Basic Radiation Safety Awareness Training

Radiation Safety Program

St. John's College

Outline

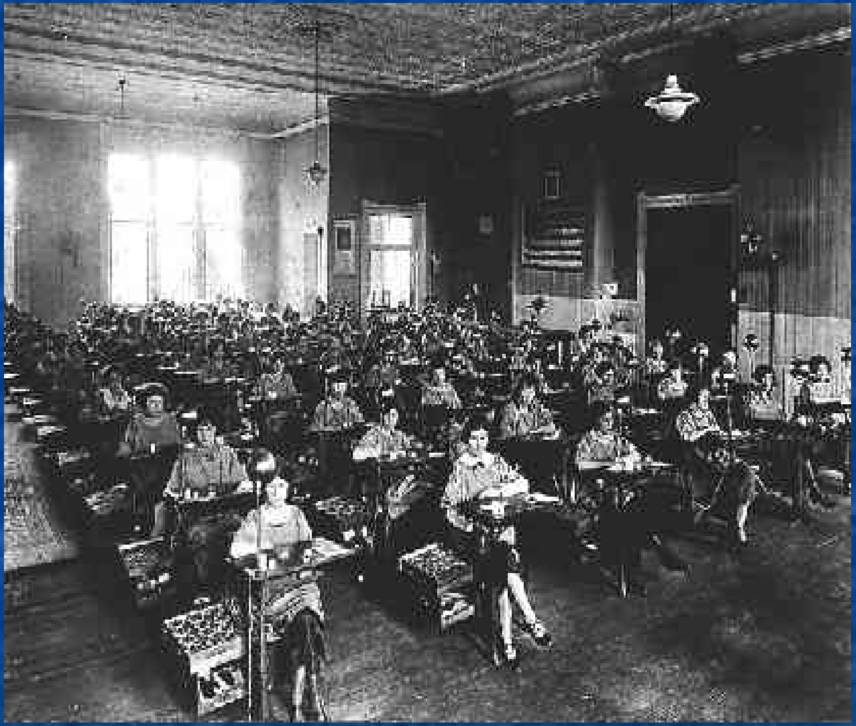
- History of Radiation
- Natural & Man-Made Background Sources of Radiation
- Fundamentals
- Exposure Limits & Regulations
- Detection of Radiation
- Safe Practices with Radiation
- Biological Effects of Radiation
- Where to Find Further Information

First Known Human Use of Uranium

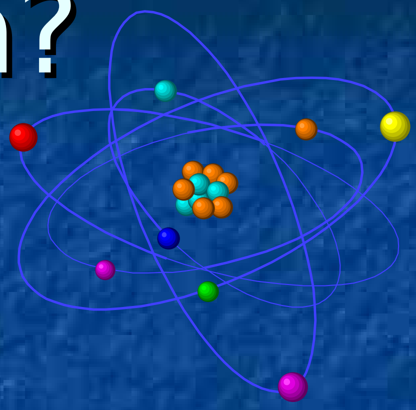
- 79 A D
- Roman artisans produce yellow colored glass in mosaic mural near Naples, Italy

Radium Effects Confirmed

- 1925
- Suspicions develop around watch dial painters' jaw lesions
- Dentists diagnose lesions as jaw necrosis due to radium deposits in jaw bone
- Doctor notes bone changes and anemia in dial painters



What is Radiation?



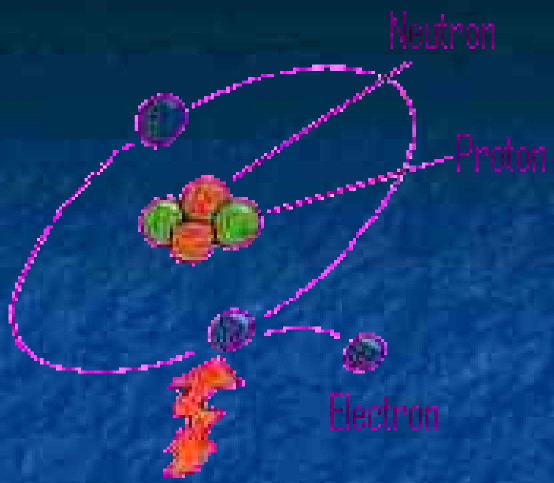
Radiation: energy in motion

Radioactivity: spontaneous emission of radiation from the nucleus of an unstable atom

