Ottawa Medical Physics Institute (OMPI)

(the Medical Physics Organized Research Unit, Dept. of Physics, Carleton University)

Newsletter #12, June 2000

Editor: Pavel Dvorak (Also on:) http://www.physics.carleton.ca/ompi

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The Ottawa Medical Physics Institute, an Organized Research Unit of Carleton University

The Ottawa Medical Physics Institute of Carleton University has 30 members involved with research and/or teaching in the Ottawa area. To provide a report on activities in the past year, this newsletter (3-25) includes a membership profile including affiliation, current research, funding, and recent publications. The Medical Physics graduate students at Carleton are an important component of the Ottawa Medical Physics Institute. A student section in this newsletter (31-35) lists their research topics and supervisors. The Executive meets about once a month and consists of a Director (Paul Johns), Past-Director (Ian Cameron), Secretary (Pavel Dvorak), Academic Officer (Giles Santyr), Seminar Coordinator (David Wilkins), and a graduate student representative (Gosia Niedbala). Other members (Ken Shortt, Cheng Ng, and Robert deKemp) attend executive meetings as observers.

A Note from the Director

This is the 12th annual Newsletter of OMPI activities, reporting on medical physics research and the graduate program centred at Carleton University. If plans are fulfilled, this will be the last Newsletter in this format - our intention is to make this a web document which is updated more frequently than once per year.

It was a pleasure to learn this spring that Robert (Bob) Clarke, the founder of our program, has been appointed Emeritus Professor of Physics at Carleton University. Although he has been retired 12 years, Bob is still active in research and university affairs. A reception was held June 1 to honour Bob and also to thank our external physicists who participate in our program by teaching and supervising graduate students. Please see the detailed story elsewhere in this issue.

In the 1999-2000 academic year OMPI welcomed one new member:

- Brad Wouters - is a Career Scientist in the Centre for Cancer Therapeutics of the Ottawa Regional Cancer Centre (ORCC). Dr. Wouters did his PhD studies at UBC in the area of medical biophysics under the supervision of Lloyd Skarsgard, completing in 1996. He followed this with a post-doc in radiation oncology at Stanford and has been with the ORCC since 1998. His research focusses on the molecular mechanisms of cell response to cancer therapy.

This year four graduate half-courses in medical physics were offered: Medical Radiation Physics, which I taught; Radiobiology, by Peter Raaphorst; Physics of Medical Imaging, by Giles Santyr (course coordinator) plus Rob deKemp, Barry McKee, and myself, and Medical Radiotherapy Physics, given by Joanna Cygler (coordinator) plus Lee Gerig, Iwan Kawrakow, and Ken Shortt. Special thanks to the off-campus instructors making their time available to teach in our program.

Three graduate student theses, all of them MSc, were completed in 1999-2000. Pascale Sévigny had her defence September 1999 and is now a physicist with the Defence Research Establishment Ottawa (DREO). Narine Kizilian (now Martel) defended her thesis in December 1999 and is now a Health Physicist with the Radiation Protection Bureau of Health Canada. Yvan Gauthier had his thesis defence in January 2000; he is now with the Operational Research Section of the Department of National Defence.

The monthly OMPI seminars were well-attended this year. Thank you to all speakers and attendees. We followed last year's pattern and ran a soccer game and barbecue in the fall and a broomball game in the winter. The seminar season was extended by adding one extra date (June 1). With 30 members and 16 students there are lots of potential speakers, and by continuing into May or June, summer students can attend and get some flavour of our program.

It is the OMPI Executive which holds our organization together and keeps things moving. This year the seminars were ably organized by David Wilkins. Jan Seuntjens, our Secretary elected in December 1998, made a career move to McGill and had to resign from the OMPI Executive at the end of 1999. Thank you Jan for your effort during 1999 and welcome to Pavel Dvorak who stood for the position of Secretary for the period Dec 1999 - Dec 2001. Pavel is one of the founding members of OMPI, and has been on the Executive continuously since its founding in 1989. Finally, the membership has seen fit for me to continue as Director for another two years and thank you for the trust you have placed in me.

In closing, thank you to all OMPI members and graduate students for your support in 1999-2000. Medical physics is a profession with healthy career opportunities in the workplace and a fast pace of research developments in imaging, cancer therapy, and biophysics. With our continued joint efforts we can look forward to another good year of medical physics in Ottawa.

OMPI Membership Profile Including Recent Research

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 research funding of the OMPI members. The editor has imposed a standard format.

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Recent Research:
- Magnetic Resonance Imaging (MRI) is used to study water diffusion in human tissue. In order to better understand, at a basic level, the effects of water diffusion in MRI, the range over which the water molecules diffuse in a given time is measured for a variety of tissues and experimental conditions in human volunteers (completely non-invasively). These results are then interpreted using a combination of analytical models and simulations based on Monte Carlo algorithms. We have also designed and built special gradient coils which allow us to study this process over a much larger range of values than would otherwise be possible.
- A second research area that we are involved with is known as functional MRI (fMRI). In fMRI the volunteer is asked to perform a specific task (e.g. finger tapping) and the part of the brain that is used to perform this task is detected. This research is applied to following the recovery of patients who have suffered a recent stroke and a group of people who were exposed prenatally to marijuana smoking.
- Another research interest is in Hyperpolarized Noble Gas (HNG) MRI. With HNG MRI a special procedure is used to polarize noble gas molecules such that when inhaled by a patient they will produce a signal that can be used to generate an MRI image. This is a very new approach to MRI but it has a lot of potential.

Funding: Co-investigator on NSERC grant to support HNG MRI research. $100k/y

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Recent Research:
- Study of tissue heating by highly focussed ultrasound beams, for the trans-cutaneous ablation of well defined cancer sites.
- Computer modelling of field patterns and temperature distribution, changes of tissue properties and MRI imaging of the resulting lesions are subjects of recent investigations.

Publications:
- Wallace JC, Clarke RL, Santyr GE, "MRI Mapping of One-Dimensional Temperature Gradients Across Ex-Vivo Liver tissue During Rapid and Slow Heating" Accepted by International Society for Magnetic Resonance in Medicine, 7 Annual Meeting (May 1999)
- Clarke RL and ter Haar GT, "Production of Harmonics *in vitro* by High-Intensity Focussed Ultrasound" *Ultrasound in Med. & Biol.* **25**, 1417-1424 (1999)
- Meaney PM, Clarke RL, ter Haar GR, Rivens IH, "A 3-D finite element model for computation of temperature profiles and regions of thermal damage during focussed ultrasound surgery exposures" *Ultrasound in Med. & Biol.* **24** , 1489-1499 (1998)

Abstracts:
- Wallace J.C., Myint W.K., Clarke R.L., Santyr G.E., "Mapping Temperature Gradients in Liver Using MRI and Thermocouple Temperature Measurements" Conference Proceedings, *44th Annual Scientific Meeting*, COMP (1998)

Talks given in 1999:
January, Laurentian University, "Old Physics for New Medicine" CAP lecture
December, Carleton University "High Intensity focussed Ultrasound Surgery"

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Recent Research:
- In the area of clinical electron beam dosimetry the verification process of the new electron beam algorithm implemented in Theraplan Plus is in progress. This algorithm attempts to use a similar approach to dose calculation as has been successfully used for photon beams. One of the explicitly required parameters to describe an electron beam is a Peak Scatter Factor, PSF. Rigorous tests are being performed to evaluate the performance of this algorithm. A special set of carefully machined phantoms with inhomogeneities of various densities embedded in them is used to carry out the verification tests. Measurements and calculations of Electron Peak Scatter Factors as a function of field size and beam energy are in progress. In parallel to this project, an effort of clinical implementation of electron beam calibration at a new reference depth is carried on. Collaboration with the NRC scientists within the OMEGA project is continued. Clinical implementations of new dosimetry devices (MOSFETS and gafchromic films) are carried on in collaboration with the Canadian industry and scientists from the NRC.
- Studies of biological equivalence of high dose rate (HDR) and pulse dose rate (PDR) brachytherapy treatments have been started in collaboration with other scientists from ORCC. Irradiations of human glioma cells and normal human fibroblasts will be carried on under several different fractionation regimes. The amount of biological damage to cells will be measured using asymmetric field inversion gel electrophoresis and other modern techniques.

Publications:
- G.X.Ding, J.E. Cygler, "Measurement of electron beam peak scatter factors", *Med.Phys.* **25**, 251-253 (1998)
- G.X.Ding, J.E.Cygler, "Measurement of P_{repl} P_{wall} factors in electron beams and in ^{60}Co beam for plane-parallel chambers", *Med.Phys* **25**, 1453-1457 (1998)
- G.G. Zhang, D.W. O. Rogers, J.E. Cygler, T.R. Mackie, "Effects of changes in stopping – power ratios with field size on electron beam ROFs", *Med. Phys*. **23**, 1711-1724 (1998)

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Recent Research:
- Semi-analytical approach in heterogeneity correction factor determination within the framework of the scatter-subtraction dosimetry model in brachytherapy.
- Development of multigroup photon cross section libraries for brachytherapy dosimetry calculations.
- Multi-dimensional discrete ordinates modelling of I-125 and Ir-192 brachytherapy sources dosimetry.
- Monte Carlo-aided dosimetry specification of low energy photon sources for brachytherapy applications.

Publications:
- G.M. Daskalov, et al, "Two-Dimensional Discrete Ordinates Photon Transport Calculations for Brachytherapy Dosimetry Applications," *Nucl. Sci. Eng.* **134**, 121-134 (2000)
- G.M. Daskalov, et al, "Dosimetric Modelling of the MicroSelectron High-Dose Rate Ir-192 Source by the Discrete Ordinates Method," accepted for publication, *Med.Phys.* (2000)
- G.M. Daskalov, J.F. Williamson, A.S. Kirov, "Analytical Approach to Heterogeneity Correction Factor Calculation for Brachytherapy," *Med. Phys.* **25**, 722-735 (1998)
- G.M. Daskalov, E. Loffler, J.F. Williamson, "Monte Carlo-Aided Dosimetry of a New High Dose-Rate Brachytherapy Source," *Med.Phys.* **25**, 2200-2208 (1998)
- G.M. Daskalov, et al, "Multigroup Discrete Ordinates Photon Transport Calculations of Water Kerma for Brachytherapy Applications," in the *Proceedings of the 1998 ANS Radiation Protection and Shielding Division* Topical Conference, vol. **2**, 261-268 (1998)

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Recent Research:
- Development of three-dimensional attenuation and scatter corrections for positron emission tomography, and automated 3D cardiac image analysis and interpretation. Current efforts are focussed on kinetic modelling of ^{82}Rb blood flow and ^{18}FDG metabolism measurements. New control algorithms will be developed for the ^{82}Rb isotope delivery system, to allow precise control of infusion dose rates as well as total injected dose and volume.

Funding: MRC grant $55k/y. Evaluating new treatments for heart disease using dynamic PET.

Publications:
- deKemp RA, Ruddy TD, Hewitt T, Dalipaj MM, Aung MT, Beanlands RSB. Detection of Serial Changes in Absolute Myocardial Perfusion with ^{82}Rb PET. *J.Nucl.Med.* (2000) (In Press)
- deKemp RA, Golanowski L, Beanlands RS, Ruddy TD. Precision and Bias of ^{82}Rb Kinetic Model Parameter Estimates: Computer Simulations and Dynamic PET Studies. *World Congress on Medical Physics and Biomedical Engineering* (2000) (In Press)
- Alvarez-Diez TM, deKemp R, Beanlands R, Vincent J. Manufacture of strontium-82/rubidium-82 generators and quality control of rubidium-82 chloride for myocardial perfusion imaging in patients using positron emission tomography. *Appl.Radiat.Isot.* **50**, 1015-1023 (1999)
- Ruddy TD, deKemp RA, Beanlands RSB. (Review) Evaluation of Myocardial Perfusion and Metabolism with Positron Emission Tomography. *CMAJ* **161**, 1131 (1999)

Grants:
Serial evaluation of myocardial perfusion using SPECT imaging
Medical Research Council of Canada – Operating Grant
RA deKemp, TD Ruddy, RS Beanlands; $188,786 over 2000-2003

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Recent Research:
- Experimental elementary particle physics, weak interactions, development of new detectors and instrumentation for particle physics and applied physics.
- Present interests are: OPAL experiment at CERN and the development of gas microstrip detectors for digital x-ray imaging for medical and industrial applications and for radiation dosimetry.

Publications:
- D.G. Gobbi, M.S. Dixit, J. Dubeau and P.C. Johns, "Photon-counting radiography with the gas microstrip detector", *Phys. Med. Biol.* **44**, 1307-1335 (1999)
- M.S. Dixit, J.C. Armitage, J. Dubeau, D.G. Gobbi, P.C.Johns, D. Karlen, and F.G. Oakham, "Development of gas microstrip detectors for digital x-ray imaging and radiation dosimetry", *IEEE Trans. on Instrumentation and Measurement* **47**, 809-813 (1998)

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Recent Research:
- Studies of patient doses from x-ray procedures, computer simulations of x-ray procedures, development of testing and measuring techniques, both in medical and non-medical x-ray applications.

Facilities:
Three phase and single phase radiographic/fluoroscopic, mammographic, dental and industrial x-ray machines, assorted phantoms, measuring equipment, an automatic film processor and an x-ray spectrometer.

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Recent 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 ionizing 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.

