As part of an introduction to the study of Radiation Health Risks and Benefits, on September 30, 2004 and October 1, 2004, the students were given guided tours of the various facilities at McMaster University and the Juravinski Cancer Centre in Hamilton. The main objective of these tours was to introduce the students to recent developments in radiation biology that have direct impact on the understanding of health risks and benefits associated with ionizing radiation. A synopsis of the information gathered during these tours is provided herein.

The tour began with a visit to the McMaster Nuclear Reactor (MNR). The MNR is a 5 MWt, pool-type reactor, with a core of enriched uranium fuel moderated and cooled by light water. The MNR has a wide range of applications in the fields of nuclear physics, biology, chemistry, earth sciences, and nuclear medicine. The reactor produces I-125, an isotope used in nuclear medicine. The MNR is also used to irradiate geological samples to be dated by the Ar-40/Ar-39 method. Electron spin resonance ('ESR') dating makes use of the Co-60 source in the Hot Cell, where the work is done via manipulators behind a one-meter thick lead and oiled lined glass window.

Neutrons produced by the MNR can be used in Neutron Radiography (NR) for photographing the interior structure of solid objects. Because neutrons can interact differently with materials of similar density, it can give a complementary view to that of X-rays. Some typical applications of neutron radiography include detecting of flaws in gas turbine blades and detecting of explosive charges.

Neutron Activation Analysis (NAA) is a non-intrusive method for determining the elemental content of samples by irradiating the sample with neutrons produced by the MNR to create radioactive forms of the elements in the sample. Quantitative determination is achieved by observing the gamma rays emitted from these isotopes in the samples.

Following the tour of the MNR, the students were given a guided tour of the McMaster University Anatomy Laboratory. Prior to the tour, brief presentations were made on radiation absorption in living tissues and physical and biological processes that influence the consequences of the exposure. Students were introduced to the biological effects from different radiation qualities, doses, and dose rates. During the tour of the Anatomy Laboratory, students had the first-hand look at the potential harmful effects of radiation on the human cell and molecular biology leading to fetus malformation and cancer. The cases of Exencephaly (brain developed outside the head), and Evisceration (intestines developed outside the body) as examples of fetus malformation were evidenced. The students were also shown samples of the brain, lung, and other specimens that bore various forms of cancers.

The day was concluded with a guided tour of the McMaster University Planetarium where the students learned about the Earth and its relationship to the solar system and the rest of the Universe. Part of the show was on constellations including the Dippers and North Star as well as currently visible planets, and their motions relative to the Earth's rotation. One of the key points made during the show was that the majority of radiation exposures received by the human population are terrestrial, cosmic, solar and galactic. Immediately outside the earth's atmosphere, the main sources of energetic particles that are of concern to spacecraft and aircraft personnel include: 1) protons and electrons trapped in the Van Allen belts; 2) heavy ions trapped in the magnetosphere; 3) cosmic ray protons and heavy ions; 4) protons and heavy ions from solar flares.

The following day began with a guided tour of the Juravinski Cancer Centre where modern technologies and techniques in radiation medicine are being applied for the diagnostic and treatment of cancer.

For cancer imaging, the students were introduced to the CT Scanner that uses x-rays to produce a detailed image of the cancerous area of an organ. As the patient lies on a movable table, he/she is moved slowly through the circular donut shaped (i.e., the gantry) part of the scanner. While the table is moving, a rotating x-ray machine inside the gantry moves around the body and the detectors collect data as the radiation passes through the patient's body. The information is transferred to a computer where a two-dimensional image is created.

For cancer treatment, the students were introduced to the Varian Linear Accelerator, a 21 MeV volt linear accelerator that delivers radiation therapy to the prescribed localized area. The Varian is housed in a treatment room that has lead-lined walls and a somewhat tortuous path to the door to ensure the radiation is completely contained within the room. There is no risk to patients, staff or visitors of unsafe radiation exposure. The radiation produced is in the form of photons and electrons. During the treatment, the patient lies on a bed that moves around a vertical axis while the Varian moves radially around the bed. This enables multiple radiation beams to be focused and delivered to the cancerous tissues from different angles, thereby concentrating the radiation dosages to the cancerous tissue while minimizing the dosages to healthy normal tissues. Specialized devices such as casts and wedges are used to protect normal tissues from the radiation beam and make the radiation beam placement as exact as possible.

The unique radiation technique for the treatment of prostate cancer was discussed. During the treatment, radioactive seeds are permanently implanted in the prostate gland using computerized axial tomography and real time ultrasound guidance. The seeds are directly placed into the prostate gland avoiding the normal, healthy adjacent structures. The implanted seeds remain in the patient and constantly emit radiation to destroy the cancerous tissues over a period of several months for the desired therapeutic results.

The last tour of the day was at the Medical Sciences Building of McMaster University. Here, the students were introduced to the Positron Emission Tomography (PET) whole body scanner and the Cyclotron. PET is an analytical imaging technology developed to use compounds labeled with positron emitting radioisotopes as molecular probes to image and measure biochemical processes in human. For cancer diagnostic, glucose drinks labeled with F-18, a positron emitter, is given to the patient. Because cancerous cells metabolize glucose at much higher rates than normal cells, the PET will detect high positron signals in areas of high glucose metabolic rates. The PET consists of a movable table and a gantry through which the table carrying the patient moves. While the patient is being moved through the gantry, the photo-multiplier tubes inside the gantry collect the positron signals and transfer the information to a computer where a three-dimensional image is created. The PET image helps to locate the cancerous areas but cannot provide accurate information on the size of the cancerous areas. As a result, the PET image is often used in conjunction with the CT Scan image that can provide accurate sizing information of the cancerous area.

It is worth noting that F-18 has a half-life that is less than 2 hours. Therefore, a PET is often in close proximity to a cyclotron that makes F-18. In the cyclotron, a magnetic field is applied perpendicular to a disk-shaped vacuum chamber containing two hollow D-shaped semi-circular electrodes. The straight portions of these hollow electrodes are open and face each other. A current of negatively charged hydrogen ions flowing perpendicular to a magnetic field experiences a force that is perpendicular to its direction of motion. With charged particles free to move in a vacuum, the hydrogen particles follow a circular path. In the cylotron, a high frequency alternating voltage applied across the “D” electrodes causes the hydrogen ions to accelerate when passing through the gap between the electrodes. The perpendicular magnetic field forces cause the hydrogen particles to follow an outwardly spiraling path as they accelerate when passing through the gap between the two D’s.

The stream of negative hydrogen ions is directed towards a carousel positioned between the accelerators and target chamber containing O-18. The carousels contain thin carbon foils strip each H^- ion of its two electrons. When the negative ions lose both electrons, they become H^+ ions (i.e., protons). Through computer-controlled movement of an extractor assembly, the proton beam is directed toward a target chamber and by means of a nuclear reaction, changes the stable target material containing O-18 into a radioactive isotope of F-18 for use in the PET.

The above guided tours have been fascinating and provided the students with information on background radiation, current understanding of short-term and long-term health effects of high and low radiation doses on human, some of the current progresses in the field of nuclear medicine and on-going researches on the risks and benefits of low radiation doses to humans.