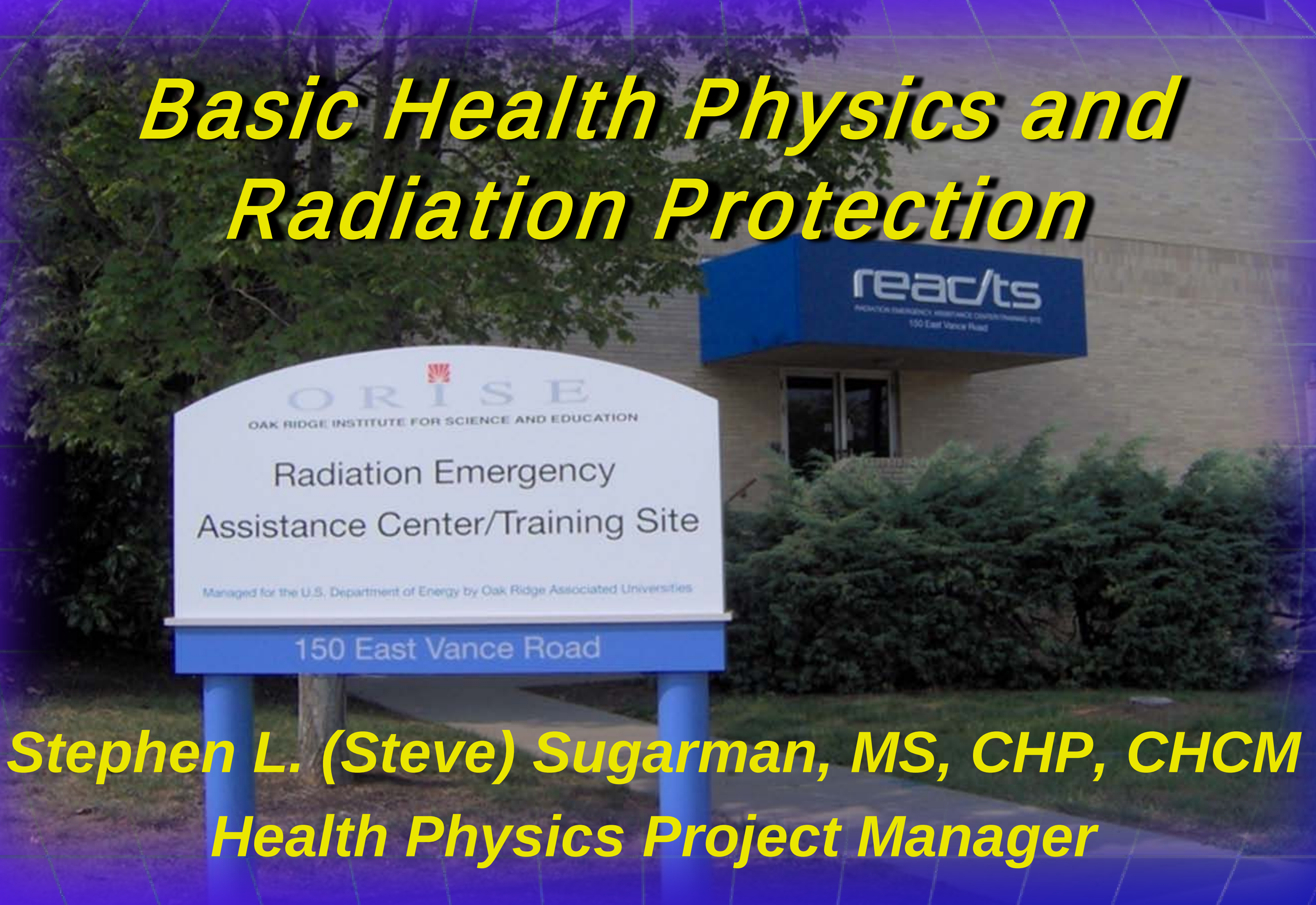
Basic Health Physics and Radiation Protection



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Importance of HP Integration

An understanding of the basic health physics concepts is important because it helps build the foundation for understanding the mechanisms of radiation injury.

Additionally, it is essential that good communications occur between the medical and health physics staffs.

Objectives

The student should be able to:

1. Discuss basic radiation terminology
2. Describe the various types of ionizing radiation
3. Discuss the difference between irradiation and contamination
4. Describe basic ALARA principles

Radiation

- According to the Health Physics Journal (HPJ-60) radiation is the emission and propagation of energy through space or through a medium in the form of waves.

What is Non-ionizing Radiation?

