided during this report period are as follows: Accidents 31 Accidents reported to State Insurance Fund 30 Pre-employment examinations 35 Non-occupational related cases 101 Health certificates completed 419 Total 246 TRAINING ACTIVITIES Seven students were enrolled in the joint PRNC-UPR School of Public Health M.S. Degree Program in Radiological Health: Luz Cabán, Puerto Rico (USA); Azucena Garzón, Ecuador; Eloy Gibbs, Panama; Edgardo Hernandez, Puerto Rico (USA); Rolando Mosquera, Peru; Karl Prado, USA; and Armando Torres, Puerto Rico (USA). STAFF ACTIVITIES Fernando Vallecillo, Acting Division Head, retired from PRNC on June 30, 1975. Ms. Nimia E. Irizarry has been

appointed Acting Division Head. Santiago Gomez attended the AEC Contractor Health Protection Conference in October 1974. He attended the Safety Seminar entitled "How to Comply with OSHA," held in San Juan, Puerto Rico, in February 1976. 175 ---Page Break--- Joint Radiation Survey Project The people of Puerto Rico have become increasingly aware of health problems caused by contamination and pollution. As each potential hazard is identified, measured, and recognized, efforts are made to reduce the hazard to its lowest possible level. X-rays are a form of ionizing radiation, and exposure of the population to any sort of ionizing radiation is a major concern of professionals and society. The Joint Radiation Survey, begun in 1968 as a joint project of the Puerto Rico Nuclear Center and the Puerto Rico Department of Health, has been conducted for the purpose of reducing radiation hazards due to x-ray diagnosis in Puerto Rico to a minimum comparable with the diagnostic objective. Results and findings of the survey from 1968 to 1973 are contained in seven reports and eleven scientific papers. The final report contains a detailed comparison of relevant results concerning medical x-ray diagnosis associated with radiation protection in Puerto Rico. The comparison includes annual rates of medical x-ray diagnostic examinations, mean gonadal dose per examination by type of examination and by sex of patient, per capita per annum gonadal dose, and genetically significant dose. In spite of an increase of 25% in the annual rate of diagnostic x-ray examinations in 1973 as compared to 1968, the quantifiers characterizing the potential risks remained practically unchanged. This indicates there has been significant improvement in x-ray diagnosis associated with radiation protection practices in Puerto Rico during the survey period. HIGHLIGHTS OF PROJECT RESULTS In 1968, 1,190,317 persons visited x-ray facilities. Of these, 1,427,745 received x-ray examinations with exposed films totaling 2,565,572. In 1973, 1,492,343 persons visited x-ray

facilities. There were 1,765,126 x-ray examinations and exposed films numbered 3,305,914. During this period, the population of Puerto Rico increased by 8%. Chest x-rays: 1968: 674,626. 1973: 738,296. During this period, the number of photofluorographies decreased. Abdominal x-rays: The annual rate increased by 161,509. Collimation: The trend is toward improved collimation in radiography. Installed variable collimators increased by 20%; installed image amplifiers for fluoroscopic examinations increased by 68.2%. The improvement was particularly marked in hospitals and private radiologists' offices. Per Capita Mean Gonadal Dose: There was a decrease from 86.43 to 81.70 millirads during the period. 176 ---Page Break--- Significant Dose: A slight increase of 2.4 millirads has been observed. Age Groups: Ages 0-14 showed the highest Pi with an



increase in flat abdominal, pelvis, and hip joint x-ray examinations. Abdominal examinations for the age groups 45-64 and +65 increased. Genetic Radiation Protection: The increase in x-ray examinations is successfully balanced by radiation protection measures. Conclusion: The most important quantifiers for somatic and genetic radiation effects remained practically unchanged between 1968 and 1973. STAFF ACTIVITIES Michael Gileadi, Scientist I, retired from the Puerto Rico Nuclear Center on June 30, 1975. Mr. Gileadi performed a unique and valuable service to the people of Puerto Rico during his tenure as Director of the Joint Radiation Survey. His findings have been published in several journals and presented at scientific meetings in Puerto Rico, the United States, France, Israel, and The Netherlands. Beginning in 1970, survey results have been published in the reports of the Bureau of Health on "Population Exposure to Diagnostic X-rays in the United States." The United Nations reports on "Exposure to Ionizing Radiation" have included his findings. The final report of the Joint Radiation Survey concludes an intensive six-year effort on the part of Mr. Gileadi. + ---Page Break---

