Lecture 14
Exposure to Ionizing Radiation

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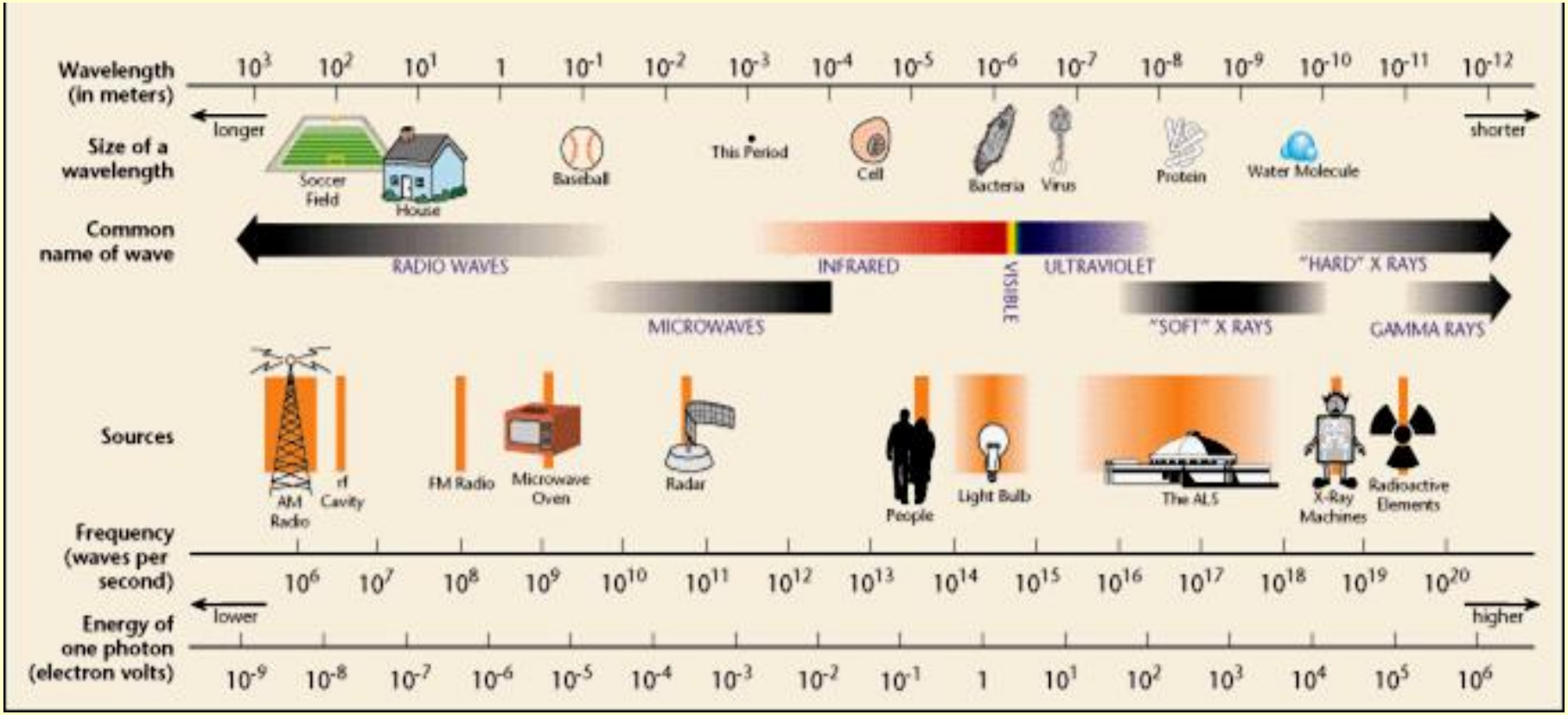
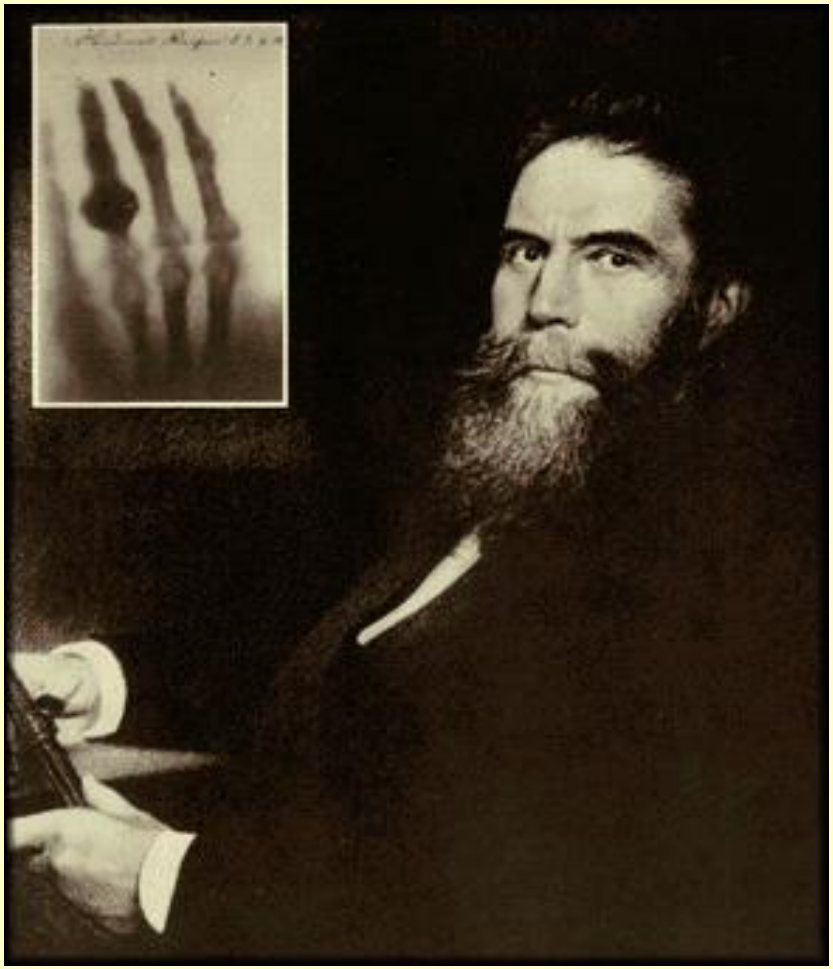
The Electromagnetic Spectrum



Wilhelm Conrad Roentgen

- November 8, 1895 – Discovers “a new kind of ray”
- He names them X-rays; X representing the unknown.
- December, 1895 – First radiograph of a living object (His wife’s hand).
- January 23, 1896 – First medical use of x-rays reported in the *Lancet*.



Uses of High-Dose Radiation in U.S.

