SAND2008-2819P

# Eldorado High School Presentation – May 7 and 8, 2008 prepared by

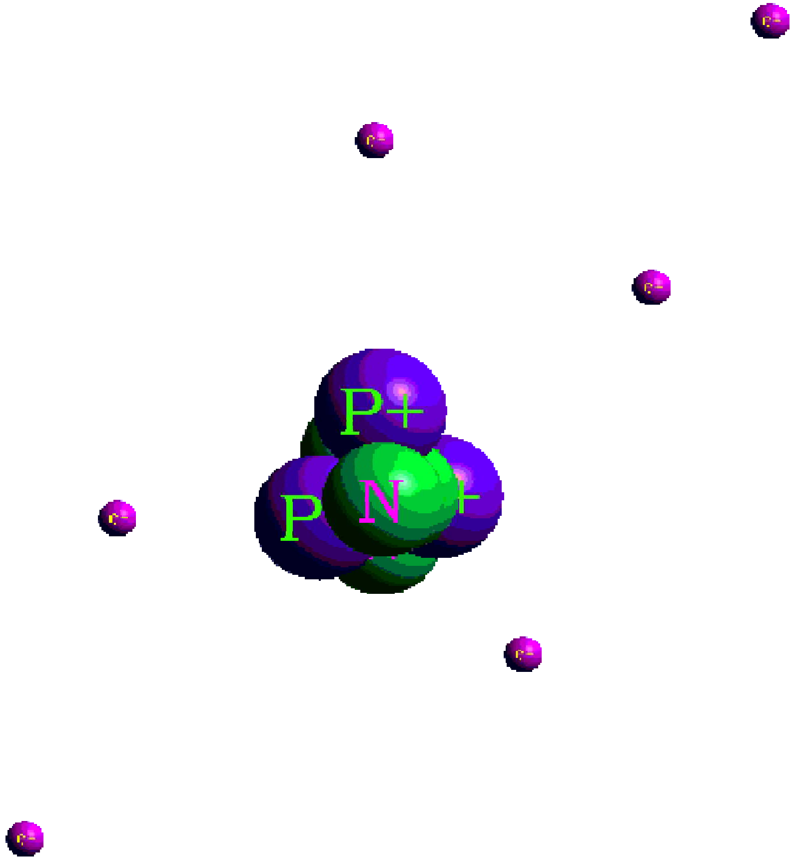
Bob Miltenberger, CHP
Cynthia Kajder

# Atomic Structure

Protons (positive) 

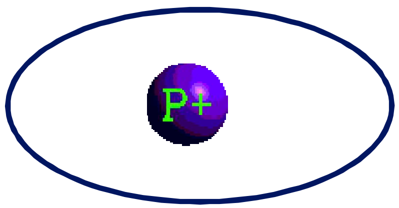

Neutrons (neutral) 


Electrons (negative) 

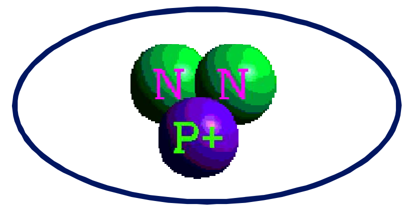



# Stable vs. Unstable Atoms

If there are too many or too few neutrons for a given number of protons, the nucleus will not be stable




hydrogen
(protium)



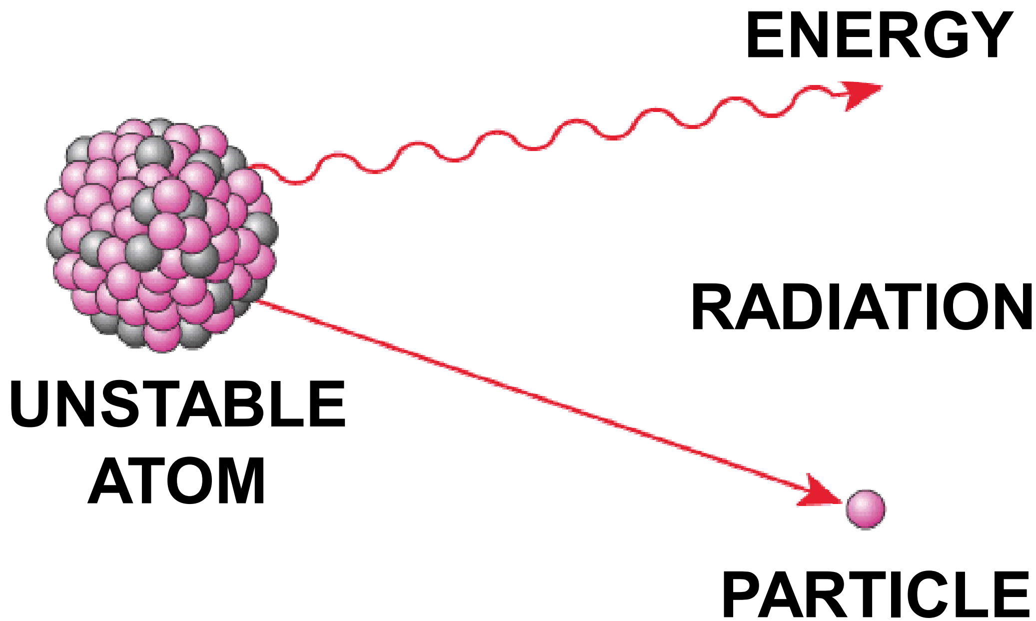

hydrogen
(tritium)

STABLE
"Non-Radioactive"

UNSTABLE
"Radioactive"

# Radiation

- **<u>Energy</u>** released from unstable atoms and some devices in the form of rays or particles
- Can be either <u>ionizing</u> or <u>non-ionizing</u>



# Non-Ionizing Radiation

- Radiation that does *<u>not</u>* have enough energy to ionize atoms with which it interacts
- Examples:

  - radio waves

  - infrared radiation

  - visible light

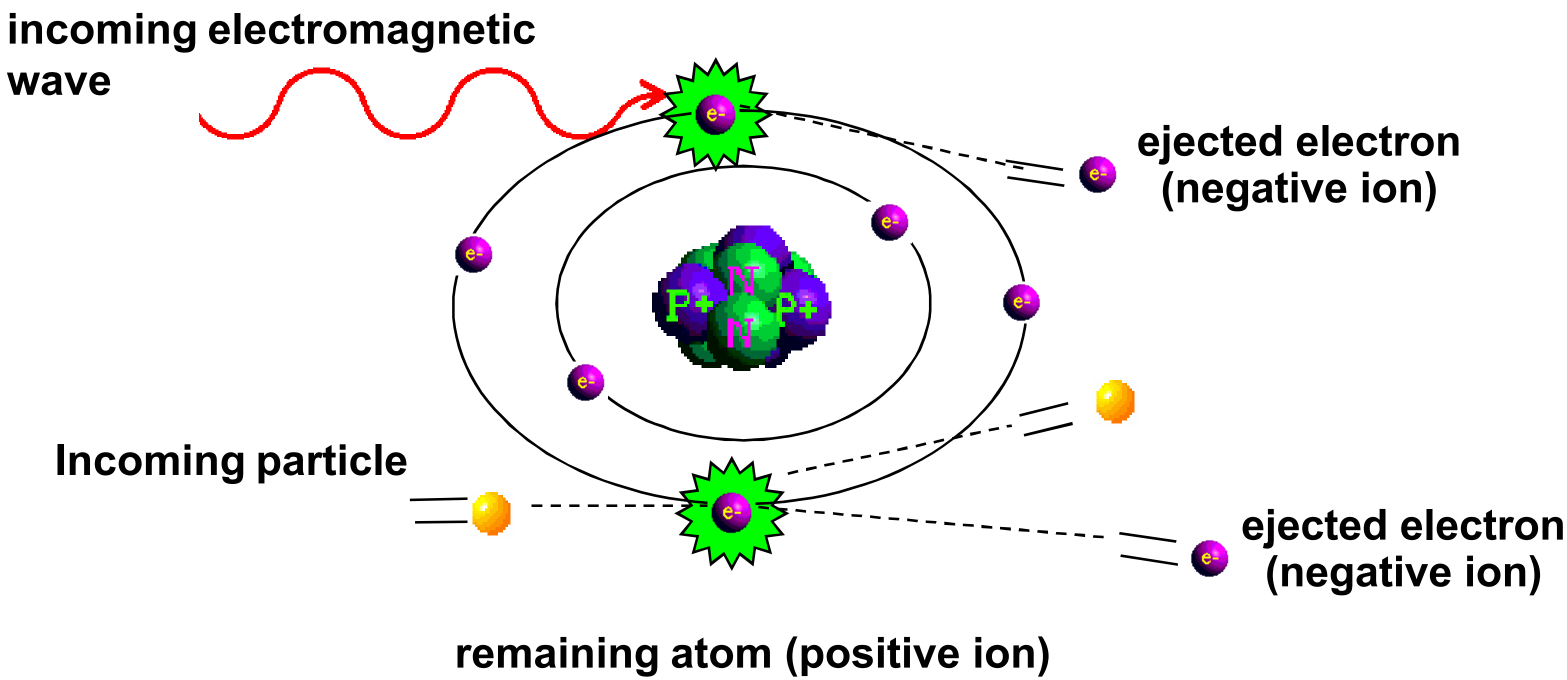
  - radar waves

  - microwaves




# Ionization

The **process** of removing electrons from neutral atoms

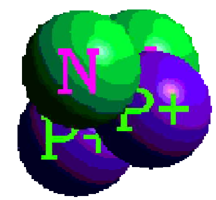


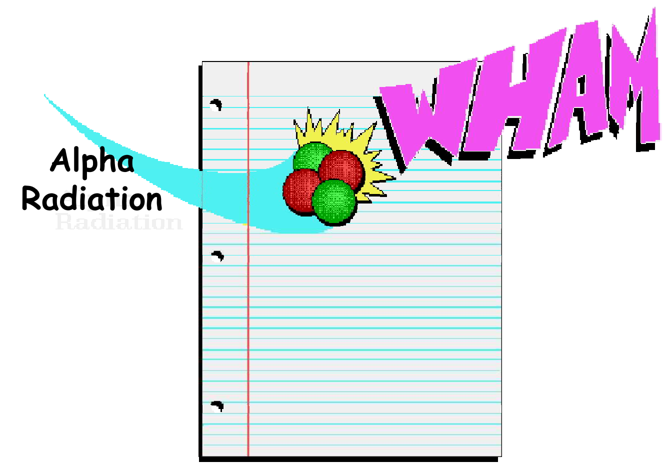
# Ionizing Radiation

- Radiation that possesses enough energy to cause ionization in the atoms with which it interacts
- Released from unstable atoms and some devices in the form of rays or particles
  - alpha $\alpha$
  - beta $\beta$
  - gamma/x-ray $\gamma$
  - neutron $\eta$

# Alpha Radiation (α)

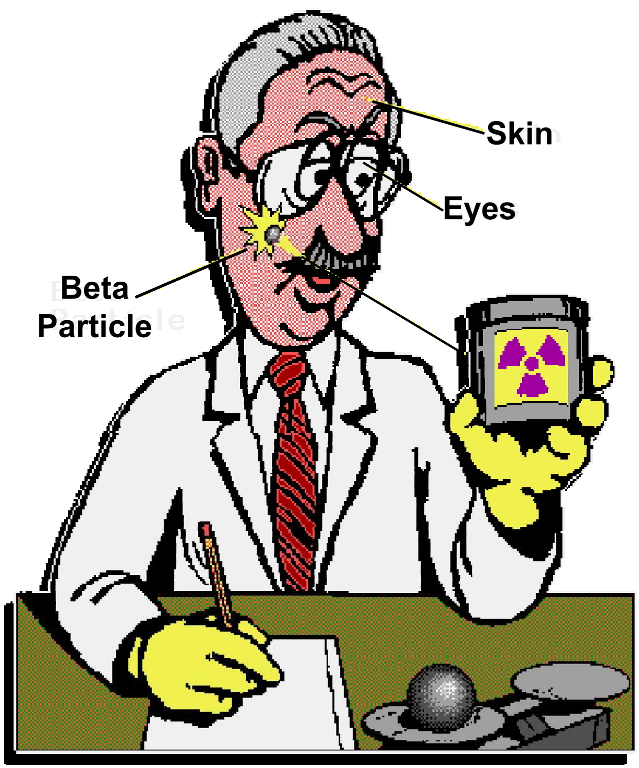
| | |
|---|---|
| Characteristics | Particle, Large Mass, +2 Charge |
| Range | Very Short<br>1 - 2” in air |
| Shielding | Paper<br>Outer layer of skin |
| Hazards | Internal |



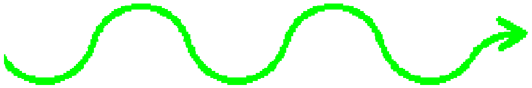
# Beta Radiation (β)

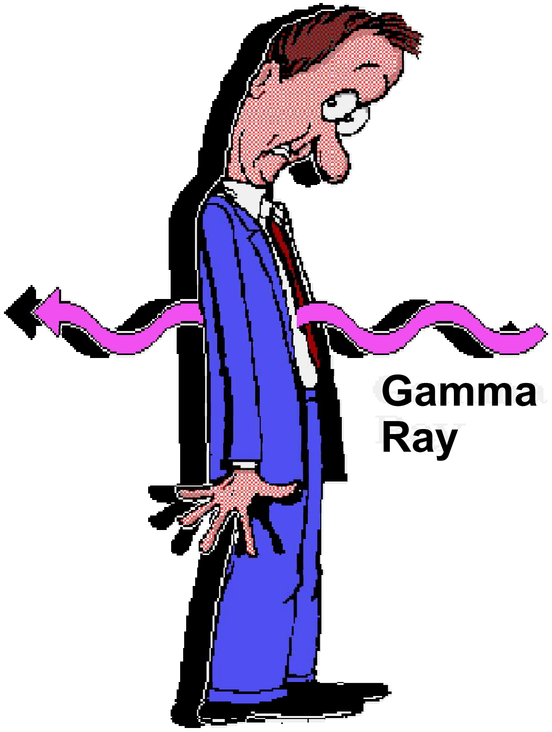
| | |
|---|---|
| Characteristics | Particle, Small Mass, -1 Charge |
| Range | 12ft / MeV in air |
| Shielding | Plastic, glass, aluminum, wood |
| Hazards | Internal and the skin and eyes |

# Gamma Rays ($\gamma$) and X-Rays

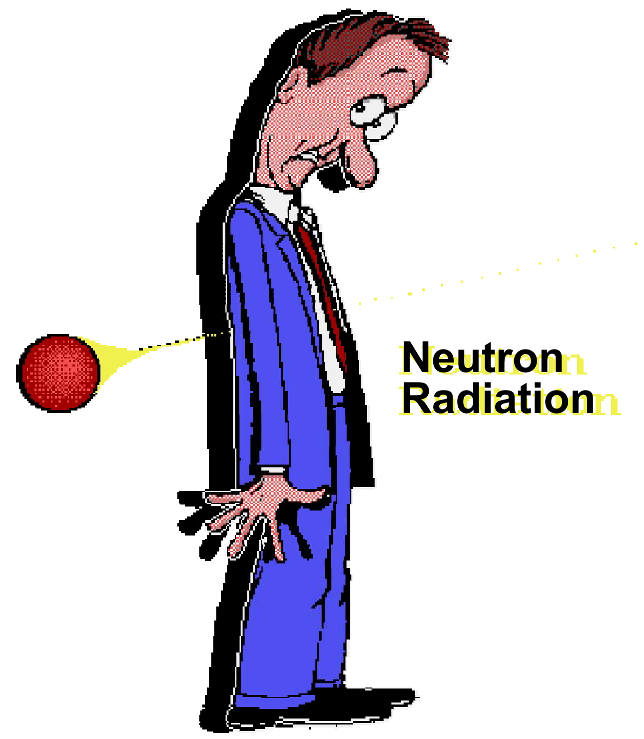
| | |
|---|---|
| Characteristics | No mass, no charge electromagnetic |
| Range | Hundreds of feet in air |
| Shielding | Lead, Steel Concrete |
| Hazards | External Source Whole Body Penetrating |