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Recent Research:

- In our present work we are developing a methodology by which one can perform a cost benefit analysis of new technology and proposed changes to patterns of practice in radiation therapy. This tool will provide a rational basis upon which we can:

    Make equipment purchase decisions
    Make patterns of practice decisions
    Determine the optimal distribution of limited resources

Cancer treatment is in many ways similar to the manufacturing industry, whereby raw product is input into a system or process and a product is produced. In cancer treatment the "input" is the patient and the resources of the health care system. These are both funnelled into the cancer treatment process and the outcome for the general population is statistical, that is a certain percentage of the patients are cured, the rest are not. For the individual the outcome is binary, either they are cured or they are not. In industry, if a process has a significantly high failure rate, whereby the product does not meet specification, the process is examined and the source of failure is identified and corrected. The various stages of the process are quality assured during manufacturing by statistical sampling. The more stringent the sampling process, the better the quality control on the product. In general this approach is not applied to cancer treatment. That is, when two seemingly identical patients enter the treatment process and one is cured while the other is not, very little is done to examine the process to determine where the failure occurred. The difference is ascribed to "biological variability". Indeed there is biological variability and much of the statistical nature of what is seen clinically can be attributed to it. However, there may also be a large, but unmeasured, variability in the day to day "treatment" process which could also play a significant role.

We are developing a model by which we can examine the entire radiation cancer treatment process, including staging, imaging, prescription, treatment planning and finally treatment delivery. The model treats the radiation therapy process as a linear chain, in that information is collected and passed from one stage of patient care to the next. The output of one stage acts as the input for the next. As a simple example, staging is determined based on the results of many tests including biochemistry, imaging and physical examination. Thus the output of the testing acts as the input for determination of the target volume. This chain continues and culminates in the delivery of treatment. As a result of the temporal and spatial dose actually delivered the patient experiences an outcome (product). Thus, any weakness or error in any part of the chain will contribute to a reduced probability of a favourable outcome. In order to achieve optimal improvement in the system with finite resources the weakest links in the chain must be identified.

The model is coupled to a biological response in order to predict outcome. We have chosen for this model the linear quadratic model with a repair term and Gompertzian growth kinetics and we will use Normal Tissue Complication Probability (NTCP) and Tumour Control Probability (TCP) as our endpoints. Combining all of these elements we hope to develop a model which would help predict the impact of various changes of practice and the introduction of new technologies. Integrating this with estimates on the cost (negative or positive) of the changes one can then make a predictive cost benefit analysis.

Publications:

- Soubra M., Gerig L.H., Szanto J. “A Study of Linear Accelerator Head Scatter Factors”, Submitted *Med. Phys*., (1999)
- Wilkins D.E., Soubra M., Gerig L.H., Szanto J. “A method of calculating head scatter factors for fields shaped with a Siemens multileaf collimator.” *Med Phys* **25**, 1075 (1998)

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Recent Research:
- Studying radiation-induced conformational changes to the human genome in living cells using time-resolved and immunofluorescence spectroscopies. Using electron spin resonance (ESR) bio-dosimetry of human samples or tissue-equivalent surrogate samples. Developing an automated multiwell cell survival assay using a redox dye as a vital stain for quantitative studies of biological response modification and the radioprotective action of antioxidants. Exploring the lymphocyte immunosurveillance system as an early-warning system for radiation, cancer-proneness, cell signalling and adaptation. An immunoassay technique (ELISA) has been set up to measure antioxidant levels in cells, and to examine their role in protecting against radiation, cancer and aging. Applying health physics and radiation protection to risk assessment.

Funding: AECL core operational and special projects funding.

Publications:
- C.L. Greenstock, Dose Control Point Processes*, Atomic Energy Of Canada Limited Publication* (abstract) **WM07.02.01**, p. 1 (2000)
- C.L. Greenstock, The Filter/Swipe Sample Retention Process, *AECL Publication* (abstract), **LP08.02.05.03**, p.1 (2000)
- C.L. Greenstock, Storage of Radioactive Material, *AECL Publication* **RPM-8.2**, p. 5 (1999)
- C.L. Greenstock and K.J. Lenton, Using the Fluorescent Molecule beta-Phycoerythrin to Screen Antioxidants and Free Radical Scavengers. *Proceedings of the 11th International Congress of Radiation Research*, **Vol. 1**, p. 292, eds. M.Moriarty, C. Mothersill & C. Seymour, Allen Press Inc. USA (1999)
- C.L. Greenstock, Health Effects: Low Dose Implications. *Proceedings of the 44th Annual Health Physics Society Conference* (abstract),**3-C**, p.1 (1999)
- K.J. Lenton and C.L. Greenstock, Ability of human plasma to protect against radiation is inversely correlated with age, *Mech. Ageing Develop*. **105**, 256-260 (1998)
- R.B. Richardson, A. Trivedi and C.L. Greenstock, Dosimetry of organically bound tritium derived from diet, *Atomic Energy Control Board Publication* **RSP-0068**, AECB Ottawa Canada pp. 55 (1998)
- D.G. Jarrett, G.C. Norris, R. Mosebar, S.J.P. Livingstone, D.A. Schauer, R. Kehlet and C.L. Greenstock, Background and overview. *Proceedings of Workshop on "Triage of Irradiated Personnel*", Armed Forces Radiobiology Research Institute Publication **AFFRI 98-2**, Bethesda MD, p. 1-5 (1998)
- W.F. Blakely, T.M. Seed, P.G.S. Prasanna, A.J. Carmichael, N.Ramakrishnan, D.A. Schauer and C.L. Greenstock, Forward-field bioindicators for dose assessment: Possible alternatives. *Proceedings of Workshop on "Triage of Irradiated Personnel*", AFFRI Publication **98-2**, Bethesda MD, p. 21-26 (1998)
- C.L. Greenstock, Review of potential biomarkers of radiation exposure. *Proceedings of Workshop on "Triage of Irradiated Personnel*", AFFRI Publication **98-2**, Bethesda MD, p. A13-19 (1998)
- K. J. Lenton and C.L. Greenstock, Antioxidants and biological radiation protection. *Proceedings of the 19th Annual Canadian Nuclear Society Conference*, **Vol. 1**, 5A, p. 1-7 (1998)
- C.L. Greenstock, Health effects and radiation protection: A primer. *Proceedings of the Annual Conference of the Canadian Radiation Protection Association*, (abstract), **IV**, p.1 (1998)
- K.J. Lenton and C.L. Greenstock, An antioxidant assay using radiation generated free radicals, *Proceedings of the Annual Conference of the Canadian Radiation Protection Association*,(abstract), **IV**, p. 3 (1998)
- C.L. Greenstock, Nuclear energy worker (atomic radiation worker) status. *Atomic Energy of Canada Limited Publication* **RPM-5.6**, p. 5 (1998)
- C.L. Greenstock, Filter/swipe retention following an incident or site emergency. *Atomic Energy of Canada Limited Publication* **OG-608**, pp. 6 (1998)
- A. Trivedi, T. Duong and C.L. Greenstock, Distribution, biokinetics and dosimetry of tritiated organics, *Radioprotection* **32**, Suppl. C-1, 365-370 (1998)

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Recent Research:
- Ultrasound waveguide interstitial applicator arrays have been studied for use in thermal therapy of brain tumours. The main interest relates to minimally invasive potential of the therapy when the array is used for treatment of brain gliomas. We concentrate on use of three- or four-applicator arrays in the heating. To characterize the array, we investigate temperature pattern in tissue phantom and in animal tissue. FEA modelling is used also to evaluate power required from individual applicators. The modelling enables appropriate planning of the array geometry that result in conformal heating with minimal heat toxicity.
- In thermal treatment of cancer, knowledge of blood flow is an important factor in heating efficacy. In FEA modelling described above effective thermal conductivity approach has been used. Recently we included discrete blood vessels in the most sensitive areas. In the modelling vessels' shapes and size, their location with respect to an applicator, their number and blood flow velocity have been studied. Proper modelling of heating effects requires information of ultrasound/tissue interaction, which has been also investigated.

Funding: NSERC operating grant $21k/y.

Publications:
- B.J. Jarosz, "Interstitial Instrumentation for Therapeutic Ultrasonic Heating: Modelling the Discrete Blood Vessels", 16th IEEE *Instrumentation & Measurement Technology Conference*/Venice, Italy/ May 24-26 (1999)
- B.J. Jarosz, "Interstitial Instrumentation for Therapeutic Ultrasonic Heating: Effects of the Blood Flow Velocity in Discrete Vessels", *COMP Conference Proceedings*/Sherbrooke, Quebec/ June 16-19 (1999)
- BJ Jarosz, D Kaytar, "Ultrasonic waveguide applicator arrays for interstitial heating: A model study", *IEEE Trans. Ultrasonics, Ferroelectrics, and Freq. Contr.* **45**, 806-814 (1998)
- BJ Jarosz, D Kaytar, "Ultrasonic heating with waveguide interstitial applicator array", IEEE Trans. Instr. Meas., **47**, 703-707 (1998)
- BJ Jarosz, "3-D temperature distribution in ultrasound hyperthermia with interstitial waveguide applicator", *Annals NY Acad. Sci.* **858**, 47-55 (1998)
- BJ Jarosz, "3-D temperature distribution in ultrasound interstitial heating with three applicator array", *Int. IEEE Instr. Meas. Conf.*, St. Paul, MN, May 18-21 (1998), Proceedings, 858-862
- BJ Jarosz, "3-D temperature distribution in ultrasound hyperthermia with interstitial applicator arrays", *Int. Symp. Heat Mass Transfer in Biolog. Med. Eng.*/Kusadasi, Turkey/June 8-12 (1998)

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Recent Research:
- Investigating means of obtaining diagnostic information using coherent and incoherent scatter. Although coherent scatter has a small cross section compared with Compton scattering, it is a forward directed process, so that coherently-scattered photons have a high probability of reaching the image receptor. Furthermore, the differential coherent cross section varies with scattering angle and photon energy in a material-specific manner, even for amorphous materials; this is the diffraction signature of the material. This dependence on Z and chemical structure suggests that it can be used

to obtain chemical information about tissues. We are in the process of a detailed investigation of scatter imaging to determine its sensitivity, i.e. the radiation dose to the patient required to detect the presence of a volume of tissue of specified dimensions against a background of other tissue. In parallel, we are using a diffractometer to measure the relative scattering cross sections of tissues.
- Member of collaboration at Carleton investigating the use of gas microstrip detectors and gas electron multipliers for medical x-ray imaging. By operating in photon counting mode, the energy of each photon event can be measured, providing input for applications such as dual-energy radiography.
- Studying iterative reconstruction techniques to reduce artefacts in computed tomography (CT) by accounting for the polyenergetic nature of the x-ray beam as well as scattered x rays.

Funding:
NSERC Operating Grant $15.75k /y

Publications:
- R.J. Leclair and P.C. Johns, "Analysis of Spectral Blur Effects in X-Ray Scatter Imaging", *Medical Physics* **26**, 1811-1816 (1999)
- P.C. Johns, "Understanding and Comparing Ionizing Radiation Doses to Patients", invited article in the *Canadian Journal of Medical Radiation Technology* **30**, 138-148 (1999)
- P.C. Johns, C. Buffet, S. Decossas, R.R. Scharf, and R.J. Leclair, "Measurement of X-Ray Scattering Properties of Biological Materials", *Proceedings of 45th Annual Meeting of the Canadian Organization of Medical Physicists*, 235-237 (Sherbrooke, June 1999). [Abstract: Medical Physics **26**, 1435 (1999)]
- R.J. Leclair and P.C. Johns, "Fundamental Information Content Accessible with Medical X-Ray Scatter Imaging", Proceedings of SPIE **3659**, 672-681 (1999). (Paper # 70, presented as a poster) (*SPIE Conference on Physics of Medical Imaging*,San Diego, California, February 1999)
- D.G. Gobbi, M.S. Dixit, J. Dubeau and P.C. Johns, “Photon-counting radiography with the gas microstrip detector”, *Phys. Med. Biol.* **44**, 1307-1335 (1999)
- M.S. Dixit, J.C. Armitage, J. Dubeau, D.G. Gobbi, P.C. Johns, D. Karlen, F.G. Oakham, and A.J. Waker, “Development of Gas Microstrip Detectors for Digital X-Ray Imaging and Radiation Dosimetry”, *IEEE Trans. Instrumentation and Measurement* **47**, 809-813 (1998)
- R.J. Leclair and P.C. Johns, “Effects of Beam Polychromaticity on X-Ray Scatter Imaging”, *Proceedings of 44th Annual Meeting of the Canadian Organization of Medical Physicists*, pp 108-110 (London Ontario, June 1998). [Abstract: *Med. Phys.* **25**, 1079 (1998)]
- R.J. Leclair and P.C. Johns, “A Semi-Analytic Model to Investigate the Potential Applications of X-Ray Scatter Imaging”, *Med. Phys.* **25,** 1008-1020 (1998)

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Recent Research:
- Development of the EGSnrc code system
EGSnrc is a package for the Monte Carlo simulation of coupled electron-photon transport. It is based on the EGS4 system but incorporates a variety of improvements in the implementation of the condensed history technique for electron transport and the underlying cross sections. Recent enhancements include:
- The implementation of spin effects for electron elastic scattering
- Incorporation of binding effects and Doppler broadening for incoherent (Compton) scattering
- Improved treatment of photo-electric absorption
- Implementation of atomic relaxations via the emission of characteristic X-rays, Auger and Coster-Kronig electrons for all K-M shells with binding energies above 1 keV. Future developments will include improved electron/positron inelastic cross sections at low energies/small energy transfers as well as the incorporation of energy loss straggling.

- Development of optimized Monte Carlo simulation techniques for application in external beam Radiation Treatment Planning

A recent re-implementation of the VMC algorithm in C++ (VMC++) that incorporates a variety of improvements in the modelling of the underlying physical processes and various new variance reduction techniques is scheduled for implementation in a commercial treatment planning system. VMC++ allows the calculation of full 3D dose distributions in a matter of seconds for electron beams and a few minutes for photon beams.
- Application of Monte Carlo techniques to dosimetry related problems
The primary interest here is the test of Spencer-Attix cavity theory and the calculation of correction factors used in primary standards and dosimetry protocols.
- Future research plans could concern the development and application of optimized Monte Carlo techniques for Brachytherapy dose calculations and the use of Monte Carlo techniques for treatment plan optimization algorithms.

Funding for students and PDFs available.