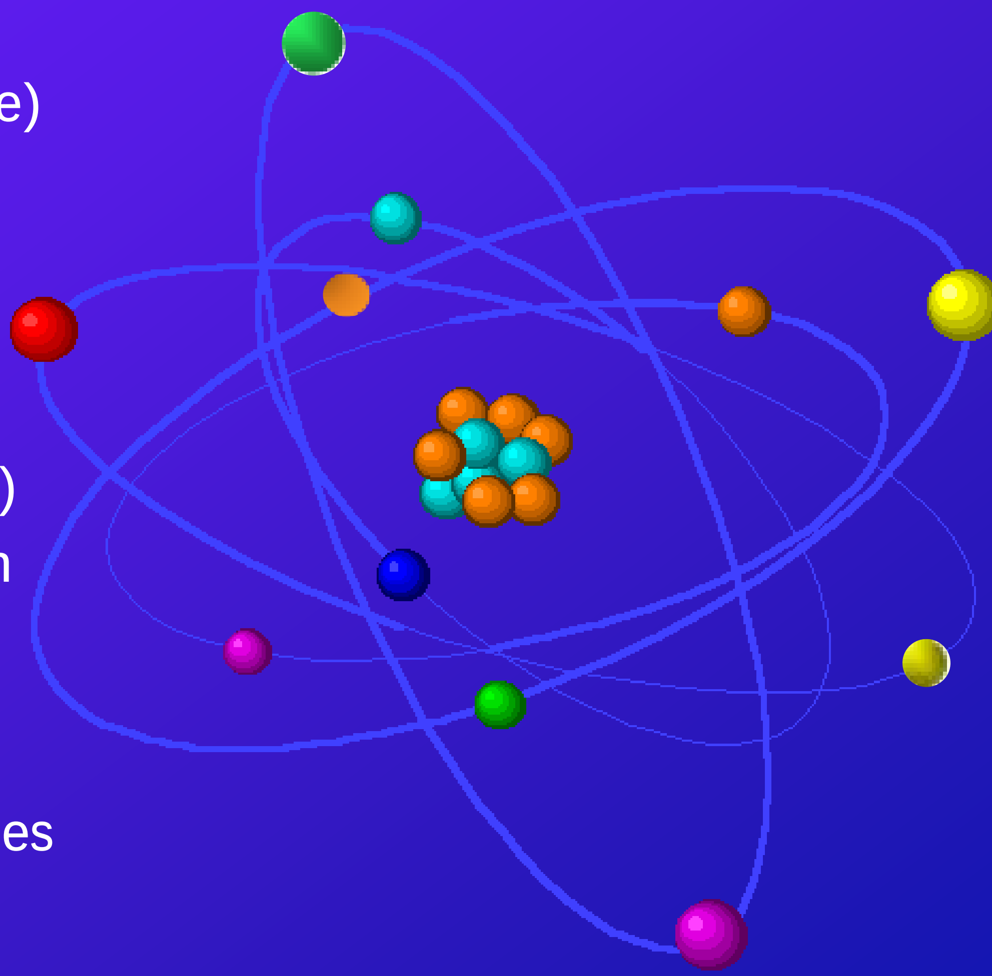
- Some forms of energy can be considered radiation but don't produce ionization
- Examples include radio waves, light, UV radiation and microwaves
- These forms of radiation will not be considered in this discussion of "radiation"

The Atom and Ionizing Radiation

In the nucleus:

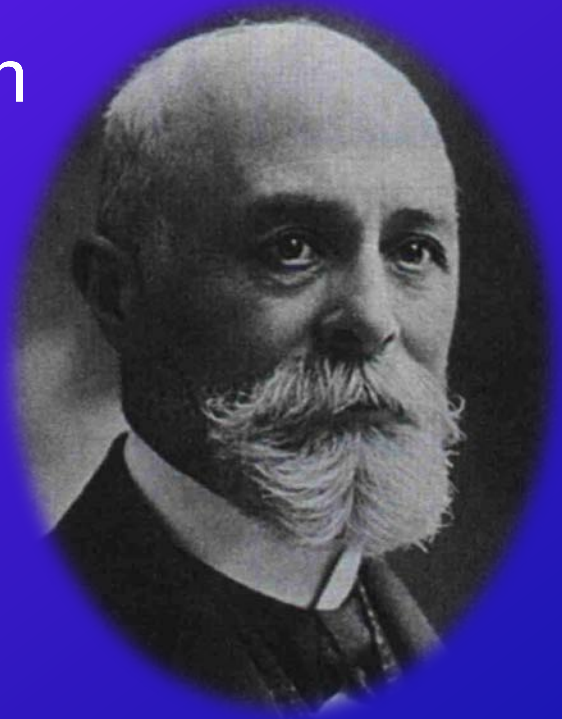
- Protons: Z (positive charge)
- Neutrons: N (zero charge)
- Each about same mass
- Z + N = A

- Outside the nucleus
  - Electrons (negative charge)
  - about 1/2000 of the proton mass
- Ionizing radiation has enough energy to strip electrons from atoms which can create changes within the cell.
- All nuclear radiation is ionizing.