Richard Brown Compos Head of R supervises the removal of spent fuel rods from the TRIGA-FLIP reactor, 178 ---Page Break---

### REACTOR OPERATIONS

'The Reactor Operations Division provides neutron and gamma irradiation services to other PRNC divisions and training and education in reactor operations and related subjects. 'The Division operates and maintains a 2 megawatt pool-type research reactor with 2000-MW pulsing capability; a 10-watt aqueous homogeneous L-77 reactor; a cobalt-60 gamma irradiation pool (two sources); a cobalt-60 reactor pool gamma irradiation facility; a 160-kV particle accelerator for the production of 14-MeV neutrons; and two high-level hot cells. Irradiation services were rendered during the period January 1, 1974, through June 30, 1975, as follows: ~ There were 1170.8 megawatt-hours of operation at a nominal power level of 1.0 MW. Total time of 39 side-of-core irradiations was 293 hours. There were 8 rabbit irradiations for a total time of 8 minutes. 'The Neutron Diffraction program utilized the neutron beams for a total time of 1170.8 hours. 5. The L-77 reactor was operated for a total of 9 hours and 20 minutes for laboratory experiments of nuclear engineering students, for rod calibrations, and for instrument checks. 6. 235 irradiations were performed in Source Number One of the gamma pool for a total of 513 hours and 30 minutes. 7. 319 irradiations were performed in Source Number Two of the gamma pool for a total of 2288 hours. 'TRIGA REACTOR MODIFICATIONS Routine reactor operations were suspended from February 21 through July 26, 1974. 'The Division of Operational Safety, AEC Washington, felt that the Safety Analysis Report (SAR) did not reflect the modifications that had been made by Gulf General Atomic to correct the power oscillations encountered during reactor startup. In order to provide the information needed by Gulf to revise and update those sections of the SAR having to do with the TRIGA core, two experiments were authorized for the month of April. The first experiment determined the worth of a full fuel bundle in the

'most reactive position in the reactor core. The second determined the amount of argon-41 produced during reactor operations and the dose to the general public at the site boundary. Following examination of the data obtained from the experiments, DOS authorized resumption of reactor operations at a maximum power level of one megawatt until a final revision of the SAR was completed. 'The Nuclear Engineering Division of PRNC has been assigned the responsibility of revising the SAR utilizing the calculations provided by Gulf and other information gained from the experiments performed by PRNC. A final revision of the SAR is expected to be ready by December 1976. 179 ---Page Break---

Preparations were made for the shipment of spent MTR-type fuel in storage in the A fu >m end boxes were cut for 51 fuel element equipment of 17 MTR more shipments were made in July and a final one in August: end box cutting machine was designed and constructed at PRNC reactor pc J bot e first ts was made in June 1\$ A total of 65 fuel elements

were shipped to Savannah River plant for reproc TRAINING ACTIVITIES As part of the M.S. program in Radiological Health, the Reactor Operations Division offered PRNC-555, Safety in Reactor Operations, during the spring of 1974 and 1975. STAFF ACTIVITIES César Picén Chavez, a graduate student from Peru, successfully completed a six-month course for reactor supervisors from August 1974 through January 1975. ost B. Rivera Guzman resigned his position as reactor supervisor in June 1975. Fish-eye" view of the TRIGA-PLIP Reactor 180 fae, ---Page Break--- APPLIED PHYSICAL SCIENCES 'The Applied Physical Sciences Division provided advanced training primarily through participation in research with high energy radiation and radioisotopes for trainees from Puerto Rico (USA) and Latin America. The program was geared to regional needs and included an introductory training course on the use of radioisotopes. Scientific personnel were encouraged to participate in the academic activities of the College of Natural Sciences of

