MPORU NEWSLETTER

Medical Physics Organized Research Unit
Physics Department, Carleton University

Editor: Carl Ross

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1. The MPORU

In the fall of 1989, an Organized Research Unit (ORU) was formed at Carleton University to encourage communication among those working in medical physics within the Ottawa area and to help coordinate the graduate studies program in medical physics at Carleton. The ORU was named the Medical Physics Organized Research Unit, or MPORU, and eight objectives were defined. They were:

1. To promote basic and applied research in those fields of medical physics in which there is local strength, in conformity with the research objectives of the institutions involved.

2. To advise the Carleton University Physics Department and the Ottawa-Carleton Institute of Physics on matters of medical physics.

3. To develop collaborative research activity in these fields.

4. To promote graduate studies in medical physics.

5. To facilitate graduate student placement with a supervisor who is a member of the MPORU.

6. To develop laboratory facilities for medical physics.

7. To encourage funding from government and from private agencies.

8. To organize seminars, meetings and other forms of communication among the members.

Membership in the MPORU is by invitation of the three-member Executive. Members are expected to be involved in teaching, research or the supervision of graduate students. The main method for the exchange of information among MPORU members is via the monthly seminar series, in which both graduate students in medical physics and MPORU members make presentations.

2. A Note from the Director

The MPORU has now had five successful years of operation and it has developed significantly over those years. We owe a great deal of appreciation to those who shaped it during the early days. In particular, I would like to acknowledge the leadership of Peter Raaphorst who was the Director of the MPORU from its inception until he stepped down in December of last year. Taking over the job of Director from Peter means that I have big shoes to fill. Fortunately, Peter has agreed to remain a member of the Executive as an observer. Thus, with his continuing guidance and the support of the membership, I am sure the MPORU will continue to function effectively.

1993 saw seven new students accepted into the Medical Physics program at Carleton bringing the number of students to a record high of 17. It is gratifying to note that the program appears to be attracting applications from a higher calibre of student with interest from a growing number of scholarship students. This bodes well for the future of the

Medical Physics program at Carleton.

In addition, thanks to the commendable support from our Adjunct Professor members, five new courses in Medical Physics have been added to the Calendar during the past five years including the Practicum course which will be offered for the first time this fall. This course is designed to give the students hands on experience with medical equipment such as they may be expected to operate when they graduate.

This past year saw the MPORU go about its business as usual with no major departures from previous years. However, there were two special events worth recalling. At our March meeting we heard from Louis Lamontagne about the Ottawa Life Sciences Technology Park. Although our practise has been to have talks from MPORU members only, it was felt that the Ottawa Life Sciences Technology Park was an exciting development for Ottawa and something that the MPORU membership should be aware of. The presentation was generally well received and it was felt to be a worthwhile initiative. In the future non-MPORU members will probably be invited to address us if the executive feels that the topic is of interest to the MPORU; however, this will be done only once in a while. The emphasis will continue to be on hearing medical physics talks from MPORU members and medical physics students.

The other departure from our normal routine occurred in April when a very successful and interesting meeting was held at the AECL labs in Chalk River. Although I was not able to attend because of a previous engagement, it is my understanding that it was very well received. Another Chalk River meeting will probably be proposed in two years when there is a new crop of students. As Director of the MPORU, let me express our thanks to our members from Chalk River for their work in organizing the trip and for their continued support even though they are so far away.

I would be remiss if I did not acknowledge the role that Carl Ross has played during his tenure as Secretary of the MPORU. He will be passing on the job to Alex Bielajew after this newsletter is published. In addition to taking the minutes at our executive meetings, he has also been the Newsletter editor and seminar organizer. Carl has spent a great deal of time and effort supporting the MPORU, mostly behind the scenes, and I think he should be commended for this efforts.

I would like to welcome Alex Bielajew and Joanna Cygler to the Executive. Alex will be our secretary and Joanna is an observer.

Congratulations are extended to Ted Lawrence and Dennis Heller who graduated during the past year.

Looking towards the future, there are two exciting developments on the horizon. Carleton University has approved a Chair in Medical Physics as part of its next fundraising campaign. This means that the University will attempt to raise funds to support an internationally renowned researcher in medical physics to come to Carleton to work for several years. Although there are still a lot of hurdles to overcome before this becomes a reality it is an exciting possibility. It is at least gratifying that the University has recognized the importance of medical physics and the need to support it in this way. Having a "Chair in Medical Physics" should raise the profile of medical physics in the area and present us with the opportunity to actively collaborate with a very well respected medical physicist. Let's all cross our fingers that it becomes a reality.

During the past six months or so the MPORU Executive has had several discussions about where we should be headed in the future. In particular, it was felt that closer ties with local industry could be mutually beneficial. In the upcoming year we will be investigating this possibility further and contacting some local industries to see if such an association would be feasible. If you have any comments or suggestions regarding such a proposal please contact a member of the Executive. Your feedback will be very much appreciated.

A special general thanks should be given to you, the members of the MPORU, since without your support we could not function effectively. I am looking forward to an exciting future for the MPORU; I hope we can count on your continued support.

Ian Cameron
Ottawa General Hospital

3. MPORU Executive and Advisory Board

The Executive of the MPORU consists of a Director (Ian Cameron), Secretary (Carl Ross), Academic Officer (Paul Johns) and a graduate student representative (Ruth Brown). The past director (Peter Raaphorst) also participates as an observer at Executive meetings. Members are elected for two year terms. The Executive meets about once a month and, in addition to the past director, several MPORU members (Joanna Cygler, Pavel Dvorak and Bog Jarosz) attend the Executive meetings as observers. The MPORU seminars for 1993-94 were organized by Carl Ross.

Formally, there is an Advisory Board which is intended to provide guidance and advice to the MPORU. However, it does not meet regularly, and its membership needs to be reconstituted. One of the goals for the coming year is to assess the role and relevance of the Advisory Board. If it is deemed to be useful, a new Board will be formed.

4. Seminars

4.1 MPORU Seminars

One of the main vehicles of the MPORU for developing and maintaining contacts is through a seminar series in which all the members and the graduate students in medical physics are required to make a presentation.

Seminars are scheduled monthly, and this year were held at 3:30 p.m. on Thursdays. The seminar location was rotated among the major centres involved in medical physics.

The following is a list of MPORU seminars held in 1993-94. Except for the session in March, the first speaker listed is a graduate student.

Date and Location	Speaker	Title
September 16 Carleton U.	Ruth Brown Carleton U.	Predicting Radiosensitivity of Normal Cells from the Radiation Response of Human Fibroblasts in Vitro
	Charlie Ma NRC	Ion Chamber Correction Factors for Medium-energy X-ray Dosimetry
October 14 NRC	Doru Kaytar Carleton U.	Interstitial Ultrasonic Applicator for Hyperthermia Therapy
	Pavel Dvorak Health Canada	X-ray and Non-ionizing Radiation Research at the Radiation Protection Bureau: An Overview
November 18 Cancer Clinic, Civic Division	Patrick Rapley Carleton U.	A New Gradient Coil Design for Fast NMR Imaging
	Norman Klassen NRC	Aerobic and Anoxic Mammalian Cell Lines Irradiated at Ultrahigh Dose Rates
December 16 Cancer Clinic, General Division	Julia Wallace Carleton U.	Evaluation of Human Ovarian Cancer by Proton Magnetic Resonance Spectroscopy
	Bog Jarosz Carleton U.	Peculiarities of Interstitial Heating by Waveguided Ultrasonic Applicator
January 20, 1994 Carleton U.	Julia Older Carleton U.	A Quick Tour of Optimization Theory
	Lee Gerig Ottawa Regional Cancer Centre	Real Time Remote Sensing of Patient Motion in Radiation Therapy
February 17 NRC	Daryoush Sheikh-Bagheri Carleton U.	Fluoroscopic Verification Imaging for HDR Brachytherapy
	Ken Shortt NRC	How Does NRC Measure Up?
March 17 Carleton U.	Louis Lamontagne Ottawa Life Sciences Technology Park	The Ottawa Life Sciences Technology Park Beyond "Brick and Mortar"
April 26 Chalk River	Kevin Lenton Carleton U.	Measurement of Antioxidants in Radiobiology

Tony Waker AECL	Smart Dosimetry in the Candu Environment
Clive Greenstock AECL	Exploring Radiation Damage and its Modification
Paul Unrau AECL	Biological Sources of Genetic and Somatic Risks

4.2 Carleton University Physics Department Seminars

Carleton University Physics Department runs a regular seminar series on Monday afternoons (with overflow to other days of the week) at 3:30 p.m. in the Herzberg Building. The following seminars of interest to medical physics were held in 1993-94:

September 27 — Paul Johns, Dept. of Physics, Carleton University - *Medical Physics: From Roentgen to Magnetic Resonance.*

October 18 — Patrick T.T. Wong, Steacie Institute for Molecular Sciences, NRC - *Pressure-Tuning Vibrational Spectroscopy and Structural Properties in Biomolecular Assemblies.*

November 22 — Barry McKee, Division of Nuclear Medicine, Ottawa Civic Hospital - *Nuclear Medicine Imaging: Attenuation and Scatter Correction in 3D PET.*

December 16 — OCIP Christmas Symposium - Ian Cameron, Department of Radiology, Ottawa General Hospital - *The Role of Water Molecule Diffusion in MR Image Contrast in Humans.*

January 10 — Ian Cunningham, Diagnostic Radiology, University of Western Ontario - *The Spatial-Frequency Dependent Quantum Sink: A Comprehensive Approach to Noise Analysis in Medical X-ray Imaging Systems.*

February 7 — Michael Patterson, Hamilton Regional Cancer Centre - *A Physicist's Guide to Photodynamic Therapy.*

March 7 — Charles Cain, Bioengineering Program, Department of Electrical Engineering and Computer Science, University of Michigan - *Deep Heating Hyperthermia with Ultrasound Phased Arrays.*

April 25 — Gail ter Haar, Institute of Cancer Research, Royal Marsden Hospital, U.K. - *Prospects for Non-Invasive Ultrasound Surgery.*

Fall Graduate Student Seminar Afternoon, November 23, 1993

George Ding - *Monte Carlo Simulation of Clinical Accelerators and Improvements on*

the Accuracy of Electron Beam Dosimetry.

Winter Graduate Student Seminar Afternoon, May 6, 1994

Doru Kaytar - *Recent Results in Ultrasonic Interstitial Hyperthermia.*

4.3 Other Seminars of Interest to the MPORU

In addition to the seminars listed in Sections 4.1 and 4.2 there are occasionally other seminars in the Ottawa area which are of interest to the MPORU. The ones which have been brought to our attention are noted below. The first line of each entry gives the date, the location and (in brackets) the sponsoring organization.

June 14, Ottawa Civic Hospital (Division of Nuclear Medicine)
Barry McKee, Physics Department, Queen's University
Development of a Small-Volume, High Resolution PET Imaging System at Queen's University.

October 20, NRC (IEEE EMBS)
N.V. Thakor, John Hopkins, Medical School, Baltimore, MD
Neurological Critical Core Monitoring

November 17, Ottawa General Hospital (Capital Region Nuclear Medicine Club)
Trevor Cradduck, Victoria Hospital, London, Ontario
Computer Networking of Medical Images within the Department, Across the City and Beyond

January 26, NRC (Institute for National Measurement Standards)
Richard Deslattes, NIST
Energy Measurement of X-ray Beams Using Crystal Diffraction Spectrometry

March 9, Carleton University (IEEE EMBS)
P.D. Van der Puije, Electronic Engineering, Carleton University
Thin Film Electrodes for Functional Electrostimulation

April 28, NRC (Institute for National Measurement Standards)
Dave Rogers, NRC
Better Radiation Standards and Radiotherapy Using Monte Carlo Simulations

May 9, NRC (Ionizing Radiation Standards)
Jan Seuntjens, Ghent University, Belgium
Improved Dosimetry of Medium Energy X-rays

5. Membership Directory of the MPORU

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6. Medical Physics Graduate Courses

The Carleton medical physics program has three specializations: imaging, therapy and biophysics. Shown below is the menu of courses for each. Required courses are marked →; the others are recommended.

Depending on the thesis weighting, the MSc typically requires six half-courses in addition to the thesis; the PhD requires four. PhD students who lack any of the relevant courses (or their equivalents) required for the MSc must complete them in their PhD. MSc students may be permitted to take up to two Fourth-Year half-courses and credit them towards the degree. PhD students can credit only graduate courses.

When a student has covered material in a prior program, such as an MSc in medical physics elsewhere, then the equivalent courses at Carleton are of course not required. The courses to be taken by a given student will be decided on in consultation with the student and the supervisor.

Listed for each course is the course number, the campus where taught and the course name. Carleton courses are numbered with the prefix "75" indicating Physics, followed by a 400-series number if Fourth Year, or either a 500- or 600-series number for graduate courses.

SPECIALIZATION IN IMAGING

Fall Term	→ 75.523 (Carleton)	Medical Radiation Physics
	→ 75.427 (Carleton)	Modern Optics (prerequisite to 75.524; additional to degree if PhD)
	75.527 (Carleton)	Radiobiology
	75.529 (Carleton)	Medical Physics Practicum
Winter Term	→ 75.524 (Carleton)	Physics of Medical Imaging
	75.526 (Carleton)	Medical Radiotherapy Physics
	75.528 (Carleton)	Radiation Protection
Fall & Winter (both terms)	ANA 7301 (Ottawa HSC)	Anatomy
	PHS 5210 (Ottawa HSC)	Physiology
Fall or Winter (one term)	→ 75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

SPECIALIZATION IN THERAPY

Fall Term	→ 75.523 (Carleton)	Medical Radiation Physics
	75.527 (Carleton)	Radiobiology
	75.529 (Carleton)	Medical Physics Practicum
Winter Term	75.524 (Carleton)	Physics of Medical Imaging
	→ 75.526 (Carleton)	Medical Radiotherapy Physics
	75.528 (Carleton)	Radiation Protection

Fall & Winter (both terms)	ANA 7301 (Ottawa HSC) PHS 5210 (Ottawa HSC)	Anatomy Physiology
Fall or Winter (one term)	→ 75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

SPECIALIZATION IN BIOPHYSICS

Fall Term	→ 75.523 (Carleton)	Medical Radiation Physics
	*→ 75.527 (Carleton)	Radiobiology
	75.529 (Carleton)	Medical Physics Practicum
Winter Term	75.524 (Carleton)	Physics of Medical Imaging
	75.526 (Carleton)	Medical Radiotherapy Physics
	75.528 (Carleton)	Radiation Protection
Fall & Winter (both terms)	*→ ANA 7301 (Ottawa HSC) *→ PHS 5210 (Ottawa HSC)	Anatomy Physiology
Fall or Winter (one term)	→ 75.5xx/6xx (Carleton or Ottawa)	Appropriate physics half-course outside of medical physics (permission may be given for 75.4xx if MSc)

*= in the Biophysics specialization, *one* of Radiobiology, Anatomy or Physiology must be taken.

Course Descriptions

75.523 - Medical Radiation Physics (1/2 course, Fall) - Basic interaction of electromagnetic radiation with matter. Sources: x ray, accelerators, nuclear. Charged particle interaction mechanisms, stopping powers, kerma, dose. Introduction to dosimetry. Units, measurements, dosimetry devices.
Reference: H.E. Johns and J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturer: P.C. Johns

75.524 - Physics of Medical Imaging (1/2 course, Winter) - Outline of the principles of transmission x-ray imaging, computerized tomography, nuclear medicine, magnetic resonance imaging and ultrasound. Physical descriptors of image quality, including contrast, resolution, signal-to-noise ratio and modulation transfer function are covered and an introduction is given to image processing.
Prerequisites: 75.523 or equivalent and 75.427 or equivalent.
Reference: H.H. Barrett and W. Swindell, *Radiological Imaging*, 1981.
Lecturers: P.C. Johns, B.T.A. McKee and I.G. Cameron.

75.526 - Medical Radiotherapy Physics (1/2 course, Winter) - Terminology and related physics concepts. Bragg-Gray, Spencer-Attix cavity theories, Fano's Theorem. Dosimetry protocols, dose distribution calculations. Radiotherapy devices, hyperthermia.
Prerequisite: 75.523 or equivalent.

References: F.H. Attix, *Introduction to Radiological Physics and Radiation Dosimetry*, 1986.
H.E. Johns and J.R. Cunningham, *The Physics of Radiology*, 4th ed., 1983.
Lecturers: J. Cygler, D.W.O. Rogers, K.R. Shortt and L.H. Gerig.