What are Radioactive Materials?

- Materials that emit ionizing radiation
- Chemically identical to their non-radioactive counterparts
- Behave in the body the same as their non-radioactive counterparts (for example, radioactive iodine behaves the same as stable iodine)



Becquerel

Effects of Ionization

- Ionizing radiation is extremely easy to detect
- Ionizing radiation may be absorbed by shielding
- Ionization, IF it causes the disruption of a biologically important molecule, CAN lead to biological damage

Energy Units for Measuring Ionizing Radiation

Radiation energies are typically measured in units of keV (1000 electron volts) or MeV (million electron volts). This is the amount of energy that an emission has available to deposit into tissue.

C-14 beta	157 keV or 0.157 MeV
Cs-137 gamma	662 keV or 0.662 MeV
Am-241 alpha	5.485 MeV

Linear Energy Transfer

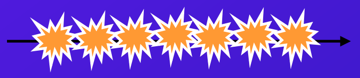
Linear Energy Transfer (LET): how much of a radiation's energy is transferred across a path.

<u>Low LET</u>

- Track average LETs ~0.2 to 3.5 keV/um
- Sparsely ionizing

<u>High LET</u>

- Track average LETs ~10s to 1000 keV/um
- Densely ionizing

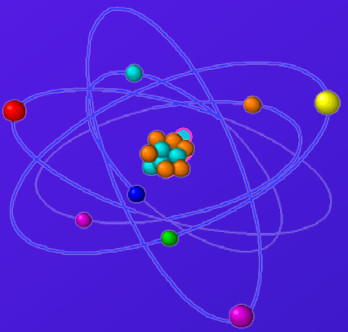


Types of Ionizing Radiation

• Alpha	α
• Beta	β
• Gamma	γ
• X-ray	X
• Neutron	n

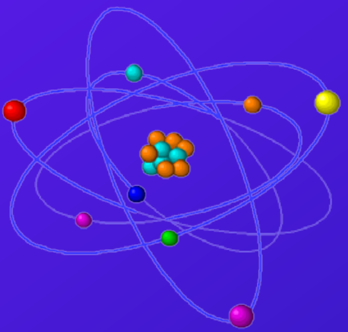
Ernest Rutherford

Alpha Particles



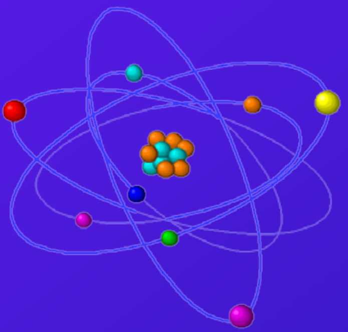
- 2 protons and 2 neutrons (plus two charge) emitted from heavy elements
- Most have energies between 4-8 MeV
- Very short penetration
  - a few cm in air
  - a few microns in tissue (less than the outer dead cell layer)
- Easily shielded
- High LET, efficient at creating ionization

Beta Particles



- High energy “electron” emitted from nucleus
- Can have wide range of energies depending upon the particular radionuclide
- Moderately penetrating
  - up to a few meters in air
  - millimeters in tissue
- Not as efficiently ionizing as alpha particles