# Neutron Radiation (η)

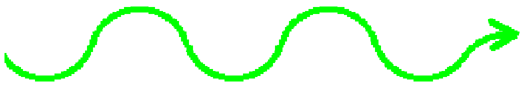
| | |
|---|---|
| Characteristics | Particle with no charge |
| Range | Hundreds of feet in air |
| Shielding | Hydrogenous material - water, polyethylene |
| Hazards | External Source Whole Body Penetrating |

# Units of Measure

- **Radiation ⟶ Energy**

  Roentgen, RAD, REM

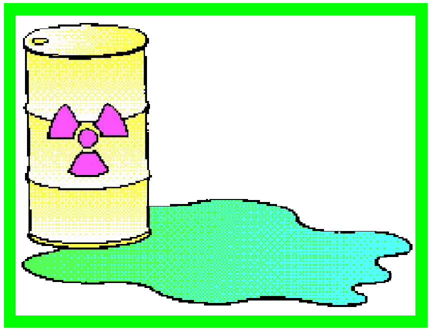


- **Radioactivity ⟶ Rate**

  dpm, Curie


- **Contamination ⟶ Spread**

  $\frac{\text{Radioactivity}}{\text{Area or volume}}$



# Roentgen (R)

- Unit for measuring exposure
- Defined only for ionization in air
- Applies only to gamma and x-rays
- Not related to biological effects

**Wilhelm Roentgen**
**1845 -1923**
**Discovered X-rays**

# RAD (Radiation Absorbed Dose)

- Unit for measuring absorbed dose in <u>any material</u>
- Applies to <u>all types of radiation</u>
- Does <u>not</u> take into account the potential effect that different types of radiation have on the body

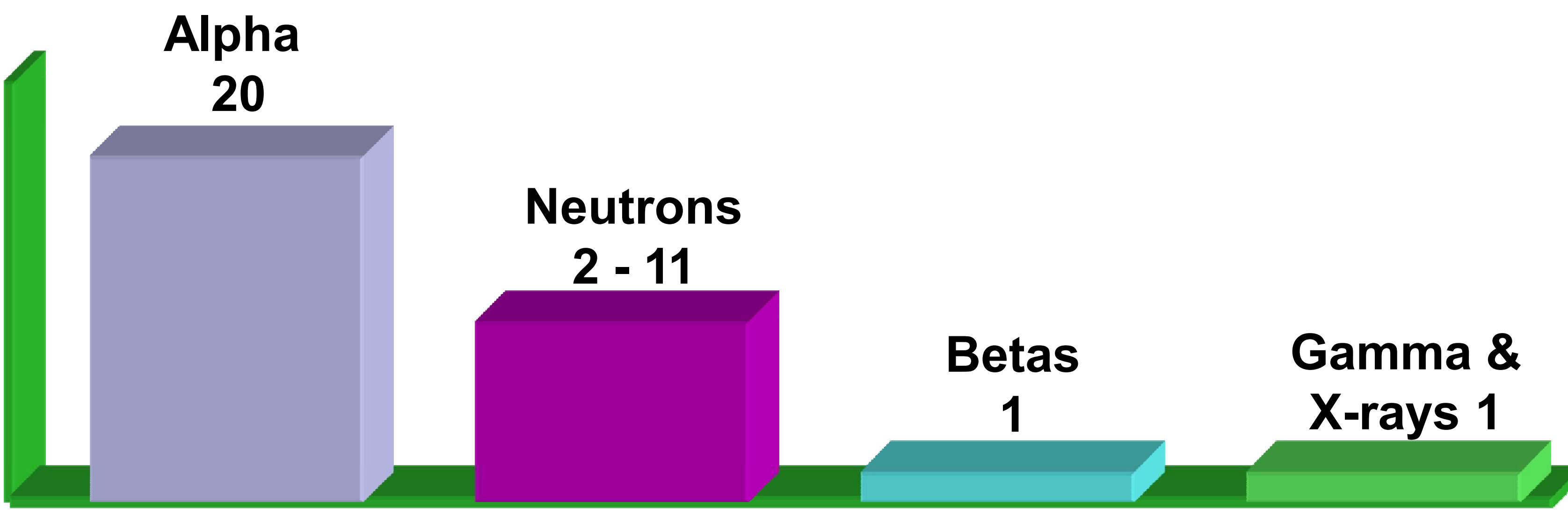
# REM (Roentgen Equivalent Man)

Takes into account the energy absorbed (dose) and the <u>biological effect</u> on the body due to the different types of radiation

# Quality Factor (QF)

The QF is used as a multiplier to reflect the relative amount of biological damage caused by the same amount of energy deposited in cells by the different types of ionizing radiation.

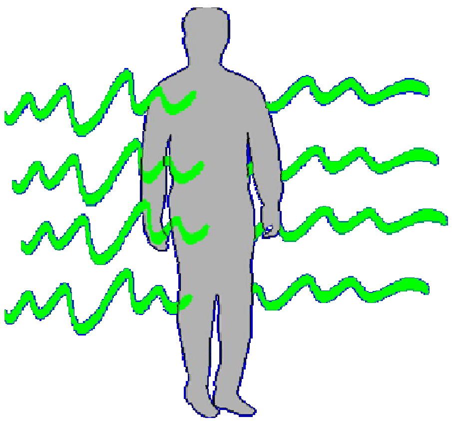
**rad x QF = rem**



# Dose vs. Dose Rate

- <u>Dose rate</u> is the *rate* at which you receive the dose.
- Dose rate = dose divided by time (rem/hr, mrem/hr).
- <u>Dose</u> is the *amount* of radiation you receive.

**Dose = Dose Rate X Time**



200 mrem/hr

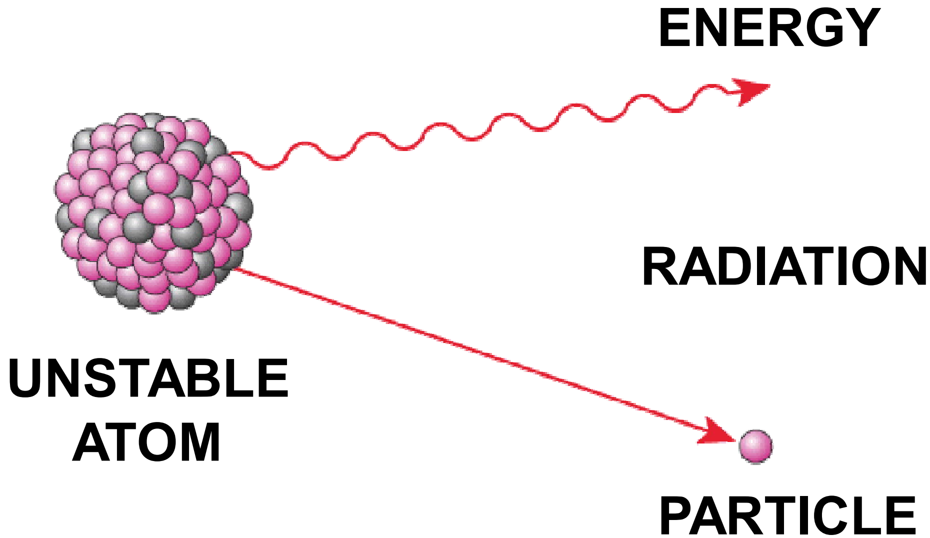
Question: How much dose would this individual receive in 2 hours?

Answer:__________

# Measuring Radioactivity

A measure of the number of disintegrations radioactive material undergoes in a certain period of time.

We measure the rate of decay which will lead us to the <u>quantity</u> of radioactive material present.