Isotope: atoms with the same number of protons, but different number of neutrons

Radioisotope: unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified

Types of Radiation



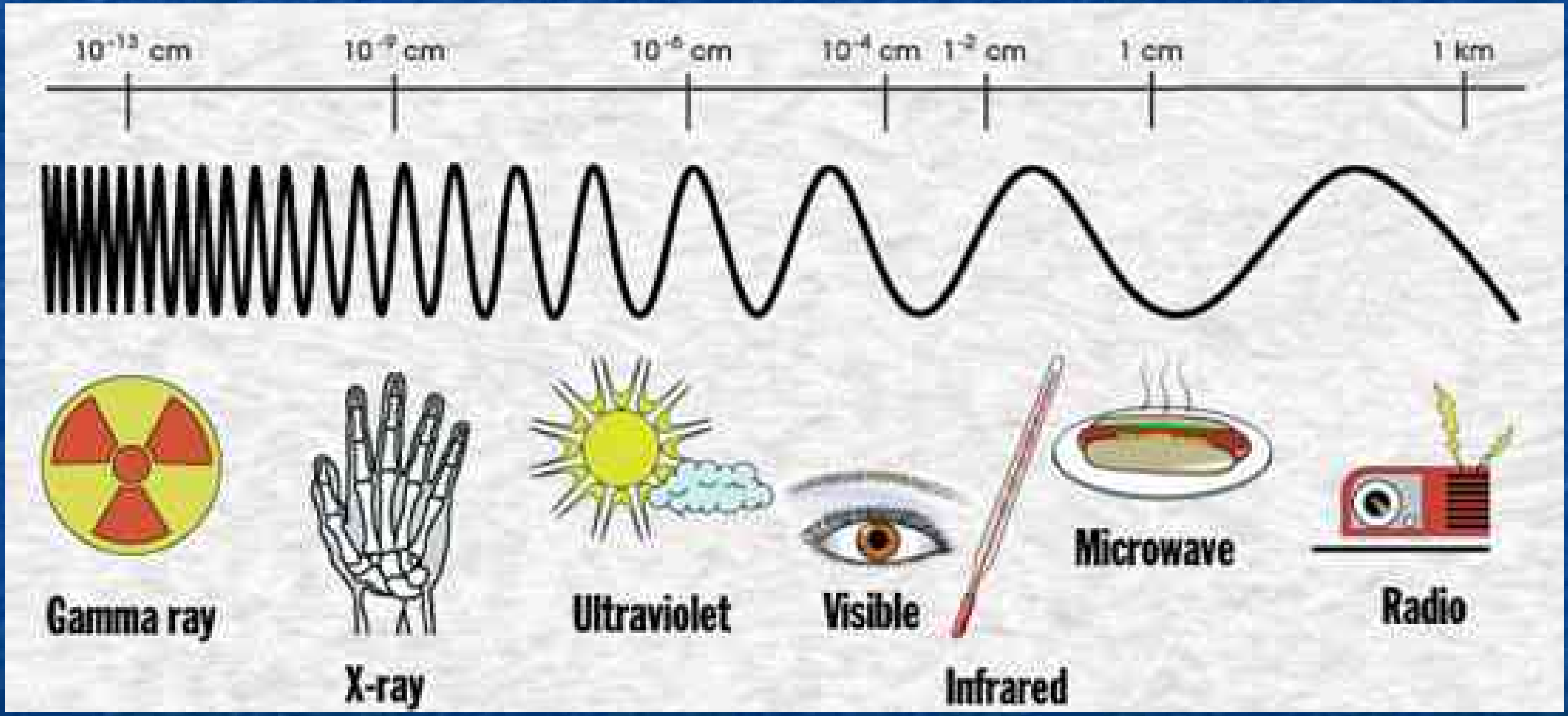
- **<u>Non-Ionizing Radiation</u>**: Radiation that does not have sufficient energy to dislodge orbital electrons.

Examples of non-ionizing radiation: microwaves, ultraviolet light, lasers, radio waves, infrared light, and radar.

- **<u>Ionizing Radiation</u>**: Radiation that has sufficient energy to dislodge orbital electrons.

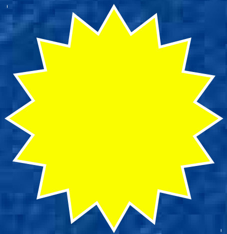
Examples of ionizing radiation: alpha particles, beta particles, neutrons, gamma rays, and x-rays.

Radiation Spectrum

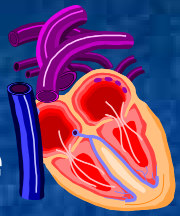


RADIOACTIVE SOURCES

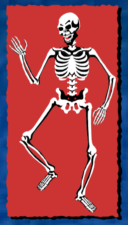
Solar Radiation



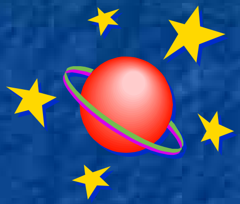
Nuclear Medicine



X-Rays



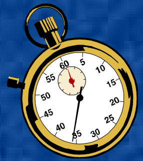
Cosmic Rays



Radon

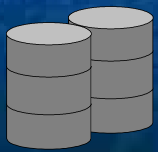
$^{4}_{2}\alpha^{++}$

Consumer Products



Each Other

Radioactive Waste



Terrestrial Radiation

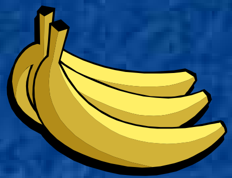
Food & Drink

Nuclear Power

Terrestrial Radiation

Terrestrial radiation comes from radioactivity emitting from *Primordial radio nuclides* - these are radio nuclides left over from when the earth was created.

- Common radionuclides created during formation of earth:
  - Radioactive Potassium (K-40) found in bananas, throughout the human body, in plant fertilizer and anywhere else stable potassium exists.
  - Radioactive Rubidium (Rb-87) is found in brazil nuts among other things.



Terrestrial Radiation

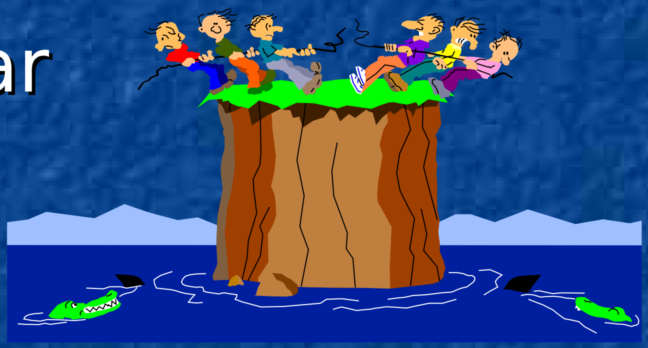
$^{4}_{2}\alpha^{++}$

- Greatest contributor is ^{226}Ra (Radium) with significant levels also from ^{238}U, ^{232}Th, and ^{40}K.
  - Igneous rock contains the highest concentration followed by sedimentary, sandstone and limestone.
  - Fly ash from coal burning plants contains more radiation than that of nuclear or oil-fired plants.