- Industrial radiography
- Power production
- Research-Tagging
- Processing food and medicines
- Medical diagnostic studies
- Medical cancer therapy
- Atomic Weapons Production

Radiation vs Radioactive Material

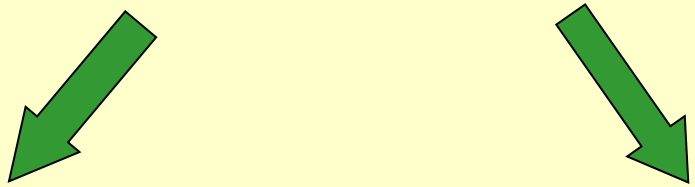
- Radioactive Material
  - Any substance that spontaneously gives off radiation
  - Can be in various chemical forms
  - If **not** contained (sealed source) can lead to contamination - External, Internal or Both
- Radiation
  - The energetic emissions of radioactive material
  - Can be subatomic particles (α, β, n), photons (X-ray, γ) or combinations
  - Results in ionization of the absorbing material (if living tissue ➔ radiation injury)

Common Radioactive Material Terms

- Radioisotope - a generic name for a radioactive element
- Radionuclide - a specific radioisotope such as Uranium-235
- These terms are often used interchangeably

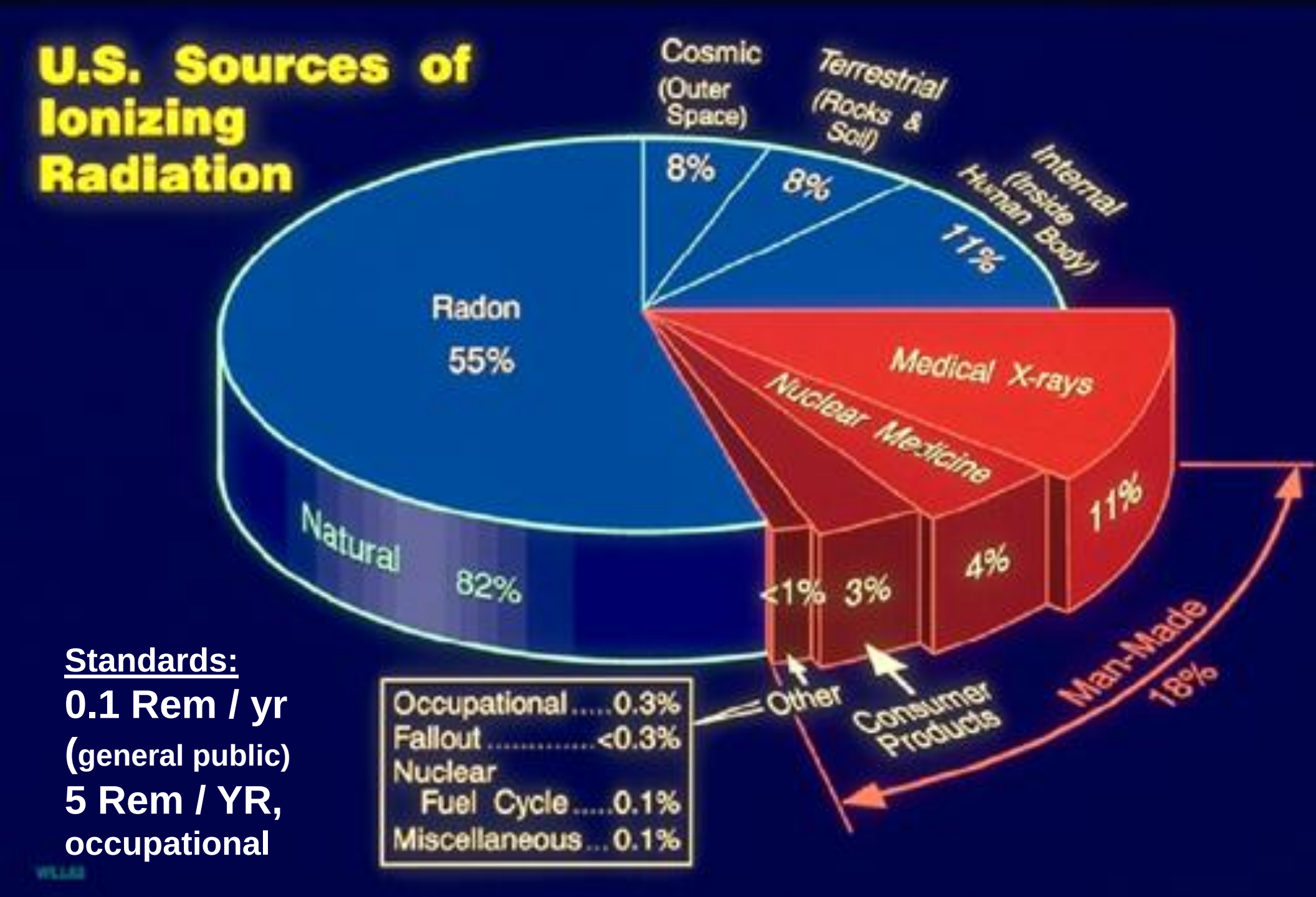
Simply stated, Ionizing Radiation carries sufficient energy to eject electrons from their atomic orbits