# Radioactivity Units

Basic unit

- disintegration per minute (dpm)
- derived from the number of counts measured by instrument and the instrument efficiency

Larger unit

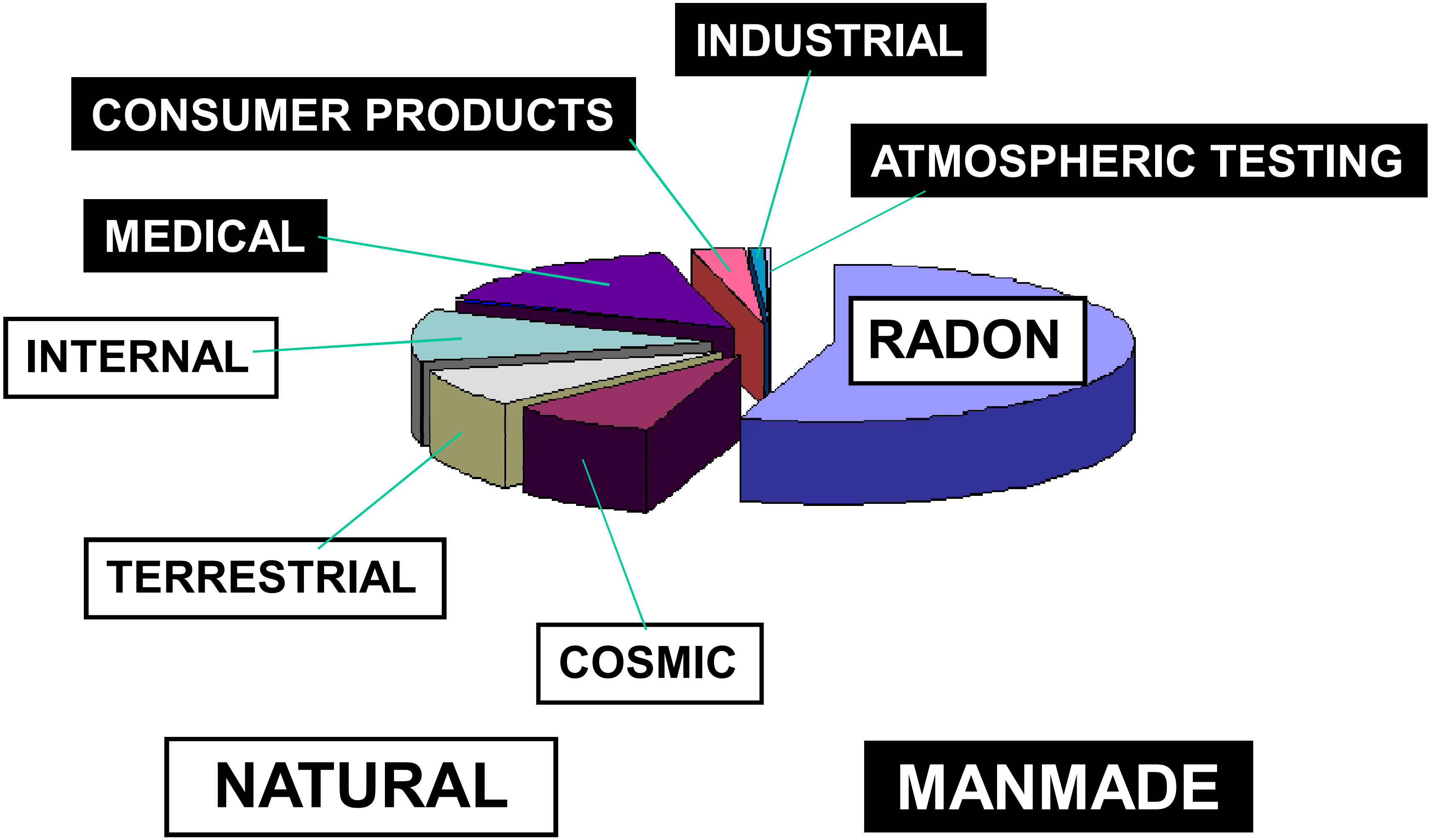
- Curie (Ci)
- 1 Ci = 2.22 x $10^{12}$ dpm
- 1 Ci = 3.70 x $10^{10}$ dps or Bq

**Marie Curie**
**1867 - 1934**
**Discovered**
**radium & polonium**

# Background Sources

- Natural
- Manmade
- U.S. Average

# Background Sources of Ionizing Radiation

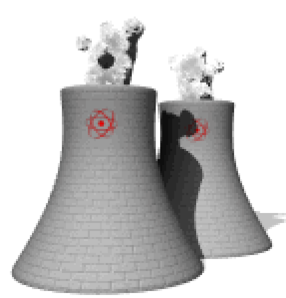


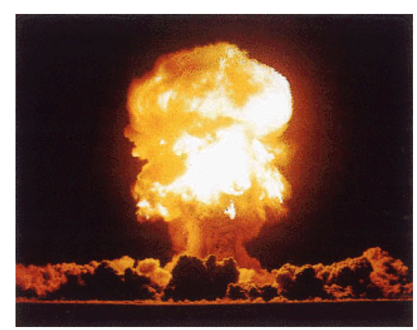
# Natural Background Sources

| SOURCE | AVG DOSE |
|---|---|
| **COSMIC - sun & outer space** | 28 mrem/yr |
| **TERRESTRIAL - Earth's crust** | 28 mrem/yr |
| **INTERNAL - our own bodies** | 40 mrem/yr |
| **RADON - Uranium in the Earth** | 200 mrem/yr |

# Man-Made Radiation Sources

| SOURCE | AVG DOSE |
|---|---|
| **Medical** | 54 mrem/yr |
| **Consumer Products** | 10 mrem/yr |
| **Industrial Uses** | < 3 mrem/yr |
| **Atmospheric Testing** | < 1 mrem/yr |





# Radiation Doses
# - Medical Procedures -

| | |
|---|---|
| **Radiation Therapy** | 600,000 mrem - tumor |
| **CAT Scan** | 5,800 mrem - head<br>1,500 mrem - lower spine |
| **Fluoroscope** | 5,000 mrem/min. - skin |
| **Mammogram** | 400 mrem - breast<br>0.2 mrem (low-dose screen) |
| **Dental X-Ray** | 55 - 65 mrem/shot - mouth |
| **Chest X-Ray** | 10 mrem/shot - chest |

# Radiation Doses
# - Consumer Products -

| PRODUCT | AVG DOSE |
|---|---|
| **Cigarettes (1.5 packs/day)** | 8,000 mrem/yr - lungs |
| **Dental Porcelain** | 60 rem/yr - gums |
| **Tinted Glasses** | 4 rem/yr - eyes |
| **Building Materials** | 7 mrem/yr - whole-body |
| **Radium Dial Watch** | 6 mrem/yr - whole-body |
| **Smoke Detector** | 1 mrem/yr - whole-body |

# U.S. Average

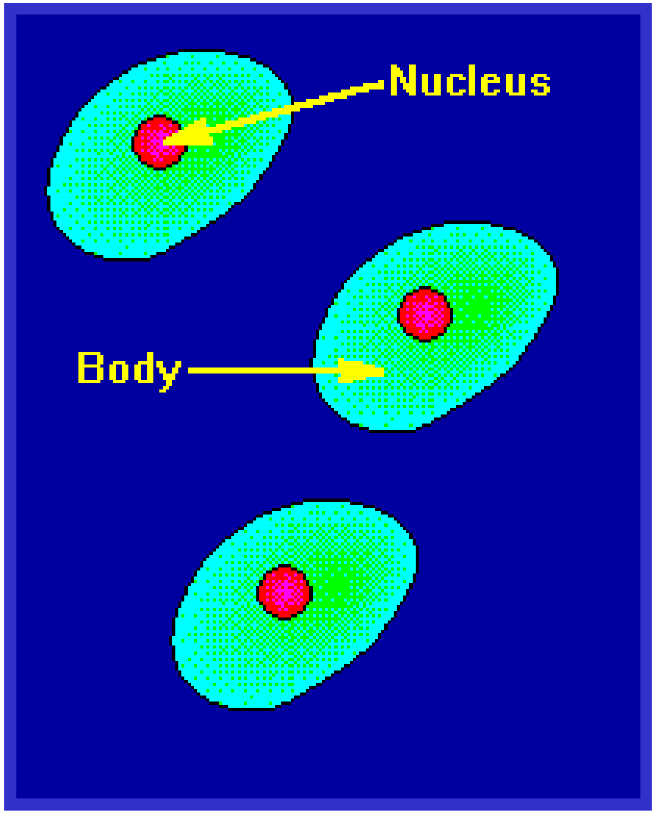
The **U.S. average** for exposure to natural background and man-made sources is approximately **<u>360 mrem</u> per year**.