75.527 - Radiobiology (1/2 course, Fall) - Introduction to basic physics and chemistry of radiation interactions, free radicals, oxidation and reduction, G values. Subcellular and cellular effects: killing, repair, sensitization, protection. Measurement methods. Survival curve models. Tissue effects, genetic and carcinogenic effects, mutations, hazards. Cancer therapy. Radiation protection considerations.
Prerequisite: 75.523 or equivalent must have been taken, or must be taken concurrently.
Reference: E.J. Hall, *Radiobiology for the Radiologist,* 3rd ed., 1988.
Lecturer: G.P. Raaphorst

75.528 - Radiation Protection (1/2 course, Winter) - Biophysics of radiation hazards, dosimetry and instrumentation. Monitoring of sources, planning of facilities, waste management, radiation safety, public protection. Regulatory agencies.
Prerequisite: 75.523 or equivalent.
Lecturer: V. Elaguppillai

75.529 - Medical Physics Practicum (1/2 course, Fall) - This course provides hands-on experience with current clinical medical imaging and cancer therapy equipment, and with biophysics instrumentation. The student is expected to complete a small number of practical experimental projects during the term on topics such as magnetic resonance imaging, computed tomographic scanning, radiotherapy dosimetry, hyperthermia, biophysics and radiation protection. The projects will be conducted at hospitals, cancer treatment facilities and NRC laboratories in Ottawa.
Prerequisite: 75.523 or equivalent. Also, as appropriate to the majority of projects undertaken, one of 75.524, 75.526 or 75.527 or other biophysics course, or permission of the Department.

ANA 7301 - Anatomy for Medical Physics Graduate Students (1/2 course, extends through Fall + Winter) - A basic course in anatomy for medical physics students utilizing the systemic approach to emphasize practical and clinical aspects of the gross structure of the human body. The course consists of lectures, laboratory demonstrations with dissected materials and a series of audio-visual presentations involving imaging techniques.

PHS 5210 - Mammalian Physiology (full course, extends through Fall + Winter) - A comprehensive study of mammalian physiology with an emphasis on regulating mechanisms. The course includes the biophysical basis of excitable tissues and the physiology of the central nervous system, blood and cardiovascular system, respiratory system, endocrine system, G.I. tract and renal physiology. It is assumed that students have a basic knowledge of chemistry, physics and biology.

75.427 - Modern Optics (1/2 course, Fall) - Diffraction theory, coherence, Fourier optics, spatial filtering; holography and its applications; laser theory: stimulated emission, cavity optics, modes; gain and bandwidth; design and characteristics of atomic and molecular gas lasers.
[This is a Fourth-Year half-course which covers material prerequisite to the Physics of Medical Imaging graduate course (75.524).]
Reference: J.W. Goodman, *Introduction to Fourier Optics*, 1968.

Lecturer: L. Resnick

Appropriate physics half-course outside of medical physics - A half-course in an area of physics outside of medical physics is required. Appropriate possibilities include nuclear, theoretical, quantum, particle, solid state and computational physics.

Paul Johns, Academic Officer, MPORU

7. Students

7.1 Graduate Students Currently Enrolled in the Medical Physics Program

Student	Date Stated*	Supervisor	Specialization	Thesis Topic
PhD Students				
Soubra, Mazen	Sept. 1988 (Part Time)	Gerig	Therapy	Asymmetric linac fields for radiotherapy
Akyurekli, Dennis	Jan. 1989 (following completion of MSc with R. Clarke)	Gerig	Therapy/ Biophysics	Physiology of blood flow during hyperthermia
Rapley, Patrick	Sept. 1989	Saunders	Imaging	MR coil design, pulse sequences for ovarian cancer
Wallace, Julia	Sept. 1989	Raaphorst	Biophysics/ Imaging	Biophysics of tumour cellular & tissue response via MRS
Ding, George	Sept. 1991 (Transferred from U. Manitoba)	Rogers	Therapy	OMEGA (online Monte Carlo radiotherapy planning)
Brown, Ruth	Sept. 1991	Raaphorst	Biophysics	Biophysics of radiation damage and repair
Gates, Larry	Sept. 1991	Cameron	Imaging	MRI measurement of water diffusion
Lenton, Kevin	Sept. 1992	Greenstock	Biophysics	Studies of radiosensitivity at cellular level
MacPherson, Miller	Feb. 1993	Ross	Therapy	Measurement of electron stopping powers

Sheik-Bagheri, Daryoush	Sept. 1993	Rogers	Therapy	OMEGA (online Monte Carlo radiotherapy planning)
Zhang, Geoffery	Oct. 1993	Rogers	Therapy	OMEGA (online Monte Carlo radiotherapy planning)
<u>MSc Students</u>				
Kaytar, Doru	Sept. 1992	Jarosz	Therapy	Ultrasonic interstitial hyperthermia array applicator for brain tumours
Corsten, Ria	Sept. 1993	Bielajew	Therapy	Theoretical study of ion chamber response to brachytherapy sources
Laporte, Pierre	Sept. 1993	Szanto/Gerig	Therapy	Dosimetry for radiotherapy field dynamic wedging
MacGillivray, Cathy	Sept. 1993	Cameron	Imaging	Diffusion-weighted MRI
Shahine, Bilal	Sept. 1993 (Part Time)	Raaphorst	Biophysics	Biophysics of radiation damage and repair

* - date first started taking courses or commenced lab work, not the official date of first registration into degree

7.2 Directory of Graduate Students

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7.3 Theses and Projects Completed in 1993-94

GRADUATE STUDENT THESES

Ted Lawrence	MSc	Thesis Title:	The Variables Controlling the Intensity and Purity of Fluorescence X Rays
		Supervisor:	Paul Johns
		Thesis Examination:	4 August 1993
Dennis Heller	PhD	Thesis Title:	Radiobiological Aspects of Cellular Recovery Following High and Low Dose-Rate Irradiation With/Without Mild Hyperthermia in a Human Glioma Cell Model
		Supervisor:	G. Peter Raaphorst
		Thesis Examination:	21 October 1993

HONOURS FOURTH-YEAR UNDERGRADUATE PHYSICS PROJECTS

Hadiyanto	75.499	Project Title:	Monte Carlo Simulation of X-Ray Imaging During a Fine Needle Biopsy Procedure
		Supervisor:	Paul Johns

8. Scientific Societies of Relevance to Medical Physics

The following scientific societies are of interest to students and scientists in medical physics. For further information contact the individuals shown:

COMP - Canadian Organization of Medical Physicists: Paul Johns, Ken Shortt.

CAP - Canadian Association of Physicists: Dave Rogers, Bob Clarke, Paul Johns.

SMR - Society for Magnetic Resonance: Ian Cameron

CRPA - Canadian Radiation Protection Association: Dave Rogers.

AAPM - American Association of Physicists in Medicine - Dave Rogers, Paul Johns.

EMBS - Engineering in Medicine and Biology Society of the IEEE - Bog Jarosz.

HPS - Health Physics Society (US): Dave Rogers.

RRS - Radiation Research Society: Peter Raaphorst.

9. Field Trip to AECL Chalk River Laboratories

The final MPORU activity of the academic year was a field trip on April 26, 1994 to the Chalk River Laboratories (CRL) of Atomic Energy of Canada Ltd. (AECL). It was a logical development of our practice of holding the monthly MPORU seminars at the major centres doing medical physics. The two MPORU members from CRL, Tony Waker and Clive Greenstock, arranged for a choice of two tours and a lunch in addition to the seminars. A total of 21 MPORU members, graduate students and guest scientists participated.

One of the available tours was of the Radiation Biology and Health Physics labs. The following were seen: ELISA (enzyme linked immunosorbent assay) lab, ESR (electron spin resonance) lab, fluorescence activated cell sorter (which can sort cells according to cell cycle, as indicated by fluorescence), chromosome painting (a technique known as FISH (fluorescent in situ hybridization) which can stain specific chromosomes, allowing abberations to be seen), TLD badge reading system, facilities for CR-39 charged particle and neutron dosimetry, D-T neutron generator, tissue-equivalent proportional counters, bonner sphere neutron spectrometer and proportional chambers for tritium monitoring (which were developed at CRL and have been commercialized).

The alternate tour was of some of the major facilities at CRL. It began with a bus tour of the campus during which the tour guide identified some of the unique facilities at CRL. The walking tour began with ZEEP, Canada's first nuclear reactor, and the forerunner of CANDU. The group then visited the control room of NRU, the reactor which is used for research and isotope production. Although NRX, the predecessor of NRU, has recently been shut down, it is still open to visitors, and members of the tour were able to stand on top of the core, and get a feeling for the size and complexity of a large reactor facility. The tour finished with a visit to TASCC, the nuclear physics research facility. The group was able to walk beside the Tandem Van de Graaff, follow the beam lines to the superconducting cyclotron, and to the "8-pi" detector facility.