Let’s Compare Backgrounds

- Sea level - 30 mrem/year

  from cosmic radiation



- 10,000 ft. altitude - 140 mrem/year

  from cosmic radiation

Consumer Products and Radioactive Material

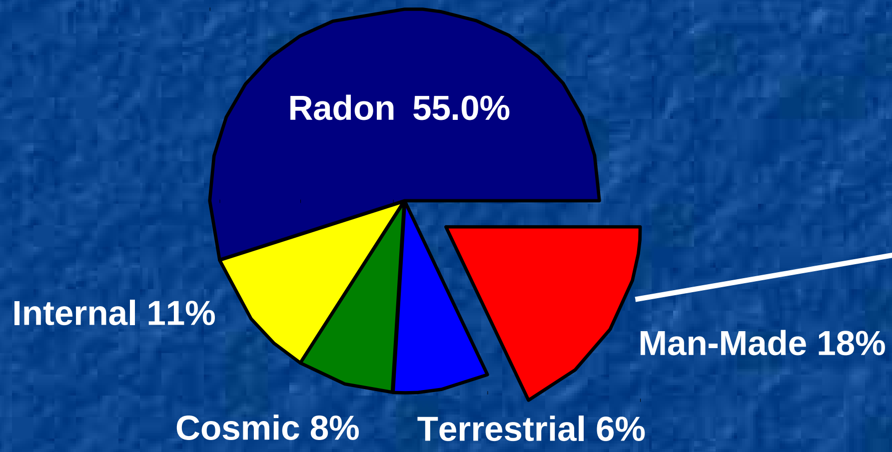
- There are more sources of radiation in the consumer product category than in any other.
  - Television sets - low energy x-rays.
  - Smoke detectors
  - Some more products or services: treatment of agricultural products; long lasting light bulbs; building materials; static eliminators in manufacturing; and luminous dials of watches, clocks and compasses

Annual Dose to the General Population From Natural and Man-made Sources

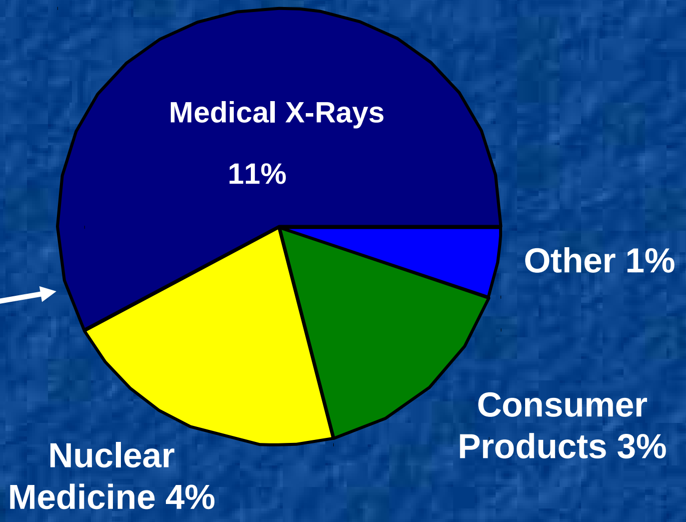
Radiation Source	Effective Dose Equivalent (mrem/year)	Percentage of Total
Natural		
Cosmic	27	8%
Cosmogenic	1	-
Terrestrial	28	8%
Inhaled (due to radon)	200	55%
In the Body	39	11%
Subtotal	295	82%
Man-made		
Medical X-rays	39	11%
Nuclear Medicine	14	4%
Consumer Products	10	3%
Others	<1	-
Subtotal	64	18%
Rounded Total	360	100%