- Atom → Ion
- Molecule → Bond Breakage
- DNA → Chromosomal Aberration



Cell Death

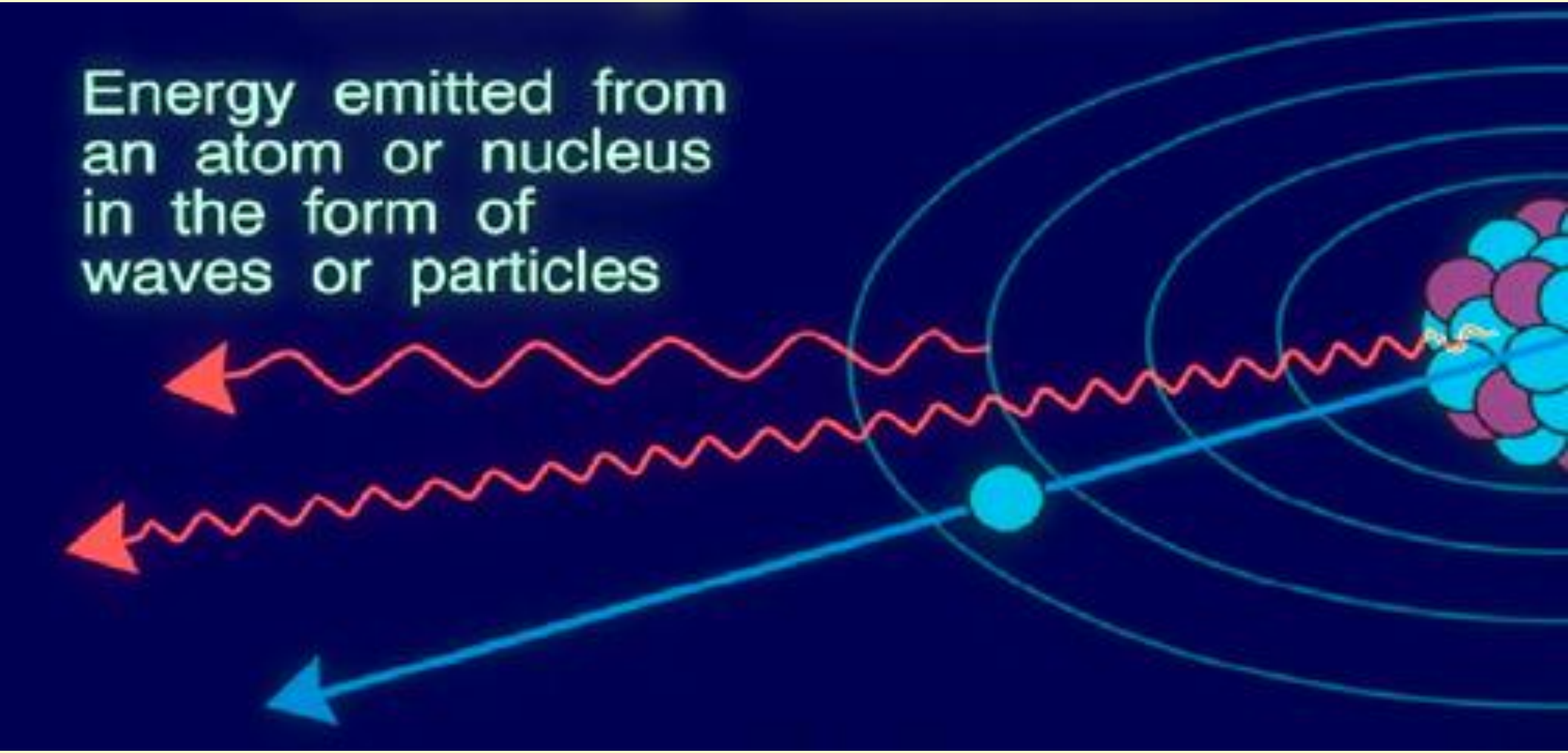
Mutation


U.S. Sources of Ionizing Radiation
Cosmic (Outer Space)
8%
Terrestrial (Rocks & Soil)
8%
Internal (Inside Human Body)
11%
Radon
55%
Natural
82%
Medical X-rays
11%
Nuclear Medicine
4%
<1%
3%
Other
Consumer Products
Man-Made
18%
Occupational 0.3%
Fallout .....<0.3%
Nuclear Fuel Cycle 0.1%
Miscellaneous ... 0.1%
Standards:
0.1 Rem / yr (general public)
5 Rem / YR, occupational

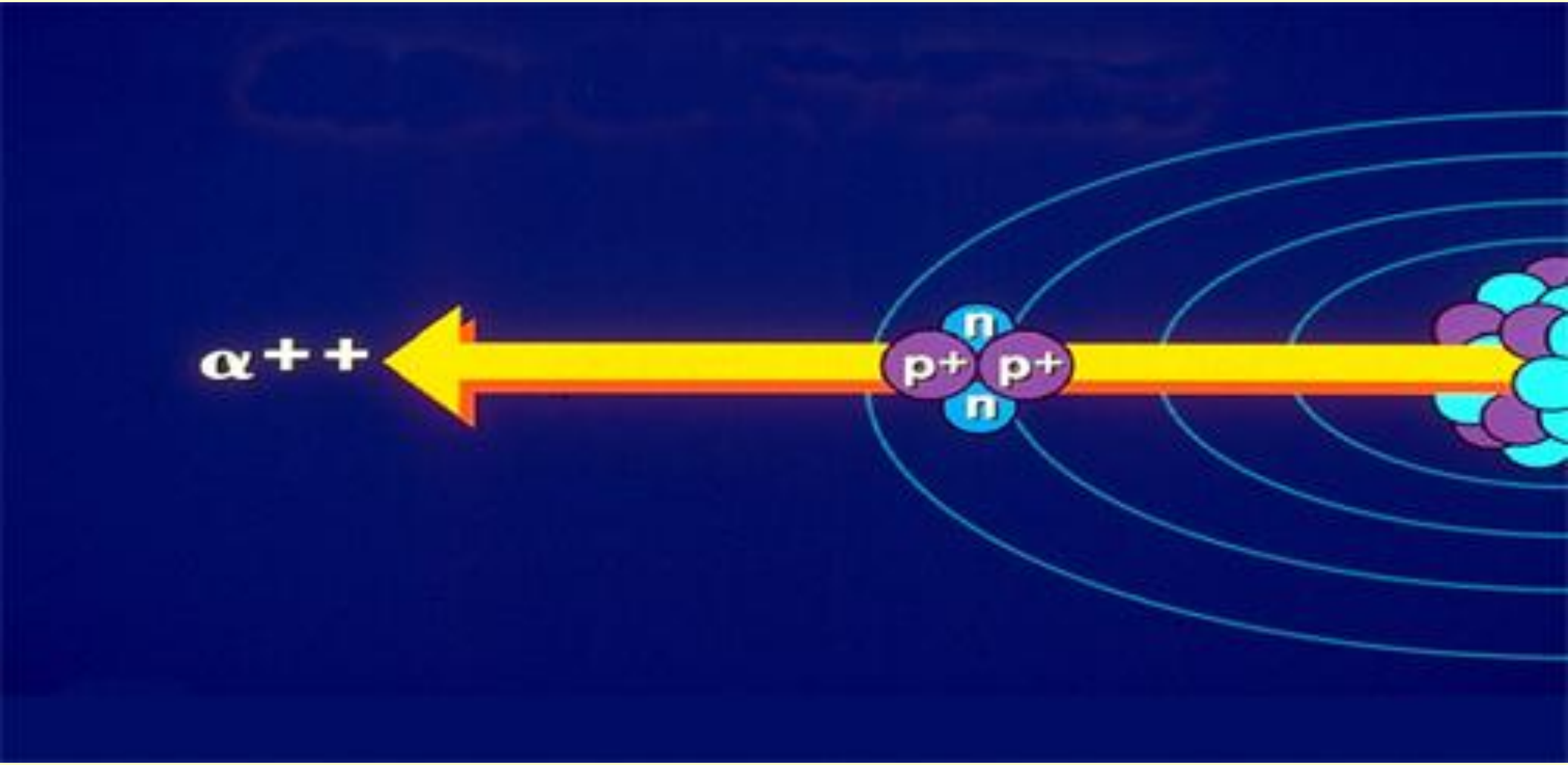
Half-Life

- The time required for a radioactive substance to loose 1/2 of its radioactivity
- Each radionuclide has a unique half-life
- Half-lives range from extremely short (fraction of a second) to billions of years

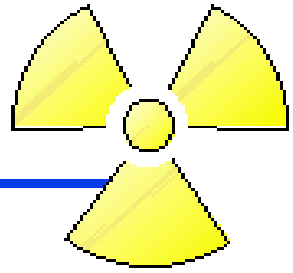
1. **Ionizing radiation is radiation with enough energy to produce ions in atoms that it strikes.**