The seminars began with greetings from Dr. Bob McElroy, Branch Manager of Radiation Biology and Health Physics at CRL, followed by a brief overview of the MPORU by Paul Johns. The April MPORU student seminar was then given by Kevin Lenton on his research attempting to measure the level of antioxidants in cells as they respond to ionizing radiation. Tony Waker followed by a seminar on his work towards dosimetry instrumentation which can recognize the type of radiation environment it is in and respond appropriately, and is robust enough to be used in a nuclear generating station. Clive Greenstock gave a general overview of the means by which radiation damages DNA and outlined what is known about repair mechanisms. The final speaker was Paul Unrau, a geneticist at CRL who is exploring the connection between disease and genes. A number of novel concepts were introduced, such as the fact that marriage to a first cousin conveys the same genetic risk to one's offspring as about 20 Gy of radiation.

The CRL field trip was very successful, and it was agreed that it should be repeated in the future.

10. The Ottawa Chapter of the IEEE Engineering in Medicine and Biology Society (EMBS)

The Ottawa-Carleton area has recently been enriched by another professional organization in the field of medical and biological research. Formation of the Ottawa Chapter of the IEEE Engineering in Medicine and Biology Society was approved by the IEEE Head Office in the late spring of 1993 after petitioning by a group of EMBS members in the area. The chapter has to date about 15 members and its two officers are Dr. Boguslaw J. Jarosz, Chairman, and Dr. Sylvain Labonte, Assistant Professor, Electrical Engineering, University of Ottawa, Vice-Chairman. The membership of the chapter derives from members of faculty of the two area universities, the two largest area hospitals, as well as from other institutions, such as BNR, Canadian Marconi and DOD.

Before giving some details on the Chapter activities, here is some general information about its roots. The Institute of Electrical and Electronic Engineers, an international professional organization, has about 320,000 members worldwide. The Institute is subdivided into ten regions of which region seven corresponds to Canadian membership. Very soon, after years of negotiations, IEEE Region 7 and other professional engineering organizations within the country will form IEEE Canada Inc. under the IEEE umbrella. IEEE groups its members of similar research interests into several Societies. Engineering in Medicine and Biology has a significant membership of nearly eight thousand members and it is one of the fastest growing societies of the IEEE. The Society publishes refereed research papers in its Transactions (two) and Magazine and it organizes annually an international conference with typically 1400-2500 participants.

Each region is organized into Sections that represent local membership. The IEEE Ottawa Section has 2414 members which constitutes about 15% of Canadian membership. The Section celebrates its 50th anniversary this year and there have been several important events in the area to commemorate the anniversary. The Ottawa Section has been praised by many for its active role and for the diligence of its members. Among many achievements of the Ottawa Section, it was involved in creation of OCRInet and of the IEEE Canada electronic Newsletter. Each Section consists of Chapters representing various Societies. Reflecting interests of the EMBS, the interest of our Chapter is the application of the concepts and methods of the physical and engineering sciences in biology and medicine.

In this setting, our Chapter strives to build on the excellence of our colleagues. The primary goal of the Chapter is, in accordance with the IEEE Constitution, ... "the advancement of the theory and practice.... of engineering and the allied arts and sciences"... and ... "the advancement of the standing of the members of the professions it serves". More generally, the goal is .... "to enhance the quality of life for all the people....". We want to achieve these goals by holding meetings for the reading and discussion of professional papers and of current issues concerning the membership. Our chapter meets every two or three months and those meetings are accompanied by talks in the area of medical and biological research.

Since the formation of the Chapter, we have had two speakers giving talks to members and a general audience. On October 20 of last year Dr. N.V. Thakor of the Department of Biomedical Engineering of the John Hopkins Medical School presented "Neurological Critical Care Monitoring" with an important clinical conclusion of the necessity for monitoring brain activity as well as cardiac intensive care at least in

neurological surgeries. On March 9 of this year Dr. P.D. van der Puije of the Department of Electronic Engineering of Carleton University gave the talk "Thin Film Electrodes for Functional Electrostimulation" that covered the application of thin film technology for the recording of neural signals and for the stimulation of nerves. Examples of the technology in the cochlear implant for profoundly deaf and in control of the bladder for the incontinent were described as some of practical applications.

These and other activities will form the basis of the Chapter exercises. We want to expand our contacts to as many professionals as possible. There are two types of IEEE membership: student-member and member. According to the Institute By-laws, any individual with .... "a baccalaureate degree or its equivalent ... from a recognized educational program" currently active in the Society field is eligible to become a member. The candidate must be endorsed by a current IEEE member prior to sending the application to the Head Office. Anyone interested in becoming a member of our Chapter might contact the Chairman or the Vice-Chairman. We will be happy to provide any assistance in that regard.

Boguslaw J. Jarosz
Carleton University

11. Recent Research by MPORU Members

In order that the Newsletter may serve as an annual report to the Dean of Graduate Studies and Research of Carleton University, this section describes briefly the research activities, recent publications and sources of funding of the MPORU members. The editor has attempted to reduce all the contributions to a standard format.

Alex Bielajew
Research: Improving Monte Carlo methods in the therapeutic range (10 keV-50 MeV) by modelling the physics more accurately. Most emphasis is on the EGS (electron gamma shower) Monte Carlo code. Using analytic and Monte Carlo methods to improve the foundations of theoretical dosimetry. Theoretical development of multiple scattering theory.
Publications:
A.F. Bielajew (1994) *Monte Carlo modelling in external electron-beam radiotherapy - why leave it to chance?* in Proceedings of the Eleventh International Conference on the Use of Computers in Radiation Therapy, North Western Medical Physics Department, Christie Hospital, Manchester, U.K. pp 2-5.
A.F. Bielajew (1994) *Improvements of elastic-scattering models employed by the Monte Carlo method for high-accuracy dosimetry applications* in Proceedings of the Eleventh International Conference on the Use of Computers in Radiation Therapy, North Western Medical Physics Department, Christie Hospital, Manchester, U.K. pp 148-149.
A.F. Bielajew (1994) *Plural and multiple small-angle scattering from a screened Rutherford cross section* (in press) Nucl. Instrum. & Meth. B.
A.F. Bielajew (1994) Comments on: *Calculation of absorbed dose ratios using correlated Monte Carlo sampling* [Med. Phys. 20 1189-99 (1993)] Med. Phys. 21 35.
P. Andreo, J. Medin and A.F. Bielajew (1993) *Constraints on the multiple-scattering theory of Molière in Monte Carlo simulations of the transport of charged particles* Med. Phys. 20 1315-1325.

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a dosimetry system based on absorbed-dose standards* in Proceedings of the International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/9 (IAEA, Vienna).

A.F. Bielajew, R. Wang and S. Duane (1993) *Incorporation of single elastic scattering in the EGS4 Monte Carlo code system: tests of Molière theory* Nucl Instrum. and Meth. B82 503-12.

A.F. Bielajew (1993) *The effect of strong longitudinal magnetic fields on dose deposition from electron and photon beams* Med. Phys. 20 (1993) 1171-1179.

J.L. Karr and A.F. Bielajew (1993) *A 1-D cubic spline routine for fitting electron elastic scattering cross sections* NRCC report: PIRS-0366.

J.L. Karr and A.F. Bielajew (1993) *PIF [Prepare Input File (for PEGS4)]* NRCC report: PIRS-0365.

C.-M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1993) *Wall correction and absorbed dose conversion factors for Fricke dosimetry: Monte Carlo calculations and measurements* Med. Phys. 20 283-92.

A.F. Bielajew and D.W.O. Rogers (1992) *Implications of new correction factors on primary air kerma standards in ^{60}Co beams* Phys. Med. Biol. 37 1283-1291.

A.F. Bielajew and D.W.O. Rogers (1992) *A standard timing benchmark for EGS4 Monte Carlo Calculations* Med. Phys. 19 303-304.

S. Walker, A.F. Bielajew and M. Hale (1992) *Installation of EGS4 Monte Carlo Code on an 80386-based microcomputer* Med. Phys. 19 305-306.

E. White and A.F. Bielajew (1992) *Optimizing sampling efficiency for Monte Carlo applications* (NRCC report: PIRS-0332).

J. Mizia and A.F. Bielajew (1992) *The density effect on electron stopping powers in condensed, granular materials* (NRCC report: PIRS-0322).

Ian Cameron

Research: We use Magnetic Resonance Imaging (MRI) to study water diffusion and perfusion of blood in capillary beds. In order to better understand the effects of water diffusion in diffusion sensitized MR images at a basic level we have designed and built special gradient coils which allow us to study this process over a much larger range than is possible with the gradient coils provided with the imager. We are also developing similar procedures for measuring placental blood flow to monitor intrauterine growth retardation.