the UPR Rio Piedras Campus through joint appointments. This academic integration also provided opportunities for graduate students of Chemistry and Physics to do their thesis research at PRNC. During fiscal year 1975, the decision was made to terminate this division as part of the reorientation of the Puerto Rico Nuclear Center under ERDA. The activities of the division were gradually phased out during this period, and it was terminated on June 30, 1975. RESEARCH ACTIVITIES Research activities of the Applied Physical Sciences Division included studies on radiation effects and radioisotopes and work supporting this research! Radiation Effects. The effects of high-energy deposition in chemical systems were studied in order to clarify the mechanisms of radiation-induced changes. In some systems, the emphasis is on the initial, or primary products of radiation; in others, the emphasis is on the final products resulting from secondary chemical reactions. Matrix Isolation Studies of the Gamma Radiolysis of Heterocyclic Molecules — G. A. Simpson, R. Arce Quintero. This project was supported by the Biomedical and Environmental Research Division of ERDA and is described elsewhere in this Annual Report. Radiation-Induced Aromatic Substitution — M. K. Eberhardt. Work on radiation-induced homolytic aromatic hydroxylation has been continued. The hydroxylation of benzene, toluene, and nitrobenzene has been investigated, and in particular, the effect of metal salts on these hydroxylations. Four papers concerning this work have appeared or are presently in print in the Journal of Physical Chemistry. Radiosotopic Studies Preparation of Tributyl Tin Oxide (TBTO) Labeled With <sup>113</sup>Sn — R. Santana de Tir and J. Castrillón. The preparation of high specific activity tributyl tin oxide (TBTO) was completed at the request of the PRNC Biomedical Sciences Division. TBTO is a potent molluscicide, and there is interest in determining the fate of the tin in mammals and other organisms. 181 ---Page Break--- Liquid Scintillation Counting — J. P.

A. Castrillén. Work on new scintillation solvents and solutes was discontinued. A paper on aromatic nitriles as scintillation solutes was published. TRAINING ACTIVITIES A summary of the training activities of the Applied Physical Sciences Division is presented in Table 1. 'Table 1: Summary of Training Activities of the Applied Physical Sciences Division January 1974 — June 1975 4, Thesis Research, Ph.D. Degree, Chemistry, UPR Rio Piedras Lorna Ramirez 2, Thesis Research, M.S. Degree, Chemistry, UPR Rio Piedras Lydia Searano Fiol Carmen Velézquez 'Marisol Rodriguez Rosario, SUBE Trainee Betzaida Castilla, 'Melisa Charron 48. Special Training in Gamma Radiolysis Luis A. Jiménez, ORAU Undergraduate Research Trainee Talia de la M. Hernández. Melisa Charron Carlos L. Vila Myrtha Trujillo Sánchez, Ph.D., ORAU Faculty tsa Violeta Jimenez, ORAU Undergrad. Res, Trainee 4. Special Training in Organic Chemistry Deborah 8. Narváez Beauchamp, SUBE Trainee Marisol Rodriguez Rosario, SUBE Trainee 'Maria Welisse Martinez, ORAU Undergrad. Res. Trainee 'Julio A. Colón Maldonado, SUBE Trainee 5. Radioisotope Techniques Course, Ramón Ricart Espinosa, Dom. Rep. Ricardo Sigurani Martinez Virgilina