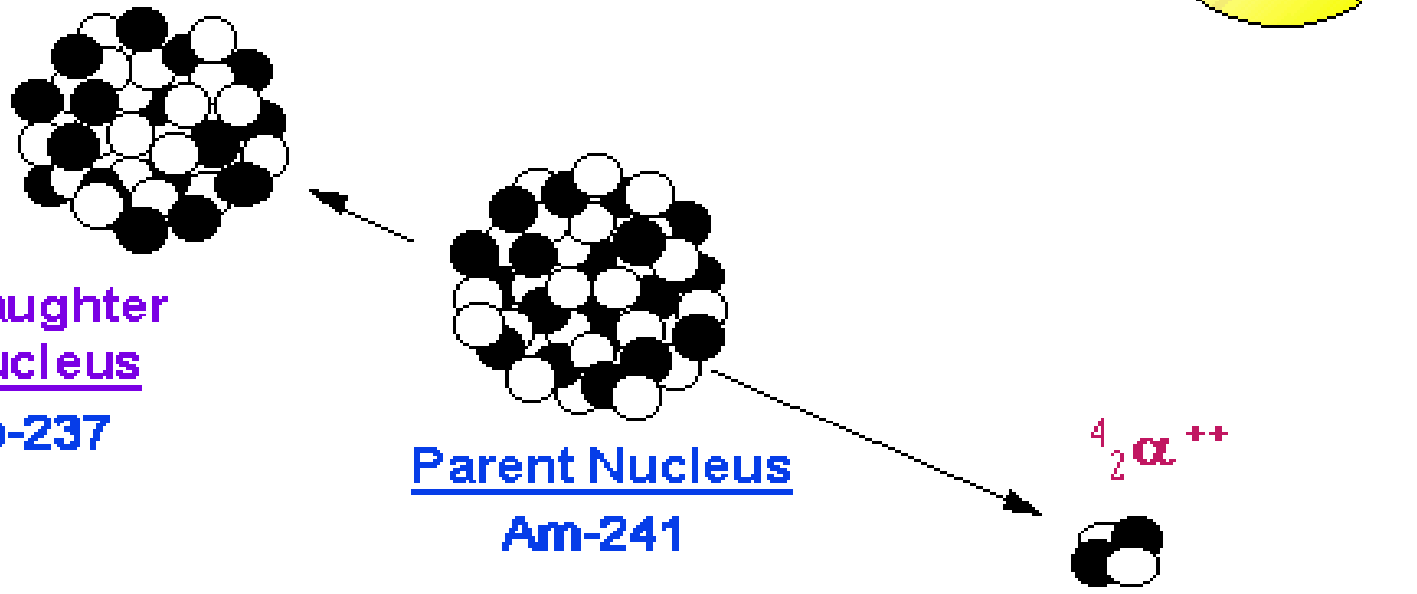


Alpha Particle



Alpha Particle Radiation





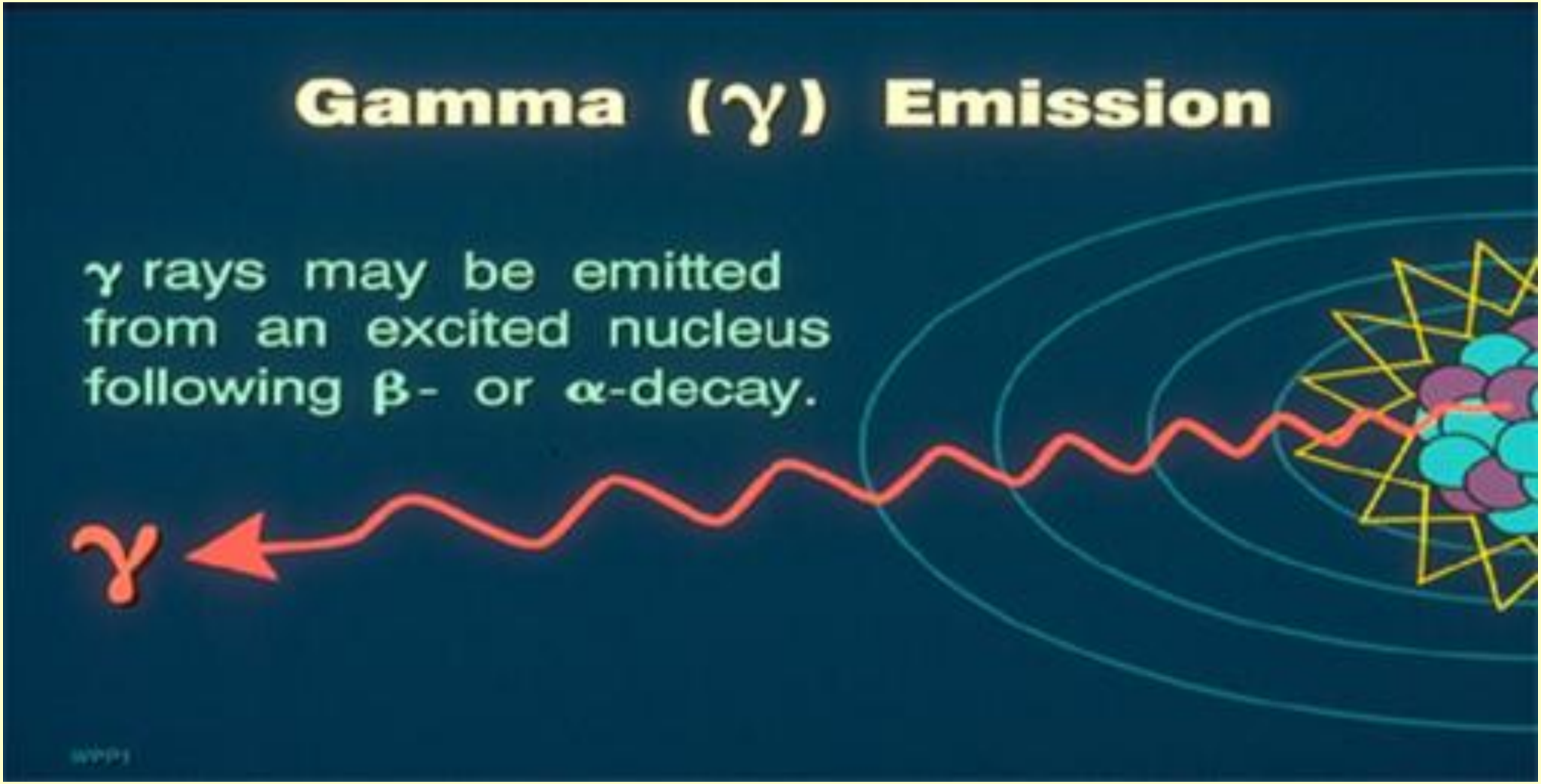
Selective Alpha Emitters

Radioisotope	Alpha Energies(MeV)	Half-Life
Ra-226	4.7 to 7.7	1620 years
Pb-210	5.3	22 years
Po-210	5.3	138 days
Ac-227	4.9 to 7.4	22 years
Pu-238	5.3 to 5.5	88 years
Pu-239	5.1	24131 years
Am-241	5.3 to 5.5	432 years