Gamma Radiation

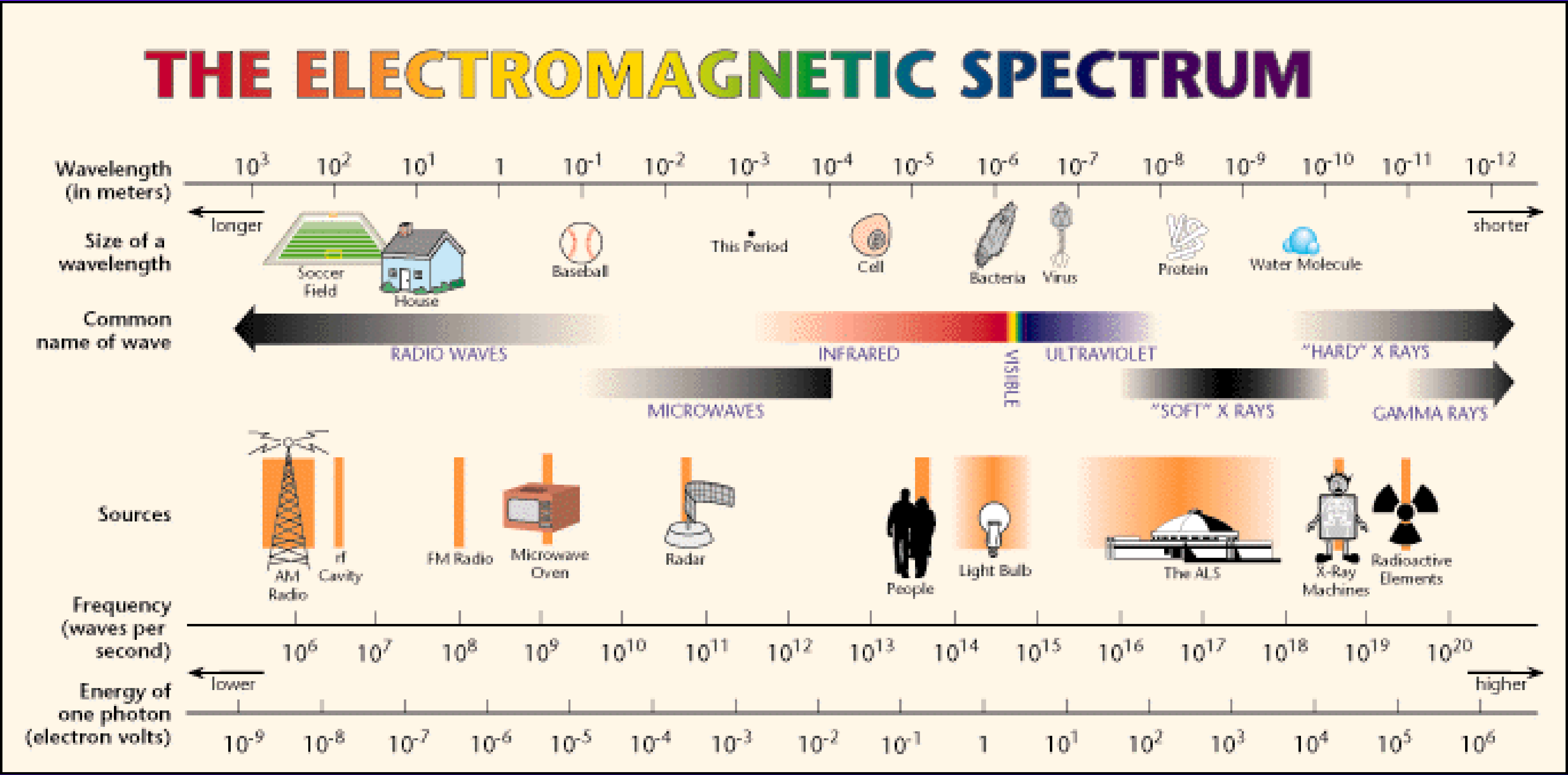


- Electromagnetic energy emitted from the nucleus
- Specific energies can be used for identification
- Very penetrating (many meters in air)
- Can be difficult to shield, often shielded with lead

X-Rays

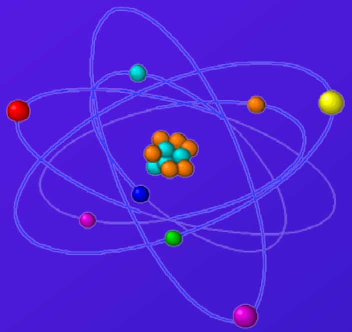
- Electromagnetic energy emitted from outside the nucleus
- May be "machine-produced" by bombarding high energy electrons on a target causing target electrons to change energy shells.
- May also be emitted from radioactive materials
- Similar shielding and penetrating powers as gamma radiation