# Radiation Effects

- **Cell Damage**
- **Cell Sensitivity**
- **Possible Effects on Cells**
- **Radiation Damage Factors**
- **Acute vs. Chronic**
- **Somatic vs. Heritable**

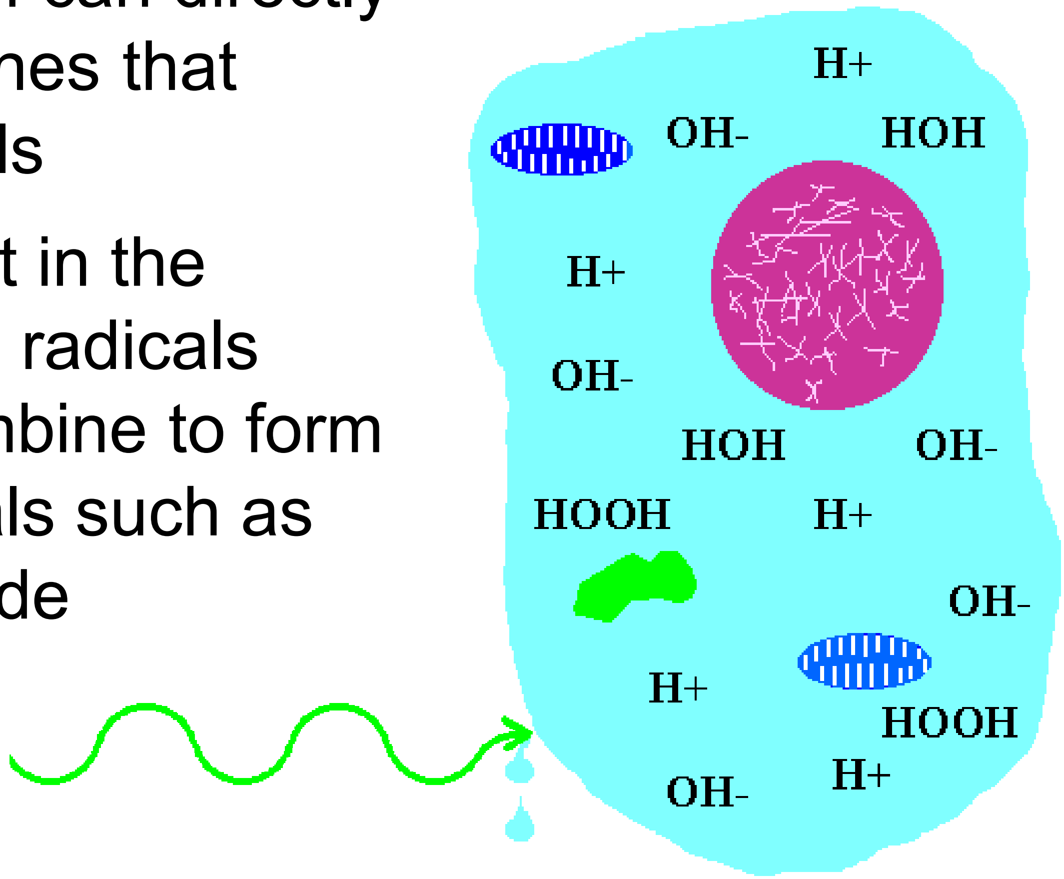
# Cell Damage

The method by which radiation causes damage to human cells is by *ionization of atoms in the cells*. Any potential radiation damage begins with damage to atoms.



# Cell Damage

- Ionizing radiation can directly rupture membranes that surround the cells
- Ionizations result in the formation of free radicals which can recombine to form harmful chemicals such as hydrogen peroxide

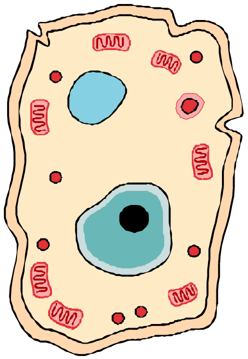


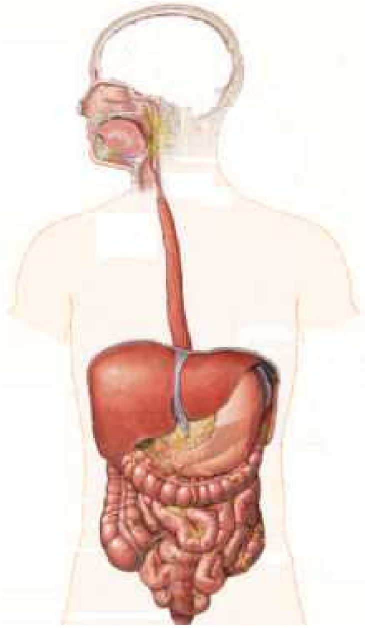
# Highest Sensitivity

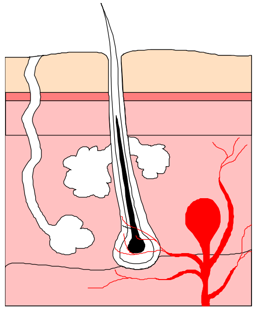
- Actively dividing cells
- Non-specialized cells

**EXAMPLES:**

- Blood forming cells
- Hair follicles
- Cells that form sperm
- Intestinal tract lining



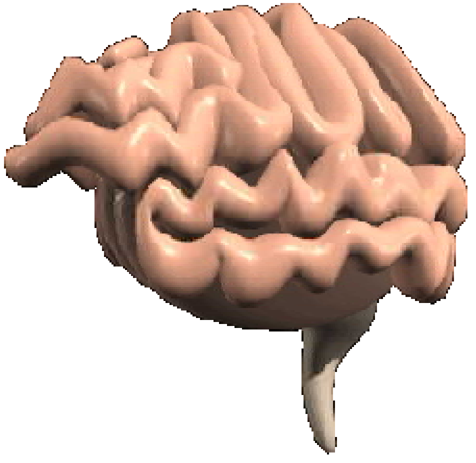


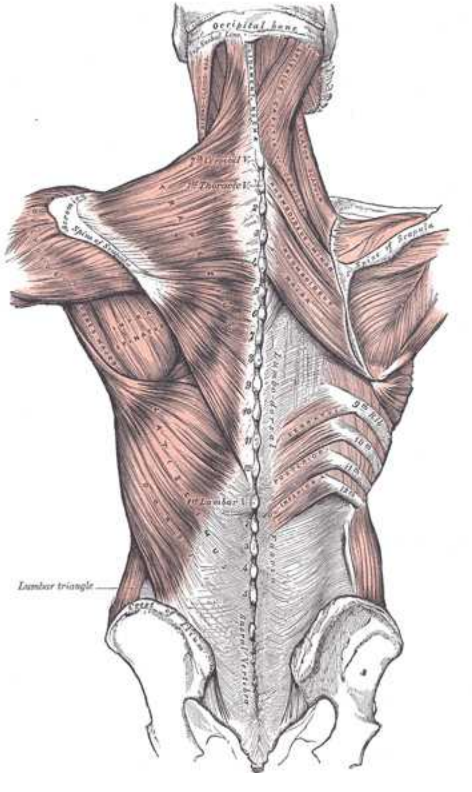


# Lowest Sensitivity

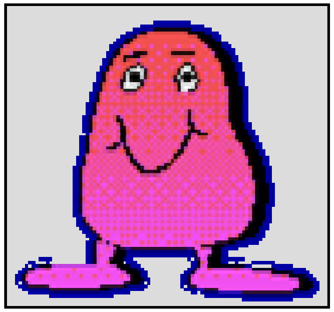
- Less actively dividing cells
- More specialized cells

- Brain cells
- Muscle cells

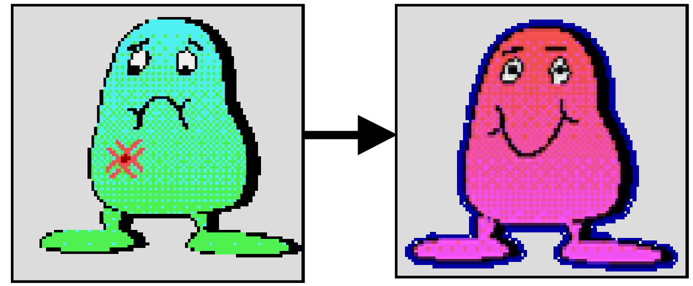




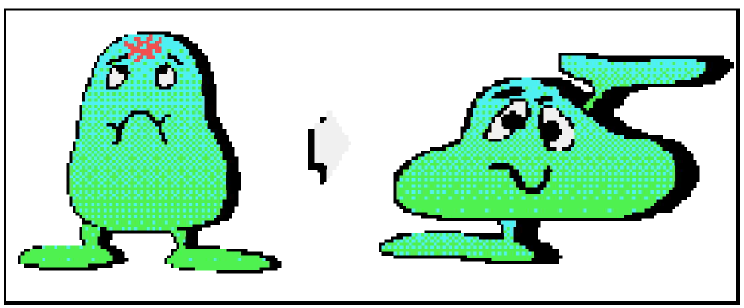
# Possible Effects of Radiation on Cells



