

**U.S. NRC**

UNITED STATES NUCLEAR REGULATORY COMMISSION  
*Protecting People and the Environment*



# Health Physics Fundamentals

**Rod Reed, Ph.D., CHP**

**Senior Health Physicist**

**US Nuclear Regulatory Commission**

**Technical Training Center**

**Chattanooga, Tennessee**

**(423) 855-6513**

**rpr1@nrc.gov**

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Producers  
JAY KOGEN  
&  
WALLACE WOLODARSKY



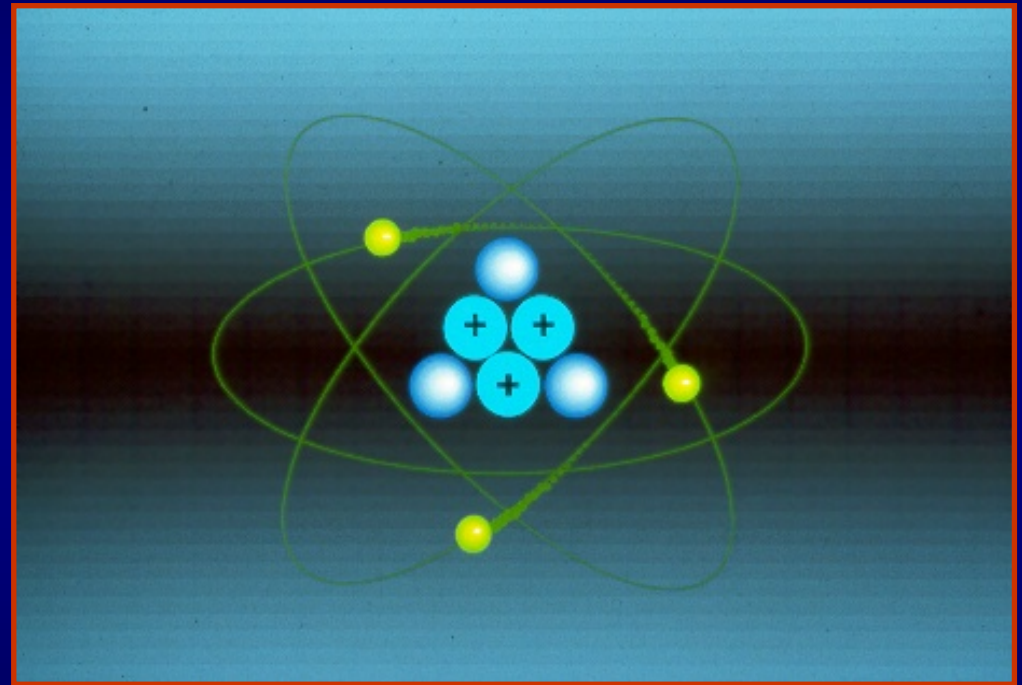
# Atomic Structure

## ➤ Atomic Structure

➤ Protons (p)

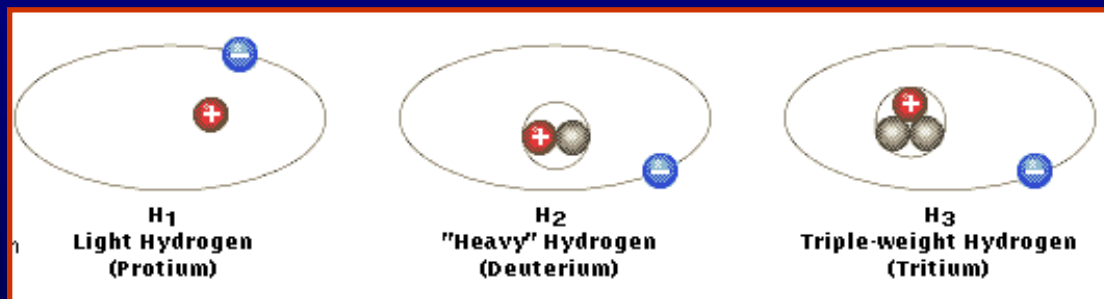
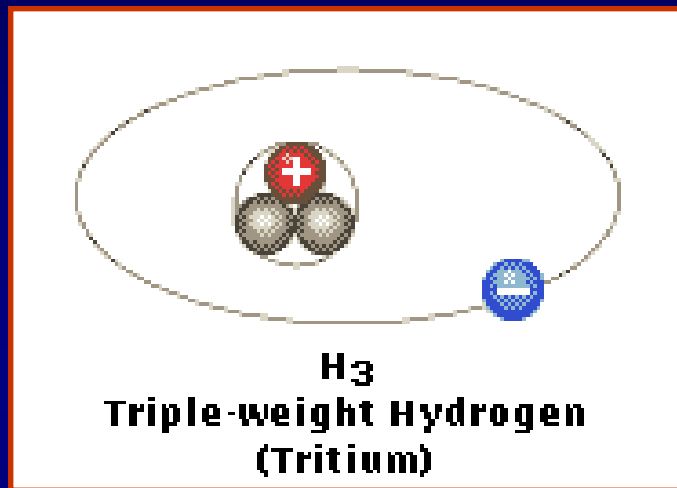
➤ Neutrons (n)