Publications:
- J. P. Seuntjens, I. Kawrakow and C. K. Ross "Revisiting convective motion in stagnant water calorimeters operated at room temperature"submitted to *Phys.Med.Biol.*
- I.Kawrakow and M.Fippel "Investigation of variance reduction techniques for Monte Carlo photon dose calculation using XVMC", *Phys. Med. Biol.*, in press (2000)
- J.Borg, I.Kawrakow, D.W.O.Rogers and J. P.Seuntjens "Monte Carlo study of Spencer-Attix cavity theory at low photon energies" *Med. Phys.*, in press (2000)
- I.Kawrakow "Accurate condensed history Monte Carlo simulation of electron transport I. EGSnrc, the new EGS4 version" *Med.Phys.* **27**, 485-498 (2000)
- I.Kawrakow "Accurate condensed history Monte Carlo simulation of electron transport II. Application to ion chamber response calculations" *Med.Phys.* **27**, 499-513 (2000)
- I.Kawrakow and A.F.Bielajew "On the representation of electron multiple elastic scattering distributions for Monte Carlo calculations" *Nucl. Instr. Meth.* **B134**, 325-336 (1998)
- I.Kawrakow and A.F.Bielajew "On the Condensed History technique for electron transport" *Nucl. Instr. Meth.* **B142**, 253-280 (1998)
- I. Kawrakow and A.F. Bielajew, “On the representation of electron multiple elastic-scattering distributions for Monte Carlo calculations”, *Nuc Inst.& Meth.* **B134,** 325-336 (1998)

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Recent Research:
- Involved in the work to establish absorbed dose standards based on water calorimetry. This is being done for high energy photons and Co-60 beams. The temperature rise in the water, caused by the absorbed dose, has a component which is due to chemical changes in the aqueous absorber. This component is simulated by computer and the simulations are tested by measuring the hydrogen peroxide in the irradiated aqueous systems. Recently, a method was developed for using GafChromic MD-55 (a thin film dosimeter) as a transfer dosimeter with an uncertainty of less than 1%. GafChromic MD-55 is currently being used to measure backscatter factors for 150 and 300 kVp x-rays.

Publications:
- C.K. Ross, J.P. Seuntjens, N.V. Klassen and K.R. Shortt, "The NRC sealed water calorimeter: correction factors and performance", *NPL Workshop on Recent Advances in Calorimetric Absorbed Dose Standards*, Teddington, U.K., December 1999
- J. Medin, J. Seuntjens, N. Klassen, C.K. Ross and G. Stucki, "The OFMET sealed water calorimeter, *NPL Workshop on Recent Advances in Calorimetric Absorbed Dose Standards*, Teddington, U.K. December 1999
- N.V. Klassen, K.R. Shortt, J.P. Seuntjens , and C.K. Ross, “Fricke dosimetry: The difference between $G(Fe^{3+})$ for ^{60}Co (γ-rays and high-energy x-rays”, *Phys. Med. Biol.* **44**, 1609-1624 (1999)

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Recent Research:
- Radiotherapy using charged particle beams including negative pi-mesons and protons. Development of dosimetry and beam delivery techniques for particle beams.
- Theoretical radiobiology of combined effects of mixtures of radiations of different qualities. Investigation of the general concept of effective dose in radiobiology and in radiotherapy.
- Theoretical studies of interaction of toxic agents. Development of general interpretation and definition of synergism and antagonism for mixtures of toxic agents with different mechanisms of action.

Publications:
- K.Gardey, U.Oelfke and G.K.Y.Lam. Range modulation in proton therapy - anoptimization technique for clinical and experimental applications. *Phys. Med. Biol.* **42**, 491-500 (1999)
- G.K.Y.Lam. A General Relationship for the Tolerance Doses of different Normal Tissues in Radiotherapy. Conference Proceedings for the 45th Annual COMP meeting at Sherbrooke, June 1999
- G.K.Y.Lam. How Medical Physicists can contribute to the determination and understanding of tolerance doses. Conference proceedings of the CCO Medical Physics Conference, Lake Couchiching, November 1999
- K. Nemoto, T. Pickles, A. Minchinton and G. Lam, "The Relative Biological effectiveness of the Modulated Proton Beam at TRIUMF", *Radiation Medicine* **16**, 43-46 (1998)

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Recent Research:
- Developing a high-resolution pinhole SPECT camera that will achieve a resolution of about 4 mm over a limited field of view. Various image reconstruction methods are being explored. Pinhole tomography should be useful for clinical imaging of the thyroid, and for research applications in radiopharmaceutical development.
- Modelling and measuring the scatter background in SPECT systems to develop and test improved correction methods.

Publications:
- T.A.Hewitt, B.T.A. McKee, F.Noo, R. Clackdoyle, and M.J. Chamberlain, "Characterization of a pinhole tomograph with 180 degree acquisition", IEEE *Trans. Med. Imaging* **MI-46**, 1093-1099 (1999)
- T.A. Hewitt, B.T.A. McKee, and M.J. Chamberlain, "Pinhole SPECT: Towards Clinical Thyroid Tomography", *Proceedings of the 1998 Canadian Organization of Medical Physicists Conference*, London, Ont. , 243-245 (1998)

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Recent Research:
- The ability of drugs to potentiate the response of human cancer cells to X-radiation and hyperthermia is being investigated. The aim of these experiments is to determine if the inhibition of cellular repair of X-radiation damage or the interaction of the drugs with hyperthermia can lead to selective killing of human tumour relative to normal cells. A selective killing of tumour over normal cells is necessary to treat tumours successfully in the clinic. In particular, two types of drugs, DNA topoisomerase poisons and cisplatin, are being emphasized. Both of these drugs are already in active use clinically; the DNA topoisomerase poisons, in particular, are also being investigated as an adjunct to radiotherapy of cancer. Recent work has also focussed on the role of the tumour suppressor, p53, in the modulation of killing by the topoisomerase poisons.

Funding:
Supported as a Career Scientist with CCO.
NCIC (Principal Investigator) interaction between X-radiation and topoisomerase poisons, $99k/y;
ORCC Foundation (Principal Investigator) mechanisms of resistance in human pancreatic tumour cells,$10k;
NCIC (Co-investigator)interaction of cisplatin with X-radiation and hyperthermia, $128k/y;
NCIC grant (Co-investigator) cellular radiosensitivity, $70k.

Publications:
- Raaphorst, G.P., Ng, C.E. and Shahine, B.H. Comparison of radiosensitization by 41°C hyperthermia during low dose rate irradiation and during pulse simulated low dose rate irradiation in human glioma cells. Int. J. Rad. Oncol. Biol. Phys., **44**, 185-188 (1999)
- Raaphorst, G.P., Ng, C.E. and Yang, D.P. Thermal radiosensitization and repair inhibition in human melanoma cells: A comparison of survival and DNA double strand breaks. Int. J. Hyperthermia **15**, 17-27 (1999)
- Ng, C.E., Banerjee, S.K., Pavliv, M., Wang, G., Raaphorst, G.P. and Aubin, R.A. p53 status, cellular recovery and cell cycle arrest as prognosticators of in vitro radiosensitivity in human pancreatic adenocarcinoma cell lines. Int. J. Rad. Biol., **75**, 1365-1376 (1999)
- Brown, R.C., Ng, C.E. and Raaphorst, G.P. A comparison of high dose rate, low dose rate and fractionation for optimizing differences in radiosensitivities in vitro. Rad. Oncol. Inv. **6**, 209-215 (1998)
- Ng, C.E., Cybulski, S.E., Bussey, A.M., Aubin, R.A. and Raaphorst, G.P. "DNA topoisomerase I content of a pair of human melanoma cell lines with very different radiosensitivities correlates with their in vitro sensitivities to camptothecin." *Anticancer Res.* **18**, 3119-3126 (1998)
- Raaphorst, G.P., Mao, J.P., and Ng, C.E. "Thermotolerance effects in thermo-radiosensitization in human glioma cells." *Int. J. Hyperthermia* **14**, 85-96 (1998)
- Ng, C.E. "Radiobiology: Mobilizing physics and chemistry for the battle against cancer. Challenge, Life with Cancer", *Magazine of the Ottawa Regional Cancer Centre*, 16-17, Fall/Winter 1998

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Recent Research:
- The study of radiosensitization of human cancer cells to radiation using hyperthermia and drugs.
This project includes the study of the response of a wide range of human tumour cells (glioma, ovarian carcinoma, breast cancer, melanoma *etc*) to radiation at different dose rates and the effect of hyperthermia (heating from 40 to 45°) on radiosensitization. In addition the effect of chemotherapy agents in combination with hyperthermia and radiation is also being evaluated. In these studies we are also assessing the mechanisms of radiation resistance and the capacity

of cells to repair radiation damage. The experimental results are being modelled in order to develop comprehensive models that can be used to predict radiotherapy outcome. These studies also include design of special radiation apparatus to deliver specific dose rates and require the development of a good understanding of radiation dosimetry.
- Prediction of radiation response. In this study we are evaluating the response of human normal and tumour cells in culture to irradiation. The normal and tumour cells are obtained from patients before undergoing radiation therapy and are assessed for the radiation response and then compared to the response of the patient undergoing radiotherapy. To date we have found a correlation between the *in-vitro* and the patient tissue response. Further studies are ongoing to model these responses and to determine whether the results can be used as a predictor of radiation sensitivity and for customised dose prescription in order to optimise radiotherapy.
- Induction of radiation resistance with low doses of radiation. Our preliminary studies have shown that low dose and low dose rate irradiation can induce radiation resistance in human cells. This can have a major impact on radiation therapy where in some cases radiation is given either in fractions or at low dose rate. In addition such resistance can also have an impact on working in low level radiation fields such as those found in some industries or in outer space. We are currently characterising this induced resistance in human cells and will develop strategies for its optimization. In addition, we are also looking at other means to induce or possibly prevent induction of radiation resistance. These results are being put into models to help predict the radiotherapy response.

Funding:
NCIC Grant for the study of cellular radiation resistance and methods of sensitization $101k/y for 3 y;
NCIC Grant for the study of combined treatment of radiation cisplatin and hyperthermia. $40k/y for 1 y;
Hoechst Marion Roussel, The study or radiosensitization in prostate cancer. $25k/y for 2 y.

Publications:
- G.P. Raaphorst, M. Niedbala, D. Smith and C.E. Ng. Evidence for adaptive response in implications in pulsed simulated low dose rate radiotherapy. Submitted to *Int J Rad Onc.*
- G. Alsbeih, S. Malone, C. Lochrin, R. Gray, B. Fertil and G.P. Raaphorst. Correlation between normal tissue complications and in-vitro radiosensitivity of skin fibroblasts derived from radiotherapy patients treated for a variety of tumours. *Int. J. Radiat. Oncol. Biol. Physics* **46**(1), 143-152 (2000)
- C. E. Ng, S.K. Banerjee, M. Pavliv, G. Wang, G.P. Raaphorst and R.A. Aubin. P53 status, cellular recovery and cell cycle arrest as prognosticators of in vitro radiosensitivity in human pancreatic adenocarcinoma cell lines. *Int. J. Radiat. Biol.* **75**, 1365-1376 (1999)
- M. Niedbala, G. Alsbeih, C.E. Ng and G.P. Raaphorst. Equivalence of pulse dose rate using tumour and normal cell lines. Radiat. Res. Submitted 1999
- G.P. Raaphorst. Interactions of Cisplatin, Radiation and Hyperthermia. 11th International Congress of Radiation Research, July 1999, Dublin, Ireland
- G.P. Raaphorst, D.P. Yang and C.E. Ng. Comparison of Survival and DNA Double Strand Breaks for Mild Hyperthermia and Low Dose Rate/Pulsed Low Dose Rate Irradiation in Human Cells. *Journal of Therm. Biol.* Accepted 1999
- G.P. Raaphorst and S. Boyden. Adaptive response and its variation in human normal and tumour cells. *Int. J. Radiat. Biol.***75**, 865-873 (1999)
- S. Malone, G.P. Raaphorst, R. Gray, A. Girard and G. Alsbeih. Enhanced in vitro radiosensitivity of skin fibroblast in two patients developing brain necrosis following AVM radiosurgery: A new factor with potential for a predictive assay. *Int. Journal of Radiation Oncology.* Accepted 1999
- G. Alsbeih and G. P. Raaphorst. Differential induction of premature chromosome condensation by calyculin A in human fibroblast and tumour cell lines. *Anticancer Research.* Vol. **19**(2A), 903-8 (1999)
- G. Alsbeih, S. Malone, L. Grimard and G.P. Raaphorst. La radiosensibilité intrinsique des fibroblasts de la peau peut identifier un groupe de patients ayant developpé des complications sérieuse dans différents tissus sais après radiothérapie. *Cancer/Radiotherapie* **3**, 318-324 (1999)
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- G.P. Raaphorst, J. Maio, D.J. Stewart and C.E. Ng. Concomitant treatment with mild hyperthermia cisplatin and low dose rate irradiation in human ovarian cancer cells sensitive and resistant to cisplatin. *Oncology Reports* **5**, 971-977 (1998)
- G.P. Raaphorst, J. Mao, H. Yang, R. Goal, B. Niknafs, F.H. Shirazi, H.M. Yazdi, P. Rippstein and C.E. Ng. Evaluation of apoptosis in four human tumour cell lines with differing sensitivities to cisplatin. *Anticancer Research* **18**, 2945-2952 (1998)
- C.E. Ng, S.E. Cybulski, A.M. Bussey, R.A. Aubin and G.P. Raaphorst. DNA topoisomerase I content of a pair of human melanoma cell lines with very different radiosensitivities correlates with their in-vitro sensitivities to camptothecin. *Anticancer Research* **18**, 3119-3126 (1998)
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- G.P. Raaphorst, J. Miao, D. Stewart and C.E. Ng. Interactions of mild hyperthermia, cisplatin and split dose irradiation in human ovarian carcinoma cells. *Cancer Chemotherapy and Pharmacology* **41**, 491-496 (1998)
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Recent Research:
- Dosimetry of tritium and ^{14}C in fission and fusion. The dose and risk from tritiated particles has been evaluated, as these particles are a potential hazard from the First Wall of tokomak reactors. Gender has been found to be important influence on the uptake and retention of tritium and ^{14}C in the human body. Current research, involves estimating the radiation dose from the dietary uptake of tritium and ^{14}C. A physiological model is being developed that quantifies the metabolism of the dietary constituents; fats, carbohydrates and proteins.
-Code for assessing internal dose. A internal dosimetry Microsoft WINDOWS-based code, called GENMOD that calculates the radiation dose to the lung and other organs from intakes of radionuclides elements and compounds, has been developed with David Dunford.
- Dosimetry of alpha-emitting particles. The plastic nuclear track detector, CR39, and an image analysis system are being used to assess the particle size, activity and radiation dose to the lung from air-borne alpha-emitters.

