# Limited Scope X-Ray Technician Course

## Module 4: Radiation Safety

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OLYMPIC HEALTH PHYSICS
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## Outline

- Radiation Biology Reminders
- ALARA (As Low As Reasonably Achievable)
- Time, Distance, & Shielding
- X-Ray Room Design
- Radiation Dose Units

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## Radiation Biology Reminders

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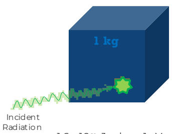
## What Is Radiation Dose?

- Dose is defined as the energy deposited per unit mass
  - 1 J/kg = 1 Gray
  - Absorbed Dose
- Measured in units of
  - Gray or Rad
  - 100 rad = 1 Gy




$1.6 \times 10^{-19}$ Joules = 1 eV

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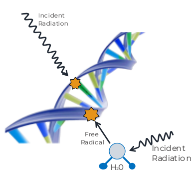
## How Does Radiation Cause Damage?

- Direct Damage vs. Indirect Damage
  - Single Strand Break
  - Double Strand Break

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## Radiation As A Carcinogen

- What is a Tumor?
  - Mass of undifferentiated tissue growing amidst differentiated tissue
- What is Cancer?
  - Growth of one or more malignant tumors
- 3 Stage Model of Cancer Formation
  - Initiator – mutational event
  - Promoter – functional change
  - Progression – tumor invasion
- Radiation is a weak carcinogen because it acts only as an initiator.

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## ALARA

- As Low As Reasonably Achievable
- Circa 1940's via Herman Muller
  - Experiments with Fruit Flies
  - Lowest dose with measurable response was 275,000 mrem
  - Data fit linear curve from 275,000 mrem to 10,000,000 mrem
- ALARA was never meant to be applied to patient exposures
  - It is a regulatory concept for occupationally exposed workers – 10 CFR 20.1101


## The Radiation Dose Problem

Unknown, and likely unknowable, behavior of dose response curve at doses less than ~ 100 mSv (10,000 mrem)

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## The Radiation Dose Problem

**Assume No LNT**

- Assume nothing happens below 10,000 mrem
- Remove rules and regulations
- Decreased cost and oversight
- Increase radiation worker limits
- Less conservative approach, but may be more appropriate based on evidence
- What if this is wrong?

**Assume LNT**

- There is an increased risk from any exposure to radiation
- Should exercise sound radiation protection principles to minimize this exposure
  - ALARA
- Increased cost, regulatory burden, oversight, etc.
- This is the more conservative approach
- We always take the conservative approach in Safety

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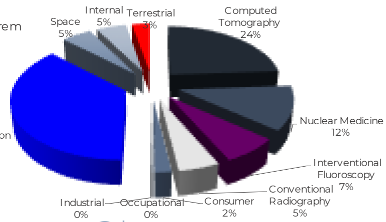
## Exposure Sources for Effective Dose

Background – 310 mrem
Medical – 300 mrem




Data from NCRP Report 160

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## ALARA

- As Low As Reasonably Achievable
  - Reasonable efforts should be made to keep occupational doses as far below regulatory limits as possible
- Fundamentals of Radiation Protection
  - Time, Distance, & Shielding
- Sources of Exposure in X-Ray
  - X-Ray Tube, Patient Scatter

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## Time

Time and dose are directly proportional

**Time ↑ Dose ↑**

$$1\frac{mrem}{hr}\times 1hr = 1\ mrem$$

$$1\frac{mrem}{hr}\times 2hr = 2\ mrem$$

**Time ↓ Dose ↓**

$$1\frac{mrem}{hr}\times 1hr = 1\ mrem$$

$$1\frac{mrem}{hr}\times 0.5hr = 0.5\ mrem$$

## Distance

$$I_1 D_1^2 = I_2 D_2^2$$

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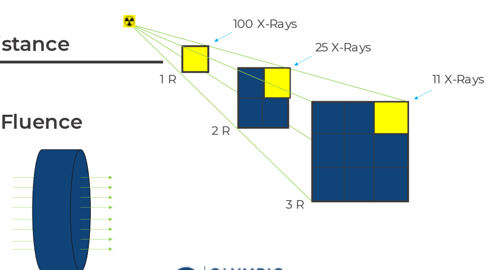
## Distance

## Fluence

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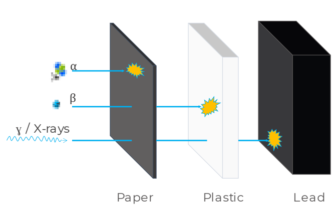
## Shielding