Magnetic Resonance Spectroscopy (MRS) can be used to determine the concentration of a variety of important molecules in a given volume of interest (VOI) inside the body. The VOI can be as small as 2x2x2 cm^3 and it can, in principle, be positioned anywhere inside the body. We are using ^{31}P MRS in conjunction with an exercise protocol as a possible screen for malignant hyperthermia. ^{1}H and ^{31}P MRS are also being used in a study of brain tumours. In addition, we have the capability of doing ^{19}F MRS and we hope to make use of this to follow the metabolism of fluorinated chemotherapy drugs in vivo.

Funding: NSERC operating grant, $15,000/year.

Robert Clarke
Research: Studying the use of highly focussed beams of ultrasound for the reduction or removal of benign and malignant lesions. The process of tissue destruction, consisting of energy deposition, diffusion and tissue response is being studied experimentally, theoretically and by computer modelling. Appropriate lens design and the dosimetry of high intensity ultrasound are also being investigated.

Publications:
M.G. Vaughan, G.R. ter Haar, R.L. Clarke and J.W. Hopewell (1994) Minimally Invasive Cancer Surgery Using Focused Ultrasound: a Preclinical, Normal Tissue Study Br. J. Radiol. 67 267-274.

Pavel Dvorak
Publications:
P. Dvorak and C. Lavoie (1992) Exotic Filter Materials for Diagnostic X-ray Equipment - *Are they superior to Commonly Available Materials?* IRPA8 Meeting 1992, Montreal, Quebec. Proceedings 1 211-214.

V. Elaguppillai
Research: Quantification of the risk to health (cancer, genetic and teratogenic effects) and environmental effects of exposure to low dose and low dose-rate of low and high LET ionising radiation, reduction of uncertainties in risk estimates, design and improvement of radiation practices at work places (hospital, research, power reactor, uranium mine, mill and refinery, radioactive waste disposal facilities) are the areas of main research interest.

Lee Gerig and Janos Szanto
Research: The Patient Position Monitoring System is being developed as a tool for the computer-controlled radiation therapy program. The design criteria are that this system will provide an independent means of measuring patient position in real time. Position can be reported in either absolute or relative terms and will provide both rotational in three planes and translational motions updating every five seconds. This is a joint project spearheaded by the ORCC and being done in conjunction with the National Research Council and Siemens Medical Laboratories.

There is a well-defined need for the development and implementation of a stereotactic radiation surgery and radiation therapy program at the ORCC. The principal difference between radiation surgery and radiation therapy is that radiation surgery delivers a very high dose in a single fraction whereas radiation therapy has all the same requirements except the dose must be delivered in a fractionated manner. The program includes the development of special radiation therapy cones to provide a very well-defined, well colimated x-ray beam, patient immobilization devices specifically for the radiation therapy component, localization devices which can be correlated to the patient immobilization devices and treatment planning and dosimetry for the verification of dose distributions. It is hoped that the stereotactic radiation therapy program will be implemented fully by May of 1993, although preliminary patient work has been done as early as November of 1992.

Clive Greenstock

Research: Studying radiation-induced conformational changes in the human genome using time-resolved- and immuno-fluorescence spectroscopy, and investigating the role of DNA synthesis and packaging enzymes in determining radiation response.

Using ESR spectrometry in Biological Dosimetry of human samples and tissue-equivalent surrogate materials, and evaluating its potential for individual dose estimation in radiation accidents and occupational exposures.

Measuring radiation damage to the lymphocyte immuno-surveillance system. Fluorescent monoclonal antibody binding to specific cell surface receptors is used to monitor an early-warning response to radiation and trigger mechanisms involved in cell signalling and adaptation processes.

An immuno-assay technique (ELISA) has been set up to measure antioxidant levels in cells and to explore their role in inducible and constitutive radiation protection mechanisms.

Publications:

C.L. Greenstock (1993) *Radiation and aging: Free radical damage, biological response and possible antioxidant intervention.* Med. Hypoth. 41 473-482.

A. Trivedi and C.L. Greenstock (1993) *Recent developments in Biodosimetry.* Atomic Energy Control Board (AECB) Report No. 7.155.1, 78 pp.

C.L. Greenstock, R.E.J. Mitchel, A. Trivedi and Y. Xu (1993) *Immunofluorescence studies of low dose radiation effects on human lymphocyte surface markers*, Proc. 4th International Conference on Anticarcinogenesis and Radiation Protection, Plenum Press, New York 217.

C.L. Greenstock and R.P. Whitehouse (1992) *Radiation chemical studies of sensitization by 5-bromouridine-5'-monophosphate* Radiat. Environ. Biophys. 31 1-9.

C.L. Greenstock and A. Trivedi (1992) *Free radical measurement in bio-organic substances using an electron spin resonance technique*, Proc. Eighth International Radiation Protection Association Congress 1 455-458.

A. Trivedi and C.L. Greenstock (1992) *Use of sugars and hair samples for ESR emergency dosimetry*, Appl. Radiat. Isot. 44 85-90.

A.B. Ross, W.G. Mallard, W.P. Helman, B.H.J. Bielski, G.V. Buxton, D.E. Cabelli, C.L. Greenstock, R.E. Huie and P. Neta (1992) *NDRL-NIST Solution Chemistry Database:-ver 1*, National Institute of Standards and Technology, Gaithersburg, 34 pp.

A.O.L. Tchen, I. Bonnot, C.L. Greenstock and A. Trivedi (1992) *An investigation of silicone/sucrose pellets: A new development in electron spin resonance (ESR) dosimetry,* Atomic Energy of Canada Limited (AECL) Research Report No. RC-702, 17 pp.

B.P. Smith, K.L. Gale, M. Einspenner, C.L. Greenstock and N.E. Gentner (1992) *Stimulated human fibroblast cell survival/clonogenicity in response to low doses of ionizing radiation,* Proc. International Conference on Low Dose Irradiation and Biological Defense Mechanisms, Elsevier, Amsterdam, 299-302.

Funding: Supported as a member of AECL Research staff

Candu Owners Group, R&D support	150K
Accelerator Business Unit, Impela dosimetry grant	15K
Atomic Energy Control Board, biolog. dosimetry grant	22K
AECL Research H.O., isotope operation/study grant	10K

Boguslaw J. Jarosz
Research: Therapeutic applications of ultrasound in hyperthermia of deeply localized tumours and ultrasound propagation in inhomogeneous media. Current research concentrates on interaction of sonic waves from the original waveguided interstitial hyperthermia applicator with tissue and mode conversion in tissues, projects that have been recently started. Research of a multi-applicator waveguided interstitial hyperthermia system for therapy of brain tumours is currently under way. Research of laser generated ultrasound is pursued, too.

Publications:
B.J. Jarosz (1993) *Time-dependent mechanisms of hyperthermia by interstitial ultrasound*, Proc. 15th Ann. Int. Conf. IEEE Eng. Med. Biol. Soc., 15 202.
B.J. Jarosz (1993) *Mechanisms of ultrasound heating in interstitial hyperthermia*, CMBES/COMP 1993 Joint Conf. Proc., 340.
B.J. Jarosz (1992) *Effects of blood flow on temperature elevation in ultrasonic interstitial hyperthermia*, Proc. 14th Ann. Int. Conf. IEEE Eng. Med. Biol. Soc. 14 344.
B.J. Jarosz (1992) *Effects of inhomogeneities and blood flow on temperature elevation in ultrasonic interstitial hyperthermia,* AAPM/COMP 1992 Ann. Meet., Abstract in Med. Phys. 19 805.

Funding: Private (Ottawa Civic Hospital Foundation)

Paul Johns
Research: Studying iterative reconstruction techniques to reduce artifacts in computed tomography (CT) by accounting for the polyenergetic nature of the x-ray beam as well as scattered x rays.

Investigating the factors controlling the spectral purity and intensity of monoenergetic x rays produced via secondary fluorescence.