There is no damage



Cells repair the damage and operate normally

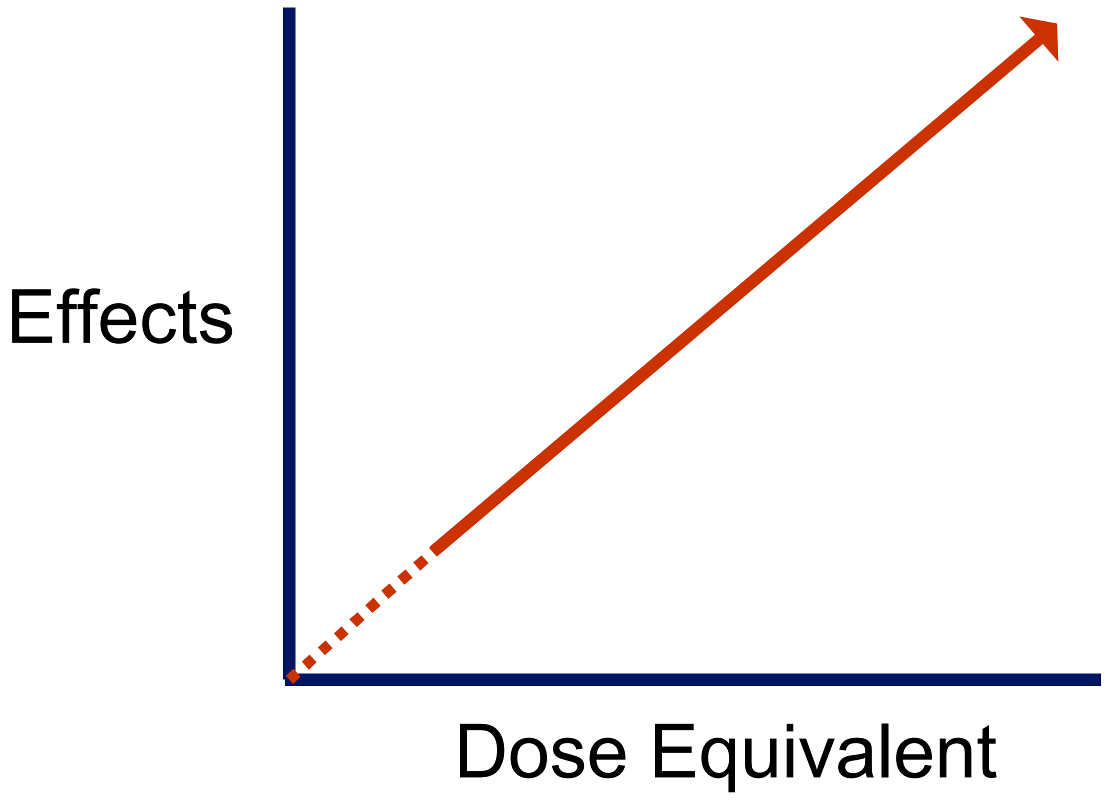


Cells are damaged and operate abnormally


Cells die

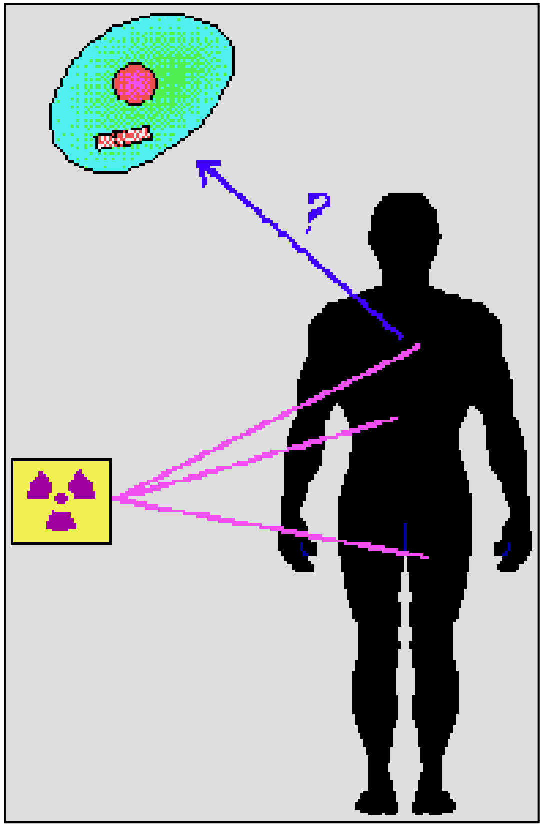
# Total Dose

In general, the greater the dose, the greater the potential for biological effects.



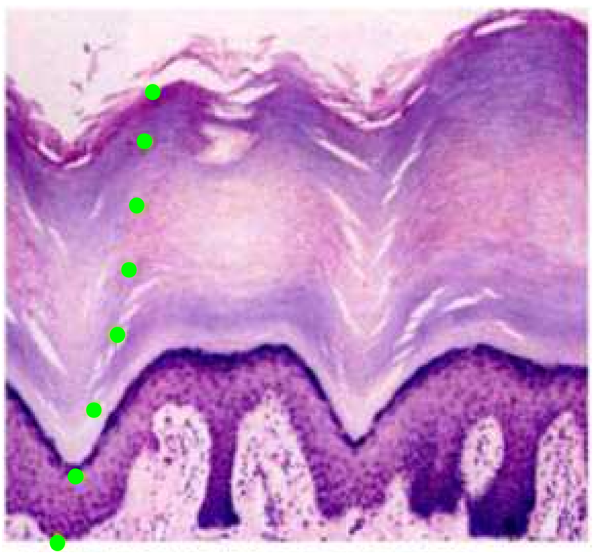
# Dose Rate

The faster the dose is delivered, the less time the body has to repair itself.

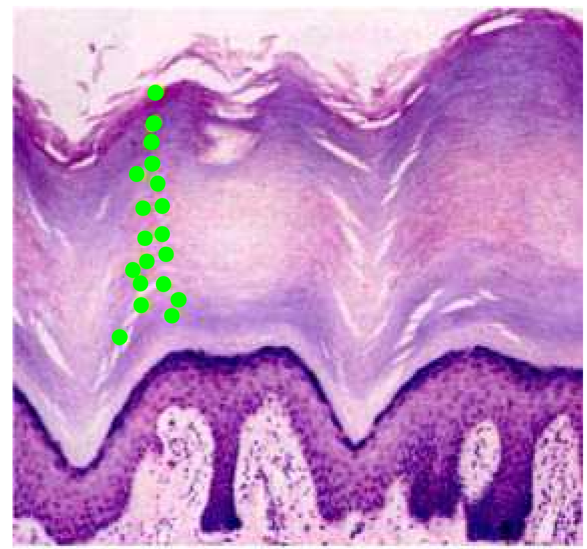


# Type of Radiation

For example, internally deposited alpha emitters are more damaging than x-rays or gamma rays for the same energy deposited.



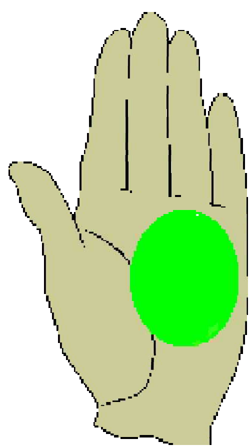
Specific ionization by X-rays or gamma rays



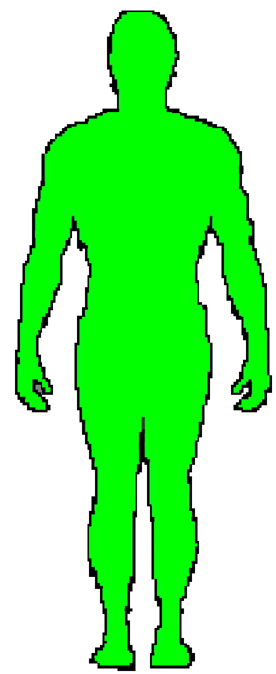
Specific ionization by alpha particles

# Area of Body Exposed

- In general, the larger the area of the body that receives a dose, the greater the biological effect.
- Extremities are less sensitive than blood forming and other critical organs.



vs.