Electromagnetic Waves



http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

Neutron Radiation

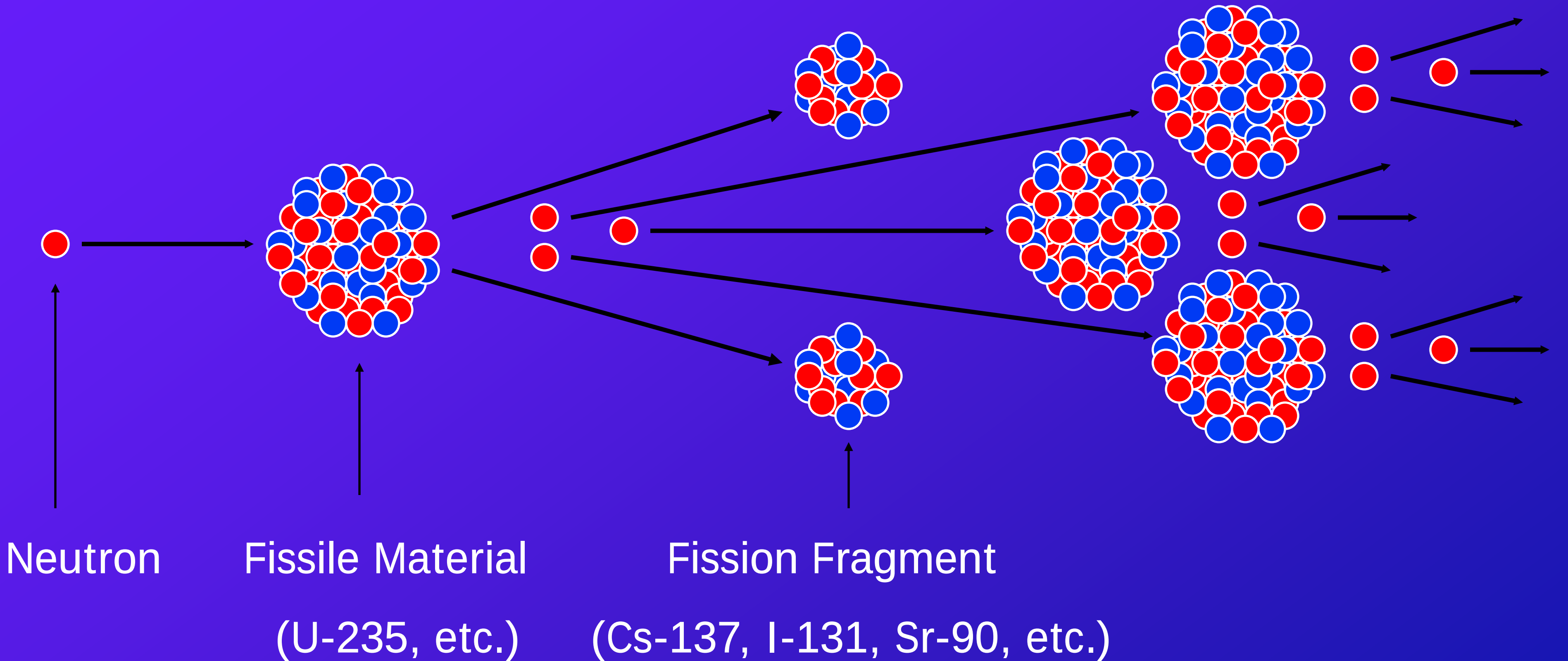


- Neutral particle emitted from the nucleus
- Can be very penetrating
- Requires special consideration for shielding
- Can induce radioactivity when absorbed by stable elements (N, Na, Al, S, Cl, P, etc.)

Basics of Criticality

- Fission - the splitting of the nucleus of the atom - generally into two fission products (atomic masses around 90 and 135) and 2-3 high-energy (fast) neutrons
- Steps of fission
  - nucleus absorbs neutron
  - excited nucleus splits into unequal fragments
  - neutrons (fast) and prompt gammas emitted
- About 200 MeV/fission (around 165 MeV kinetic energy, rest particles/photons/decay energies)

Nuclear Fission



Activity and Activity Units

- Activity is the number of disintegrations (or transformations) per time occurring in a radioactive material
- Conventional unit (USA): curie (Ci)
  - 1 Ci = 3.7×10^{10} disintegrations per second
- SI unit: becquerel (Bq)
  - 1 Bq = 1 disintegration per second
- 1 Ci = 3.7×10^{10} Bq

Note: 1 µCi = 2.22 million dpm = 37 kilobecquerels (0.037 MBq)

