Radiation Safety
benefits and risks

Accidental and avoidable exposure to ionizing radiation is a risk.

Effects of ionizing radiation on life depend on types of radiation, rates of receiving, and dosages (amounts) received.

Natural ionizing radiation include cosmic rays, X-rays and gamma rays from space, and natural radioactivity.

Risk will be discussed in terms of types, rate of receiving, and dosages using well defined units and quantities.
Radiation

- **Radiation**: Energy in the form of particles or electromagnetic waves

- **Ionizing Radiation**: Radiation with sufficient energy to remove an electron from an atom or molecule.
Radioactivity

• The process by which unstable atoms spontaneously transform to new atoms* and in the process emit radiation.

* The “new atom” may be the same atom in a lower energy state.
Definitions

• **Exposure** R (roentgen): Amount of charge produced per unit mass of air from x-rays and gamma rays.
• **Absorbed Dose** rad: Amount of Energy deposited per unit mass of material. 1 Gy = 100 rad.
• **Dose Equivalent** rem: Risk adjusted absorbed dose. The absorbed dose is weighted by the radiation type and tissue susceptibility to biological damage. 1 Sv = 100 rem.
• Radiation weighting factors: alpha(20), beta(1), n(10).
• Tissue weighting factors: lung(0.12), thyroid(0.03), and gonads(0.25).

For whole body x or gamma-ray exposure

\[ 1 \text{ R} \approx 1 \text{ rad} \approx 1 \text{ rem} \]
The amount of energy absorbed from exposure to radiation is called a dose. The radiation effect measured by a dosimeter reflects an equivalence of certain dosage of X-rays. The amounts are defined in certain units as shown here.
The factor reflecting the relative harmfulness of various types of radiation is called the **quality factor** ($Q$) or **relative biological effectiveness** ($rbe$).

<table>
<thead>
<tr>
<th>Radiation</th>
<th>$Q$ or $rbe$</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-, $\gamma$- and $\beta$ rays</td>
<td>1</td>
</tr>
<tr>
<td>Thermal neutrons (n)</td>
<td>3</td>
</tr>
<tr>
<td>Fast n, $\alpha$, and protons</td>
<td>10</td>
</tr>
<tr>
<td>Recoil nuclei</td>
<td>20</td>
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</tbody>
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Biological dose = $Q \times$ exposure dose
Early Experiences of Radiation Effects

Early workers exposed to X-rays developed dermatitis.

Uranium miners developed skin lesions.

People working with radioactivity experienced illness.

Researchers exposed to radioactivity suffered radiation sickness at advanced age.

Manhattan project workers in Los Alamos, Oak Ridge, Hanford, and atomic worker in the former USSR suffered anorexia, fatigue, headache, nausea, vomiting, and diarrhea.
Collective Response to Radiation Risk

In 1928, the International Committee on X-ray and Radium Protection was formed to look into the risk of radiation. It is now called International Commission on Radiological Protection, ICRP.

In 1942, a group of health physicists had the responsibility to assess problems and implement safe operation procedures regarding radioactivity.

After WW2, the (American) National Council of Radiation Protection (NCRP) was formed in 1946.

Guidelines are given for radioactive material handling and applications.

Today, safety committee is set up to deal with radiation risks.
Mission Statement of the ICRP

The International Commission on Radiological Protection, ICRP, is an independent Registered Charity, established to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation.

From www.icrp.com check with ICRP for up-to-date guidance regarding radiation.
National Policies on Ionizing Radiation

The Environmental Health Directorate of Canada is concerned with radiation risks. Safety Codes were prepared by the Radiation Protection Bureau of Health Canada. The latest change was made in October 1999.

Working with ionizing radiation must follow guidelines for the organization and for the workers. Safe practice is more than follow guidelines to the letter. Apply common sense to avoid as much exposure as possible.

Radiation Effects

Somatic effects
damages to cells passed on to succeeding cell generations.

Genetic effects
damages to genes that affect future generations. Genes are units of hereditary information that occupy fixed positions (locus) on a chromosome. Genes achieve their effects by directing the synthesis of proteins.

Somatic effects and genetic effects show no immediate symptoms.
Somatic Effects

Damages to cell membranes, mitochondria and cell nuclei result in abnormal cell functions, affecting their division, growth and general health.

Organs such as skin, lining of gastrointestinal tract, embryos, and bone marrow, whose cells proliferate rapidly are easily damaged.

Bone marrow makes blood, and its damage leads to reduction of blood cell counts and anemia.

Damage to germinal tissues reduces cell division, and induces sterility.
Genetic Effects

Human cells contain 46 chromosomes. Germ or ovum cells contain 23.

A chromosome contains a deoxyribonucleic acid (DNA) molecule.