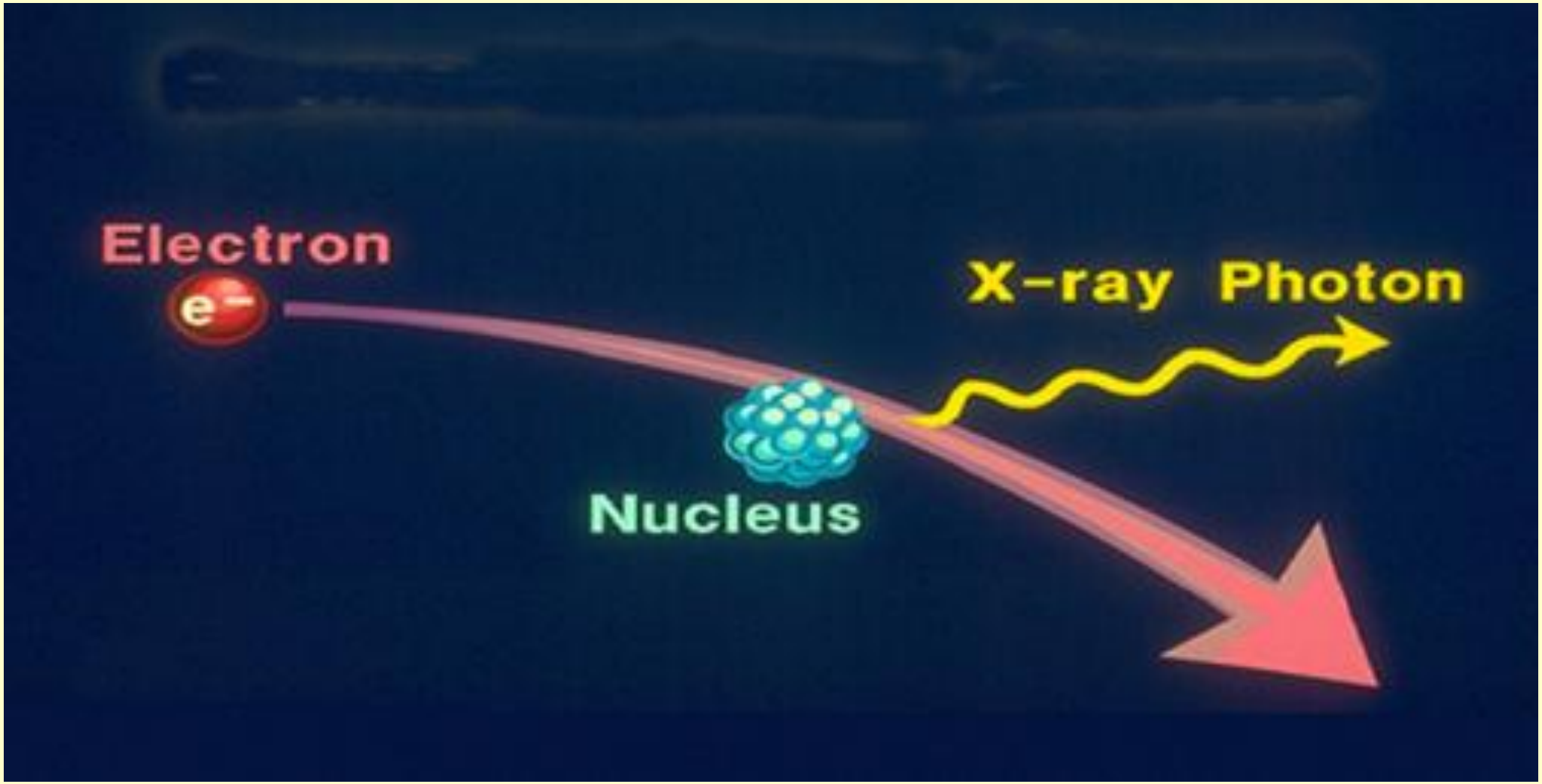
Fig. 86 - Alpha emitters commonly used for neutron sources

Beta Particle

Gamma Ray

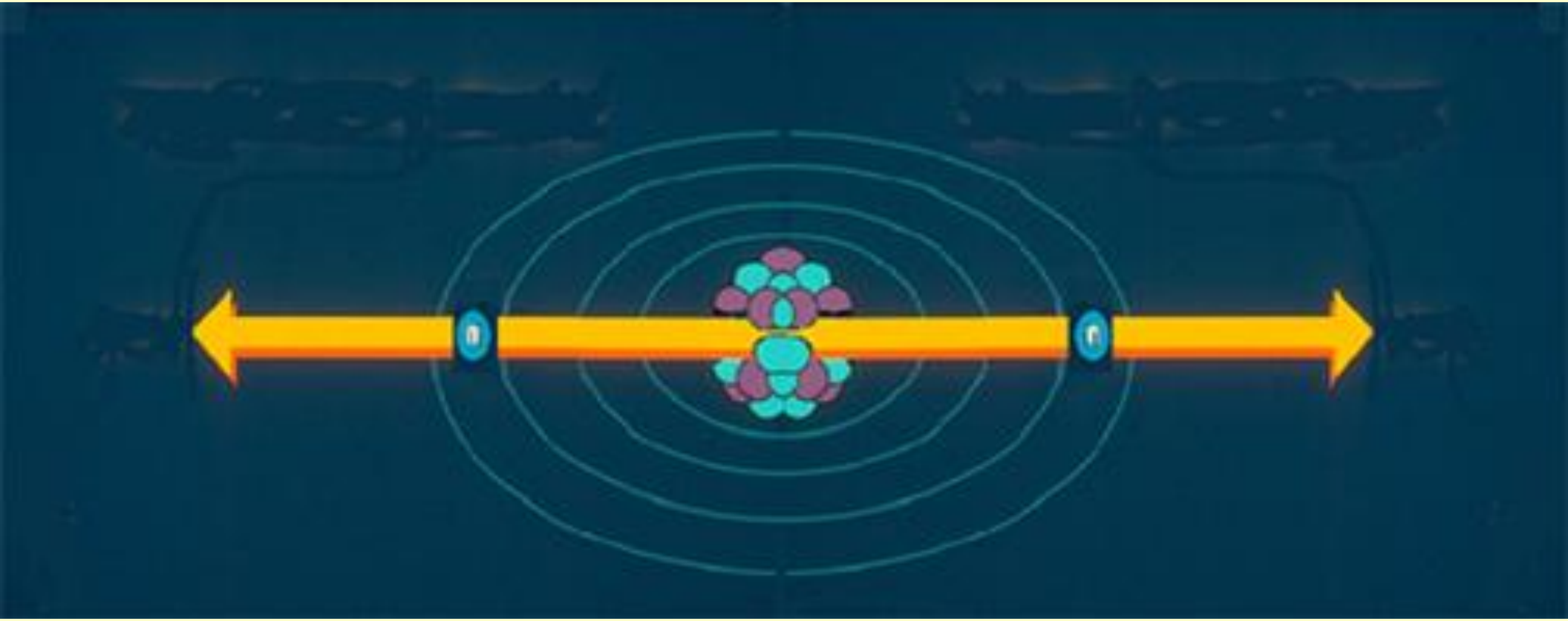

Gamma (γ) Emission
γ rays may be emitted from an excited nucleus following β- or α-decay.
γ