Research Funding:
Dosimetry of organically bound tritium derived from diet. AECB, Canada (1996-Present)

Publications:
- R.B. Richardson, J. Dubeau and A. Trivedi "Dose to the cell nucleus from tritiated pump oils or formaldehyde." *Health Phys.* (in press)
- R B. Richardson and A. Hong "Dose to lung from inhaled tritiated particles." *Health Phys.* (in press)
- R.B. Richardson, D.W. Dunford and Peterson, S-R. Gender-dependent tritium and carbon-14 dose using the Genmod-PC dosimetry code. *Health Phys.* (in press)
- R.B. Richardson and D.W. Dunford. The ICRP tritium and carbon-14 dose models implemented in the Genmod-PC code. *Health Phys.* (in press)
- R.B. Richardson and D.W. Dunford. “Incorporation of current ICRP recommendations in the Genmod internal dosimetry code.” *Radiat. Protect. Dosim*. **79**, 375-378 (1998)
- R.B. Richardson, A. Trivedi and C.L. Greenstock. “Dosimetry of organically bound tritium derived from diet - Phase 1.” Atomic Energy Control Board, Ottawa, Ontario, Canada, *AECB report* RSP-0068

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Recent Research:
- Active in the development of the AAPM's TG-51 protocol for external beam radiotherapy reference dosimetry which is based primarily on NRC work.
- Development of Monte Carlo codes for radiotherapy, in particular the BEAM code which simulates radiotherapy accelerators and ^{60}Co units and DOSXYZ which calculates the dose in a patient based on CT information.
- Development of general purpose codes for simulating transport of electrons and photons in arbitrary geometries. The EGSnrc code, a new version of the EGS4 code, was released in May, 2000.
- Application of Monte Carlo techniques to calculate correction factors required for primary radiation standards and dosimetry protocols.
- Measuring fundamental data using the NRC linear accelerator (with Carl Ross). A recent project has accurately measured electron stopping powers which play a fundamental role in radiation dosimetry but have never been measured with an accuracy of better than 5%.

Funding:
Main funding is NRC base funding.
2 NIH grants are currently held, one in conjunction with Jeff Williamson (PI) at the University of Washington in St Louis and the other (just ending) for measurement of kQ factors and development of standards for ^{192}Ir. Total about $200k/year.
We generated about $100k of revenue in the last year from courses we taught on Monte Carlo techniques.
Licensing revenue last year was $48k.

Publications:
- P. R. Almond, P. J. Biggs, B. M. Coursey, W. F. Hanson, M. S. Huq, R. Nath and D. W. O. Rogers, AAPM's TG--51 Protocol for Clinical Reference Dosimetry of High-Energy Photon and Electron Beams, *Med. Phys.* **26**, 1847-1870 (1999)
- G. Mora, A. Maio, and D. W. O. Rogers, Monte Carlo simulation of a typical 60-Co therapy source, *Med. Phys.* **26**, 2494-2502 (1999)
- J. Borg and D. W. O. Rogers, Spectra and Air-Kerma Strength for Encapsulated 192-Ir Sources, *Med. Phys.* **26**, 2441-2444 (1999)
- D. W. O. Rogers, Correcting for electron contamination at dose maximum in photon beams, *Med. Phys*. **26**, 533-537 (1999)
- D. W. O. Rogers and C. L. Yang, Corrected relationship between %dd(10)x and stopping-power ratios, *Med. Phys.* **26**, 538-540 (1999)
- G. G. Zhang, D. W. O. Rogers, J. E. Cygler, and T. R. Mackie, Monte Carlo investigation of electron beam output factors vs size of square cutout, *Med. Phys.* **26**, 743-750 (1999)
- Comment on "On the beam quality specification of high-energy photons for radiotherapy dosimetry" [Med. Phys. **27** 434-440 (2000)] , *Med. Phys.* **27**, 441-444 (2000)
- D. W. O. Rogers, A new approach to electron beam reference dosimetry, *Med. Phys.* **25**, 310-320 (1998)
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- I. Kawrakow and D. W. O. Rogers, The EGSnrc Code System: Monte Carlo simulation of electron and photon transport, *NRC Report* PIRS-701, 2000

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Recent Research:

- The general goal of our research is to develop new Magnetic Resonance (MR) imaging methods for improved patient care. Our primary clinical focus is breast cancer. Current research activities in our laboratory include: the use of spin locking and magnetization transfer contrast for improving detection of lesions in radiodense breasts, characterization of breast lesions (benign vs. malignant) using rapid imaging of gadolinium-based contrast agents, measurement of tumour blood flow and 3-D image display issues. Clinical studies to evaluate the usefulness of these techniques are in progress. Our clinical collaborators include The Ottawa Hospital, General Site (see: Ian Cameron), the Kingston General Hospital and the Children's Hospital of Eastern Ontario.
- A relatively recent area of research involves the imaging of hyperpolarized noble gases (HNG), in particular ^{129}Xe and ^{3}He. As part of an NRC/NSERC Research Partnership, we are investigating the large-scale production, storage, transport and delivery of HNG as well as MR imaging applications for both in vivo imaging of gas and dissolved phases (e.g. blood flow) and non-biological material testing. This collaborative research involves investigators at the NRC Steacie Institute for Molecular Sciences as well as The Ottawa Hospital, General Site.

Funding:

NRC/NSERC Research Partnership Grant: "Research Partnership in Hyperpolarized Noble Gas (HNG) Technology", $150k/yr.
Ontario Research and Development Challenge Fund (ORDCF): "Carleton Magnetic Resonance Facility", awarded 10/99, $200k.
NSERC Operating Grant: "Magnetic Resonance Imaging of Hyperpolarized Xenon", $25k/yr.
Canadian Breast Cancer Research Initiative (CBCRI): Hyperpolarized Xenon MR Imaging of Breast Cancer", $35k.
Heart and Stroke Foundation of Canada (Co-Investigator):"Chronic Ischemia of Brain and Retina", awarded 04/99-04/03, $68k/yr.

Publications:

- Wilson G.J., G.E. Santyr, M.E. Anderson, P.M. DeLuca, T_1 Relaxation Times of ^{129}Xe in Rat Tissue Homogenates at 9.4 T, *Magn. Reson. Med.* **41**, 933-938 (1999)
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- Cameron I., G. Santyr, S. Lang, S. Breeze, J. Wallace, P. Sevigny, I. Moudrakovski, B. Simard, J. Ripmeester, A Centralized Approach to Production and Distribution of Hyperpolarized Xenon, *Eur. J. Radiology* **9**, B35 (1999)
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- L. Moudrakovski, S. Lang, C. I. Ratcliffe, B. Simard, G. Santyr and J. A. Ripmeester, Chemical Shift Imaging with Continuously Flowing Hyperpolarized Xenon for the Imaging of Materials, submitted to *J. Magn. Reson*
- I. L. Moudrakovski, A. Nossov, S. Lang, S, Breeze, C. I. Ratcliffe, B. Simard, G. Santyr and J. A. Ripmeester, Continuous Flow NMR with Hyperpolarized Xenon for the Characterization of Materials and Processes, submitted to *J. Phys. Chem.*
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- Sevigny P., G. Santyr, J. Wallace, S. Breeze, S. Lang, I. Moudrakovski, C. Ratcliffe, B. Simard and J. Ripmeester, Optimization of Gradient-Echo Imaging for Hyperpolarized Xenon Gas, *American Physical Society*, Atlanta, 1999
- Wilson G.J., G.E. Santyr, M.E. Anderson and P.M. DeLuca, T_2 of ^{129}Xe in Rat Tissue Homogenates and Blood at 9.4 T, *Intl. Society of Magnetic Resonance in Medicine*, Philadelphia 1999
- Wallace, J.C., R.L. Clarke and G.E. Santyr, MRI Mapping of One-Dimensional Temperature Gradients Across Ex-Vivo Liver Tissue During Rapid and Slow Heating, *Intl. Society of Magnetic Resonance in Medicine*, Philadelphia 1999

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- Cron G.O., J.C. Wallace, T. Fortin, W.D.Stevens, B.A. Pappas, F. Kelcz and G.E. Santyr, Non-Invasive Measurement of the Arterial Input Function for Quantitative Dynamic Contrast- Enhanced MR Imaging of Cancerous Lesions in the Rat, *Canadian Organization of Medical Physicists*, Sherbrooke, 1999
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- Santyr G., G. Wilson, P. Sevigny, J. Wallace, S. Lang, S. Breeze, M. Anderson, P. DeLuca, J. Ripmeester, Transverse Relaxation Times of ^{129}Xe in Rat Tissue Homogenates and Blood, Hyperpolarized Gases in Magnetic Resonance: Biomedical Investigations and Clinical Applications, Les Houches, 1999
- Cameron I., G. Santyr, S. Lang, S. Breeze, J. Wallace, P. Sevigny, I. Moudrakovski, B. Simard, J. Ripmeester, A Centralized Approach to Production and Distribution of Hyperpolarized Xenon, Hyperpolarized Gases in Magnetic Resonance: Biomedical Investigations and Clinical Applications, Les Houches, 1999
- Cron G.O., J. Wallace, W.D. Stevens, T. Fortin, B.A. Pappas, F. Kelcz and G. Santyr, Quantitative Dynamic Contrast-Enhanced MR Imaging of Rat Tumour: Limitations of Using Changes in T_2* in the Aorta to Measure the Arterial Input Function, submitted to *Intl. Society of Magnetic Resonance in Medicine*, Denver 2000
- McDonald M., A. Cross and G. Santyr, Feasibility of a Low-Field MR Imager Using Hyperpolarized ^{129}Xe, submitted to the *World Congress on Medical Physics and Biomedical Engineering*, Chicago 2000
- Cross A., D. McPhee, W.D. Stevens, M. McDonald and G.E. Santyr, Hyperpolarized Xenon Relaxation Times in Perfluorocarbon Emulsion and Plasma Mixtures, submitted to the *World Congress on Medical Physics and Biomedical Engineering*, Chicago 2000
- Cron G.O., J. Wallace, W.D. Stevens, T. Fortin, B.A. Pappas, F. Kelcz and G. Santyr, Measurement of the Arterial Input Function Using Changes in T_2* in the Aorta for Dynamic Contrast-Enhanced MR Imaging of cerous Lesions in the Rat, submitted to the *World Congress on Medical Physics and Biomedical Engineering*, Chicago 2000

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Recent Research:

- Successful treatment of tumors using radiotherapy requires accurate knowledge and verification of absorbed dose delivered by the treatment unit. The first step in determination of the dose to the tumour is calibration of the treatment unit in terms of the quantity absorbed dose to water. The IRS group is working on calibration methods to allow the clinical physicist to directly determine absorbed dose to water with unprecedented accuracy. These methods are based on the calibration of ionization chambers, the commonly used instrument in clinical dosimetry, in terms of absorbed dose by comparing them with a water calorimetric technique. Using calorimetry the dose can be determined from first principles by measuring the temperature rise in water caused by radiation. The Canadian standard for absorbed dose to water is now based on the sealed water calorimeter.
- In one part of the work we concentrate on establishing the water calorimetry technique to measure absorbed dose in Co-60 beams, and linear accelerator photon and electron beams. Various high precision measurements and numerical modelling of heat transport in water have improved our understanding and correction factors on the sealed water calorimeter.
- In a second part of the work we use the water calorimeter to measure absorbed dose beam quality dependence correction factors (k_Q) of commonly used cylindrical ionization chambers in high energy photon beams. By studying these correction factors various problems in the procedures currently employed by the clinical physicists can be identified. This part of the project goes hand in hand with Monte Carlo simulations, in order to understand the various

effects related to wall correction factors of ion chambers.
- In the framework of the American Association of Medical Physicists' RTC Task Group No 61, we are working on a new dosimetry guide for kV X-rays for clinical physicists and radiobiologists. Various smaller research projects and publications are carried out to optimize the recommendations of the new protocol.