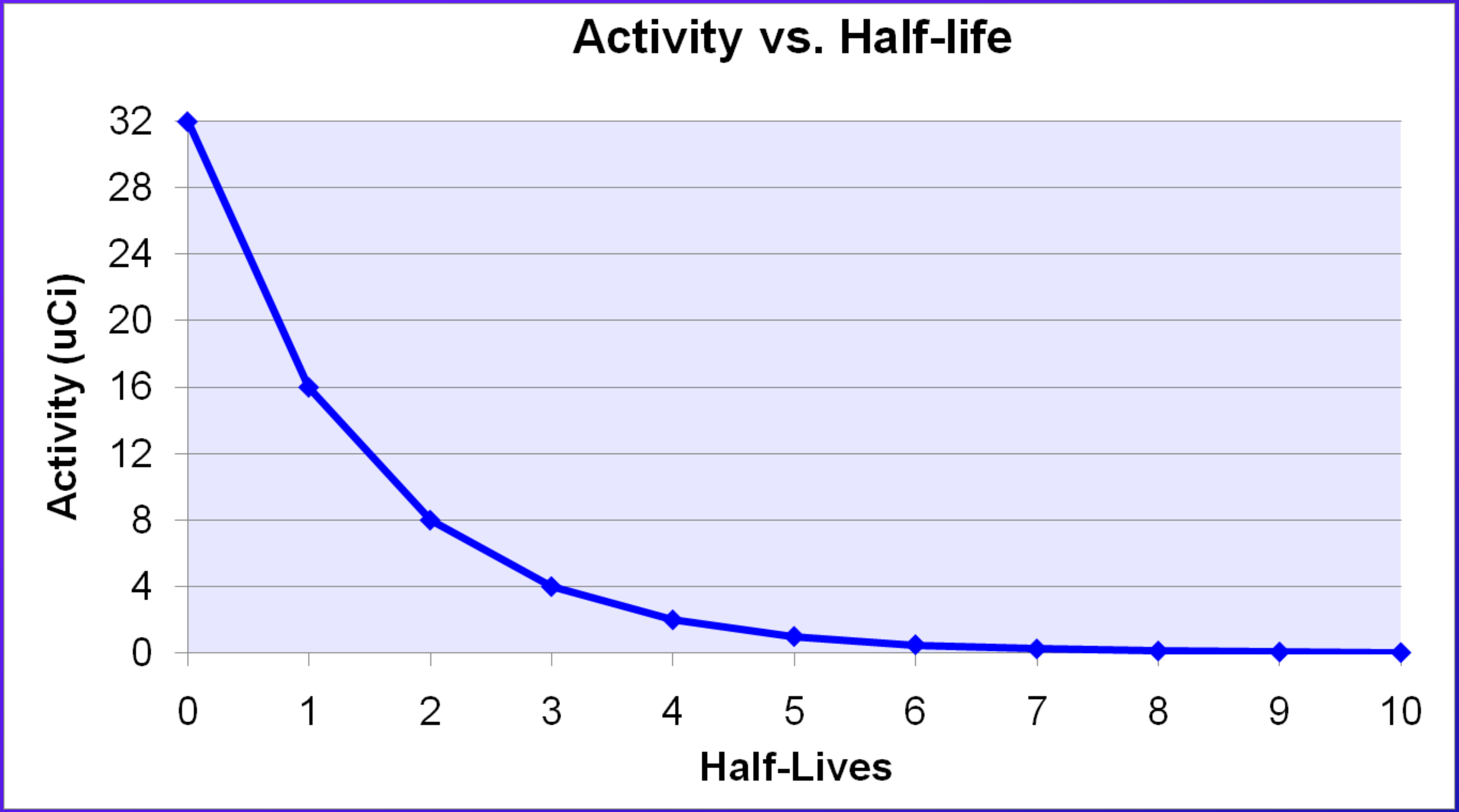
Specific Activity

- Defined as activity per unit mass
  - Ci/g, Bq/g, etc.
- Ci/g = $(1.3 \times 10^8)/(T_{1/2}$ in days x A)
- Long $T_{1/2}$ = low SpA; short $T_{1/2}$ = high SpA
- Remember the mass, or amount of matter, is different from the amount of activity present


Source
Source

Half-Life

- Time required for a radioactive substance to lose 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



Half-lives	0	1	2	3	4	5	6	7	8	9	10
Activity	32	16	8	4	2	1	0.5	0.25	0.125	0.0625	0.03125

Irradiation

- With an Irradiation there is no radioactive material transferred.
- An irradiated patient is NOT radioactive and cannot transfer contamination or radiation to a health care provider.

Radiation Quantities and Units

Quantity	Measures	Old Units	SI Units
Exposure	Ionization	roentgen (R)	Coulomb/kg
Absorbed Dose	Energy deposition	rad	Gray (Gy)
Dose Equivalent	Biological damage/risk	rem	Sievert (Sv)

Dose rates are given in quantity per time units, such as absorbed dose rate, Gy/hr.
For external exposure to beta, gamma, and X-rays, 1 R = 1 rad = 1 rem.

What are Quality Factors ?