➤ Electrons (e)





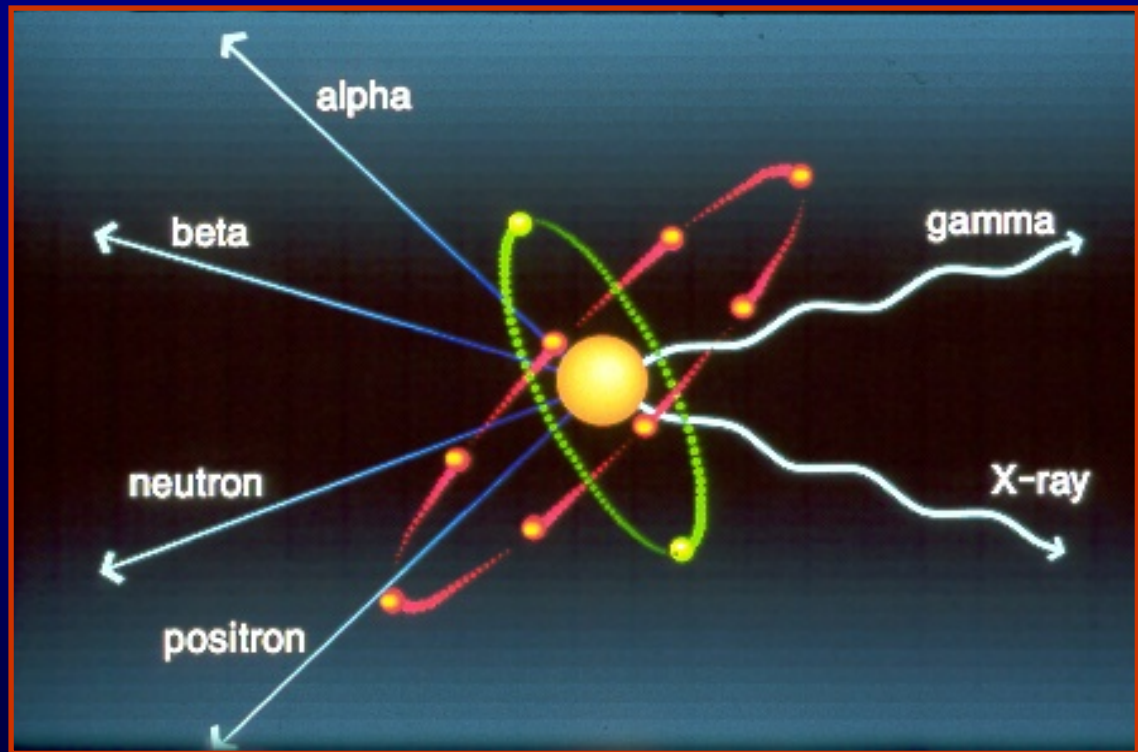
# Isotopes of the Element Hydrogen





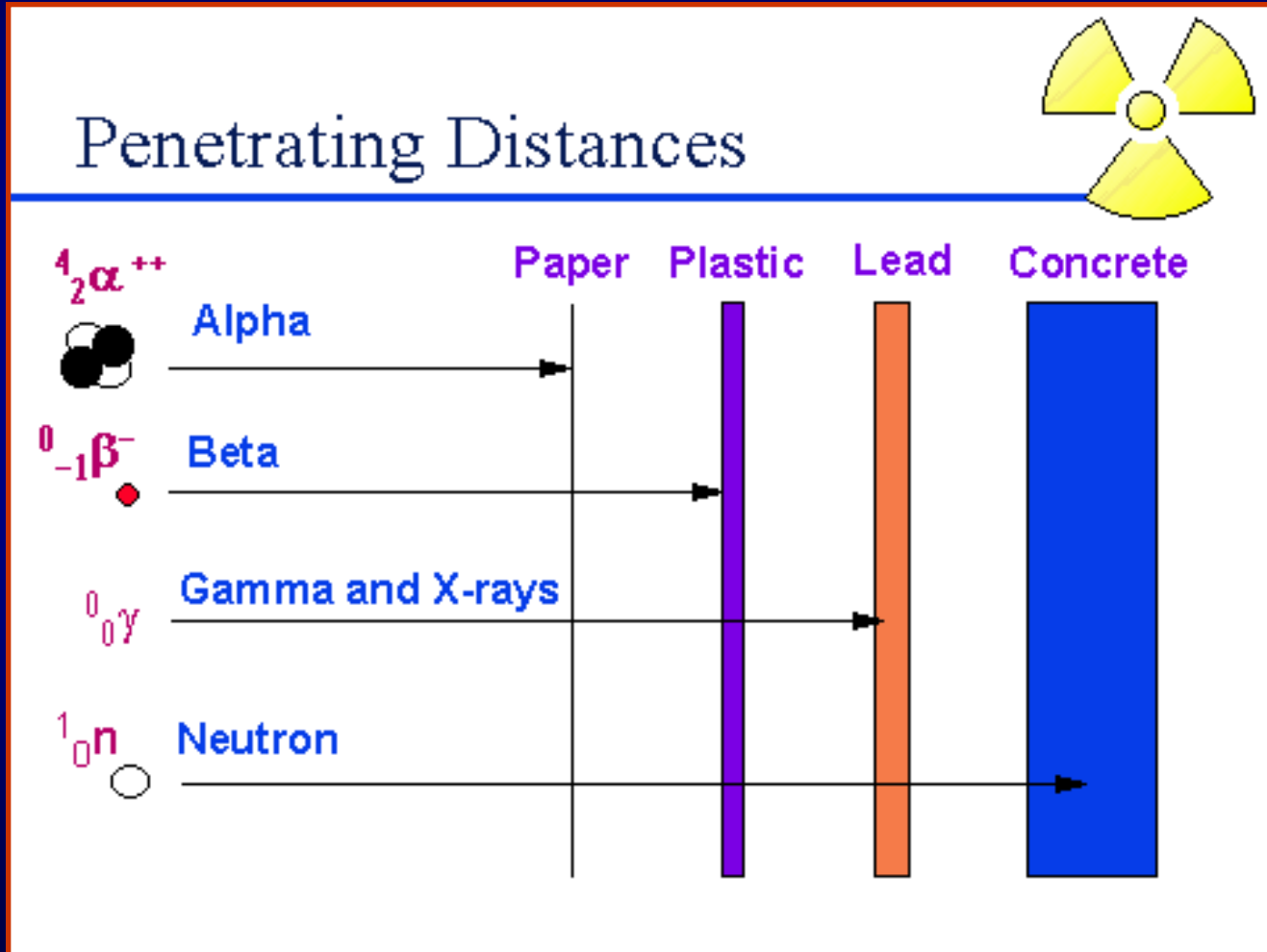
# Radioactivity and Radiation

- **Types of Radiation**
  - **Particle emission ( $\alpha$ ,  $\beta^-$ ,  $\beta^+$ )**
  - **Photon emission ( $\gamma$ , x-ray)**





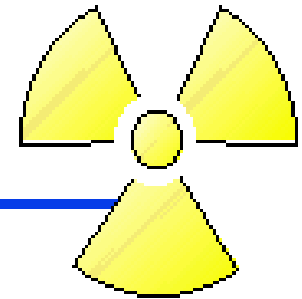