Annual Dose from Background Radiation

Total exposure

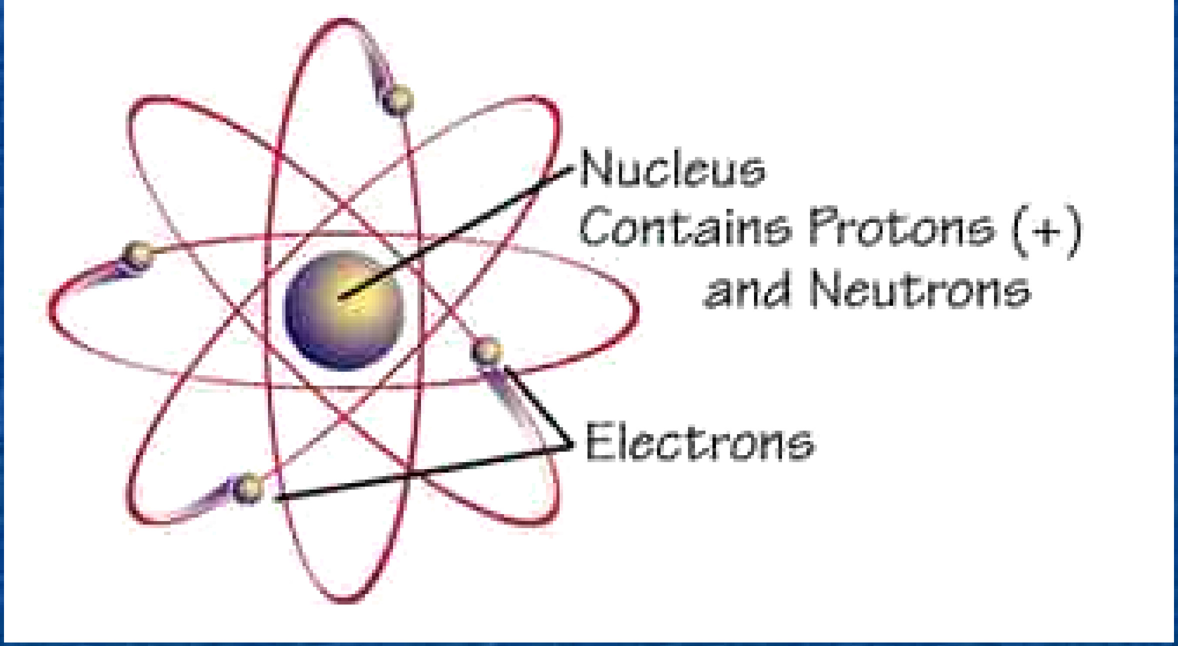


Man-made sources



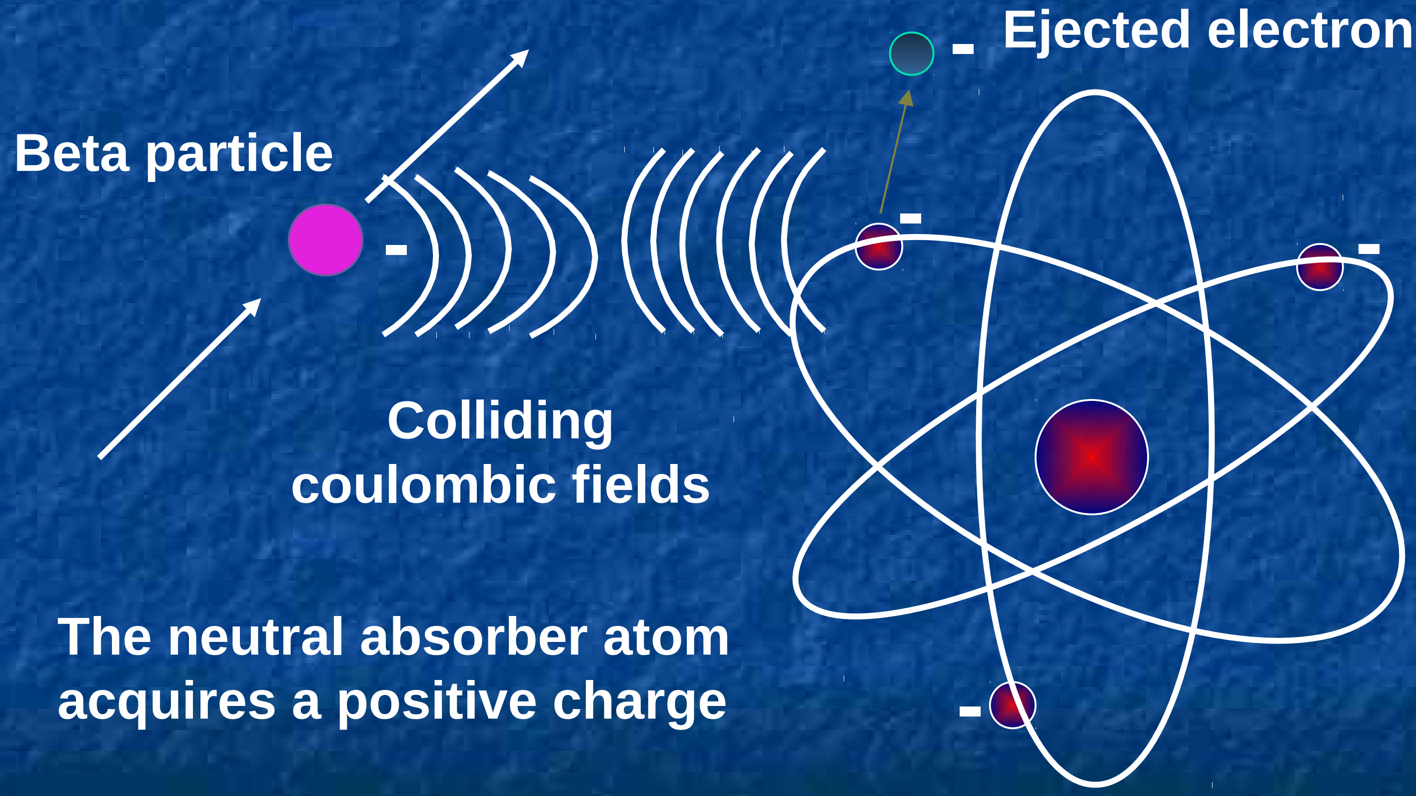
Total US average dose equivalent = <u>360 mrem/year</u>