Member of collaboration at Carleton investigating the use of gas microstrip detectors for medical x-ray imaging, especially mammography. By operating in photon counting mode, these detectors could achieve significantly higher DQE than do screen-film systems.
Publications:
S.G. Gilbert, P.C. Johns, D.C. Chow and R.C. Black (1993), *Relation of Vertebral Bone Screw Axial Pullout Strength to Quantitative Computed Tomographic Trabecular Bone Mineral Content*, J. of Spinal Disorders 6 513-521.
P.L. Pattee, P.C. Johns and R.J. Chambers (1993) *Radiation Risk to Patients from Percutaneous Transluminal Coronary Angioplasty*, J. Am. College Cardiology 22 1044-1051.
J.K. Older and P.C. Johns (1993) *Matrix Formulation of Computed Tomogram Reconstruction* Phys. Med. Biol. 38 1051-1064.
P.C. Johns and J.K. Older (1993) *Matrix Formulation of CT Reconstruction Theory*, Proceedings of Joint Conference of the Canadian Organization of Medical Physicists and the Canadian Medical and Biological Engineering Society 154-155 [Abstract: Medical Phys. 20 1591 (1993)].
E.R. Lawrence and P.C. Johns (1993) *The Variables Controlling the Intensity and Purity of Fluorescence X Rays*, Proceedings of Joint Conference of the Canadian Organization of Medical Physicists and the Canadian Medical and Biological Engineering Society 80-81 [Abstract: Medical Physics 20 1587 (1993)].

Funding: NSERC Operating Grant $15,000.

Norman Klassen

Research: Involved with work to establish absorbed dose standards based on water calorimetry. One initiative is to extend the work done at 20 MV to ^{60}Co. Another is to compare experimentally determined H_2O_2 yields in water irradiated in the calorimeter under normal operating conditions to the yields predicted by computer simulation and the temperature rise measured in irradiated water.

Publications:

N.V. Klassen, P.R. Walker, C.K. Ross, J. Cygler and B. Lach (1993) *Two-stage Cell Shrinkage and the OER for Radiation-induced Apoptosis of Rat Thymocytes*, Int. J. Radiat. Biol. 64 571-581.

Funding: Supported as a member of NRC staff.

Charlie Ma

Research: Using Monte Carlo techniques to improve our understanding of cavity theory and dosimeter response for radiotherapy dosimetry.

Using the EGS4 Monte Carlo code system to calculate correction factors for Fricke dosimeters and ionization chambers in medium-energy x-ray beams and in high-energy photon and electron beams.

Working on the OMEGA project. This is a collaboration between the NRCC and the University of Wisconsin to develop a Monte Carlo code to calculate dose distributions in a patient irradiated by a high-energy electron beam.

Publications:

C.-M. Ma and A.E. Nahum (1994) *Ion chamber stem effect corrections for medium-energy x-ray dosimetry*, Phys. Med. Biol. submitted.

C.-M. Ma and A.E. Nahum (1993) *Ion chamber displacement corrections for NE2561 and NE2571 chambers in medium energy x-ray beam*, submitted Phys. Med. Biol. (1993)

C.-M. Ma (1994) *Implementation of a Monte Carlo radiation transport code on a parallel-computer system*, Parallel Computing (1994) in press.

C.-M. Ma, R. Knight, A.E. Nahum and P. Mayles (1993) *Measurement of C_e factors for the NPL prototype plane-parallel chamber*, submitted Phys. Med. Biol.

C.-M. Ma and A.E. Nahum (1993) *Implementation of correlated sampling variance reduction technique in EGS4 code system* Med. Phys. submitted.

C.-M. Ma and A.E. Nahum (1993) *Monte Carlo calculated correction factors for a NE 2571 chamber in medium-energy x-ray beams*, Proc. International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/5 in press Vienna.

C.-M. Ma and A.E. Nahum (1993) *Theoretical and experimental investigation of the prototype NPL design of plane-parallel chambers*, Proc. International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/4 in press Vienna.

C.-M. Ma and A.E. Nahum (1993) *Plane-parallel chambers in electron beams: Monte Carlo findings on perturbation correction factor*, Proc. International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/7 in press Vienna.

C.-M. Ma and A.E. Nahum (1993) *Effect of size and composition of central electrode on the response of cylindrical ionization chambers in high-energy photon and electron beams* Phys. Med. Biol. 38 267-293.
C.-M. Ma (1992) *Monte Carlo simulation of dosemeter response using transputers,* Institute of Cancer Research, Report No. ICR-PHYS-1/91, Sutton, U.K..
C.-M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1993) *Wall correction and absorbed dose conversion factors for Fricke dosimetry: Monte Carlo calculations and measurements* Med. Phys. 20 283-293.
C.-M. Ma and A.E. Nahum (1993) *Correction factors for Fricke dosimetry in high-energy electron beams* Phys. Med. Biol. 38 423-438.
C.-M. Ma and A.E. Nahum (1993) *Calculation of absorbed dose ratios using correlated Monte Carlo sampling* Med. Phys. 20 1189-1199.
C.-M. Ma and A.E. Nahum (1993) *Dose Conversion and Wall Correction Factors for Fricke Dosimetry in High-Energy Photon Beams: Analytical Model and Monte Carlo Calculations* Phys. Med. Biol. 38 93-114.
C.-M. Ma and A.E. Nahum (1992) *A new algorithm for EGS4 low-energy electron transport to account for the change in discrete interaction cross section with energy,* Nucl. Instr. Med. B72 319-330.
C.-M. Ma and A.E. Nahum (1992) *Monte Carlo calculated correction factors for ion chamber dosimetry in medium-energy photon beams,* report commissioned by the IPSM working party on kilovoltage x-ray dosimetry, Physics Dept., Institute of Cancer Research, Sutton, U.K.

Funding: Supported as a member of NRC staff.

Barry McKee

Research: Developing a high-resolution pinhole SPECT camera that will achieve a resolution of about 3 mm over a limited field of view. This will be useful for clinical imaging of wrists, etc., and for research applications in radiopharmaceutical development.

Modelling and measuring the scatter background in SPECT systems to develop and test improved correction methods. This takes advantage of recent experience in developing scatter correction methods for 3D PET imaging.

Publications:

B.T.A. McKee, A.W. Dickson and D.C. Howse (1994) *Performance of QPET, a high-resolution ED PET imaging system for small volumes*, IEEE Trans. Med. Imaging, MI-13 176-185.
L.G. Hiltz, P.J. Harvey, D.C. Howse and B.T.A. McKee (1993) *3D attenuation correction for PET using uncollimated flood source transmission measurements,* Conference Record of the 1992 IEEE Medical Imaging Conference, 963-965.
B.T.A. McKee, A.T. Gurvey, P.J. Harvey and D.C. Howse (1992) *A deconvolution scatter correction for a 3D PET system,* IEEE Trans. Med. Imaging, MI-11 560-569.

Alan Mortimer
Research: Studying the way the environment in the immediate vicinity of the cell surface affects what happens to the cell. Ultrasound is known to increase the transport of messenger ions across the cell membrane. Also, the space environment decreases the immune response of cells in suspension. This may be due to reduced convection, leading to reduced surface interaction. Work is underway to study cell surface binding and transport across membrances in simulated micro gravity. Studies are also planned to determine how ultrasound changes the properties of cell membranes thereby affecting wound healing.

Cheng E. Ng
Research: Magnetic Resonance Spectroscopy (MRS) techniques are being investigated for distinguishing drug-resistant from drug-sensitive human ovarian tumour cells perfused in vitro. MRS techniques are also being investigated for monitoring and/or predicting effects of treatment with x-rays, drugs or hyperthermia on the same cells. The goal of these studies is to establish if MRS can play a role in the diagnosis and/or prognosis of cancer. The effects of drugs which inhibit the ability of human skin cancer cells to repair x-radiation and hyperthermic damage in culture are also being investigated. The aim of these studies is to establish if inhibition of cellular repair can lead to more effective killing of tumour cells.

Publications
K.A. McGovern, J.S. Schoniger, J.P. Wehrle, C.E. Ng and J.D. Glickson (1993) *Gel-entrapment of per fluorocarbon: A Fluorine-19 NMR spectroscopic method for monitoring oxygen concentrations in cell perfusion systems.* Mag. Res. In Medicine 29 196-204.
G.P. Raaphorst, M. Thakar and C.E. Ng (1993) *Thermal radiosensitization in two pairs of CHO wild-type and radiation-sensitive mutants*, in press Int. J. Hyperthermia.
G.P. Raaphorst, D.P. Heller, A.M. Bussey and C.E. Ng (1993) *Thermal radiosensitization by 41°C hyperthermia during low dose-rate irradiation in human normal and tumour cell lines* in press Int. J. Hyperthermia
C.E. Ng, A.M. Bussey and G.P. Raaphorst (1993) *Inhibition of potentially lethal and sublethal radiation damage repair by comptothecin and etoposide in human melanoma cell lines.* Submitted
C.E. Ng, K.A. McGovern, J.P. Wehrle and J.D. Glickson (1992) *^{31}P NMR spectroscopic study of the effect of gamma-irradiation on RIF-1 tumour cells perfused in vitro*, Mag. Res. in Medicine 27 296-309.