Guimaraes, M.D., Brazil Gladys Rodriguez Gata, Cuba Mario A. Garcia Hernandez, Cuba Carlos Jiménez Ferrer Mercedes Rodríguez Nieves dan 1974 — Jun 1974 Jul 1973 — Jun Jul 1973 — dan Gul 1974 — Jun Aug 1974 — Dec Jul 1974 — Jun 1974 1974 1975 1974 1975 Jul 1973 — Jun Jun 1974 — Aug Jul 1973 — Jun 1978 1974 1974 1974 Jun 1974 — Aug 1974, 194 Sep 1973—Aug Jul 1973 — Jun Jun 1974 — Jul Sep 1974—Jun 1974 1974 1974 1975. Jun 3—Jul 5, 1974 Francisco A. Fuentes Salem Hallum Hasan, Israel Bhio de Freitas Gomez, M.D. Brazil Calixto Pérez Ostalaza, Colombia Barnes Nelson Cuello Suarez, Dom. Rep. Support for University Biomedical Education (SUBE) Program — The Applied Physical Sciences Division staff have collaborated with the University of Puerto Rico faculty in the SUBE Program. The main objective of this program is to

Provide opportunities to undergraduate and graduate students from socially, educationally, and culturally limited backgrounds for research and creativity in the biomedical sciences and related areas. In 1974, the SUBE Program included 9 projects. The project submitted by the PRNC Applied Physical Sciences Division is entitled "Thioxanthone Derivatives as Potential Trypanosomicides" and was sponsored by Dr. José P. A. Castrillón. At PRNC, it has been shown that thioxanthone derivatives are highly active "in vitro" against *Trypanosoma cruzi*, the organism responsible for Chagas Disease. It must be emphasized that Chagas Disease poses a formidable health problem in Latin America, where it can be estimated that more than ten million people are infected. Moreover, the first effective drug was put on the market recently. The project is directed toward obtaining chemotherapeutic substances against this disease by introducing suitable substituents on the side phenyl rings of the thioxanthone molecule while preserving the central highly polar ring, which is assumed to be responsible for the effect against *T. cruzi*. In addition, some of the compounds prepared under this Program are being tested against cancer at the National Cancer Institute and against Schistosomiasis by Dr. George Hillyer of the University of Puerto Rico. One graduate student, Miss Marisol Rodriguez, and two undergraduate students, Mr. Julio Colén and Mr. José Luis Ramirez, from the UPR Rio Piedras Campus have participated in the Thioxanthone Project under the auspices of SUBE. Thesis Research: Miss Marisol Rodriguez, the SUBE Graduate Student mentioned above, is finishing her MS degree thesis under the direction of Dr. José P. A. Castrillón. The thesis is entitled "Search For Optical Activity in 2-Carboxythioxanthone, Its Sulfoxide, and Sulfone." Heterocyclic Molecules Project: The objective of the Heterocyclic Molecules Project has been the identification of labile intermediates produced in biological systems.

through physical measurements of simple 'molecular systems which may model the more complex biological ones. The major activities during this period have consisted of studies of chemiluminescence phenomena and of absorption spectra of intermediates stabilized within a rigid glass. It is believed that compounds giving rise to chemiluminescence may be produced within irradiated cellular 'materials. The studies mentioned herein on a dioxetane compound and on singlet molecular oxygen are of current interest. Financial support for the Heterocyclic Molecules Project from ERDA was terminated on June 30, 1975. Work at PRNC during FY1976 will be limited to submission of pending work for publication. It is anticipated, however, that Dr. Rafael Arce of the UPR Chemistry Department in Rio Piedras will continue certain aspects of the project at the UPR under the sponsorship of a "SUBE" Grant from N.L.H. RESEARCH ACTIVITIES Singlet Acetone Efficiency and Importance of Triplet Acetone Induced Decomposition of Tetramethyl-1,2-Dioxetane From Direct Chemiluminescence — W. Adams, N. Duran, and G. A. Simpson. From absolute emission intensities and decay lifetimes of the direct chemiluminescent decomposition of tetramethyl-1,2-dioxetane it was established that the singlet excited acetone yields ( $\alpha$ ) are  $9.1 + 3.3 \times 10^{-3}$  and  $5 + 1 \times 10^{-3}$  at  $72^\circ$  and  $22^\circ$  respectively. The activation energy for

tetramethyl-1,2-dioxetane thermolysis was  $25 \pm 2$  kcal/mol; but the singlet yield was independent of temperature. The induced decomposition efficiency ( $\phi$ ) of the 1,2-dioxetane by triplet acetone was found to be unity in the presence or absence of molecular oxygen, indicating that  $\phi$  is independent of the lifetime of the triplet acetone sensitizer. The results for the direct chemiluminescent decomposition of tetramethyl-1,2-dioxetane implicate a mechanism in which sensitizing acetone triplets are efficiently replenished. This study has been presented and accepted for publication by the J. Am. Chem. Soc. Radiation Induced Anions of Nitrogen