# Radiation Penetration





# Activity

## Measures of Radioactivity



**Activity: The quantity of radioactive material present at a given time:**

– Curie (Ci) :  $3.7 \times 10^{10}$  disintegration per second (dps)

**or**

– Becquerel (Bq): 1 dps



# Mass vs Activity

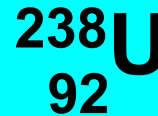
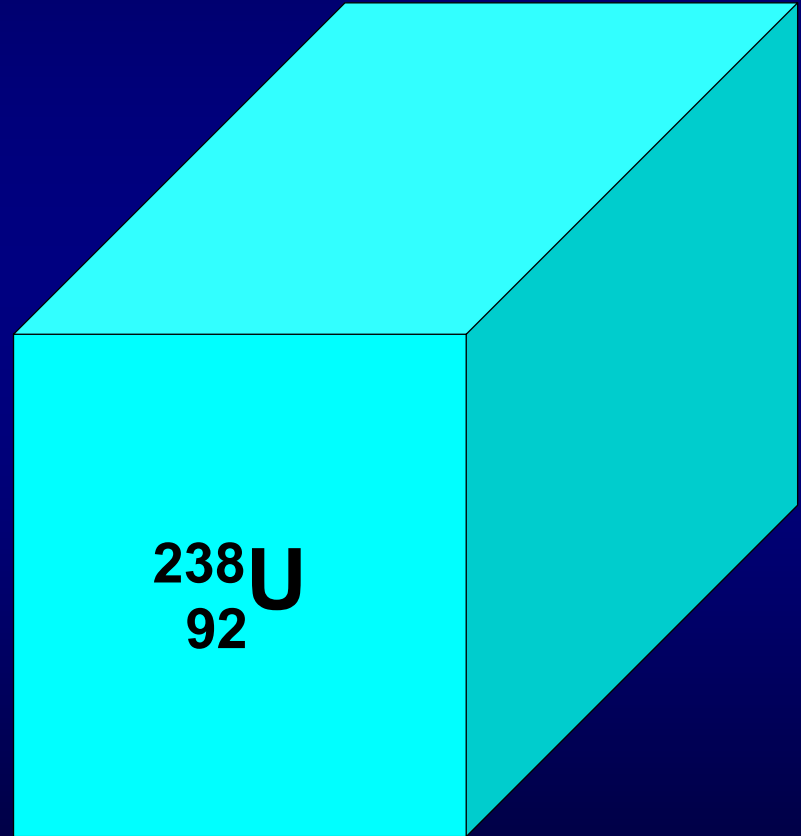
0.001 gm