Publications:
- C.-M. Ma and J.P. Seuntjens "Mass-energy absorption coefficient and backscatter factor ratios for kilovoltage x-ray beams". *Phys. Med. Biol.* **44,** 131 – 143 (1999)
- J.P. Seuntjens and H. Palmans "Correction factors and performance of a 4°C sealed water calorimeter". *Phys. Med. Biol.* **44,** 627 – 646 (1999)
- N.V. Klassen, K.R. Shortt, J.P. Seuntjens , and C.K. Ross, "Fricke dosimetry: The difference between $G(Fe^{3+})$ for ^{60}Co (γ-rays and high-energy x-rays", *Phys. Med. Biol.* **44**, 1609-1624 (1999)
- T.W.M. Grimbergen, A.H.L. Aalbers, J. Van Dam, B.J. Mijnheer, J. Seuntjens, H. Thierens, F.W. Wittkamper and J. Zoetelief "The NCS code of practice for dosimetry of low and medium energy x--rays." *Proceedings of the kV X-Ray Workshop*, eds C.-M. Ma and J.P. Seuntjens p 55 – 68 (1999)
- C.M. Ma, X.A. Li, and J.P. Seuntjens Consistency study on kV dosimetry, *Proceedings of the kV X-Ray Workshop*, Stanford University, eds C.-M. Ma and J.P. Seuntjens p 69 – 88 (1999)
- C.-M. Ma, X.A. Li, J.P. Seuntjens "Study of dosimetry consistency for kilovoltage x-ray beams". *Med. Phys*. **25**, 2376-2384, 1998
- C.-M. Ma and J.P. Seuntjens "Correction factors for water-proofing sleeves in kilovoltage x-ray beams". *Med. Phys*. **24**, 1507-1513, 1997
- J.P. Seuntjens, C.K. Ross, N.V. Klassen, and K.R. Shortt, "A status report on the NRC sealed water calorimeter," *Technical Report PIRS-584*, NRC Canada, Ottawa, K1A-0R6 (1999)
- J. Borg , J.P. Seuntjens, and D.W.O. Rogers "Monte Carlo calculations of fluence spectra in air for several ^{192}Ir Source configurations", *Proc. 1998 COMP Annual Meeting*, London, Ontario, p 177-179
- C.L. Yang, D.W.O. Rogers, and J.P. Seuntjens, "Calculation of photon beam quality specifiers", *Proceedings of the COMP Annual Meeting*, London, Ontario p 186 – 188 (1998)
- T.W.M. Grimbergen, A.H.L. Aalbers, J. Van Dam, B.J. Mijnheer, J. Seuntjens, H. Thierens, F.W. Wittkamper and J. Zoetelief Dosimetry of low and medium energy x-rays. A code of practice for use in radiotherapy and radiobiology, NCS Report 10, Netherlands Commission on Radiation Dosimetry (1997)

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Recent Research:
- All the data of the 1998 comparisons of the dosimetric systems of Canada with those of Australia, United States, France, Switzerland and the BIPM, have been analysed and the various publications have been drafted. Our work on the energy dependence of $G(Fe^{3+})$ has been published. A report describing measurements of k_Q for Farmer-like ionisation chambers has been submitted for publication. A collaboration with Ph. D. student, Eva Bergrstrand, of Oslo, Norway has shown some positive results for the linearity and reproducibility of the ESR response of alanine irradiated at linac energies. Thao Tran, a co-op student from McMaster U., has written a report summarizing our work on polyacrylamide gels used for radiation dosimetry. A series of four lectures was given in Havana, Cuba, as part of an IAEA training course on calibration procedures for secondary dosimetry laboratories.

Publications:
- N.G. Tarr, G.F. MacKay, K. Shortt and I. Thomson, A floating gate MOSFET dosimeter requiring no external bias supply, *IEEE Tran. Nuc. Sci.* **45**, 1470-1474 (1998)
- N.V. Klassen, K.R. Shortt, J.P. Seuntjens and C.K. Ross, Fricke dosimetry: the difference between $G(Fe^{3+})$ for ^{60}Co ?-rays and high-energy x-rays, *Phys. Med. Biol.* **44**, 1609-1624 (1999)
- Ken Shortt, Primary standards for the measurement of air kerma, *IAEA,* Vienna (1999)
- Ken Shortt, Primary standards for the measurement of absorbed dose to water, *IAEA,* Vienna (1999)

- Ken Shortt, Reporting and comparison of calibration results, IAEA, Vienna (1999)
- Ken Shortt, Air kerma and absorbed dose to water calibration of thimble and parallel plate ionization chambers, *IAEA,* Vienna (1999)
- K. Shortt, J. Shobe and S. Domen, Comparison of dosimetry calibration factors at the NRCC and the NIST, *Med. Phys.* (in press) (1999)
- J.P. Seuntjens, C.K. Ross, K.R. Shortt and D.W.O. Rogers, Absorbed-dose beam quality conversion factors for cylindrical chambers in high-energy photon beams, *Med. Phys.* (submitted) (1999)

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Recent Research:
- 3-D external beam, brachytherapy and stereotactic radiosurgery dose calculation algorithms
- Radiation treatment planning optimization methods
- Dynamic radiotherapy techniques and their implementation in 3-D treatment planning systems

Publications:
- J. Sun, G. Doswell and J. R. Cunningham, "Modelling off-axis beam-softening to improve 3D dose-calculation accuracy for wedged photon beams", submitted for presentation at *AAPM Annual Meeting*, Chicago, 2000
- J. Sun, D. Sheikh-Bagheri and G. Doswell, "Modelling primary fluence distribution of high energy photon beams in the Theraplan Plus treatment planning system", *Proceedings of COMP Annual Conference*, Sherbrooke, Quebec, 44-46 (1999)
- J. Sun, U. Orhun and J. R. Cunningham, "Improvement of dose calculation accuracy under small block for high-energy photon beam by using an effective transmission factor", *Proceedings of COMP Annual Conference*, London, Ontario, 52-54 (1998)

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Recent Research:
- Design and Dosimetry of a Fractionated Stereotactic Radiotherapy System.
- At the Ottawa Regional Cancer Centre we have developed a unique system for the delivery of fractionated stereotactic radiotherapy. Patients are immobilized in a very accurate, stable, reproducible, non-invasive, relocatable stereotactic frame which is based on a custom made Cobalt-Chrome bite-block that locks into the undercuts of the teeth. The patient motion is measured by our optically based patient position monitoring system and found to be within ± 1mm.
- The dosimetry of small, high energy X-ray beams has been investigated both experimentally and by Monte-Carlo calculations. Some difficulty arises from the lack of lateral electronic equilibrium and the detectors' relatively large sizes.

Akhilesh Trivedi (Associate Member)

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Resent Research:
- Monitoring and dosimetry of internally deposited radionuclides: tritium and ^{14}C.
- Issues in radiological protection.
- Ecological dosimetry and risk assessment.
- Retrospective physical and biological dosimetry, and risk prediction.
- Development of advanced bioassay methods.
- Biological and physiological effects of exposure to environmental factors.
- Biochemistry and biophysics of biomembranes and mitochondria.

Funding: Candu Owners Group (COG), Atomic Energy Control Board (AECB)

Publications:

Monitoring and dosimetry of internally deposited radionuclides: tritium and ^{14}C.

- W. J. Workman, A. Trivedi and R. J. Cornett. Tritium Concentrations Inside the Home of Occupationally Exposed Workers: Dosimetric Implications. *Health Physics* **75** 55-58 (1998)
- A. Trivedi. Do Physiological Factors Affect Organically Bound Tritium Dose? Radiation Prot. Environ. **21** (1998) 107-109
- T. Kotzer and A. Trivedi. Ultra Low-level Measurement of Organically Bound Tritium in Bioassay Samples. *AECL-11956/COG-98-131-I*, Chalk River, Ontario, Canada (1999)
- A. Trivedi. Relevance of the ICRP Biokinetic Model for Dietary Organically Bound Tritium. *AECL-12023*, Chalk River, Ontario, Canada (1999)
- A. Trivedi. Age-dependent Dose Coefficients for Tritium in Asian Population. *AECL-12024*, Chalk River, Ontario, Canada (1999)
- A. Trivedi and N.E. Gentner. Dosimetry and Health Effects of Tritium. RC-2243, *AECL*, Chalk River, Ontario, Canada (1999)
- A. Trivedi and T. Duong. Characterization of tritium exposures by measuring tritiated metabolites in urine. *J. Radioanaly. Nucl. Chem.* **243** 567-571 (2000)
-A. Trivedi, T. Duong and J. Leon. A Rapid Fecal Bioassay Method for Pu/am. *J. Radioanaly. Nucl. Chem.* **243** (2000) 491-494
- A. Trivedi, D. Galeriu and E.S. Lamothe. Dose Contribution From Metabolised Organically Bound Tritium After Chronic Tritiated Water Intakes in Human. Health Physics 78 2-7 (2000)
- A. Trivedi. Is Dosimetry for Dietary Organically Bound Tritium Adequate? *Radiation Prot. Environ.* (in press)
- R.B. Richardson, J. Dubeau and A. Trivedi. Dose to Nucleus From Skin-contact Exposure to Tritiated Oils Or Formaldehyde. *Health Physics* **78** (2000).
- A. Trivedi and Y.S. Cheng. Biokinetics and Dosiemtry of Tritiated Aerosols. Proceedings of 10th International Radiation Protection Association, Hiroshima, Japan, 2000 May 14-19 (in press)
- T. Kotzer and A. Trivedi. Dosimetric Implications of Tritium Atmospheric Dispersal. *Radiat. Prot. Dosim.* (Submitted)

Issues in radiological protection

- A. Trivedi and R.E.J. Mitchel. How Relevant to Radiation Protection is the Adaptive Response Mechanism? In: Proceedings of Canadian Nuclear Society (Jenkins, D.A., ed.), CNS, Toronto, 1998
- F. Cucinotta, J.W. Wilson, R.E.J. Mitchel and A. Trivedi. Multistage Carcinogenesis Models and Cosmic-ray Exposures. *Adv. Space Res.* (in press)
- N.E. Gentner and A. Trivedi. The "Controllable Dose" Concept: Implications for Public Perception. RC-2362, *AECL*, Chalk River, Ontario, Canada (2000)
- A. Trivedi, D.P. Morrison, K. Gale and L. Paterson. The relative radiotoxicity of tritium compounds: Phase 1. *Atomic Energy Control Board*, Ottawa, Ontario, Canada (2000)

Ecological Dosimetry and risk assessment

- A. Trivedi and N.E. Gentner. Assessment and Measurement Endpoints for Radioecological Impacts. *Proceedings of 2nd International Symposium on Ionizing Radiation*: Environmental Protection Approaches for Nuclear Facilities, Ottawa, May 10-14, 1999 (in press)
- A. Trivedi and N.E. Gentner. Ecodosimetry Weighting Factor (E_r) for Non-human Biota. *Proceedings of 10th International Radiation Protection Association*, Hiroshima, Japan, May 14-19, 2000 (in press)
- A. Trivedi, D. Wismer and N.E. Gentner. A Framework for Selecting Ecological Endpoints for Ecological Risk Assessment of Canadian Nuclear Power Stations. *Proceedings of 10th Candian Nuclear Society*, Toronto, Canada, June 11-14, 2000
- A. Trivedi and N.E. Gentner. A Basis for Ecological Risk Assesment of Radionuclide Releases from CANDU Facilities. COG-00-44/RC-2424, *AECL*, Chalk River, Ontario, Canada (2000)
- A. Trivedi and N.E. Gentner. A Technical Review of Aecb/ec Draft Report on "Assessment of Releases of Radionuclides From Nuclear Facilities: Supporting Document". COG-00-052, *AECL*, Chalk River, Ontario, Canada (2000)

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Recent 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 collaborative work on the dosimetric properties of Gas Microstrip Detectors developed at Carleton University and the Centre for Research in Particle Physics at Carleton.
- The development of experimental methods based on laser desorption and time-of-flight mass spectrometry for the study of radiation damage to DNA as part of a program of microdosimetry at the molecular level for studying fundamental aspects of radiation quality.

Publications:
- V.V. Moiseenko, R.N. Hamm, A.J. Waker and W.V. Prestwich Modelling "DNA damage induced by different energy photons and tritium beta-particles". *Int. J. Radiat. Biol.* **74** (5), 533-550 (1998) [Also AECL-12006]
- V.V. Moiseenko, R.N. Hamm, A.J. Waker and W.V. Prestwich "The cellular environment in computer simulations of radiation induced damage to DNA." *Radiat. Environ. Biophys.* **37,** 167-172 (1998) [Also AECL-11971]
- M.S. Dixit, J.C. Armitage, J. Dubeau, D.G. Gobbi, P.C. Johns, D. Karlen, F.G. Oakham and A.J. Waker "Development of gas microstrip detectors for digital X-ray imaging and radiation dosimetry." *IEEE Trans. on Instr. and Measurement* **47** (3), 809-813, (1998)
- A. Pejovic-Milic, F.E. McNeill, W.V. Prestwich, A.J. Waker and D.R. Chettle, "Development Of An Accelerator Based Determination Of Aluminium Burden In Peripheral Bone By Neutron Activation Analysis", *Appl. Radiat. Isot.* **49**, 717-719 (1998)
-V. Moiseenko, A.J. Waker and W.V. Prestwich, "Modelling Early Physical And Chemical Events For DNA Damage Induced By Photons And Tritium Beta Particles", *AECL-11850*, COG-97-374-I (1998)

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Recent Research:
- Our group is developing MR imaging methods to detect and diagnose disease and to contribute to the treatment of diseases. We are investigating the accuracy of MR thermometry for monitoring tissue temperatures during focussed-ultrasound thermal therapies. We are also evaluating BANG dosimetry gels for equipment calibrations and for 3D visualization of prescribed radiation treatments. In addition, we are investigating the use of both established and novel contrast agents for the early diagnosis of breast cancer.

Funding:
Co-investigator on Hyperpolarized Xenon Imaging of Breast Cancer, Canadian Breast Cancer Research Initiative, $35k/y

Publications:
- Cron, G.O., Wallace, J.C., Stevens, WD, et al, Quantitative Dynamic Contrast-Enhanced MR Imaging of Rat Tumour: Limitations of Using Changes in T2* in the Aorta to Measure the Arterial Input Function, *Intl. Society of Magnetic Resonance in Medicine*, Denver (2000)
- Wallace, J.C., R.L. Clarke and GE Santyr, MRI Mapping of One- Dimensional Temperature Gradients Across Ex-Vivo Liver Tissue During Rapid and Slow Heating, *Intl Society of Magnetic Resonance in Medicine*, Philadelphia (1999)

- Santyr, G., Wilson, G., Sevigny, P., Wallace, J. et al., Transverse Relaxation Times of 129Xe in Rat Tissue Homogenates and Bllod, Hyperpolarized Gases in Magnetic Resonance: Biomedical Investigations and Clinical Applications, Les Houches, 1999
- Wallace, J.C., Clarke, R.L. and Santyr, G.E., "MRI Mapping of One-dimensional Temperature Gradients Across Ex-vivo Liver Tissue During Rapid and Slow Heating", *Conference Proceeding, ISMRM 7th Annual Conference, Philadelphia*, PA (1999) (abstract)
- Cron, G.O., Wallace, J.C., Fortin, T., et al., "Non-invasive Measurement of the Arterial Input Function for Quantitative Dynamic Contrast-Enhanced MR Imaging of Cancerous Lesions in the Rat", *Conference Proceeding, ISMRM 7th Annual Conference, Philadelphia*, PA (1999) (abstract)
- Sevigny, P., Santyr, G., Wallace, J.C., et al., "Optimization of Gradient-Echo Imaging for Hyperpolarized ^{129}Xe Gas", *Proceeding of the American Physical Society* **9**, Atlanta, GP0 (1999) (abstract)

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Recent Research:
- Radiation therapy is normally delivered in daily fractions over a period of many weeks, partly to allow for repair of radiation damage to normal tissue. During extended fractionated treatments, the effects of tumour proliferation can become important to the treatment outcome. Computer models, based on the linear quadratic model of cell survival and the Gompertzian-Exponential model of tumour proliferation, have been formulated to provide a tool for evaluating the effectiveness of particular fractionation schemes. These models are being used to evaluate novel fractionation schemes such as hyperfractionation and pulse dose rate brachytherapy, as well as to evaluate the effects of unplanned treatment interruptions on treatment outcome for rapidly proliferating tumours.