The Anatomy of the Atom



Ionization

Formation of a charged and reactive atom

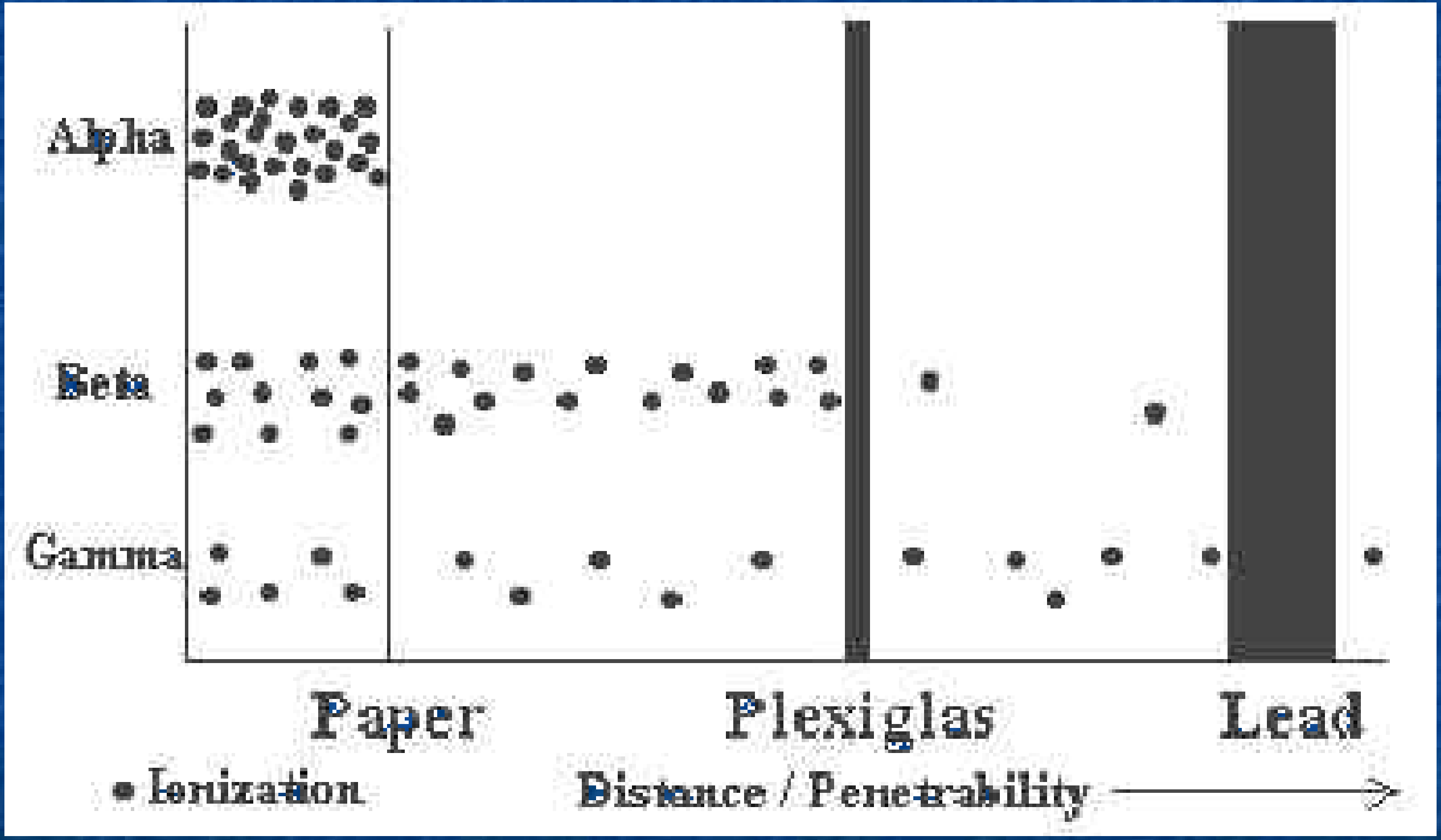


Ionizing radiation

- Occurs from the addition or removal of
  electrons from neutral atoms
- Four main types of ionizing radiation
  - alpha, beta, gamma and neutrons

α	**Alpha**
β	**Beta**
γ	**Gamma (X-ray)**
n	**Neutron**

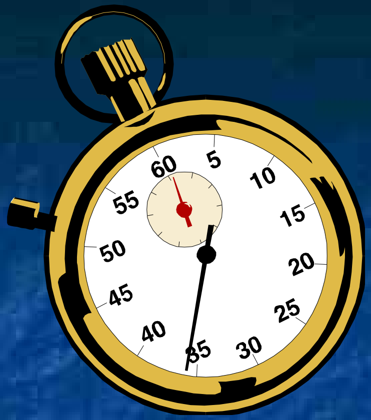
Linear Energy Transfer



ALARA

- **A**s **L**ow **A**s **R**easonably **A**chievable

- How?
  - Time
  - Distance
  - Shielding
- Why?
  - Minimize Dose

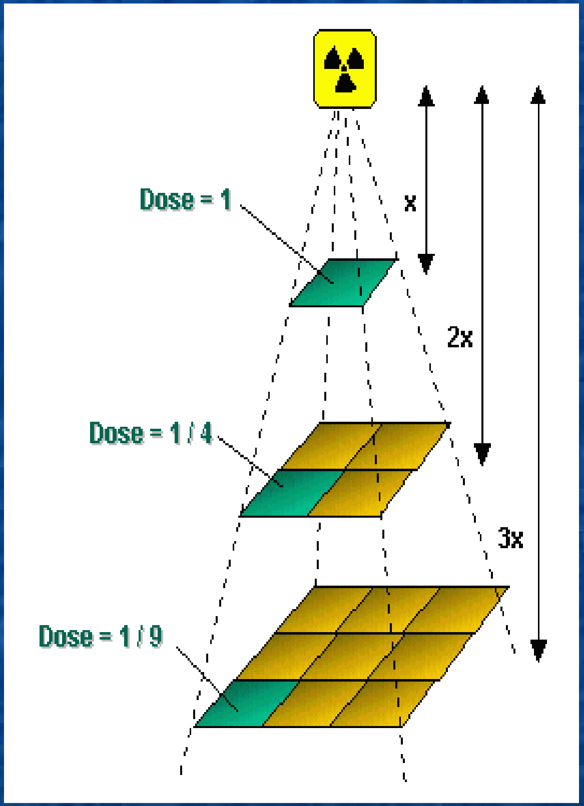


Time

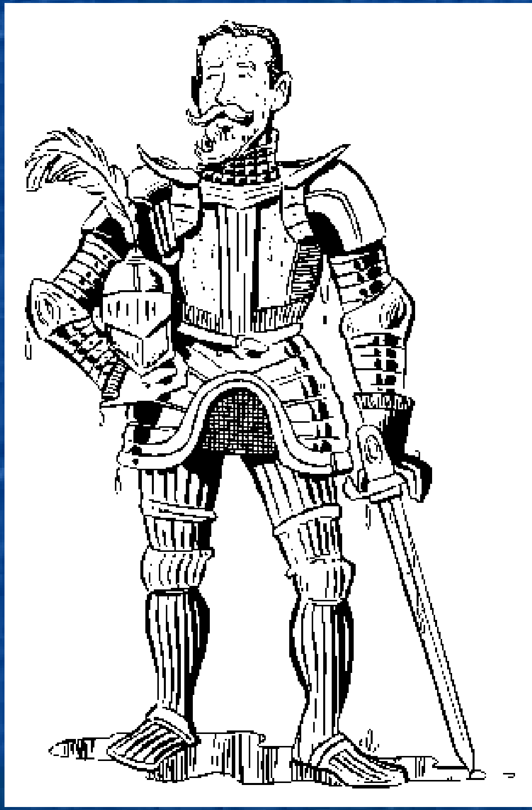
- Less time = Less radiation exposure
- Use RAM only when necessary
- Dry runs (without radioactive material)
    - Identify portions of the experiment that can be altered in order to decrease exposure times
- Shorten time when near RAM
- Obtaining higher doses in order to get an experiment done quicker is NOT "reasonable"!