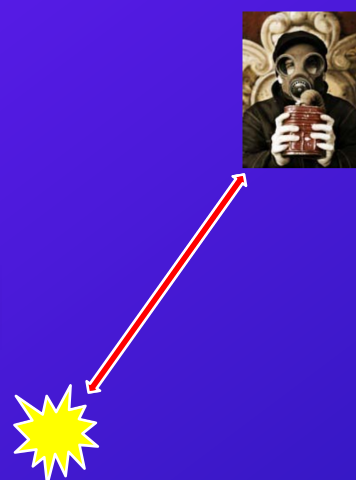
- The QF relates the amount of biological damage, and resulting risk, caused by any type of radiation to that caused by the same absorbed dose of x- or gamma-rays.
- QF (x, gamma, beta) = 1
- QF (alpha) = 20 (internal only)
- QF (neutron) = 3--20, depending on energy

ALARA

ALARA ("As Low As Reasonably Achievable") means making every reasonable effort to maintain exposures to ionizing radiation as far below the regulatory dose limits as practical, taking into account economic, societal, and other relevant considerations.

Reduction of External Dose

- Minimize the time spent near the radiation source
- Maximize the distance away from the source ($1/R^2$)
- Make use of available shielding
- Minimize the quantity of radioactive materials handled



What is Contamination?

- Contamination is simply the presence of radioactive material where it is not wanted
- Persons may be contaminated either externally, internally, or both
- Exposure does not necessarily imply contamination

Internal Deposition

- Annual Limit on Intake (ALI)
  - The amount if a radionuclide that, if taken into the body, will result in a regulatory limit being met.
- The ALI can be used to determine the magnitude of a contaminating event.
- ALI and DAC tables can be found in Federal Guidance Report #11 (EPA)

Reduction of Internal Dose

- Minimize and control contamination
- Properly use protective clothing
- Do not eat, drink, or smoke in contamination areas
- Check yourself for contamination prior to leaving a potentially contaminated area

Annual Regulatory Limits

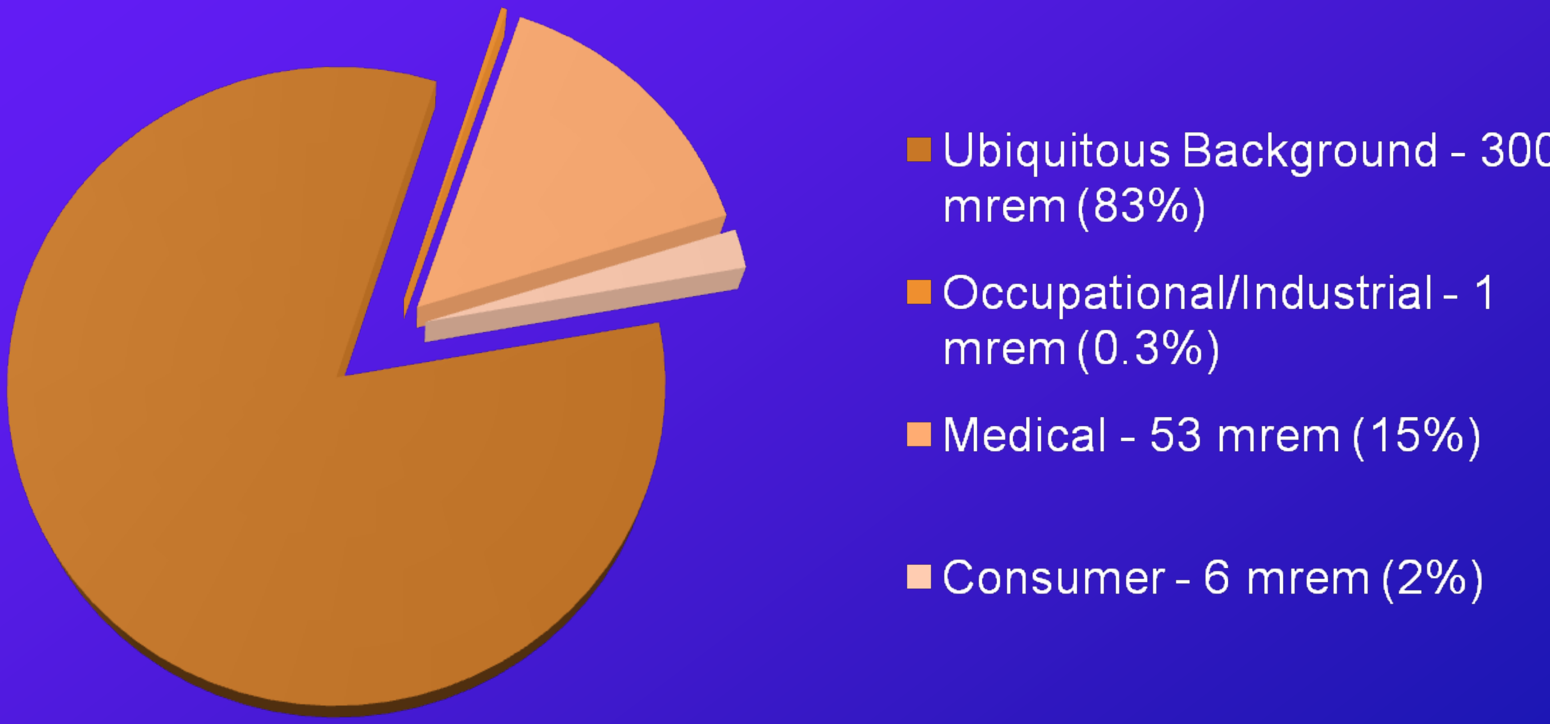
	rem	Sv
Members of the public	0.100	0.001
Occupational limits		
Total effective dose equivalent	5	0.05
Single organ dose equivalent	50	0.5
Lens of the eye	15	0.15
Skin dose equivalent	50	0.5
Extremity dose equivalent	50	0.5
Fetal dose (declared pregnancy)	0.5	.005