1 gm



635,600 gm



Amount in grams of  
each isotope equaling  
one curie of activity

${}_{84}^{210}\text{Po}$  . 0.00022 gm

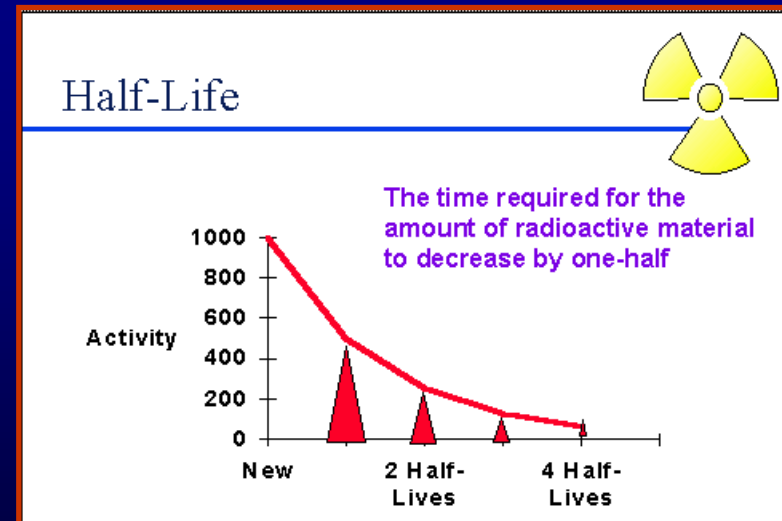




# Ionizing Radiation

## Half Life

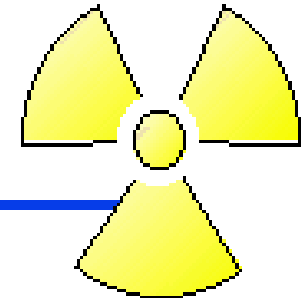
- amount of time for half of the activity to decay
- half life is unique to each radionuclide
  - N-16 is 7 seconds (BWRs)
  - Co-60 is 5.3 years
  - Cs-137 is 30.17 years
  - Po-210 is 138 days





# Radiation Units

## Radiation Units



- ◆ Roentgen: A unit for measuring the amount of gamma or X rays in air
- ◆ Rad: A unit for measuring absorbed energy from radiation
- ◆ Rem: A unit for measuring biological damage from radiation