Publications:
- D.E. Wilkins, S. Gupta, J.E. Cygler, G.P. Raaphorst. Calculated biological effect of interruptions in radiotherapy treatment using the Gompertzian-Exponential model of tumour proliferation and the L-Q model with repair. *Radiation Research Society 47th Annual Meeting*, Albuquerque NM, poster#60, April 2000
- D. E. Wilkins, J.E. Cygler, D. Smith, B. Esche, G.P. Raaphorst. Radiobiological effects of HDR/PDR brachytherapy using asymmetric field inversion gel electrophoresis. *European Society for Therapeutic Radiation Oncology 17th Annual Meeting*, Edinburgh, Scotland, Sept. 1998

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Recent Research:
- Tumour Hypoxia - Challenges and Opportunities for Cancer Treatment
As a result of improper vascular development, cells in solid human tumours are often poorly oxygenated. Hypoxic cells, particularly those at intermediate levels of oxygenation, limit the success of cancer therapy because they are resistant to both radiotherapy and chemotherapy. We are investigating the mechanism of action of tirapazamine (TPZ), a bioreductive drug in phase II and III clinical trials developed to exploit tumour hypoxia. This drug becomes toxic only under hypoxic conditions where an enzyme catalyzes a 1-electron reduction to a short-lived radical that causes DNA damage and cell death. Although TPZ can be metabolized by a number of different enzymes, the enzyme responsible for the cytotoxic activation of TPZ is unknown. TPZ also acts synergistically with the conventional chemotherapeutic agent cisplatin. Data suggest that this synergism is mediated at the genetic level. We are using a controlled gene-knockout strategy to identify both the relevant TPZ activating enzyme as well as the genes that control the synergy observed with cisplatin. We have adapted a retrovirus-based method that uses regulated antisense RNA to create random

functional knockouts of multiple gene alleles. We are constructing a "bank" of these random knockouts, and selecting those that are resistant to TPZ alone or in combination with cisplatin. The retrovirus based knockout strategy allows for rapid cloning of the targeted gene once a resistant clone has been identified. This strategy is also being used to identify genetic mutations that allow cells in solid human tumors to continue to survive and proliferate within the harsh tumour microenvironment.

- The role of novel polyubiquitin chains in DNA repair and cancer.

Cells possess several DNA repair systems to counteract the constant damage produced by endogenous and exogenous agents. The lesions produced by UV light and some chemotherapy drugs block the progression of DNA polymerases, and cells have developed mechanisms to bypass such lesions, allowing synthesis of nascent DNA chains opposite the blocking lesion. Several of the genes in this post-replication repair pathway encode for ubiquitin (Ub) conjugating E2 enzymes, and there is genetic and biochemical evidence that in yeast, the assembly of novel polyubiquitin chains is required at some step of this pathway. We are investigating the role of this pathway in the development and treatment of cancer. We have created mutant forms of Ub that cannot participate in the novel chains required for this DNA repair pathway and shown that these cells expressing this mutant are sensitive to chemotherapy. We have also recently developed a transgenic mouse model to study the role of this pathway in development and in UV induced carcinogenesis. We are also attempting to understand the mechanism of lesion bypass repair by identifying the specific proteins targeted with K63-linked polyubiquitin chains. This is carried out using our tagged ubiquitin mutants and analytical protein techniques coupled with mass-spectrometry.

- A functional genomic and proteomic analysis of hypoxia induced gene-expression

We are developing a new genomic technology to identify and characterize genes important in the response of tumors to cancer therapy. Tumour-associated hypoxia has been demonstrated to adversely influence the efficacy of both radiation therapy and chemotherapy as well as serve as a stimulus for angiogenesis and metastasis. It is therefore critical to identify the genes involved in these important processes and to gain insights into how these genes and their associated proteins are regulated. To this end, we are developing a novel gene trap technology coupled with the use of fluorescent reporter genes and high-speed cell sorting flow cytometry that not only will rapidly identify hypoxia-induced genes but also facilitate the creation of gene knockout mice to study their function.

- Current evidence indicates that the hypoxia-responsive transcription factor HIF-1is a critical regulator of hypoxia-responsive gene expression under both physiologic and pathophysiologic conditions. We are using HIF-1 knockout cells for studies of HIF-1 dependent protein expression in response to hypoxia. Characterization of differential hypoxia-responsive protein expression is performed using 2-D gel methods coupled with mass spectrometric analysis of tryptic peptides derived from in-gel digestion. We plan to expand these proteomic studies of hypoxia-regulated gene expression by focusing specifically on subpopulations of cellular proteins.

Funding:

NCIC Grant for the study of novel polyubiquitin chains in DNA repair and cancer $112k/y for 3y

MRC Grant for the study of determinants of resistance to cancer therapy isolated by functional genetic knockouts $80k/y for 3y

ORCC Foundation grant for the development of a new genomic technology to identify and characterize genes important in the response of tumours to cancer therapy $25k/y

Publications:

- Wouters, B.G., and Brown, J.M., Apoptosis, p53 and Tumour Cell Sensitivity to Anticancer Agents, *Cancer Research* **59**, 1391-1399 (1999)

- Kovacs, M.S., Hocking, D., Evans, J.E., Siim, B., Wouters, B.G., and Brown, J.M., Potentiation of Cisplatin Antitumor Efficacy By Tirapazamine in the Result of a Hypoxia-Dependent Interaction at the Cellular Level, *British Journal of Cancer* **80**(8), 1245-1251 (1999)

- Wouters, B.G., Giaccia, A.J., Denko, N.C., and Brown, J.M., A p53 and apoptotic independent role for $p21^{wafl}$ in tumour response to radiation therapy, *Oncogene* **18**, 6540-6545 (1999)

- Wouters, B.G., Wang, L.H., and Brown, J.M., Tirapazamine: A New Drug Producing Tumour Specific Enhancement of Platinum-Based Chemotherapy in Non-Small Cell Lung Cancer, *Annals of Oncology* **10**, S29-33 (1999)

Curriculum Vitae of New Member

Bradly G. Wouters

EDUCATION

1992-1996 Ph.D. in Physics, Department of Medical Biophysics, University of British Columbia, BC Cancer Research Centre,Vancouver, BC

1991-1992 Physics M.Sc. candidate, Department of Medical Biophysics, University of British Columbia, BC Cancer Research Centre,Vancouver, BC

1987-1991 Bachelor of Engineering Physics, University of Saskatchewan, Saskatoon, Saskatchewan

PROFESSIONAL EXPERIENCE

1999-present Associate Research Scientist Research Institute, Ottawa Hospital, Ottawa, ON

1999-present Assistant Professor University of Ottawa, Faculty of Medicine - Department of Radiology, Ottawa, ON

1998-present Career Scientist Centre for Cancer Therapeutics, Ottawa Regional Cancer Centre, Ottawa, ON

1996-1998 Post-doctoral fellow in Radiation Oncology, Stanford University School of Medicine, Department of Radiation Oncology, Stanford, CA

RESEARCH INTERESTS

Our lab is interested in determining the molecular mechanisms responsible for the ways in which our cells respond to cancer therapy. Our two main research activities are focussed on the implications of tumour hypoxia on cell genotype and phenotype, and on the mechanisms of DNA repair.

PROFESSIONAL AFFILIATIONS

1992-present Member of the Radiation Research Society

1997-present Member of the American Association for Cancer Research

1997-present Member of the American Association for the Advancement of Science

ADDITIONAL PUBLICATIONS THAT ARE NOT INCLUDED IN THE MEMBERSHIP PROFILE

- Wouters, B.G. and Skarsgard, L.D., The Response of a Human Tumour Cell Line to Low Radiation Doses: Evidence of Enhanced Sensitivity. Radiation Research **138**, S76-S80 (1994)

- Wouters, B.G., Lam, G.K.Y., Oelfke, U., Gardey, K., Durand, R.E., and Skarsgard, L.D., Measurements of Relative Biological Effectiveness of the 70 MeV Proton Beam at TRIUMF Using V79 Cells and the High Precision Cell Sorter Assay. *Radiation Research* **146**, 159-170 (1996)

- Wouters, B.G., Sy, A.M., and Skarsgard, L.D., Low Dose Hypersensitivity and Increased Radioresistance in a Panel of Human Tumour Cell Lines With Different Radiosensitivity. *Radiation Research* **146**, 399-413 (1996)

- Wouters, B.G., Sy, A.M., and Skarsgard, L.D., Hypoxic Cell Sensitization: Low Dose Intrinsic Radiosensitivity is Predictive for Etanidazole Efficacy in a Panel of Human Tumour Cell Lines. *International Journal of Radiation Biology*, **70**, 719-733 (1996)

- Wouters, B.G. and Brown, M.J., Cells at Intermediate Oxygen Levels Can Be More Important Than the "Hypoxic Fraction" in Determining Tumour Response to Fractionated Radiotherapy. *Radiation Research* **147**, 541-550 (1997)

- Wouters, B.G. and Skarsgard, L.D., Low-Dose Radiation Sensitivity and Induced Radioresistance to Cell Killing in HT-29 Cells is Distinct from the "Adaptive Response" and Cannot Be Explained by a Subpopulation of Sensitive Cells. *Radiation Research* **148**, 435-442 (1997)

- Wouters, B.G., Giaccia, A.J., Denko, N.C., and Brown, J.M., Loss of $p21^{Waf1/Cip1}$ Sensitizes Tumors to Radiation by an Apoptosis-independent Mechanism, *Cancer Research* **57**, 4703-4706 (1997)

Seminars

OMPI Seminars

One of the main vehicles of the OMPI for developing and maintaining contact 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 for the last several years have been held at 3:30 p.m. on Thursdays. The seminar location is rotated among the major centres involved in medical physics. Seminar information is posted on the web at http://www.physics.carleton.ca/ompi

Thursday, September 23, 1999 at Carleton University

A. Trivedi, AECL	*Biokinetics and Dosimetry of Tritiated Aerosols*
G. Cron, Carleton U & U of Wisconsin	*Non-invasive Measurement of the Arterial Input Function for Quantitative Dynamic Contrast-Enhanced MR Imaging of Cancerous Lesions in the Rat*

Thursday, October 21, 1999 at Ottawa Regional Cancer Centre, General Division

Robert deKemp, OHI	*Detecting Serial Changes in Myocardial Perfusion with SPECT and PET Imaging*
Narine Kizilian, Carleton U.	*Prediction of Radiosensitivity by Measurement of Radiation-Induced Apoptosis in Human Blood Using the Comet Assay*

Thursday, November 18, 1999 at Ottawa Hospital, General Division

Cheng Ng, ORCC	*Phenomenal and Mechanistic Aspects of the Potentiation of X-Radiation Killing by Camptothecin*
Mei Li, Carleton University	*GEM: A New Detector for Scanned Projection Radiography*

Thursday, December 16, 1999 at NRC

Giles Santyr, Carleton U.	*Hyperpolarized Xenon: A Novel Contrast Agent for Magnetic Resonance Imaging*
Gosia Niedbala, Carleton U.	*Response to Damage Due to Various Types of Radiation Treatments Using Cell Lines of Different Radiosensitivities*

Thursday, January 13, 2000 at Radiation Protection Bureau

Brad Wouters, ORCC	*A P53 Independent Role for P21 in Radiotherapy*
Mark McDonald, Carleton U.	*Low-field MRI of Hyperpolarized ^{129}Xe*

Thursday, February 10, 2000 at Carleton University

Peter Raaphorst, ORCC	*Increased Radiation Resistance by Low Doses of Radiation: Myth or Reality*?
Kenji Myint, Carleton University	*Examination of the Non-Homologous Repair Process in Cisplatin Radiosensitization and Sublethal Damage Repair*

Thursday, March 9, 2000 at Ottawa Regional Cancer Centre, General Division

Robert Clarke, Carleton U.	*The Use of High Intensity Focussed Ultrasound in the Treatment of Cancer*
Juan M. Parra Robles, Carleton U	*Image Post-Processing and Quantitative Characterization in Low-Field MRI Systems*

Thursday, April 27, 2000 at Ottawa Heart Institute

Tony Waker, AECL	*Applied Classical and Molecular Microdosimetry*
Carey Feagan, Carleton University	*The Role of P21 in Thermal Radiosensitization*

Thursday, June 1, 2000 at Carleton University

Clive Greenstock, AECL	*Fluorescence Screening of Antioxidants and Radioprotectors*
Robert Leclair, Carleton U.	*Model of X-Ray Scatter Imaging: Experimental Validation*

Carleton University Physics Department Seminars

Carleton University Physics Department runs a regular seminar series usually on Monday afternoons (with overflow to other days of the week) at 3:30 p.m. in the Herzberg Building. Information on upcoming seminars is posted on the website: (http://www.physics.carleton.ca/seminars). The following seminars of interest to medical physicists were held in 1999-2000:

September 13, 1999:	Julia Wallace (Carleton): MRI Thermometry of Tissue During Heating
October 25, 1999:	Mike Sherar (University of Toronto): Image Guided Thermal Therapy in Oncology
November 15, 1999:	Carlos Cabal (Santiago de Cuba): Magnetic Resonance (MRI and Relaxation) - Studies in the Medical Biophysics Center of Santiago de Cuba
November 22, 1999:	Robert deKemp (Ottawa Heart Institute): Quantitative Positron Tomography in the Management of Ischemic Heart Disease
January 31, 2000:	Ken Shortt (NRC): Metrology of Ionising Radiation in Canada
March 20, 2000:	Ruth Wilkins (Health Canada): Development of a biological dosimeter for ionizing radiation

OCIP Graduate Student Seminars

Fall Graduate Student Seminar Afternoon, Monday, November 29, 1999, Mackenzie Building, Carleton University

Daron Owen:	*Potentiation of Low Dose Rate Irradiation by Camptothecin*
Debbie Smith:	*The Radiobiological Equivalence of Pulsed Dose Rate and Low Dose Rate Irradiation Using the U87-MG Cell Line*

Spring Graduate Student Seminar Afternoon, Tuesday, May 30, 2000, University of Ottawa Campus, Colonel By Building:

Mei Li:	*GEM: A New Detector for Scanned Projection Radiography*
Mark McDonald:	*Feasibility of a Low-Field MR Imager Using Hyperpolarized ^{129}Xe*
Kenji Myint:	*Examination of the Non-Homologous Repair process in Cisplatin radiosensitization and SLDR*

Christmas Symposium, Friday, December 17, 1999, Colonel By Building, University of Ottawa Campus

Robert Clarke:	*High Intensity Focussed Ultrasound Surgery*

Other Seminars of Interest to the OMPI

In addition to the seminars listed in the above sections, there are a variety of other seminars in the Ottawa area which are of interest to the OMPI. The ones which have been brought to our attention in the last year were:

IRS informal Seminar Series (IRS Journal Club Seminars)

These seminars usually deal with radiation physics and dosimetry, Monte Carlo calculations, instrumentation and electronics, but can occasionally be about more broad topics. The speakers are members of the IRS group (National Research Council) as well as external visitors. The usual time is 10:00 unless otherwise indicated. Seminar organizer: Blake Walters.

Speaker	**Date**	**Topic**
Matthias Fippel	Sept 30'99	XVMC--voxel Monte Carlo for photons
Weihua Zhang	Oct 12 '99	Errors caused by summing K X-rays with photons
Ken Shortt	Oct 26 '99	Cuban RUM (Radiation Unit's Metrology)
Iwan Kawrakow	Nov 9 '99	The XVMC Project

Dallas Santry	Dec 7 '99	4π-γ ionization chamber. An amazing secondary standard.
Len Van der Zwan	Jan 25 '00	Comparison of exposure rate measurements with free air and extrapolation chambers at 75 keV
Carl Ross	Feb 8 '00	Absorbed Dose to Water Detectors
Blake Walters	Mar 21 '00	EGSnrc QA
George Daskalov	Apr 11 '00	Discrete ordinates modelling of 125I 6702 seed using a broad energy group cross-section representation
Norman Klassen	May 9 '00	Cell radiosensitivity and condensed chromatin
Dave Rogers	May 30 '00	Why use TG-51?
Leo Heistek	June 6 '00	Ghost in the machine

Brian George (BAe Systems) presented the W.B. Lewis Lecture for 2000 at Carleton University on Feb. 15 2000: *Energy and Climate Change*

Jean-Paul Soucy (Hopital Notre Dame, Montreal) gave a seminar at the Heart Institute on Feb. 23 2000. Title: *SPECT and Neurology: An available tool for advanced in-vivo characterization of brain function*

Donald Russell (Carleton University) presented a lecture *Advances in Prosthetic Limb Design - Variable Stiffness* at the IEEE EMBS Ottawa Chapter Meeting, Herzberg Laboratories, Carleton University on May 17, 2000.

University of Ottawa, International Centre for Low Dose Radiation Research, held a seminar on *Radiation Risk at Low and very Low Doses of Ionizing Radiation*, at University of Ottawa Health Sciences Centre, Roger Guindon Hall, on Nov. 8, 1999, with the speakers:
Professor Maurice Tubiana, MD, Member of the Academy of Sciences and of the Academy of Medicine, France; Former Director, Institut Gustave Roussy, France, and
Dr. Roland Masse, DVM, Associate Member of the Academy of Sciences, Former Director, Office de Protection contre les Rayonnements Ionisants (OPRI), France; Former Head, Pathology and Experimental Toxicology Department, Atomic Energy Commission (CEA), France

Themes were:
- Recent development in the knowledge of radiological risk at doses and dose rates comparable to the natural radiation background
- Implications for radiological protection of the public and of the workers
- Regulatory implications
- Research to be undertaken to reduce the uncertainty in radiological risk

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 course numbers are printed in **underlined bold font**; the others are recommended.

Depending on the thesis weighting, the Ph.D. typically requires four half-courses in addition to the thesis. The normal M.Sc. course requirement is 5 half-courses in addition to the thesis. Ph.D. students who lack any of the relevant courses (or their equivalents) required for the M.Sc. must complete them in their Ph.D. M.Sc. students may be permitted to take up to two fourth-year half-courses and credit them towards the degree. Ph.D. students can credit only graduate courses. When a student has covered material in a prior program, such as an M.Sc. 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
	75.423	Carleton	Physical Applications of Fourier Analysis[1]
	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	ANA 7301	Ottawa HSC[2]	Anatomy
(both terms)	PHS 5210	Ottawa HSC[2]	Physiology
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

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	ANA 7301	Ottawa HSC[2]	Anatomy
(both terms)	PHS 5210	Ottawa HSC[2]	Physiology
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

Specialization in Biophysics

Fall Term	**75.523**	Carleton	Medical Radiation Physics
	75.527	Carleton	Radiobiology[4]
	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	**ANA 7301**	Ottawa HSC[2]	Anatomy[4]
(both terms)	**PHS 5210**	Ottawa HSC[2]	Physiology[4]
Fall or Winter	**75.5xx/6xx**	Carleton or Ottawa	Half-course outside of medical physics[3]

[1] Prerequisite to 75.524; additional to degree if PhD
[2] HSC = Health Sciences Centre, Smyth Road
[3] Subject to approval. Permission may be given for 75.4xx if MSc
[4] In the Biophysics specialization, one of Radiobiology, Anatomy or Physiology must be taken.

Course Descriptions

75.523F--- Medical Radiation Physics (½ 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

75.524W--- Physics of Medical Imaging (½ 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: Medical Radiation Physics or equivalent and knowledge of Fourier optics at the senior undergraduate level.
Reference: S. Webb, *The Physics of Medical Imaging*, 1992.
Lecturers: G. E. Santyr (coordinator), P.C. Johns, R. deKemp, and B.T.A. McKee.

75.526W--- Medical Radiotherapy Physics (½ 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: Medical Radiation Physics 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 (Coordinator), K.R. Shortt, I. Kawrakow, and L.H. Gerig.

75.527F---Radiobiology (½ 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: Medical Radiation Physics or equivalent.
Reference: E.J. Hall, *Radiobiology for the Radiologist*, 4th ed., 1994.
Lecturer: G.P. Raaphorst

75.528W---Radiation Protection (½ course, Winter) Biophysics of radiation hazards, dosimetry and instrumentation. Monitoring of sources, planning of facilities, waste management, radiation safety, public protection. Regulatory agencies.

Prerequisite: Medical Radiation Physics or equivalent.
Reference: Herman Cember, *Introduction to Health Physics*, 3rd ed., 1996.
Lecturer: V. Elaguppillai

75.529F---Medical Physics Practicum (½ course, Fall) This course provides hands-on experience with current clinical medical imaging and cancer therapy equipment, and dosimetry and biophysics instrumentation. Experimental projects on medical imaging, radiotherapy, dosimetry, and biophysics, conducted at local clinics and NRC laboratories in Ottawa.

Prerequisites: Medical Radiation Physics or equivalent, plus, as appropriate to the majority of projects undertaken, one of Physics of Medical Imaging, Medical Radiotherapy Physics, or Radiobiology or other biophysics course.
Coordinator: B. J. Jarosz

The following life science courses are available at the University of Ottawa and are appropriate to medical physics graduate students:

ANA 7301---Anatomy for Medical Physics Graduate Students (½ course, extends through Fall and 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 and 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.

In addition, the following physics half courses are particularly relevant:

Physics 75.502---Computational Physics
Computational methods used in analysis of experimental data. Introduction to probability and random variables. Monte Carlo methods for simulation of random processes. Statistical methods for parameter estimation and hypothesis tests. Confidence intervals. Multivariate data classification. Unfolding methods. Examples primarily from particle and medical physics. Also offered at the undergraduate level, with different requirements, as Physics 75.487, for which additional credit is precluded.
Prerequisite: An ability to program in FORTRAN, Java, C, or C++ and permission of the Department.
Lecturer: D. Karlen

75.423---Physical Applications of Fourier Analysis (½ course, Fall) Laplace transform and its application to electrical circuits. Fourier transform, convolution. Sampling theorem. Applications to imaging: descriptors of spatial resolution, filtering. Correlation, noise power. Discrete Fourier transform, FFT. Filtering of noisy signals. Image reconstruction in computed tomography and magnetic resonance. Integral transforms and their application to boundary-value problems.
Prerequisite: Physics 75.387; or permission.
Reference: R.N. Bracewell, *The Fourier Transform and its Applications*, Revised 2nd ed., 1986.
Lecturer: P.C. Johns

Half-course outside of medical physics Also required is a graduate physics course outside of medical physics. Appropriate possibilities include nuclear, theoretical, quantum, particle, and solid-state physics. Selection is subject to the approval of the Academic Officer.

Giles Santyr, Academic Officer, OMPI

Students

Medical Physics Programme Graduate Students
Note: "Starting date" is the date first taking courses or commenced lab work, not registration date.

Ph.D. Students

Cron, Greg
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1073 (voice) 520-4061 (fax) gcron@physics.carleton.ca (e-mail)
Starting date: 9/95 **Supervisor**: Santyr **Specialization**: Imaging
Thesis topic: Quantitative dynamic MRI of the breast [Registered at U. of Wisconsin at Madison]

Leclair, Robert
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1854 (voice) 520-4061 (fax) robert@physics.carleton.ca (e-mail)
Starting Date: 9/94 **Supervisor**: Johns **Specialization**: Imaging
Thesis topic: X-ray imaging using scattered radiation

Niedbala, Malgorzata
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) niedbala@physics.carleton.ca (e-mail)
Starting Date: 1/99 [on completion of M.Sc.] **Supervisor**: Raaphorst **Specialization**: Biophysics
Thesis topic: Biophysics of radiation damage and repair

Parra-Robles, Juan
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x4307 (voice) 520-4061 (fax) jprobles@physics.carleton.ca (e-mail)
Starting Date: 1/00 **Supervisor**: Santyr **Specialization**: Imaging
Thesis topic: A low field MR imaging system using hyperpolarized xenon

M.Sc. Students

Feagan, Carey
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) cfeagan@physics.carleton.ca (e-mail0
Starting Date: 9/99 **Supervisor**: Ng **Specialization**: Biophysics
Thesis topic: The role of p21 in thermal radiosensitization

Gao, Zhanrong
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) zgao@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisor**: Gerig **Specialization**: Therapy
Thesis topic: Meta-analysis of Radiotherapy Treatment Delivery

Gauthier, Yvan
MRI Unit, Department of Radiology, Ottawa Hosp., General Site, 501 Smyth Road, Ottawa K1H 8L6
737-8476 (voice) 737-8611 (fax) ygauthie@physics.carleton.ca (e-mail)
Starting Date: 1/98 **Supervisor**: Cameron **Specialization**: Imaging
Thesis topic: Measurements of diffusion in the brain using MR imaging **Thesis defence**: Jan. 10/00

Jelveh, Salomeh
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1864 (voice) 520-4061 (fax) sjelveh@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisor**: Jarosz **Specialization**: Therapy
Thesis topic: Thermal therapy using interstitial ultrasound applicators

Kalach, Nina
Ionizing Radiation Standards, Institute for National Measurement Standards, NRC, Ottawa K1A 0R6
993-2197 (voice) 952-9865 (fax) nkalach@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisor**: Rogers **Specialization**: Therapy
Thesis topic: Monte Carlo radiotherapy planning

Kizilian, Narine
Radiobiology Section, RPB, Health Canada, 775 Brookfield Road, Ottawa K1A 1C1
954-9584 (voice) 941-1734 (fax) Narine_Kizilian@hc-sc.gc.ca (e-mail)
Starting Date: 9/97 **Supervisor**: Raaphorst **Specialization**: Biophysics
Thesis topic: The comet assay for radioresistance **Thesis Defence:** Dec. 20, 99

Li, Mei
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1854 (voice) 520-4061 (fax) mli@physics.carleton.ca (e-mail)
Starting Date: 9/98 **Supervisors**: Johns and Dixit **Specialization**: Imaging
Thesis topic: Gas electron multiplier detectors for x-ray imaging

McDonald, Mark
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1855 (voice) 520-4061 (fax) mmcdonald@physics.carleton.ca (e-mail)
Starting Date: 9/98 **Supervisor**: Santyr **Specialization**: Imaging
Thesis topic: Low field MRI of hyperpolarized xenon

Myint, Kenji
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) kmyint@physics.carleton.ca (e-mail)
Starting Date: 9/98 **Supervisor**: Raaphorst **Specialization**: Biophysics
Thesis topic: Cisplatin Radiosensitization in Radiotherapy

Nkongchu, Ken
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x4307 (voice) 520-4061 (fax) knkongch@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisors**: Santyr (Shortt) **Specialization**: Imaging
Thesis topic: MRI dosimetry using polymer gels