X-Ray



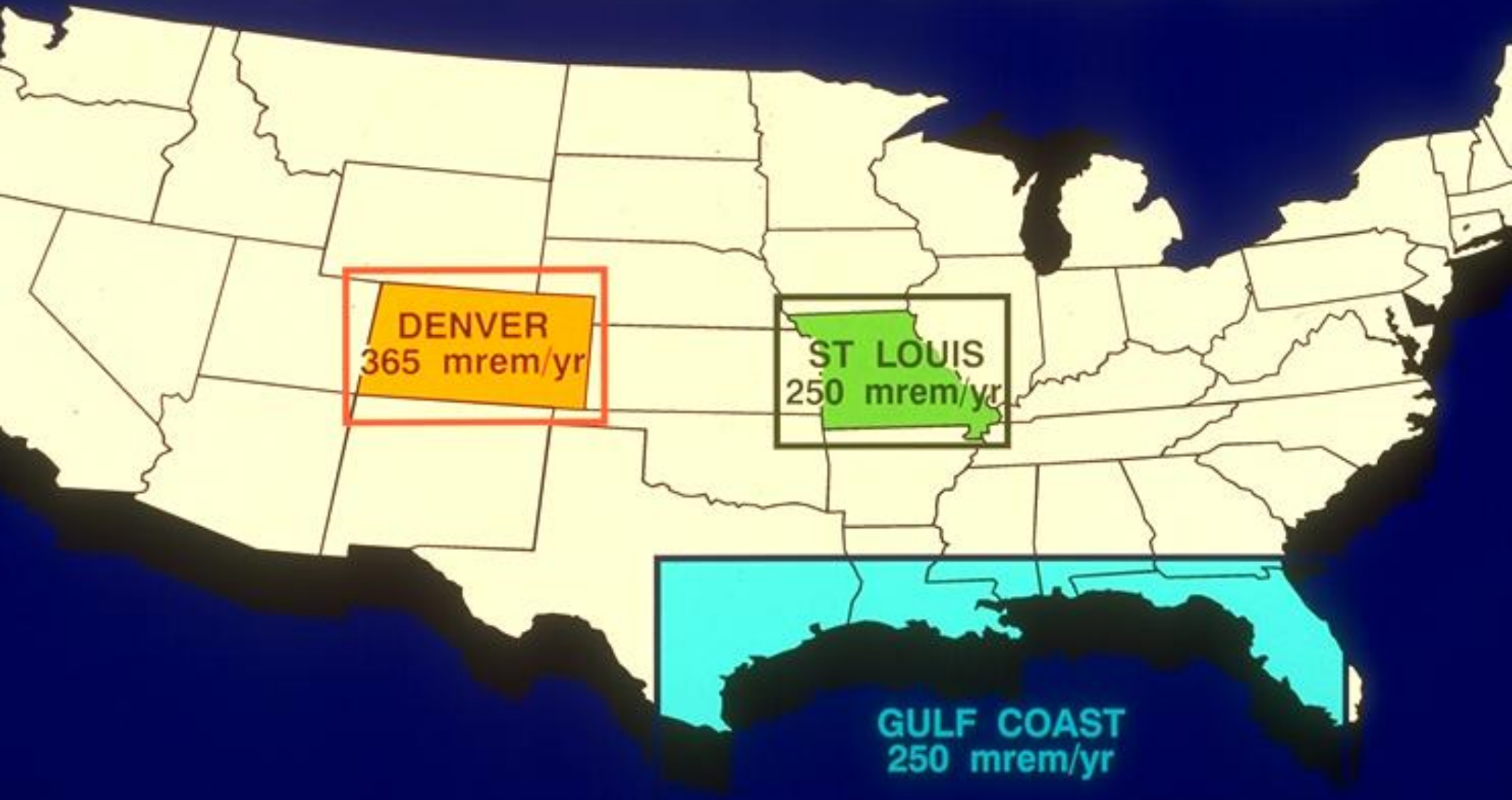
Neutron

Uncharged, heavy



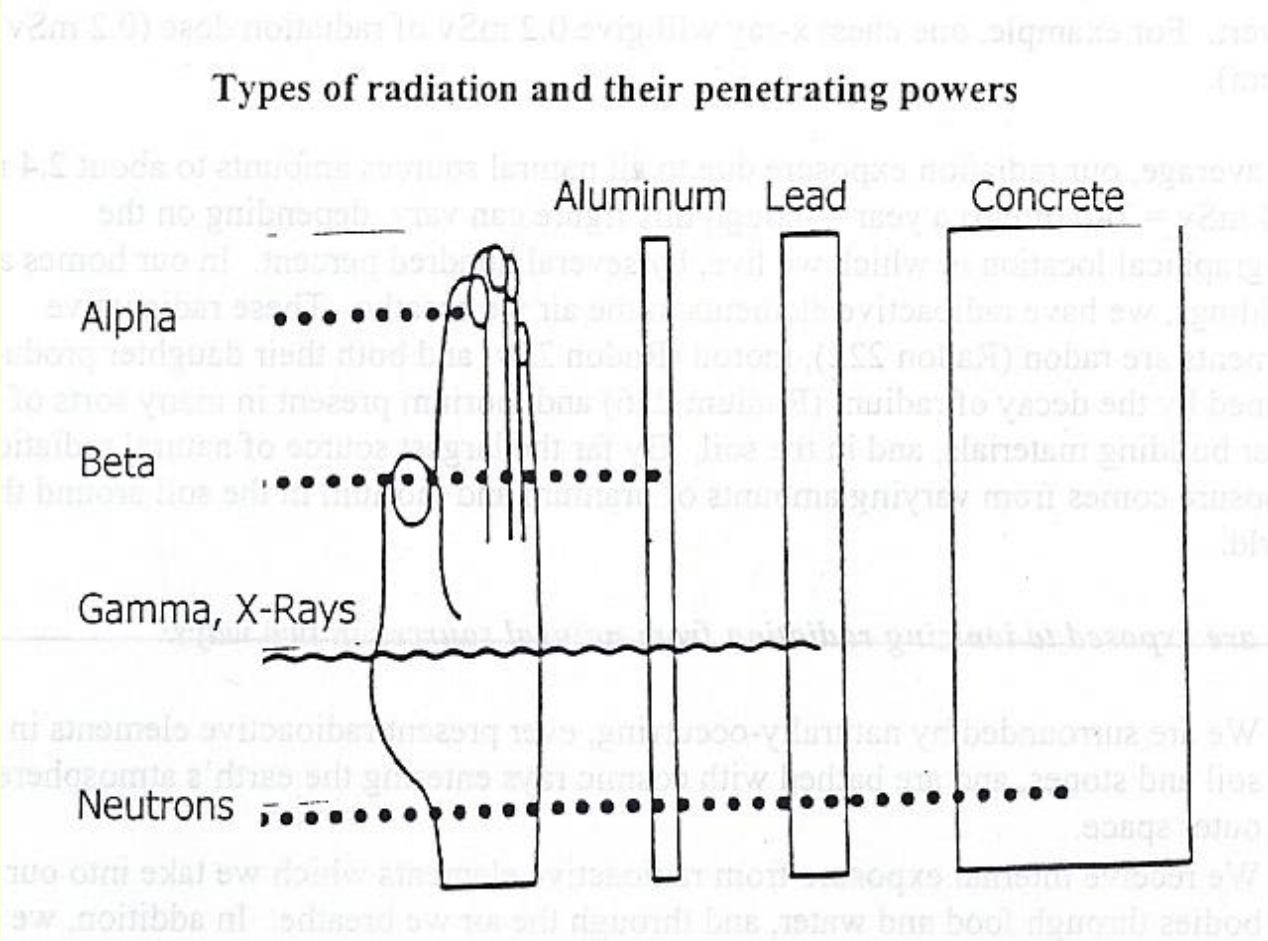
Critical Mass and a Chain Reaction!