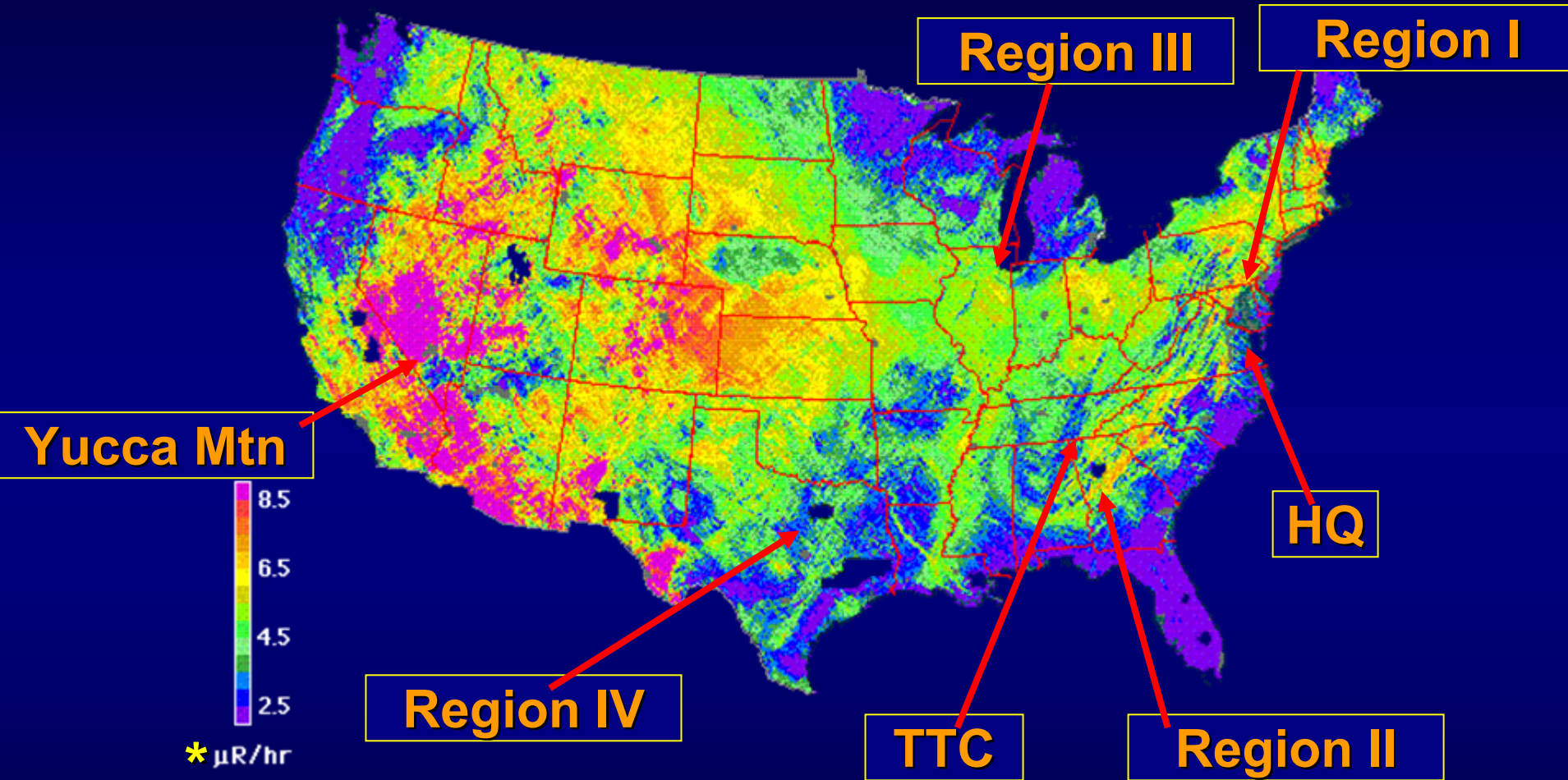


# SI vs Special Units

| SI Unit   | Special Unit | Conversion                     |
|-----------|--------------|--------------------------------|
| Gray      | Rad          | 1 Gy = 100 rad                 |
| Sievert   | Rem          | 1 Sv = 100 rem                 |
| Becquerel | Curie        | 1 Ci = $3.7 \times 10^{10}$ Bq |

**1 rem = 1,000 millirem (mrem)**  
**1 Curie = 1,000 millicuries (mCi)**

# Terrestrial Gamma-Ray Exposure at 1m above ground



\*  $1 \mu\text{R} = 1/1,000,000 \text{ R}$

Source of data: U.S. Geological Survey Digital Data Series DDS-9, 1993

1 milliroentgen (mR) = 1,000  $\mu\text{R}$



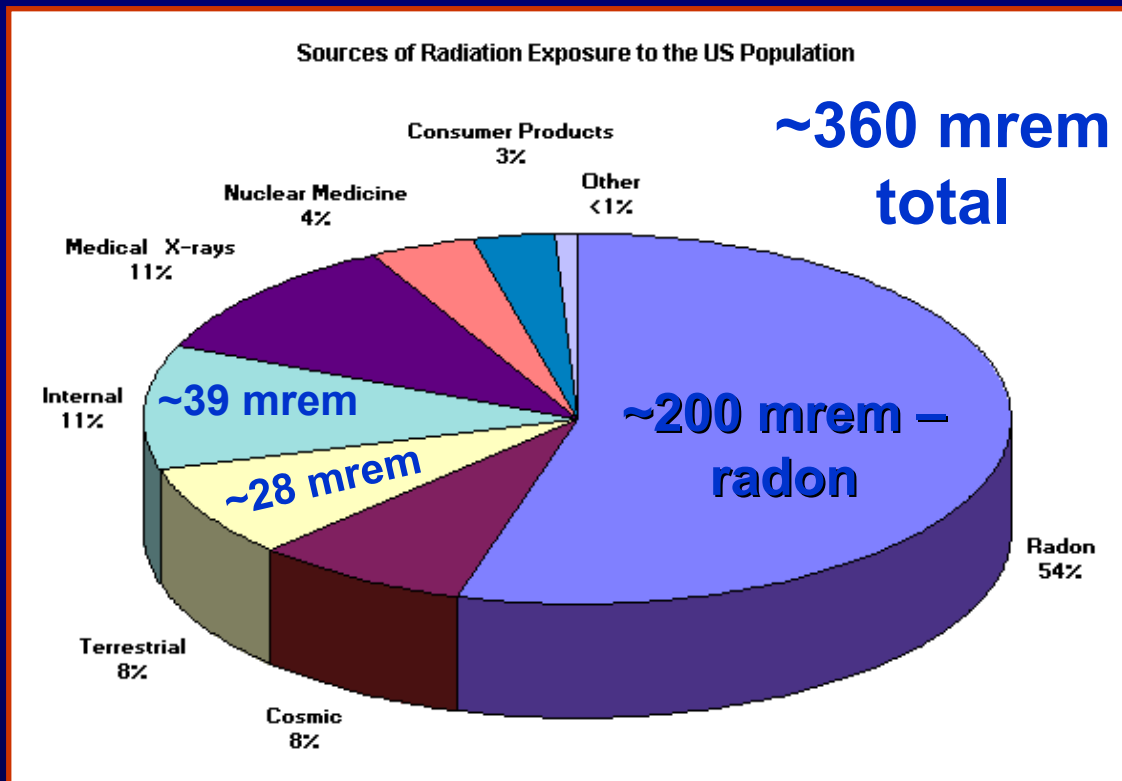
# Medical Procedures

| Procedure               | Dose (mrem) |
|-------------------------|-------------|
| <b>X-Rays</b>           |             |
| Abdomen                 | 40          |
| Chest                   | 6           |
| Pelvis                  | 60          |
| Dental                  | 3           |
| Mammography             | 40          |
| CT (full body)          | 130         |
| <b>Nuclear Medicine</b> | 400         |