Typical Radiation Exposures

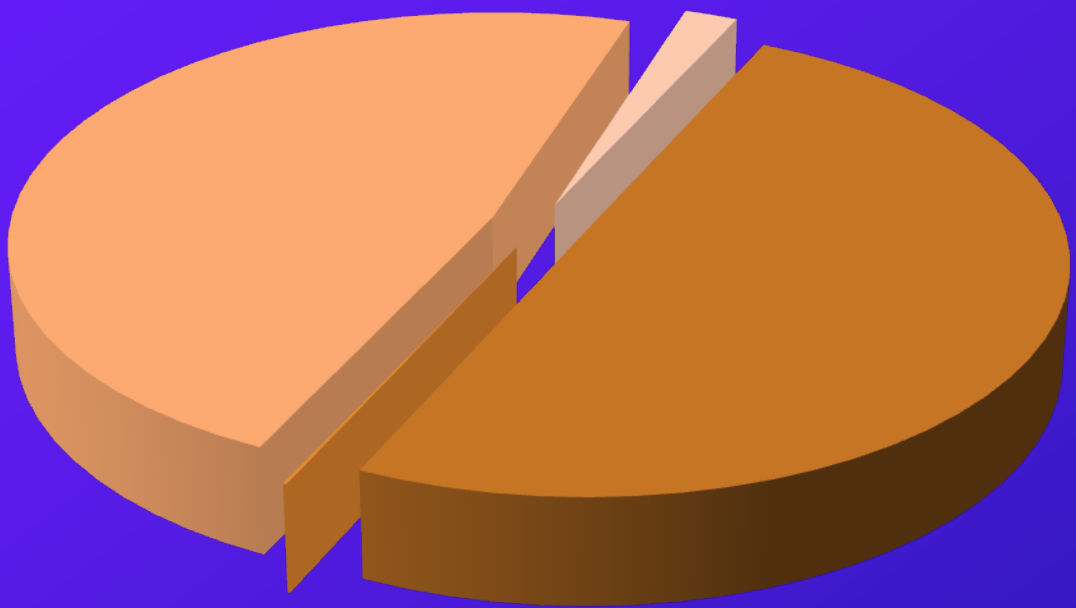
Natural background and manmade radiation (annual average dose equivalent, inc. radon)	6.25 mSv / 625 mrem
Diagnostic chest x-ray	0.1 mSv / 10mrem
Flight from LA to Paris	0.048 mSv / 4.8 mrem
Barium study	8 mSv / 800 mrem
Smoking 1.5 packs per day - 1 year dose	0.16 Sv / 16 rem
Heart catheterization	0.45 Gy / 45 rad
Mild Acute Radiation Sickness*	2 Gy / 200 rad
LD50 for Irradiation*	4.0 Gy / 400 rad

*acute exposure

360 mrem: Ionizing Radiation Exposure of the US Population – Early 1980s (NCRP-160)



625 mrem: Ionizing Radiation Exposure of the US Population - 2006 (NCRP-160)



- Ubiquitous Background - 311 mrem (50%)
- Occupational/Industrial - 0.8 mrem (0.1%)
- Medical - 300 mrem (48%)
- Consumer - 13 mrem (2%)

Review

- What are the types of ionizing radiation?
- What units are used for activity?
- What are the units of dose? Dose equivalent?
- How do you get contaminated?
- How do you get irradiated?
- How can you limit your dose?

The Medical Aspects of Radiation Incidents

Topics covered include:

- Basic health physics
- Basic external/internal dose calculation
- Acute local and whole body injuries/illnesses
- Treatment for internal contamination
- Patient decontamination
- Delayed effects
- Psychological aspects

http://orise.orau.gov/files/reacts/medical-aspects-of-radiation-incidents.pdf reac/ts

QUESTIONS????

Remember, medical care takes priority over contamination concerns.