Estimated Radiation Dose Rates From Natural Background Radiation in the United States

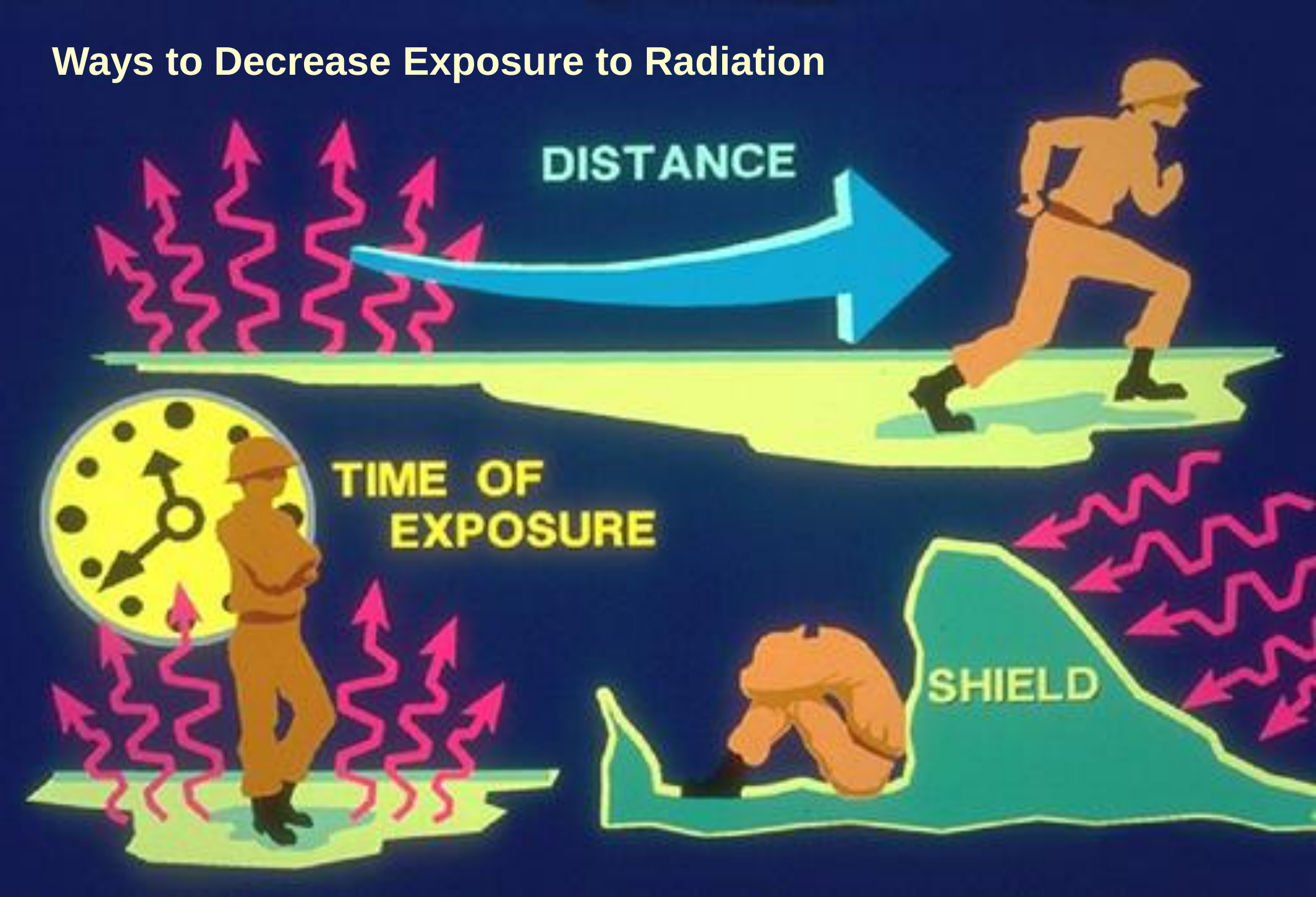


WLL61

Penetrating Power of the Various Types Radiation



Ways to Decrease Exposure to Radiation



Dose

- **Roentgen (R) -** X, γ-ray exposure, ions in air
- **Rad (R) -** traditional unit, absorbed dose (Radiation Absorbed Dose) (= 100 ergs/g)
- **Gray (Gy) -** SI unit of absorbed dose

  1 Gy = 100 rad = 100 cGy (= 1 J/Kg)
- **Rem (R) -** effective dose (Rad x weighting factors: tissue, radiation type)
- **Sievert (Sv) -** SI unit effective dose, 100 Rem

Energy Deposited

Dose is the energy imparted to matter per unit mass of irradiated material

The unit of absorbed dose is the Gray (Gy) or centigray (cGy).

One Gy equals 10,000 ergs deposited per gram of tissue.