Heterocyclics Stabilized in Various Glassy Materials at 77K — M. Charron, R. Arce, and G. A. Simpson. Radiolysis of solutions of methyltetrahydrofuran containing indole at 77K produces an indole anion. The indole concentration sufficient to produce 50% scavenging of trapped electrons is  $2.5 \times 10^{-4}$  M. The indole anion may be characterized by  $\lambda_{\text{max}}$  at 360 nm ( $\epsilon = 3.1 \times 10^4 \text{ M}^{-1} \text{ cm}^{-1}$ ), an absorption band in the near IR (ca. 1200 nm), and marked photosensitivity. Other work is in progress involving either basic aqueous or MTHF glassy solutions of purine and uracil. While the solubility of these compounds in these matrices is not high, some evidence for electron attachment and anionic intermediate absorption is present.

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Singlet Molecular Oxygen Chemiluminescence Yields — M. Trujillo Sanchez and G. A. Simpson. The yield of luminescence in the reaction of  $\text{H}_2\text{O}_2$  (H) plus  $\text{ClO}_2$  (C) was studied for the concentration range  $0.75 > (\text{C}) > 0.02$  and  $10.3 > (\text{H}) > 0.10$  M when the reagents were mixed in the vicinity of a calibrated photomultiplier. At the highest concentrations, the yield corresponded to  $4.1 \times 10^4$  photons of the 633 nm  $^1\text{Ag}$  dimol emission per molecule of either H or C when present in large excess of either C or H. The yield was found to be quadratic in either H or C and suggests a mechanism of SMO annihilation to be dominant in the production of emitting species, in spite of the kinetic limitation imposed by the mixing of the reagents. When the fluorescent dyes, Methylene Blue, Rhodamine-B, Fluorescein, or Eosin Y, are present in the reaction mixture, enhancement of the yields by factors in the range 1.2-10 were observed. The variation of enhancement efficiency with the known energy levels of the dyes is consistent with an energy transfer process involving the dimol to be the "energy pooling" process. This system is recommended for kinetic studies only under conditions where mixing is a small fraction of the total reaction time, and thereby requiring extremely sensitive.

analytical procedures. 'The data is being analyzed currently, and submission of the results for publication in the immediate future is anticipated. TRAINING ACTIVITIES Dr. George Simpson, Senior Investigator of the Heterocyclic Molecules Project taught the Radiation Chemistry Course offered as part of the M.S. Degree Program in Radiological Health offered by UPR School of Public Health with the collaboration of PRNC. 'The following students from the UPR Rio Piedras Campus participated in the Project during FY 1975: 1. L. Ramirez, Ph.D. Candidate Chemistry "Triplet-Triplet Absorption Spectra of Some Nitrogen Heterocycles." 2. M. Charron, M.S. Candidate, Chemistry "Radiation Induced Anions of Nitrogen Heterocyclics Stabilized in Various Glassy Matrices at 77K." 3. L. Jiménez, M.S. Candidate, Chemistry "Flash Photolysis of Purine in Aqueous Solutions." 4. E. Jiminez, Undergrad. Res. Participant "Measurements on the Luminescence Quantum Yield of Quinoline in MTHF." 5. I. Hernández, "Research on Radiation Induced Intermediates of Uracil." In addition, Dr. Mirtha Trujillo Sánchez, Faculty Research Participant from the UPR University College of Cayey, investigated the chemiluminescence yields of singlet molecular oxygen generated by the hydrogen peroxide-hypochlorite ion reaction, 185 ---Page

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