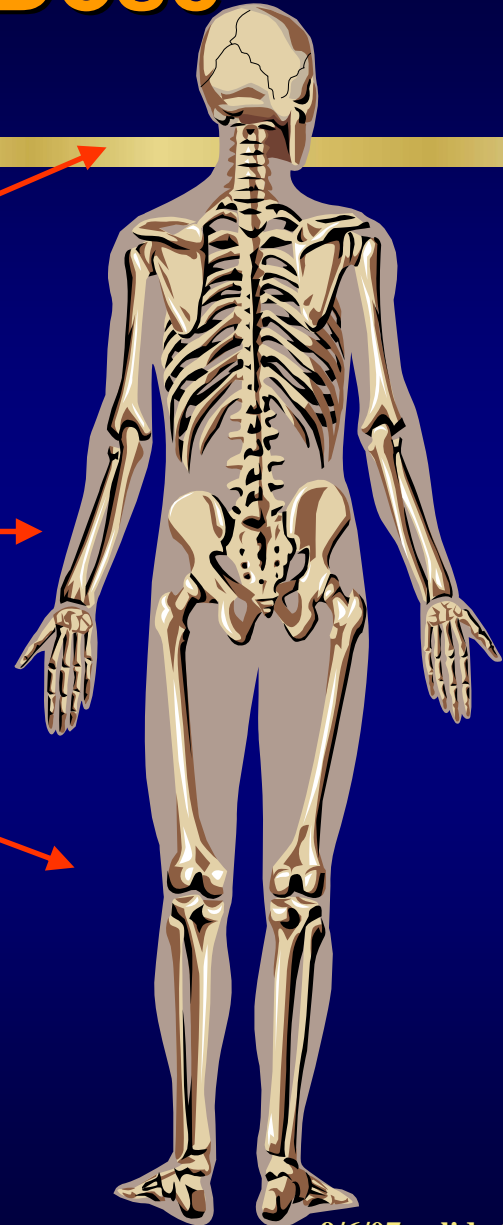
# Annual Background Radiation Dose to Average US Citizen

**Natural Background  
VS  
Artificial Background**





# External Radiation Dose



**Gamma, beta or neutron radiation emitted by radioactive material outside the body exposing the skin, lens of the eye, extremities & the whole body (i.e. internal organs)**





# Internal Radiation Dose

**RAM is inhaled  
or swallowed**

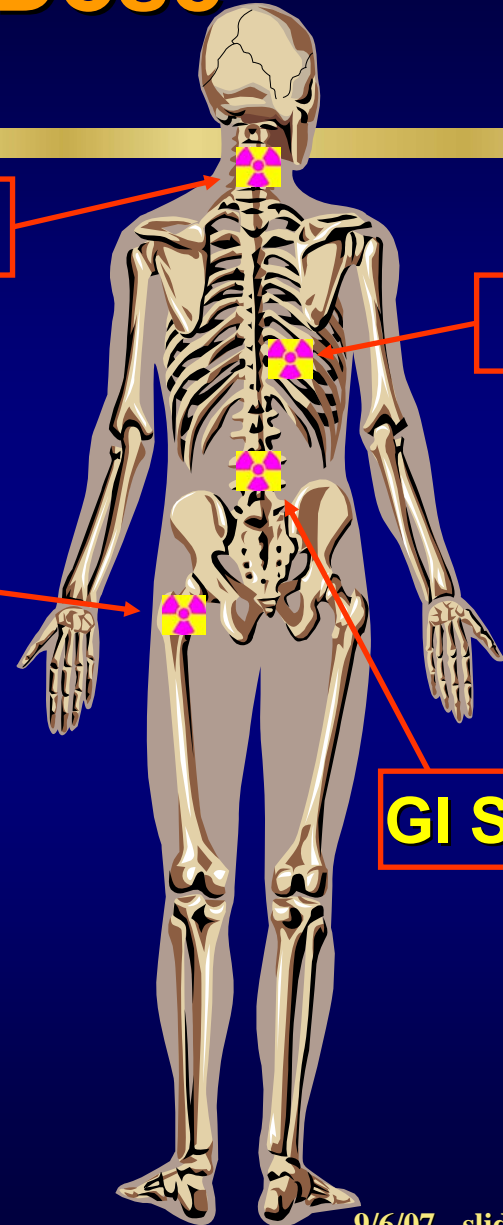
**Alpha, beta or gamma radiation  
emitted by radioactive material  
inside the body exposing  
internal organs such as:**