Funding: Supported as a Career Scientist with the Ontario Cancer Foundation; Co-investigator on NCIC grant for the study of cellular radiosensitivity, three years ($53,000/year).

Peter Raaphorst, Joanna Cygler and Douglas Salhani

In vitro studies of the role of repair in the radiation resistance of various human tumour cell lines are underway. Hyperthermia is used to cause radiosensitivity and to inhibit repair. Low dose rate measurements are underway, and they show large increases in survival as the dose rate is lowered. The effects of hyperthermia at low dose rates is

being evaluated. These data show a large enhancement of radiation sensitivity, which is primarily caused by the presence of hyperthermia during irradiation, blocking systems which repair radiation damage. The response of human glioma cells to very high dose rates is also being studied.

The effect of radiation resistance is also being evaluated. Cell lines expressing radiation sensitivity as well as radiation resistance are being tested for characteristics of this resistance such as increased repair of radiation damage and methods are being investigated to overcome this resistance such as combinations of hyperthermia drugs combined with radiation. In addition, mechanisms of resistance are also being explored and survival curve models are being developed to predict and assess resistance.

The evaluation of patients' radiation sensitivity before treatment is also being investigated. The determination of genetic variation of radiation response can lead to better prescription of dose to individual patients depending on their relative radiation sensitivity.

Hyperthermia in animal model and in the clinic is also being evaluated. To date we have treated 35 patients and have shown that hyperthermia in combination with radiation can provide benefit in superficial tumours. This clinical trial has been completed. In addition, we are evaluating the effect of hyperthermia on blood flow in pigs. The data show that hyperthermia can effect blood flow in muscles, brain and kidney. These data are being analyzed and will contribute to developing a hyperthermia model which can be used in treatment planning in a prediction of thermal dose.

Magnetic resonance spectroscopy is being used to study ^{1}H and ^{31}P in human ovarian carcinoma and rat glioma cells both in vitro and in vivo. It is shown that there are differences in the ^{1}H spectra between cells expressing a normal response and a resistant response to chemotherapeutic agents. Results also show that the stress of cancer therapeutic agents causes changes in the high energy phosphorous metabolites within cells. The effects of hyperthermia, radiation and chemical agents are also being studied.

Various aspects of external beam radiotherapy are being studied. This includes the evaluation of methods for calculating the dose for irregularly shaped fields; the development and implementation of asymmetric arc therapy; the development of a radiosurgery program; the development of a patient position monitor; the evaluation of therapy using asymmetric collimator jaws; the development of dynamic wedges; the development of algorithms for fitting treatment unit data, and the inverse problem is being studied. High dose rate brachytherapy is also being evaluated and a clinical program is ongoing.

Publications:

Azzam, E.I., Raaphorst, G.P. and Mitchell, R.E.J. (1993) *Radiation-induced adaptive response for protection against neoplastic transformation in C3H-10T1/2 mouse embryo cells.* Radiat. Res. In press.

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Klassen, N.V., Walker, P.R., Ross, C.K., Cygler, J. and Lach, B. (1993) *Two-stage cell shrinkage and the OER of the radiation -induced apoptosis of rat thymocytes*. Int. J. Rad. Biol. 64: 571-581.

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Raaphorst, G.P. Mao, J.P. and Ng, C.E. (1993) *Sublethal radiation damage repair and its inhibition by hyperthermia in two human melanoma cell lines of different radiosensitivity*. Melanoma Res. Submitted.

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Raaphorst, G.P., Mao, J.P. and Ng, C.E. (1993) *Repair of potentially lethal damage: Its inhibition by hyperthermia in two melanoma cell lines with different radio-and heat sensitivities*. Melanoma Res. 3: 351-356.

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Well, M.C.M., Mackie, T.R., Podgorsak, M.B., Papanikolau, N., Holmes, M., Reckwerdt, P., Attix, F.H.and Cygler, J. (1994) *Electron dose distribution measurements in inhomogeneous phantom using a plastic scintillation detector.* Rad.

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Wilkins, D.E., Raaphorst, G.P., Saunders, J.K. and Smith, I.C.P. (1994) *A new technique for implanting intracranial 9L tumors in rats.* Lab. Animal Sci. In press.
Wilkins, D.E., Raaphorst, G.P. and Heller, D.P. (1993) *Inhibition of potentially lethal damage recovery by cisplatin in the 9L rat brain cell lines.* Anti. Cancer Res. 13: 2137-2142.

Funding:
NCIC grant for the study of cellular radiosensitivity, three years - $101,000/year
NCIC grant for the study of cisplatin in combination with low dose rate irradiation, three years - $95,000/year
NIH Grant, Study of hyperthermic and low dose rate irradiation, three years- $128,000/year
Industrial funding for development of patient positioning monitor system, five years $500,000
ORCC capital and operating fund - $16,000
$16,000/year MRC graduate fellowship
$16,000/year, NSERC graduate fellowship.

Dave Rogers

Research: Monte Carlo techniques are used to calculate correction factors required for primary radiation standards. Recent examples are the calculation of wall correction factors for ionization chambers used for air kerma standards, and the calculation of the wall effect for Fricke dosimeter vials. These correction factors have a significant impact on several national standards.

Developing more accurate and easily used clinical dosimetry protocols. In this regard, the effect of beam size and beam quality on ionization chamber calibration factors is being calculated. Also, work is underway on a formalism which will use absorbed dose, rather than exposure, calibration factors.

Measuring fundamental data using the NRC linear accelerator. A recent project has accurately measured the bremsstrahlung yield from thick targets as a function of energy and angle and compared the results to Monte Carlo calculations. Another project is underway to measure electron stopping powers which play a fundamental role in radiation dosimetry but have never been measured with an accuracy of better than 5%.

Working on the OMEGA project. This is a collaboration with Rock Mackie's group at the University of Wisconsin to develop a Monte Carlo based code to calculate the dose in a patient undergoing electron beam radiotherapy. We are developing a general purpose code to model radiation beams from clinical accelerators.

Publications:
D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a Dosimetry System Based on Absorbed-Dose Standards* IAEA-SM-330/94 to be published in IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of* TPR_{10}^{20} *as a Beam Quality Specifier for High-Energy Photon Beams,* Proceedings, International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/10 (Vienna).
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330/48 to be published in Proceedings of Symposium on Measurement Assurance in Dosimetry (IAEA, Vienna).
D.W.O. Rogers (1993) *How Accurately Can EGS4/PRESTA Calculate Ion Chamber Response?* Med. Phys. 20 319-323.
A. Kosunen and D.W.O. Rogers (1993) *Beam Quality Specification for Photon Beam Dosimetry* Med. Phys. 20 1181-1188.
C.-M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1993) *Wall correction and absorbed dose conversion factors for Fricke dosimetry: Monte Carlo calculations and measurements* Med. Phys. 20 283-292.
X.A. Li and D.W.O. Rogers (1993) *Reducing electron contamination for photon beam-quality specification*, submitted to Med. Phys.
G.X. Ding, D.W.O. Rogers, A.F. Bielajew and T.R. Mackie (1993) *Calculation of stopping-power ratios using realistic clinical electron beams* Med. Phys. 20, 1293.
P.R. Almond, F.H. Attix, S. Goetsch, L.J. Humphries, H. Kubo, R. Nath and D.W.O. Rogers (1993) *The Calibration and Use of Parallel-Plate Ionization Chambers for Dosimetry of Electron Beams: Report of AAPM Radiation Therapy Committee Task Group 39* submitted to Med. Phys.
D.W.O. Rogers (1992) *Calibration of Parallel-Plate Ion Chambers: Resolution of Several Problems by Using Monte Carlo Calculations*, Med. Phys. 19 889-899.
A.F. Bielajew and D.W.O. Rogers (1992) *Implications of new correction factors on primary air kerma standards in ^{60}Co beams*, Phys. Med. Biol. 37 1283-1291.
D.W.O. Rogers (1992) *The Advantages of Absorbed Dose Calibration Factors*, Med. Phys. 19 1227-1239.
B.A. Faddegon, C.K. Ross and D.W.O. Rogers (1992) *Measurement of Collision Stopping Powers of Graphite, Aluminium and Copper for 10 and 20 MeV electrons,* Phys. Med. Biol. 37 1561-1571.
X.A. Li and D.W.O. Rogers (1993) *Electron Mass Scattering Powers Calculated Using Monte Carlo Simulation* submitted to Med. Phys.
M.A. Holmes, T.R. Mackie, W. Sohn, P.J. Reckwerdt, T.J. Kinsella, A.F. Bielajew and D.W.O. Rogers (1993), *The Application of correlated sampling to the computation of electron beam dose distributions in heterogeneous phantoms using the Monte Carlo method*, Phys. Med. Biol. 38 675-688.