Distance

- Effective & Easy
- Inverse Square Law
  - Doubling distance from source, decreases dose by factor of four
  - Tripling it decreases dose nine-fold
- More Distance = Less Radiation Exposure
- Tongs, Tweezers, Pipettes, Pliers

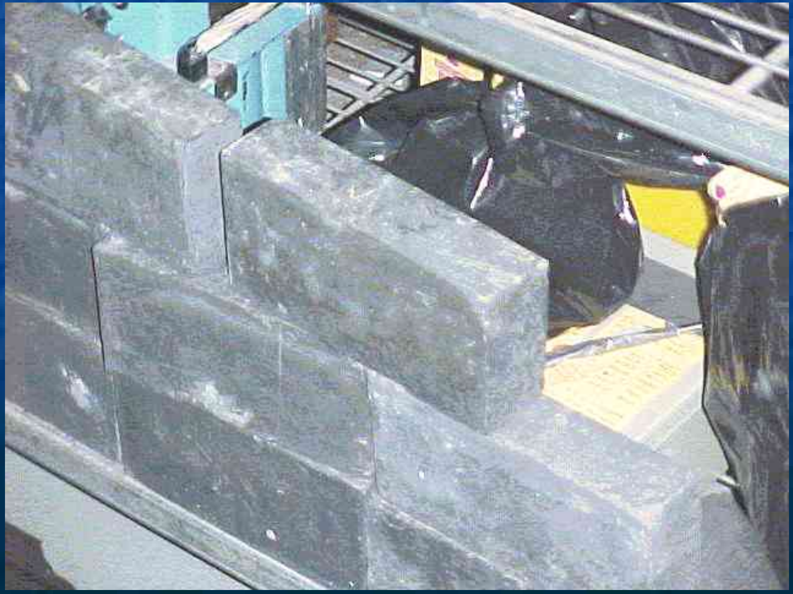


Shielding



- Materials “absorb” radiation
- Proper shielding = Less Radiation Exposure
- Plexiglass vs. Lead

Shielding Examples



Radiation Shielding

- Shielding used where appropriate
- Significantly reduces radiation effects

Plexiglas

Lead

Radiation Postings

- Radiation use will be labeled on door, work area & storage area
- The St. John's College Senior Laboratory works with very low levels of radioactive materials in the Millikan Oil Drop experiment and in the Rutherford Scattering experiment
- Safety can check for potential contamination prior to work in a lab that uses radioactive materials
- As a precaution: wear gloves, safety glasses and wash hands

Inappropriate Lab Attire

Appropriate Lab Attire

- Eye protection
- Closed toe shoes
- Personnel monitoring
- Gloves

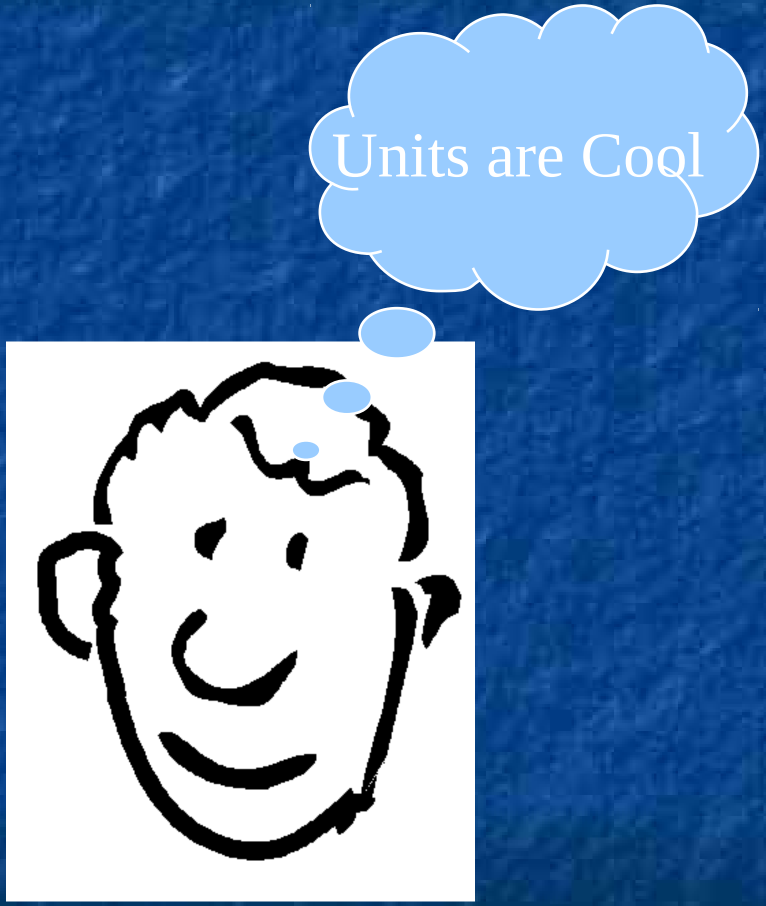
No Food or Drinks During Millikan Oil Drop or Rutherford Scattering Experiments!

What are Laboratory Wipe Tests?

- We take wipes of surfaces (10 cm^2) in the experimental apparatus (both Millikan and Rutherford experiments).
- Run wipes every six months for possible contamination
- Document all information and keep records with the Director of Laboratories and the Radiation Safety Officer

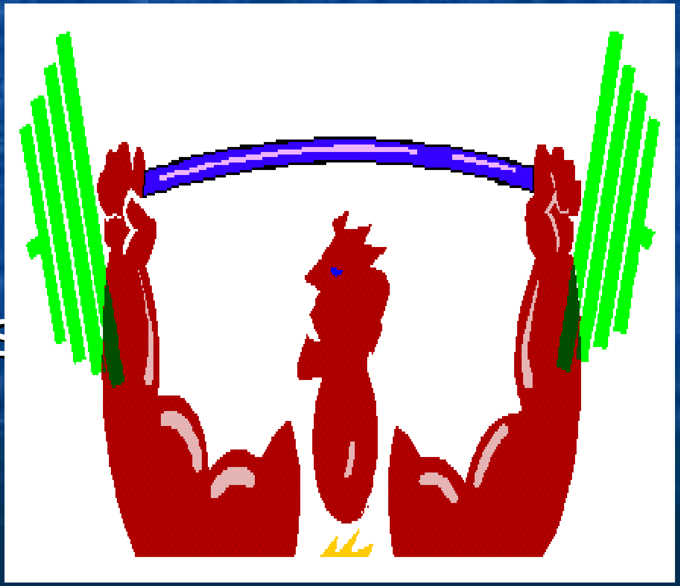
Common Units

- Radioactivity
- Exposure
- Absorbed Dose
- Dose Equivalent



Radioactivity

- Rate of Decay / Potential to Decay
- “Strength”
- Curie (Ci) - 1 gram of radium disintegrates
- 3.7×10^{10} disintegration/ second (dps)
- Becquerel (Bq)
  - = 1 disintegration/second (dps)
- 1 mCi = 37 MBq