Owen, Daron
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) dowen@physics.carleton.ca (e-mail)
Starting Date: 9/97 **Supervisor**: Ng **Specialization**: Biophysics
Thesis topic: Effects of low dose rate radiation with campothecin

Sévigny, Pascale
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x4307 (voice) 520-4061 (fax) psevigny@physics.carleton.ca (e-mail)
Starting Date: 9/97 **Supervisor**: Santyr **Specialization**: Imaging
Thesis topic: MR imaging of hyperpolarized xenon **Thesis Defence**: Aug. 31, 99

Smith, Debbi
Department of Medical Physics, Ottawa Regional Cancer Centre, 501 Smyth Road, Ottawa K1H 8L6
737-7700x6942 (voice) 247-3507 (fax) dsmith@physics.carleton.ca (e-mail)
Starting Date: 9/97 **Supervisor**: Raaphorst **Specialization**: Biophysics
Thesis topic: Pulsed Dose Rate Brachytherapy

Wassenaar, Richard
Ottawa Heart Institute, 40 Ruskin St., Ottawa K1Y 4W7
798-5555x6327(voice) 761-4690 (fax) rwassena@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisor**: deKemp **Specialization**: Imaging
Thesis topic: Partial volume corrections in cardiac PET imaging

Wismayer, Matthew
Physics Department, Carleton University, 1125 Colonel By Drive, Ottawa K1S 5B6
520-2600x1854 (voice) 520-4061 (fax) mwismaye@physics.carleton.ca (e-mail)
Starting Date: 9/99 **Supervisor**: Johns **Specialization**: Imaging
Thesis topic: Diffraction data for X-ray scatter imaging

Graduate Student Theses Completed in '99-'00

Student	Degree	Supervisor	Thesis Title	Exam Date
Sévigny, Pascale	M.Sc.	G. Santyr	MR Imaging of Hyperpolarized ^{129}Xe: A Feasibility Study for Biomedical Applications	August 31/99
Kizilian, Narine	M.Sc.	P. Raaphorst	Prediction of Radiosensitivity by Measurement of Radiation-Induced Apoptosis in Human Blood using the Comet Assay	December 20/99
Gauthier, Yvan	M.Sc	I. Cameron	Measurement of the Apparent Diffusion Coefficient of Water in White Matter Using Magnetic Resonance Imaging: A Phantom Study	January 10/00

Undergraduate Honours Physics Project Completed in '99-00

Student	Course	Project Title	Supervisors
Badeen, Adam	75.499	Predicting Head Scatter Factors for Radiotherapy Linacs by Analysis of Monte Carlo Simulations	Lee Gerig Bog Jarosz

Past Student Graduates

Below are listed the current positions held by graduates from the Carleton Physics program in Medical Physics.

BSS Rao	MSc	1970	
Holo Devnani	MSc	1971	
Alan Mortimer	MSc	1974	Scientist, Canadian Space Agency
Donald Richardson	MSc	1975	
Mike White	MSc	1977	Ontario Hydro
Michael Ebifegha	MSc	1980	
Kulvir Kapoor	PhD	1981	Ontario Hydro
Hripsime Shahbazian	MSc	1984	Associate Manager, Office of Science, Health Canada
Bruce Faddegon	PhD	1990	Radiotherapy physicist, Toronto-Sunnybrook Regional Cancer Centre
Elias Zakhour	MSc	1991	
Reza Dokht	MSc	1991	Sessional instructor in medical physics, Tehran
Julia Older	MSc	1991	(BSc, 1989) Physics assistant, Ottawa Regional Cancer Centre
Andrew Weber	MSc	1991	(BSc, 1988) telecommunications industry
David Wilkins	PhD	1993	Radiotherapy physicist, Ottawa Regional Cancer Centre
Ted Lawrence	MSc	1993	Radiotherapy physicist, Sydney, N.S.
Dennis Heller	PhD	1993	Faculty of Medicine, Univ. of Cincinnati
George Ding	PhD	1995	Radiotherapy physicist, Vancouver
Doru Kaytar	MSc	1995	software industry
Dennis Akyürekli	PhD	1995	(MSc, ‘88, BSc, ‘85) Radiotherapy physicist, Kingston Regional Cancer Centre
Bilal Shahine	MSc	1995	PhD student at Univ. British Columbia
Ria Corsten	MSc	1995	Radiotherapy physicist, St. John's, Nfld.
Julia Wallace	PhD	1996	Research Associate with Prof. Giles Santyr (CMRF)
Patrick Rapley	PhD	1996	Radiotherapy physicist, Kelowna, B.C.
Cathy MacGillivray	MSc	1996	Manitoba Cancer Treatment and Research Foundation, Winnipeg
Ruth Wilkins	PhD	1996	Research Scientist, Radiation Protection Bureau, Health Canada
Larry Gates	PhD	1997	Post-doc in clinical MRI, Halifax
David Gobbi	MSc	1997	PhD student at Univ. Western Ontario
Mazen Soubra	PhD	1997	Radiotherapy physicist, upstate New York
Kevin Lenton	PhD	1998	Post-doc in biophysics at Univ. Sherbrooke
Sheri Boyden	MSc	1998	MD student at McMaster University
Miller MacPherson	PhD	1998	Radiotherapy Physicist, Ottawa Regional Cancer Center
Geoff Zhang	PhD	1998	Physicist at JDS Uniphase in Ottawa
Malgorzata Niedbala	MSc	1998	Currently a Ph.D. student in our program
D. Sheikh-Bagheri	PhD	1999	Medical Physicist at Theratronics
Tanya Hewitt	MSc	1999	software industry
Pascale Sevigny	MSc	1999	Physicist with the Defence Research Establishment Ottawa
Narine Martel	MSc	2000	Health Physicist at Radiation Protection Bureau
Yvan Gauthier	MSc	2000	Operational Research Section, Department of National Defence

Membership in 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 listed:

AAPM	American Association of Physicists in Medicine	Paul Johns, Dave Rogers
CAP	Canadian Association of Physicists	Bob Clarke, Paul Johns, Dave Rogers
COMP	Canadian Organization of Medical Physicists	Paul Johns, Lee Gerig, Ken Shortt
CRPA	Canadian Radiation Protection Association	Clive Greenstock, Dave Rogers , Pavel Dvorak
EMBS	IEEE Engineering in Medicine and Biology Society	Bog Jarosz
HPS	Health Physics Society	Dave Rogers, Clive Greenstock
IRPS	International Radiation Physics Society	Paul Johns
RRS	Radiation Research Society	Peter Raaphorst, Clive Greenstock
ISMRM	International Society for Magnetic Resonance in Medicine	Ian Cameron, Giles Santyr
CNS	Canadian Nuclear Society	Clive Greenstock

OMPI Social Activities over the last year

As in the previous year, our institute has organized a limited number of social activities. The purpose is more informal get-togethers for members and students in connection with the professional and student seminars. A social activity usually consists of an outdoor sports or non-sports activity followed by dinner at a local restaurant or a BBQ. Over the last year the social activities included a soccer game and broomball, organized in connection with OMPI seminars, and a reception to celebrate Bob Clarke's appointment as Professor Emeritus at Carleton University (see page 36).

Appointment of Dr. Robert L. Clarke as Professor Emeritus

In the spring of 2000, President Richard Van Loon, acting on the recommendations of the Faculty of Science and the Department of Physics and following strict criteria for bestowing this high honour, appointed Robert (Bob) Clarke as Professor Emeritus.

A reception was held at the Carleton University Club on 1 June 2000 following the final OMPI seminars of the year. The reception was to thank the external graduate supervisors and course instructors for participating in the research and teaching life of the Department of Physics and most especially to celebrate Robert Clarke's appointment. Public remarks were made by John Armitage (Chair of Physics), Peter Watson (Dean of Science), Paul Johns (OMPI Director), Vera Clarke, Don Wiles ((retired) Professor of Chemistry), and last, by Bob Clarke.

The following sketch of Robert Clarke's career to date is excerpted from the 28 October 1999 submission written by the Tenure and Promotion Committee of the Dept of Physics (members for 1999-2000: John Armitage, Stephen Godfrey, Bog Jarosz, Dean Karlen, Lazer Resnick).

Professor Clarke has had a long and distinguished career in Physics and has contributed tremendously to the academic life of Carleton University. He graduated with a Ph.D. from McGill in 1948 and pursued a career in Nuclear Physics, working first as a Scientific Assistant at the NRC in Ottawa, and then moving to AECL at the Chalk River Labs. At that time, he was working on the physics of nuclear reactions and most of his early papers are in this field. He then became interested in particle reactions at higher energies and took a sabbatical leave at the Rutherford Laboratory in the U.K. where he had an appointment as Principal Scientific Officer. He participated in experimental work on proton scattering using the early cyclotrons and published works in that area. It was after he returned to AECL that his contact with Carleton's Physics Department began.

In 1964, the close collaboration between Carleton's Physics Department and the National Research Council had been strengthened by the appointment of Dr. E.P. Hincks, from the NRC's High Energy Physics group, as Chair of the Department. Dr. Hincks established a clear direction for the Department in this discipline and started to build up the group. Professor Clarke was one of the first people to join, initially as a Visiting Honorary Research Professor, commuting regularly from Chalk River and then as a Full Professor. During this period, he pioneered the building of a 3 MV accelerator, known as the Dynamitron. This was a joint project with the University of Ottawa and both Departments worked closely together, to build and install the machine in the basement of the Physics Department at the University of Ottawa. Under the Directorship of Professor Clarke, the Dynamitron Lab produced data for several graduate theses at both the M.Sc. and Ph.D. level.

High Energy Physics was developing rapidly in those days, and new accelerator labs were springing up in many places around the world. In the pursuit of still higher energies, Dr. Hinck's group decided to concentrate their efforts at the Brookhaven National Laboratories, on Long Island near New York. It was at this point that Professor Clarke took an important decision that was later to have great implications for the department. He decided to move into the discipline of Medical Physics. He developed and tested several devices: tomographic imaging by Compton scattered gamma rays from ^{60}Cobalt, and absolute bone density measurements using gamma ray scattering. The papers he published in the early to middle seventies attest to his success in this area. Following a sabbatical leave spent learning about the rapidly rising medical uses of ultrasound, a breast imaging system was developed based on conical focussing. Professor Clarke continues to work in the ultrasound area to the present day, and is considered an authority on the subject.

In the mid-eighties, the Department decided to move into a second major research area. Because of Professor Clarke's pioneering work in Medical Physics this seemed to be a natural area to concentrate on. In 1988, the first faculty member in Medical Physics was recruited and currently there are three faculty and eleven adjunct professors working in this area. The on-campus research has expanded from ultrasound to x-ray imaging and magnetic resonance imaging. Overall, this choice of discipline has been very good for the department and has attracted a large number of graduate students (35 students have graduated in Medical Physics and there are 17 'in the pipeline' for a total of 52). Through Professor Clarke's influence, a large group of Adjunct Professors have been recruited from professionals working in the local hospitals. Professor Clarke was also instrumental in the founding of what is now known as the Ottawa Medical Physics Institute. As well as the faculty and adjuncts, this includes many other researchers working in the local area. There are

now 30 professional members from local hospitals, government organizations and Carleton University. They hold monthly seminars and meet to exchange views on the different aspects of what is now a rapidly growing science: medical physics.

Professor Clarke has also been active in administration. He was appointed Chair of the Department in 1971 and continued in that position until 1977. He has served the Department, the Faculty and the University well, on numerous committees. He has been appointed to several provincial committees, including the Council of Ontario Universities' Physics Departments committee. At the national level he has played an important role in the Canadian Association of Physicists having been an Executive Member and Secretary-Treasurer as well as several other posts in this same organization. He has also been active at the international level, as he was appointed Secretary-General of the International Union for Physical and Engineering Science in Medicine.

Although Professor Clarke officially retired 12 years ago, he remains very active in research and in service to the University. He has formed a collaboration with researchers at the Institute of Cancer Research, Royal Marsden Hospital in Surrey, England. There he has been involved in the use of ultrasound for the treatment of cancers. The principal objective is the treatment of certain cancer sites by tissue coagulation through intense heating. Other applications in obstetrics and vascular occlusion are also feasible. His latest publications in 1994 and 1995 and most recently in 1999, result from this work. He has also given several professional talks on the subject including an invited CAP lecture last year at Laurentian University. Professor Clarke continues to provide important service to the University community. Most recently he was asked to help sort out the problems concerning the Universities' Radiation Safety License. He was able to sort things out with the Atomic Energy Control Board, and additionally made recommendations that set the Radiation Safety issue on a firm footing.

In summary, Professor Clarke provides an indispensable intellectual stimulus for the rest of the department. His imagination and breadth of knowledge serve not only as a resource but as a goad for his colleagues and has produced many successful innovations. His latest project, mapping the temperature of ultrasound heated tissue using magnetic resonance imaging techniques is a reminder that he still has much to give to the world of Medical Physics research. In recommending him for promotion to Professor Emeritus the committee is mindful of this and looks forward to many more stimulating interactions with him. We unreservedly endorse this recommendation.

Kudos

OMPI member **Dave Rogers** won the 1999 Farrington Daniels Award of the AAPM for the best paper in radiation dosimetry published in 1998 for his paper "A new approach to electron beam reference dosimetry", *Med. Phys.* **25**, 310-320 (1998). This same paper was runner up for the 1998 Sylvia Fedoruk prize of COMP for the best paper published in 1998.

OMPI member **Brad Wouters** won Ontario's top prize for young scientists, the 1999 Polanyi Prize, worth $15,000, for research focussed on the treatment of cancer. Specifically, his work concentrates on examining genes and molecular pathways that determine both the characteristics of malignant tumours, and the way those tumours respond to various treatments. The final goal is to understand better how and why chemotherapy and radiation therapy work at the molecular level.

OMPI E-mail Bursters

E-mail sent to the following addresses is broadcast to all users on the respective lists by the e-mail burster at Carleton.

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