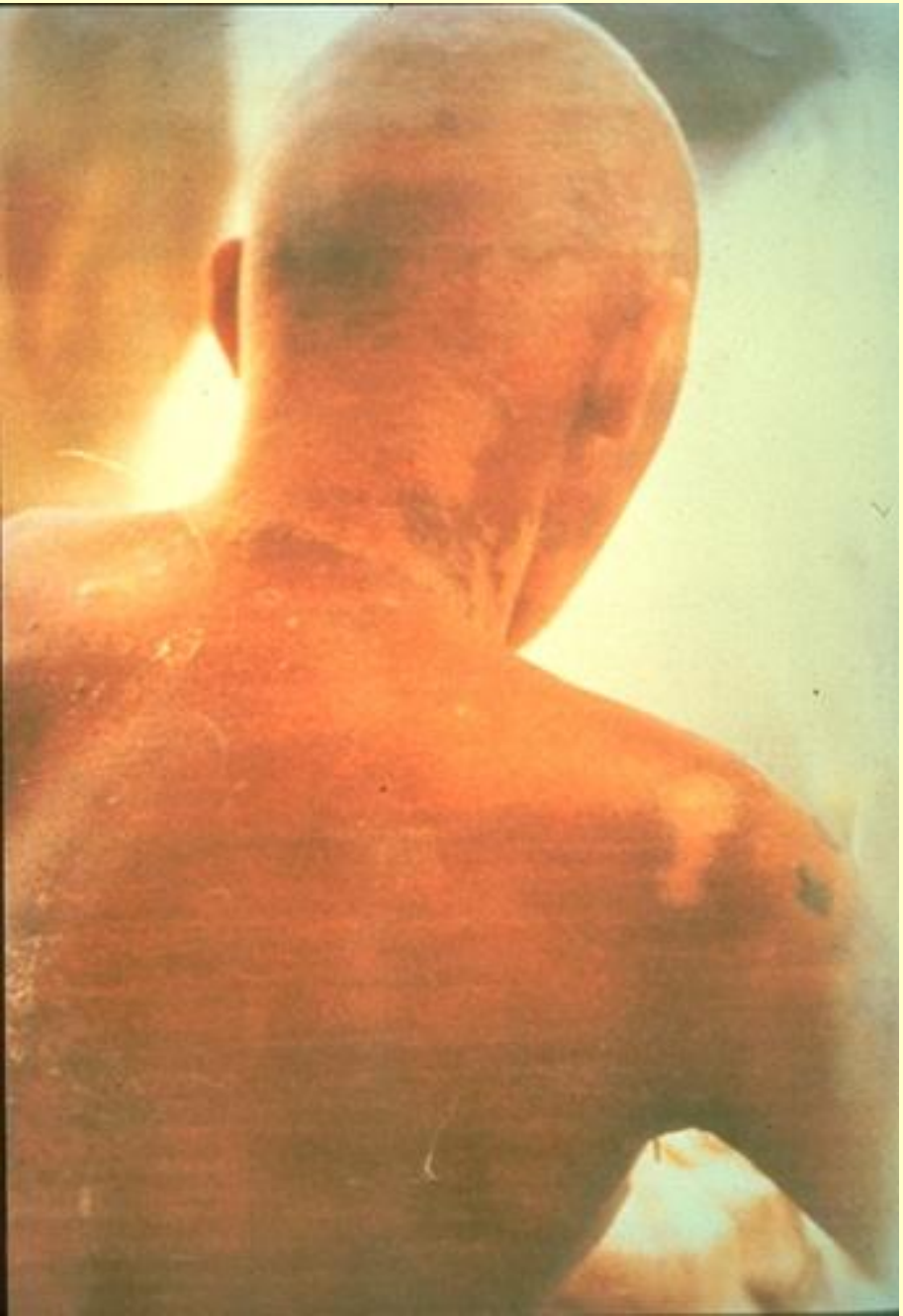
1Gy = 100 rads or 1 cGy = 1 rad

Types of Ionizing Radiation in Decreasing Order of Weighting Factor

1. Alpha
2. Neutron
3. Proton
4. Beta
5. Gamma
6. X-ray

Effect of Radiation Weighting per Unit of Absorbed Dose

A tissue absorbing 1 cGy of proton radiation sustains five times (5X) as much biological damage as a tissue absorbing the same quantity of X-rays.



Radiation Effects Depend Upon

- Energy deposited
- Radiation type
- Distribution of deposited energy:
  - Whole-body/external
  - Local
  - Internal contamination

Classification of Radiation Induced Health Concerns

- Acute Radiation Syndrome
- Local Radiation Injury
- External Radionuclide Contamination
- Local Trauma with Radionuclide Contamination
- Internal Radionuclide Contamination

Atomic Veterans

- New proposal – August 2001
- Expansion of “radiation-risk activities” to include:
  - Exposure from underground nuclear tests at Amchitka Island, Alaska before Jan. 1, 1974.
  - Service at gaseous diffusion plants in Paducah, KY., Portsmouth, OH., and Oak Ridge, TN (area K25).

- List of illnesses to include:
  - Cancer
    - Bone
    - Brain
    - Colon
    - Lung
    - Ovary

BEIR V, 1990
Excess Cancer Mortality Estimates

Excess Lifetime Cancer Deaths per
100,000 Persons Exposed to 100 mSv

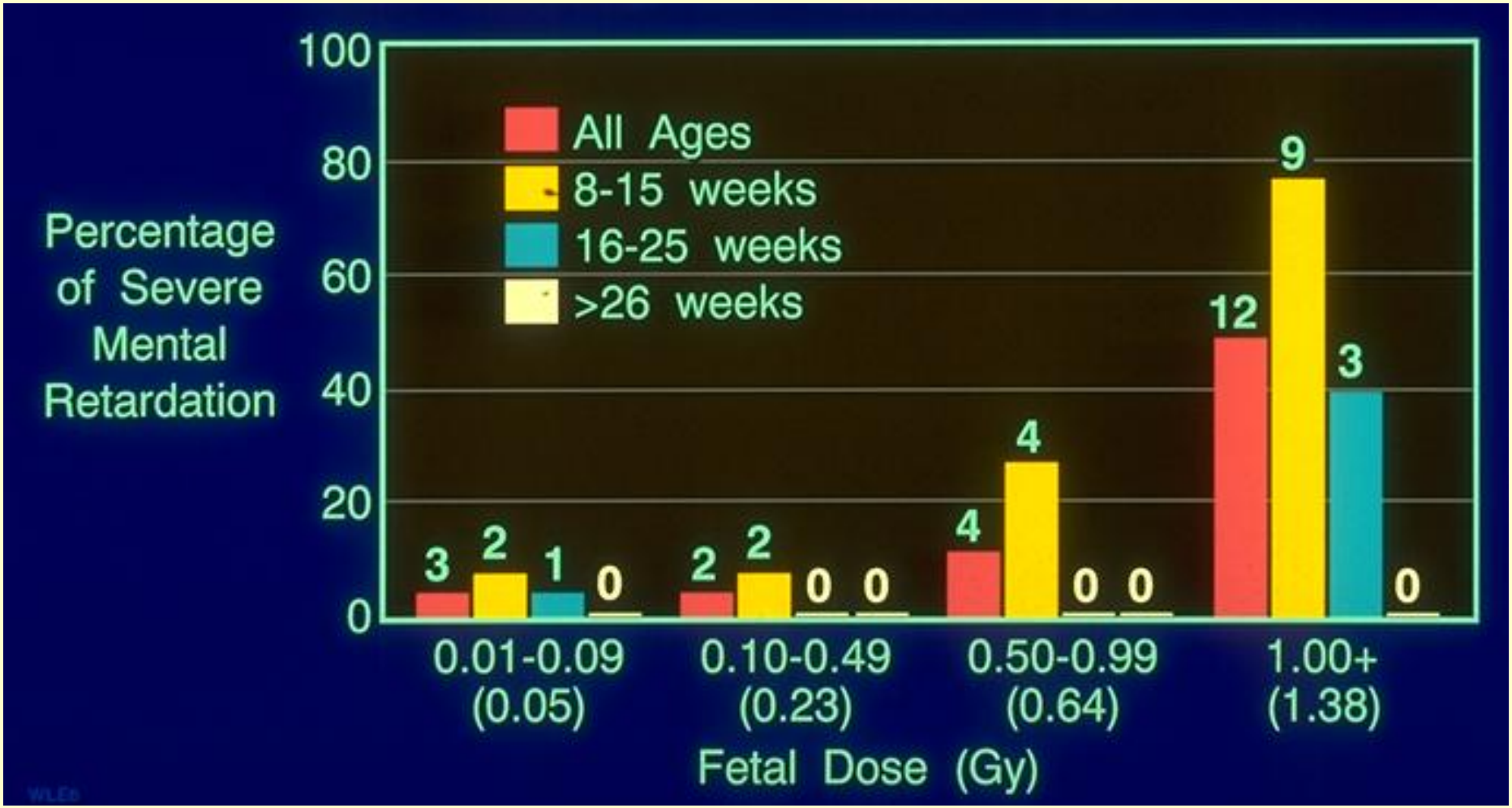
Cancer Type	Excess Risk (males)	Excess Risk (females)
Leukemia, adult	110	80
Respiratory system	190	150
Digestive system	170	290
Breast, female	---	70
All other sites	300	220
TOTAL	770	810

Note: Predicted approximately 20% lifetime cancer deaths U.S. (without added radiation dose)

Radiosensitivity (most to least):

- Lymphocytes
- Erythroblasts
- Myeloblasts
- Epithelial Cells
  - Intestinal crypts
  - Testis
  - Ovary
  - Skin
  - Secretory glands
  - Lungs and bile ducts
- Endothelial Cells
- Connective Tissue Cells
- Tubular Cells of Kidneys
- Bone Cells
- Nerve Cells
- Brain Cells
- Muscle Cells

Mental Retardation & Fetal Doses [Combined A-bomb Data (BEIR V)]



Recommended Dose Limits

	Dose Limit	
Application	**Occupational**	**Public**
TEDE (whole body)	5 Rem or cSv	100 mrem or .1 cSv
Annual equiv. dose		
- Lens of the eye	15 Rem or cSv	1.5 Rem or cSv
- Skin	50 Rem or cSv	5 Rem or cSv
- Hands & feet	50 Rem or cSv	-