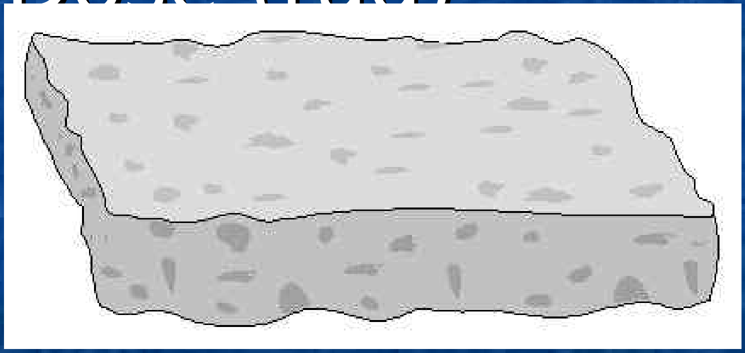


Exposure

- Radioactivity is measured in Roentgens (R) or milliRoentgens
- Charge produced in air from ionization by gamma and x-rays
  - ONLY for photons in air
  - Rather infrequently used unit
- A measure of what is emitted

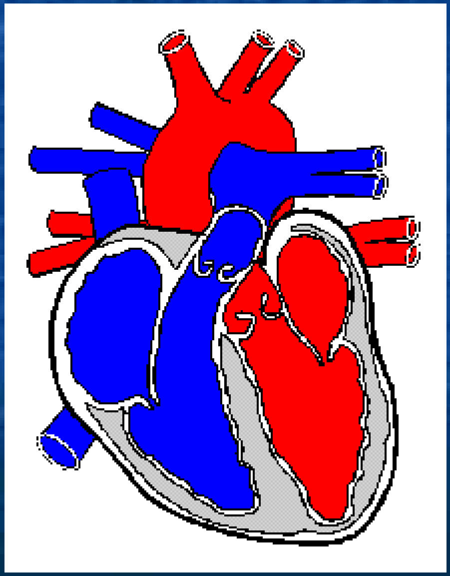
Absorbed Dose

- Energy deposited by any form of ionizing radiation in a unit mass of material
- Roentgen Absorbed Dose (rad)
- Gray (Gy)
- 1 Gy = 100 rad



Dose Equivalent

- Scale for equating relative hazards of various types of ionization in terms of equivalent risk
- Damage in tissue measured in <u>rem</u>
  - (Roentgen Equivalent Man)
- Q:risk of biological injury
- rem = Q * rad
- Sievert (Sv)
- 1 Sv = 100 rem



What do we really need to know?

- 1 R ≈ 1 rad = 1 rem
  - For gammas & betas*
- 1 rad ≠ 1 rem
  - For alphas, neutrons & protons
  - 1 rem = 1 rad * Q

And why do we want to know it?

- Dosage and dosimetry are measured and reported in rems. We have no measurable dosage for individuals using our experimental apparatus.

- All the Federal and State regulations are written in rems.

- The regulators must be placated with reports in rems.

Annual Radiation Exposure Limits

Occupationally Exposed Worker:

	rem	mrem
Whole body	5	5000
Eye	15	15,000
Shallow	50	50,000
Minor	0.5	500
Pregnant Worker	0.5*	500*

*9 months

General Public: 100 mrem/year or 2mrem/hour

Why Establish Occupational Exposure Limits?

- We want to eliminate ability of non-stochastic effects (Acute) to occur
  - Example: Skin Reddening
- We want to reduce the probability of the occurrence of stochastic effects (Chronic) to same level as other occupations
  - Example: Leukemia

- Established from Accident Data

Whole Body

- Total Effective Dose Equivalent (TEDE)
- TEDE = Internal + External
- Assume Internal Contribution Zero
  - Unless Ingestion, Absorption or Inhalation Suspected
- Limit = 5 rem / yr

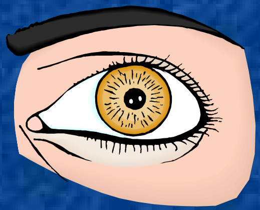
How to Ensure Compliance to Radiation Exposure Limits

- Use the established activity limit for each isotope
- Compare with similar situations
- Estimate with meter
- Calculate
  - Time, Distance, Shielding, Type, Energy, Geometry
- Measure
  - TLD Chip, Luxel
  - Bioassay

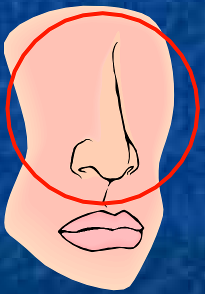
Who should wear radiation dosimeters or badges?

- Those “likely” to exceed 10% of their annual limit are required
- Those who would like a badge
- Minors & Declared Pregnant Workers*

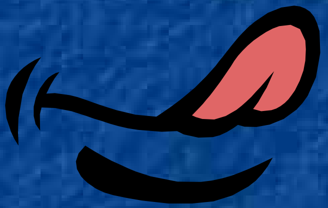
Detection of Radiation? Usually invisible, odorless, and tasteless



The Human Eye

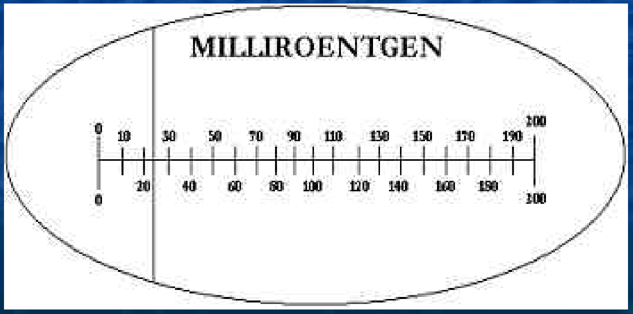


The Nose



Radiation Detectors

- General Classes of Detectors
  - Gas-Filled Detectors
  - Solid Detectors
  - Liquid Detectors