# Individual Sensitivity

- Age

  The human body becomes less sensitive to ionizing radiation with increasing age; however, elderly people are more sensitive than middle-aged adults.

- Genetic make-up

  Some individuals are more sensitive to environmental factors.

# Acute vs. Chronic Dose

Potential biological effects depend on <u>how much and how fast</u> a radiation dose is received.

Radiation doses are grouped into:

- **<u>Acute</u>** - high dose of radiation received in a short period of time (seconds to days)
- **<u>Chronic</u>** - a small dose of radiation received over a long period of time (months to years)

# Acute Exposure Effects

| AVG DOSE | DAMAGE |
|---|---|
| 2 - 5 rem | Annual Limit |
| 25 - 50 rem | Slight Blood Changes |
| 100 - 200 rem | Radiation Sickness |
| 200 - 500 rem | Blood System Damaged |
| 450 - 600 rem | LD 50-60 |
| > 500 rem | Gastrointestinal Damage |
| > 5000 rem | Death Within 2-3 days |

# Effects of High-Level Acute Doses (Skin/Extremities)

Burns (Erythema)

Necrosis

Loss of fingers / limbs

# Chronic Dose

A small dose of radiation received over a long period of time.

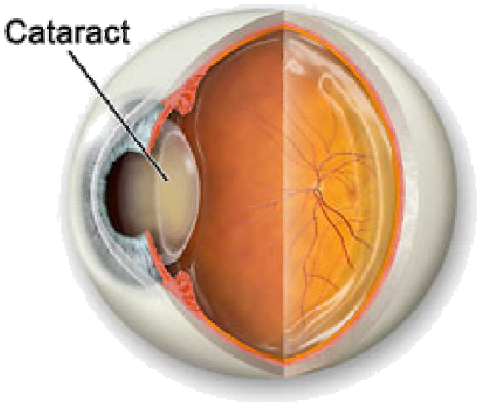
Typical examples are:

- The dose we receive from natural background
- The dose we receive from occupational exposure

Body is better equipped to tolerate chronic doses

# Effects of Chronic Doses

- Increased risk of cataract formation (if over 450 rem)
- Increased risk of developing cancer




# Cancer Risk

- Current rate of cancer death among Americans is about 20%.
- An individual who receives 25,000 millirem over a working life increases his/her risk of cancer by 1% to about 21%.
- The average annual dose to workers in nuclear industry is less than 100 millirem (work in nuclear power workers receive more than average) .

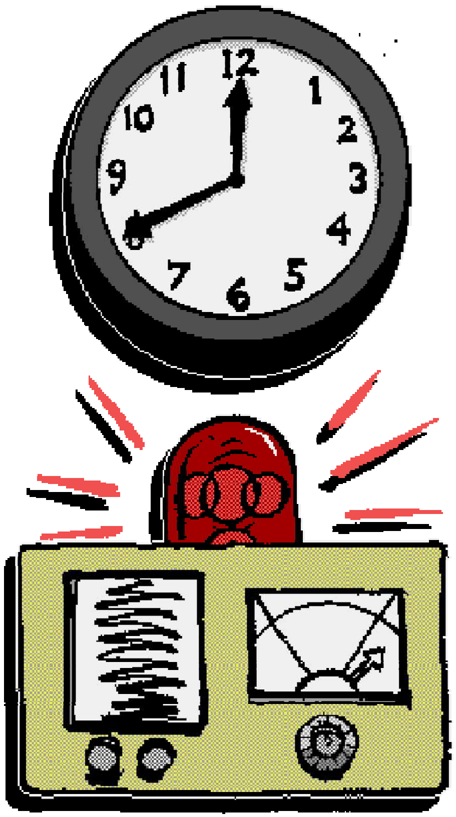
# Comparison of Health Risks

| Health Risk | Days Lost |
|---|---|
| Unmarried Male | 3500 |
| Tobacco User | 2250 |
| Unmarried Female | 1600 |
| Overweight Individual | 777 |
| Alcohol Consumer | 365 |
| Motor Vehicle Driver | 207 |
| **100 mrem/yr for 70 yrs** | **10** |

# Comparison of Occupational Risk

| Industry | Days Lost |
|---|---|
| Coal Miner | 328 |
| Farmer | 277 |
| Transportation Worker | 164 |
| U.S. Average | 74 |
| Manufacturer | 43 |
| **Radiological Worker** | **40** |
| Trades Employee | 30 |

# Radiation Limits

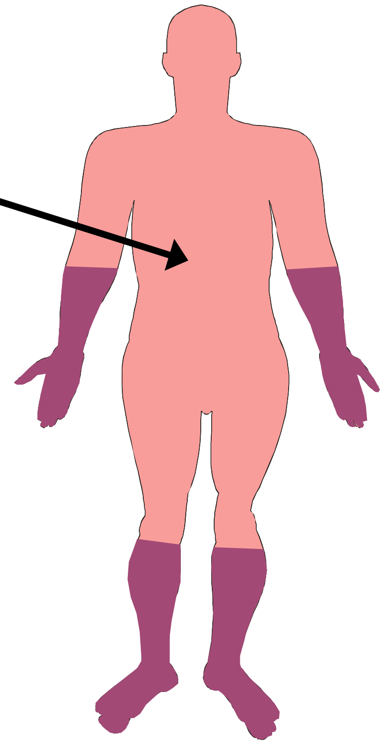



- Basis and Purposes for Dose Limits and Administrative Control Levels
- Dose Limits and Administrative Control Levels
- Worker Responsibilities

# DOE Whole Body Dose Equivalent Limit

“Whole Body”
**5 rem/yr**

ACL
**2 rem/yr**



“The whole body extends from the top of the head down to just below the elbow and just below the knee.”

NOTE: The whole body dose equivalent limit is based on the sum of internal and external dose.

# Members of the Public

Member of the public - An individual who is not a general employee.

Public limited to 100 mrem in a year as a consequence of all routine activities.

# As Low As Reasonably Achievable (ALARA)


Personal radiation exposure shall be maintained As Low As Reasonably Achievable.

Radiation exposure to the work force and public shall be controlled such that:

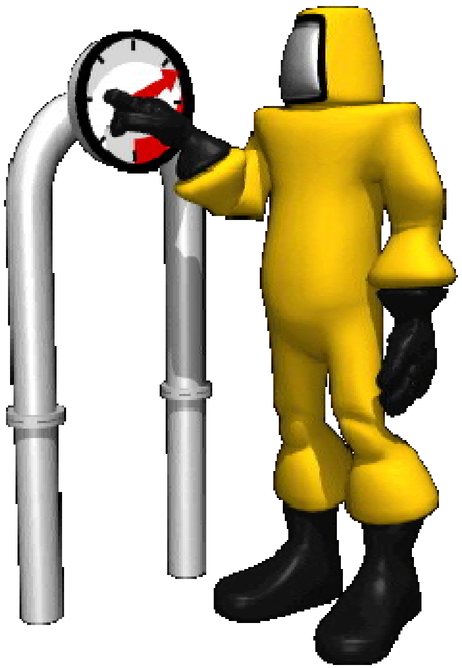
- Radiation doses are well below regulatory limits.

- There is no radiation exposure without an overall benefit.