**thyroid**

**lung**

**bone**

**GI System**







# KI Effectiveness vs Time of Administration

**KI can reduce thyroid dose in an emergency involving radioactive iodine**

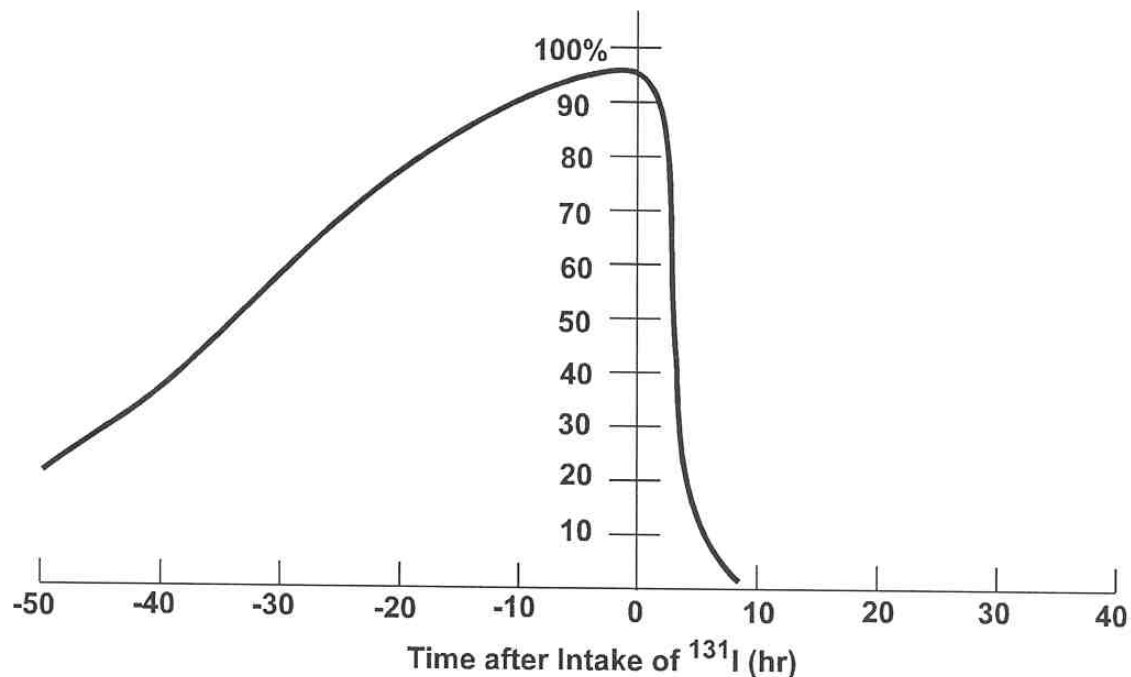
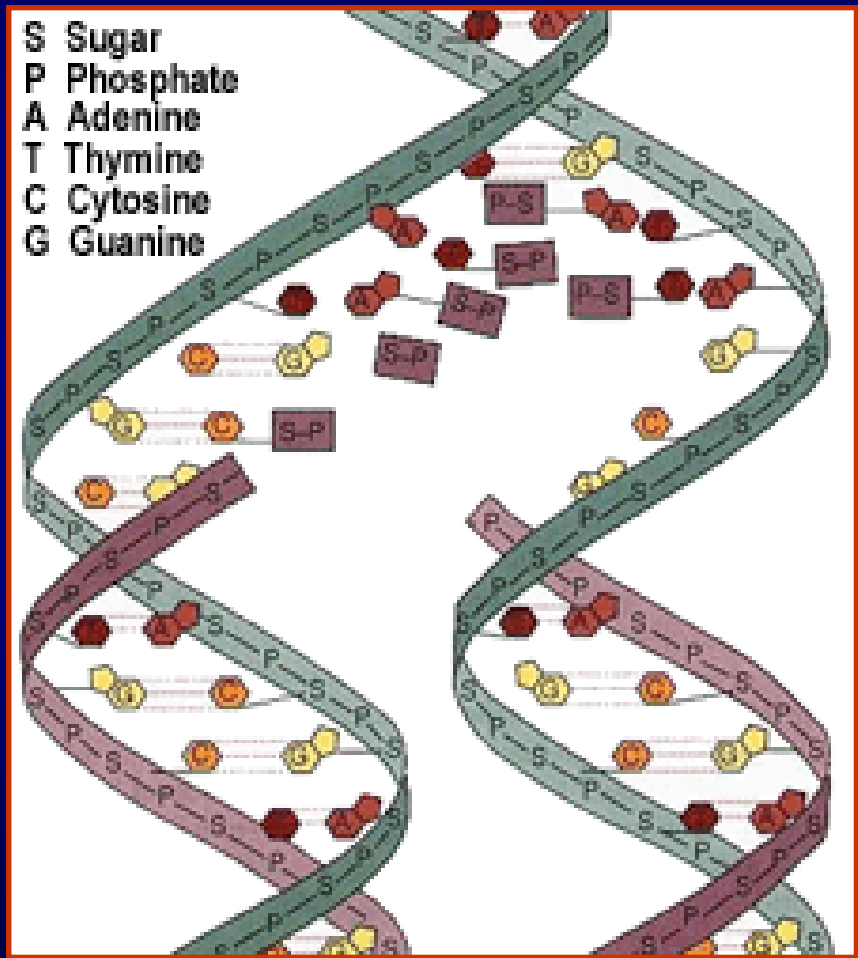
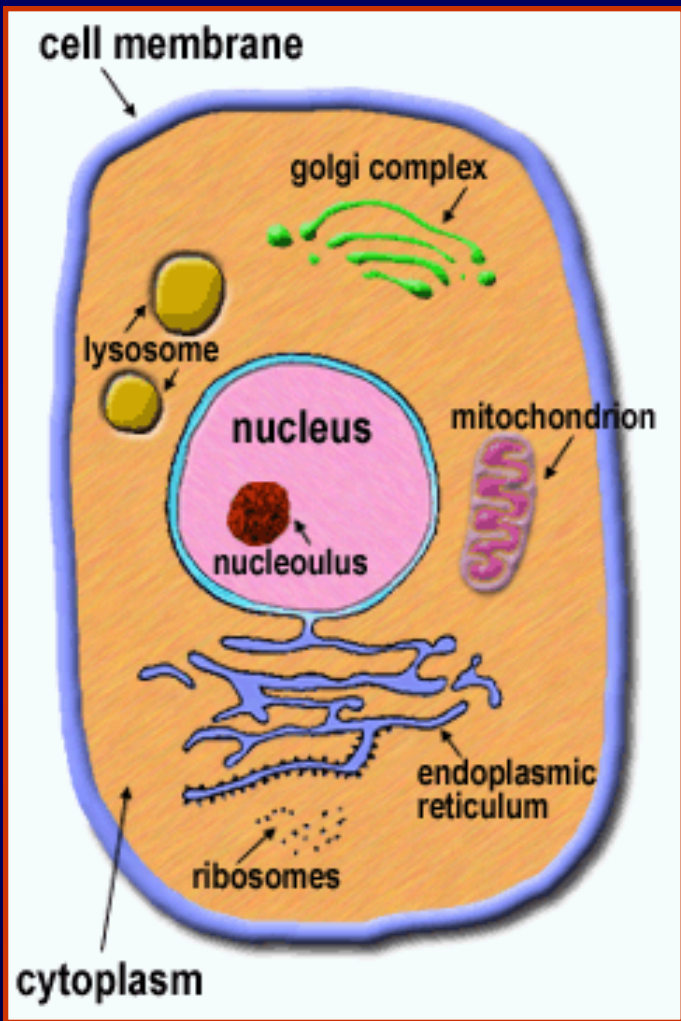