Funding: NRC - ongoing operations and capital funds
NSERC - graduate student support of $10k/year
NIH - $130k/year (to Ottawa) for three years for the OMEGA project

Carl Ross

Research: Using water calorimetry to establish absorbed dose standards for ^{60}Co γ-rays and high energy x-rays. An important consideration in the dissemination of these standards is the specification of beam quality. We are studying various quality specifiers which are either in routine use or have been proposed in the literature.

We have done a series of measurements of high-energy x-ray spectra using a large NaI detector. We are now starting a project to measure electron stopping powers using the same detector. This requires operating our linear accelerator with an average beam current of less than 0.5 electrons per beam pulse.

Publications:

N.V. Klassen, P.R. Walker, C.K. Ross, J. Cygler and B. Lach (1993) *Two-stage Cell Shrinkage and the OER for Radiation-induced Apoptosis of Rat Thymocytes*, Int. J. Radiat. Biol. 64 571-581.

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of* TPR_{10}^{20} *as a Beam Quality Specifier for High-Energy Photon Beams,* Proceedings, International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/10 (Vienna).

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew (1993) *Towards a Dosimetry System Based on Absorbed-Dose Standards* IAEA-SM-330/94 to be published in IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

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I. Janovsky and C.K. Ross (1993) *The IRS Thermoluminescent Dosimetry System*, PIRS-0369.

B.A. Faddegon, C.K. Ross and D.W.O. Rogers (1992) *Measurement of Collision Stopping Powers of Graphite, Aluminium and Copper for 10 and 20 MeV electrons,* Phys. Med. Biol. 37 1561-1571.

C.K. Ross and K.R. Shortt (1992) *The Effect of Waterproofing Sleeves on Ionization Chamber Response*, Phys. Med. Biol. 37 1403-1411.

Funding: Supported as a member of NRC staff.

Ken Shortt

Research: Involved with the establishment of a primary standard of absorbed dose to water for high energy x-rays. The approach is to use a water-filled calorimeter whose heat defect can be calculated or measured to calibrate a Fricke chemical dosimeter solution. The calibrated solution is placed in small glass vials to determine the dose at a point. The Canadian dose standard has been compared to those of other countries using transfer ionization chambers. A number of perturbations, such as those caused by vial walls and water proofing sleeves are under investigation. The x-ray energy range is being extended to go from ^{60}Co to 25 MV.

Publications:

K.R. Shortt, C.K. Ross, M. Schneider, K. Hohlfeld, M. Roos and A.-M. Perroche (1993), *A Comparison of Absorbed Dose Standards for High Energy X-rays*, Phys. Med. Biol. 38 1937-1955.

C.K. Ross, K.R. Shortt, D.W.O. Rogers and F. Delaunay (1993) *A test of* TPR_{10}^{20} *as a Beam Quality Specifier for High-Energy Photon Beams,* Proceedings, International Symposium on Measurement Assurance in Dosimetry, IAEA-SM-330/10 (Vienna).

D.W.O. Rogers, C.K. Ross, K.R. Shortt, N.V. Klassen and A.F. Bielajew, *Towards a Dosimetry System Based on Absorbed-Dose Standards* submitted to IAEA Symposium on Measurement Assurance in Dosimetry, April 1, 1993 (invited paper).

C.-M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1993), *Wall-correction and absorbed-dose conversion factors for Fricke dosimetry: Monte Carlo calculations and measurements*, Med. Phys. 20, 283-292.

Funding: Supported as a member of NRC staff.

Tony Waker
Research: The application of microdosimetric methods and counters in radiation protection mixed field dosimetry and monitoring, with particular emphasis on the radiation environment within CANDU power plants. The development of low pressure tissue equivalent proportional counters with enhanced sensitivity and neutron spectrometry based on moderating spheres. Fundamental aspects of the physical basis of radiation quality. Critically accident dosimetry.

Publications:
A.J. Waker (1994) *Microdosimetric Radiation Field Characterization and Dosimetry in a Heavy Water Moderated Reactor Environment*, Rad. Prot. Dosim. 52 No. 1/4 415-418.
P.K. Verma and A.J. Waker (1992) *Optimization of the Electric Field Distribution in a Large Volume Tissue Equivalent Proportional Counter*, Phys. Med. Biol. 37 10 1837-1846.
D.J. Thomas, A.J. Waker, J.B. Hunt, A.G. Bardell and B.R. More (1992) *An Intercomparison of Neutron Field Dosimetry Systems*, Rad. Prot. Dosim 44 No. 1/4 219-222.
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A.J. Waker, B. Oldroyd and M. Marco (1992) *The Application of Microdosimetry in Clinical Bone Densitometry Using a Dual-Photon Absorptiometer*, Brit. J. Radiol. 65 523-527.
A.J. Waker and M. Marco (1992) *The Application of Microdosimetry to the Metrology of Low Energy X-rays Used in Mammography*, Br. J. Radiol. 65 258-261.

Funding: Candu Owners Group

12. Kudos

Dave Rogers was awarded the R.S. Landaurer Memorial Lectureship by the Bay area Chapters of the Health Physics Society and the American Association of Physicists in Medicine. This award is presented annually for distinguished contributions to the fields of radiological physics and radiation health and protection.

Paul Johns was an invited lecturer at the first Mayneord-Phillips Summer School which was held at Oxford in July 1993.

13. CVs for New MPORU Members

This year we welcome Charlie Ma (NRC) and Barry McKee (Ottawa Civic Hospital) as new members of the MPORU. Highlights from their CVs are given below.

Chang-ming (Charlie) Ma

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Current Position: Research Associate, working on the OMEGA project

Previous Positions: 1991-1993 Research Fellow, Institute of Cancer Research, Sutton
1987-1988 Academic Visitor, Imperial College, London
1986-1987 Lecturer, Shanghai Inst. of Mech. Eng., Shanghai
1982-1983 Assistant Lecturer, Zhejiang University, Hangzhou

Education: BSc - Zhejiang University
MSc - Shanghai Institute of Mechanical Engineering
PhD - University of London
Post doc - Inst. of Cancer Research/Royal Marsden Hospital

Sample publications:

C.-M. Ma, D.W.O. Rogers, K.R. Shortt, C.K. Ross, A.E. Nahum and A.F. Bielajew (1933) *Wall correction and absorbed dose conversion factors for Fricke dosimetry: Monte Carlo calculations and measurements* Med. Phys. 20 283-293.

C.-M. Ma and A.E. Nahum (1993) *Effect of size and composition of central electrode on the response of cylindrical ionization chambers in high-energy photon and electron beams* Phys. Med. Biol. 38 267-293.

C.-M. Ma and A.E. Nahum (1991) *Bragg-Gray theory and ion chamber dosimetry for photon beams* Phys. Med. Biol. 36 413-428.

C.-M. Ma and R. Smith (1988) *Theoretical and Experimental Research on Super-resolution of Microscopes: 1. Illumination and Resolving Power*, SPIE 1028 Scanning Imaging 45-52.

C.-M. Ma and R. Smith (1988), *Theoretical and Experimental Research on Super-resolution of Microscopes: 2. Object Extent and Resolving Power*, Proc. Optika '88 3rd International Symposium on Modern Optics, Vol. II (Budapest, Hungary) 386-391.

C.-M. Ma and T.H. Dong (1988), *Effect of Ametropia on Laser Interferometric Visual Acuity* SPIE 1013 Optical Design Methods, Applications and Large Optics 128-134.

Barry T.A. McKee

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Current Position: Physicist, Division of Nuclear Medicine, Ottawa Civic Hospital
Adjunct Professor, Department of Physics, Carleton University
Associate Professor, Department of Radiology, University of Ottawa

Previous Positions: Assoc. Prof., Dept. of Physics and Medicine, Queen's, Kingston
Assist. Prof., Dept. of Physics, Dalhousie University, Halifax
Visiting Scientist, Brookhaven Nat. Lab., Brookhaven

Education: PhD, Physics, Dalhousie University
MSc, Physics, Dalhousie University
BSc, Physics, McGill University

Sample publications:

B.T.A. McKee, A.W. Dickson and D.C. Howse (1994) *Performance of QPET, a high-resolution ED PET imaging system for small volumes*, IEEE Trans. Med. Imaging, MI-13 176-185.

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