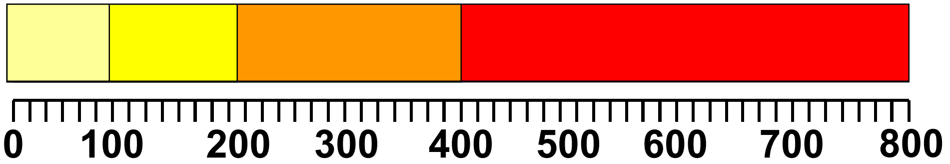
# Time

Minimize time in a field of radiation

100 mrem/hour field



Time in Area = **8 hours**



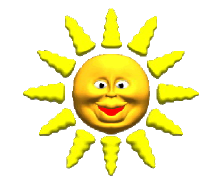

mrem received

# Distance

Maximize distance from a source of radiation

**2 x Distance = Dose Rate / 4**

Point Source

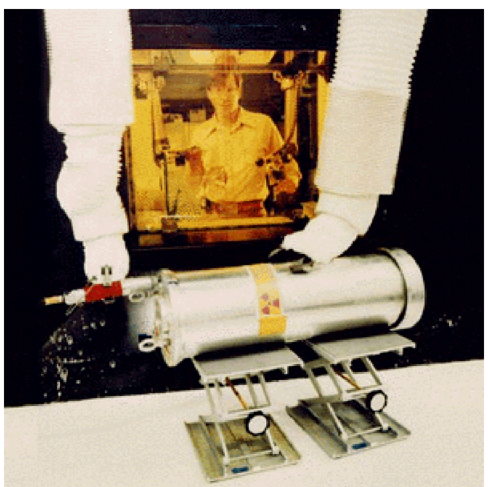


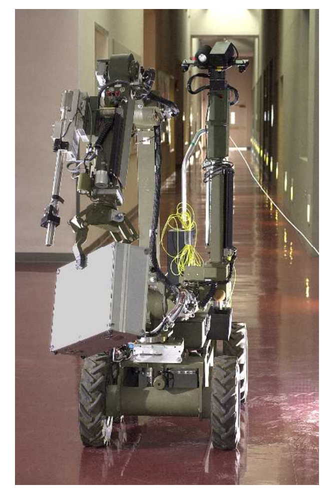
Distance = 8 feet

100 mrem/hr

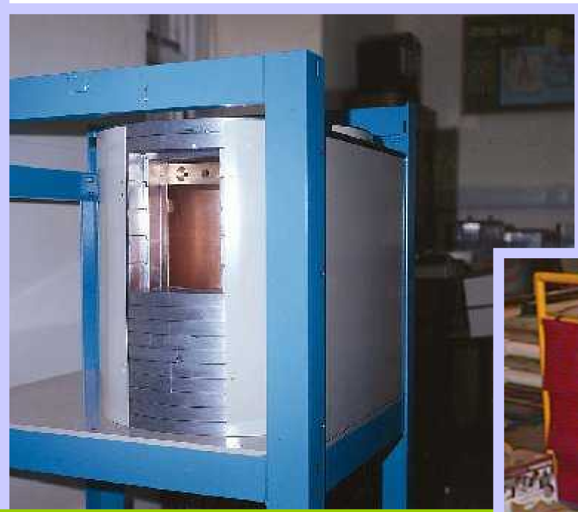
# Methods for Increasing Distance

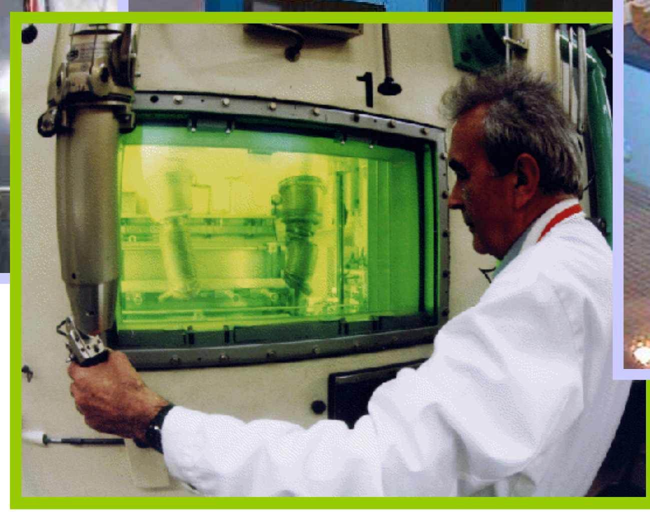
- ✓ Be familiar with radiological conditions in the area
- ✓ Move to lower dose rate areas during work delays
- ✓ Use remote handling devices when possible





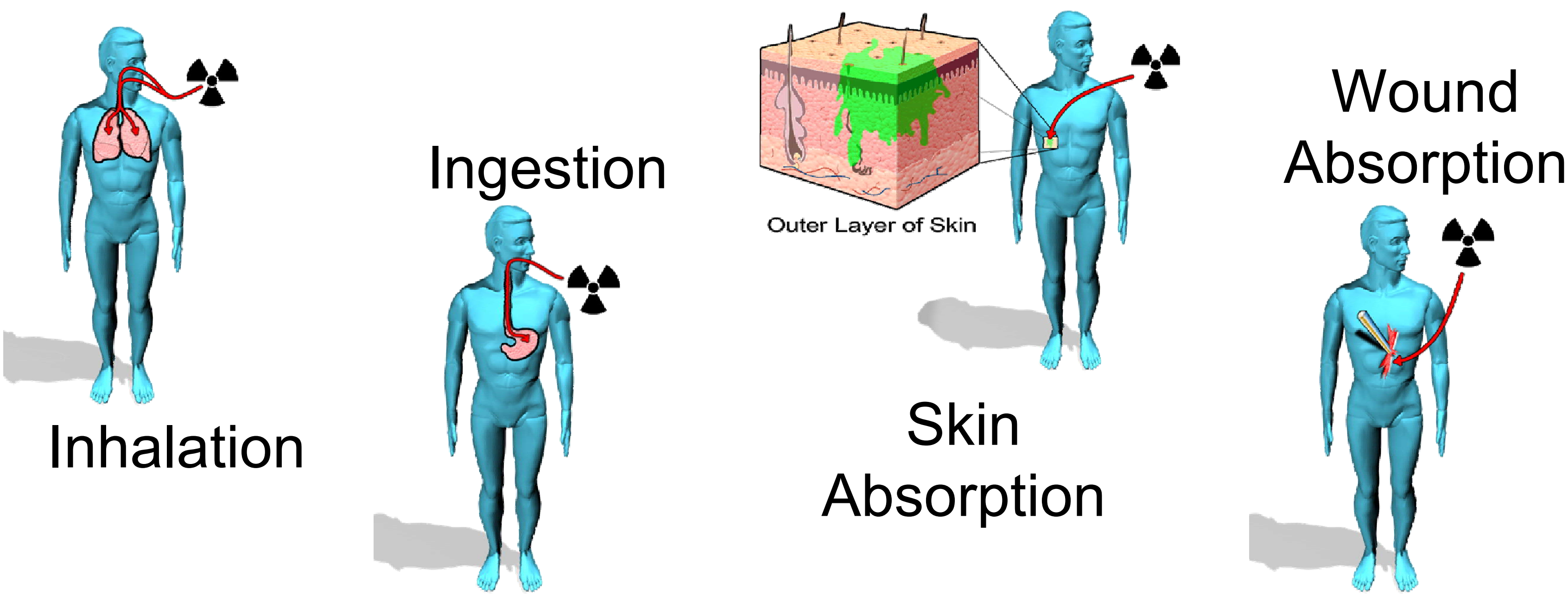
# Shielding Examples





# Internal Exposure Pathways

Internal dose results from radioactive material being taken into the body through:



# Preventing Internal Exposure

- Engineering Controls
  - Fume Hood
  - Glove Bag
- Personnel Protective Equipment
  - Safety Glass
  - Lab Coats
  - Coveralls

# Engineering Controls

- Glove Bag

- Glove Box

# Personnel Monitoring Devices

Various types of dosimetry devices are used to measure personnel dose received from exposure to external sources of radiation:

**Whole-Body Dosimeter**


**Extremity Dosimeter**

**Electronic Dosimeter**


**Pocket Ion Chamber**

# Internal Monitoring Methods

- Bioassay

- Whole-body counting


- Monitor air

# Careers in New Mexico

- National Laboratories (Sandia and Los Alamos)
- Waste Isolation Pilot Project (Carlsbad)
- Fuel Fabrication (Eunice)
- Mining (Grants)
- Government
- Universities (UNM and NMSU)

# Careers in New Mexico

- Technician
  
  Education - H.S. Diploma
  
  Salary $30,000 to $50,000
  
  Demand exceeds availability
- Professional
  
  Education – B.S or M.S HP or hard science
  
  Salary $70,000 to mid $150,000
  
  Demand exceeds availability