Gas-Filled Detectors

- Proportional Counter
- Ion Chambers
- Geiger-Mueller Counters – used in the SJC Senior Lab

- Liquid Scintillation Counter (LSC)

Summary of Biological Effects of Radiation

- Radiation may…
  - Deposit Energy in Body
  - Cause DNA Damage
  - Create Ionizations in Body
    - Leading to Free Radicals
- Which may lead to biological damage

Radiation Effects on Cells

- Radio sensitivity Theory of Bergonie & Tribondeau.
  - Cell are radiosensitive if they :
    - Have a high division rate
    - Have a long dividing future
    - Are of an unspecialized type
      - These are the underlying premise for ALARA

Response to radiation depends on:

- Total dose
- Dose rate
- Radiation quality
- Stage of development at the time of exposure

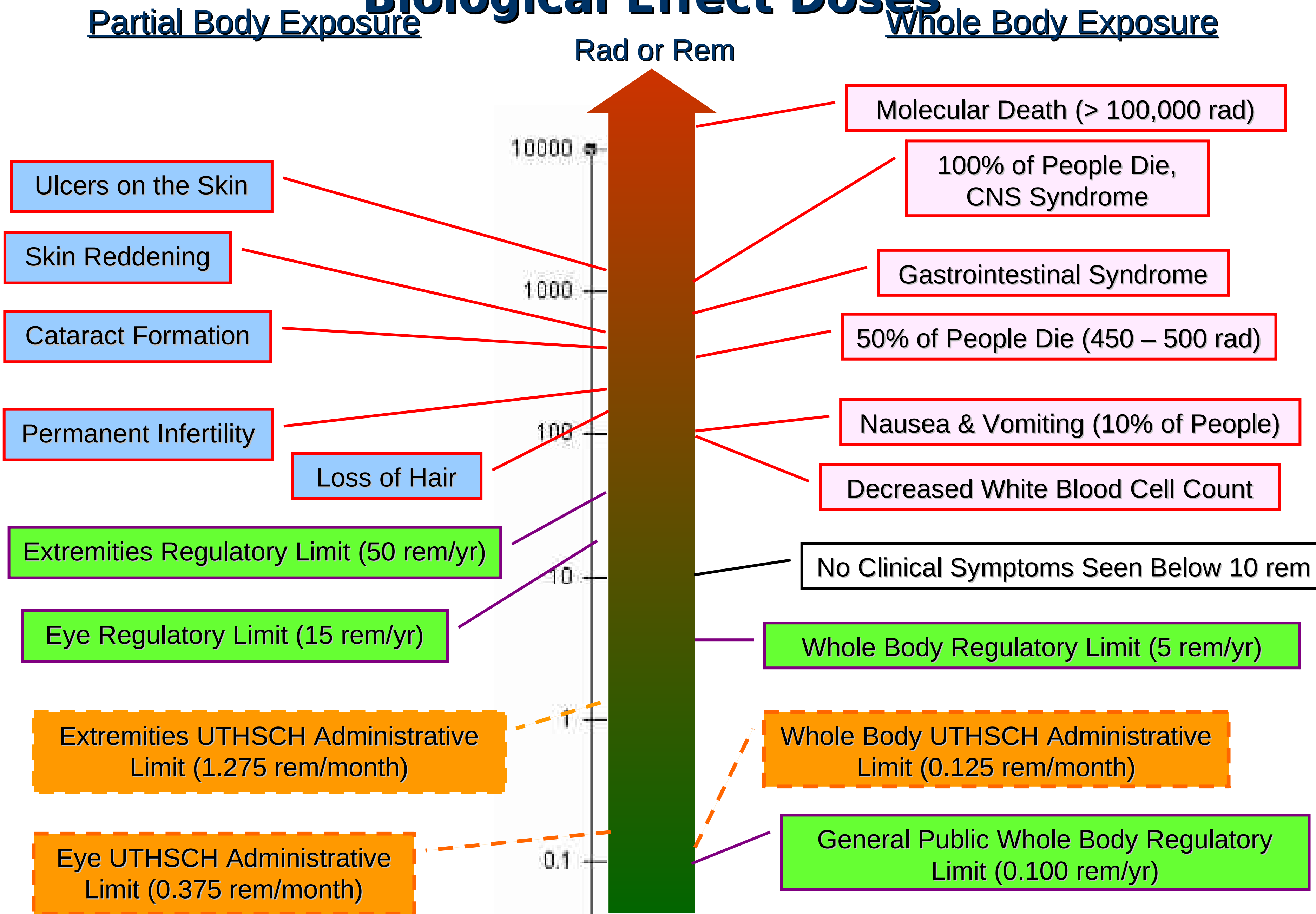
Whole Body Effects

- Acute or Nonstochastic
  - Occur when the radiation dose is large enough to cause extensive biological damage to cells so that large numbers of cells die off.
  - Evident hours to a few months after exposure (Early).
- Late or Stochastic (Delayed)
  - Exhibit themselves over years after acute exposure.
    - Genetic
    - Somatic
    - Teratogenic

Most and Least Radiosensitive Cells

Low Sensitivity	Mature red blood cells Muscle cells Ganglion cells Mature connective tissues
High Sensitivity	Gastric mucosa Mucous membranes Esophageal epithelium Urinary bladder epithelium
Very High Sensitivity	Primitive blood cells Intestinal epithelium Spermatogonia Ovarian follicular cells Lymphocytes

Comparison of Administrative, Regulatory and Biological Effect Doses



Medical Treatment

- External Decontamination
  - Mild cleaning solution applied to intact skin
    - Betadine, Soap, Rad-Con for hands
  - Never use harsh abrasive or steel wool

- Internal Decontamination
  - Treatment which enhances excretion of radionuclides

Contact:

- Director of Laboratories, Mr. Mark
- Daly (410 295 6911),

- Radiation Safety Officer,
- Dr. J.H. Beall (410 295 6915),
- or
- Health Center (410 626 2553)

with any concerns or questions.