Figure 5.3-6 Percent of thyroid blocking afforded by 100 mg of stable iodine (130 mg of potassium iodide) as a function of time of administration before or after a  $1\text{-}\mu\text{Ci}$  intake of  $^{131}\text{I}$



# The Cell



**DNA**



# Low-level Radiation Effects (most exposures)

- **Cancer – proven at higher doses (e.g. > 10 rad acute); assumed to occur at lower doses, with no threshold**
- **Genetic effects - occur in mice and fruit flies; assumed to occur in humans but never proven**



# Can Radiation Exposure Cause This?





# Low-Level Effects - Cancer

- **Natural cancer rate = 20% or 1 in 5 (or 2,000 out of every 10,000 people)**
- **Radiation risk of cancer (hypothetical) = 0.04% or 4 in 10,000 per rem**
- **Thus, 1 rem might increase total cancer risk to an exposed person to 20.04%**



# High Levels of Radiation (occur rarely)

## Acute Radiation Syndromes:

- **100 rad - hematopoietic (blood)**
- **500 rad – gastrointestinal (GI)**
- **2,000 rad - central nervous system (CNS)**
- **LD<sub>50/60</sub> - lethal dose to 50% of people within 60 days, approximately 400 rad (whole body exposure)**





# NRC Occupational Dose Limits

|                             |                       |
|-----------------------------|-----------------------|
| <b>Whole Body (TEDE)</b>    | <b>5,000 mrem/yr</b>  |
| <b>Any Organ (TODE)</b>     | <b>50,000 mrem/yr</b> |
| <b>Skin (SDE)</b>           | <b>50,000 mrem/yr</b> |
| <b>Extremity (SDE)</b>      | <b>50,000 mrem/yr</b> |
| <b>Lens of Eye (LDE)</b>    | <b>15,000 mrem/yr</b> |
| <b>Embryo/Fetus of DPW</b>  | <b>500 mrem/yr</b>    |
| <b>Member of the Public</b> | <b>100 mrem/yr</b>    |

Note: 1,000 mrem = 1 rem



**THE END**