The double-helix DNA has two strands of phosphoric-acid and sugar linked bases of Adenine, Guanine Cytosine or Thymine.

The A-T and G-C pairs stack on top of each other.

The DNA codon transcripts mRNA, which directs the amino-acid sequences of protein. DNA Damages result in somatic and genetic effects.

When DNA molecules replicate (pass on to next generation), they are sensitive to radiation damage. Joining wrong ends of broken DNA is called Translocation, which cause mutation and deformation at birth.

Genetic effects increase frequency of mutation.
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http://www.accessexcellence.org/AB/GG/dna_molecule.html
Genetic Effects - Replication of DNA

http://www.accessexcellence.org/AB/GG/possible.html
1. Transcription

DNA → mRNA

RNA polymerase

RNA nucleotides

nuclear membrane

2. Translation

mRNA → tRNA → rRNA → amino acids → proteins

Anticodon

polypeptide chain

Ribosome

codon

Protein synthesis

AL-MADA'IN, Iraq - Dozens of people are showing up every day at a hospital near a defunct Iraqi nuclear plant, suffering from rashes, bloody noses and other symptoms of radiation poisoning, doctors said Saturday.

The Tuwaitha nuclear facility, 12 miles south of Baghdad, was left unguarded after Iraqi troops fled the area on the eve of the war. (News, Jun, 2003)
Artificial Radiation Sources

X-rays are generated by stopping fast moving electrons. A chest X-ray exam is exposed to less than 0.01 Sv, more if multiple images are taken.

Accelerators generate high-speed electrons, atomic nuclei, high-energy particles, and synchrotron radiation.

Nuclear explosions leave radioactive fission products.

Nuclear reactors are sources of ionizing radiation.

Leakage of radioactive nuclides contaminates environment.

Nuclear-waste areas are sources of radiation.

Uranium mining tailings are more radioactive than natural sources.
Radiation Injuries

Whole-body radiation victims mostly suffer from injuries to the hemopoietic, gastrointestinal (GI), and central nervous (CN) systems.

Injuries to the hemopoietic system lead to bone marrow syndromes with low red and white cells and platelet counts.

The GI syndromes are anorexia, fatigue, nausea, vomiting, and diarrhea. GI system failures weakens body defence.

Damages to the isolated and non-renewable CN system show ataxia (loss of motion control), disorientation, apathy, depression, prostration (exhaustion), convulsions, and shock.

Organs such as skin, gonads, and eyes are sensitive to radiation.
X-Ray Burns

500+ rad

Exposure of 5-10 seconds
Appearance of wound after 25 days

5,000+ rad

P-32 - 6.5 rad/hr/uCi

S-35 - 2.5 rad/hr/uCi
Cancer

• Radiation can damage cells through two methods;
  – Production of free radicals and
  – Direct damage to the DNA.

• Risk factor for radiation dose:
  – 4% increase in risk of dying of cancer for every 100 rem of dose.
  – Normal cancer risk is 20%.
Dose Response Relationship

- Risk is not Predictable below 20 rem
- Predictable Effects
- Effect is Detrimental if risk level is uncertain

Risk of death from cancer vs. Committed Lifetime Dose (rem)

Occupational dose – above background
ALARA

- ALARA - As Low As Reasonably Achievable
- **Time**
- **Distance** (inverse square law)
- **Shielding**
- **Contamination Control**
Radioactive Sealed Sources

- Sealed sources used as a source of radiation
  - Alpha particles
  - Beta particles
  - Gamma ray
  - Bremsstrahlung
  - Neutron sources
- Permanently enclosed in either a capsule or another suitable container designed to prevent leakage or escape of the radioactive material
- Inventory and Use records are required
Radioactive Sealed Sources

• Tested for surface contamination and leakage
  – Sources may leak radioactive material
  – Tested usually once every 6 months for beta & gamma emitters that are $\geq 100 \text{ uCi}$
  – Tested every 3 months for alpha emitters $\geq 10 \text{ uCi}$
  – Allowable limit is less than 0.005 uCi

• A leaking source shall immediately be removed from use
  – Action to be taken to prevent contamination
  – Source to be repaired or disposed of
Security and Transportation

- All radiation sources must be kept locked up when not in use.
- Experiments left unattended should be labeled “Experiment in Progress.”
- An up-to-date use log of all sources must be kept at the storage location.
- All radiation laboratories will be locked when unattended for extended periods.
- When you are the means for security, you must challenge unknown persons entering the lab.
- Sources can only be used in a registered radiation laboratory.
General Radiation Safety

- **No** food or beverages in the lab
- Keep a survey meter conveniently close by
- ALARA - time, distance, and shielding
- Label radioactive materials and equipment
- Never remove sources from the Jr Physics Lab