- Some Considerations
  - What types of radiation are you shielding?
  - What is the energy and activity?
  - What shielding material do you have available?
- Useful shielding in X-Ray
  - Portable Shields, Control Wall, Lead Aprons
- Considerations of Bremsstrahlung

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## Shielding Examples

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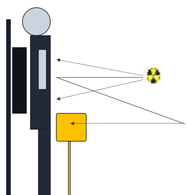
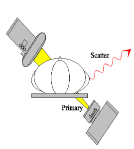
## Use of Patient Shielding

- Gonadal Shields & Contact Shields
- Never place a shield in the area of interest!
- Required by many states and possibly other regulatory and/or accrediting agencies
- But the reality is....
  - Somatic radiation effects have never been observed in humans....EVER!
  - Sterility has a threshold of 2500 – 6000 mGy
  - Radiation induced malformations (pregnant patients)
    - Threshold is 100 – 200 mGy, not considered "significant" risk until > 1000 mGy
  - An X-Ray of the pelvis is ~ 1.1 mGy

## Shielding Out-Of-Field Body Parts



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## Patient Shielding

- Potential to drive tube current up and deliver more dose
- Little to no actual dose savings to the patient
- Potential to impact clinical study
- Alternative (and better) methods are available to control radiation dose to the patient

## Regulatory & Other Considerations

- Each state has rules and regulations that govern the use of X-Rays in the Healing Arts
  - Some regulations may pertain to patient shielding – specifically gonadal shielding
  - Careful attention should be paid to those regulations
- Patients may request or feel more comfortable with lead shielding

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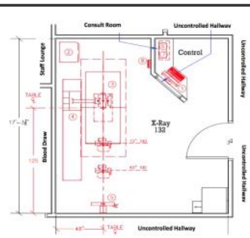
## X-Ray Room Design

- What gets shielded?
- Primary vs. Scattered vs. Leakage
- Factors that affect shielding
  - Design Goal (Dose Limits)
  - Workload
  - Occupancy
  - Distance
  - Use Factor
  - Shielding Material (Concrete, Lead, etc)
- Control Booth Design

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## Signage & Postings




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## Types & Sources of Radiation

- Machine Produced
  - X-ray, CT, Cath Lab, etc
  - Linear Accelerators
  - Other particle accelerators
- Radioactive Materials
  - Nuclear Medicine
  - Radiation Therapy
  - The Environment
  - YOU!

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## How Does Radiation Go Away?

- Machine Produced
  - TURN IT OFF!!!
- Radioactive Materials
  - Radioactive Decay


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# Radiometric Units

Quantifying Radiation

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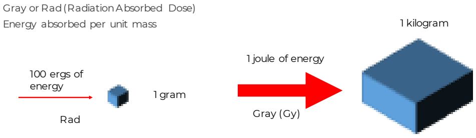
## Absorbed Dose

- Gray or Rad (Radiation Absorbed Dose)
- Energy absorbed per unit mass




1 Gray (Gy) = 100 Rad

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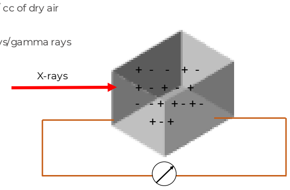
## Radiation Exposure

- Roentgen = 1 esu / cc of dry air
- $2.58 \times 10^{-4}$ C / kg
- Only valid for x-rays/gamma rays

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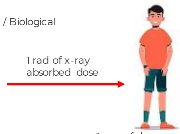
## Dose Equivalent

- Sieverts or Rem (Roentgen Man Equivalent)
- Absorbed Dose x Quality Factor
- Quality Factor = Biological Effect of Radiation / Biological Effect of 250 keV X-rays
- For diagnostic x-ray exposures, QF = 1




1 rem of dose equivalent (biological effective dose)

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## Roentgen, Rad, & Rem

- 1R of X-ray Exposure results in 0.96 rad of soft tissue absorbed dose.
- The Quality Factor (QF) for x-rays is 1
- 1R of X-ray Exposure = 0.96 rem of equivalent dose.

For diagnostic x-ray radiation exposure

**1 R = 1 Rad = 1 Rem**

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## Units of Measurement

| Mathematical Notations: Prefixes | | |
|---|---|---|
| giga | G | $10^9$ |
| Mega | M | $10^6$ |
| kilo | k | $10^3$ |
| milli | m | $10^{-3}$ |
| micro | μ | $10^{-6}$ |
| nano | n | $10^{-9}$ |

| Units Describing Radiation Field | | |
|---|---|---|
| Roentgen (R) | Radiation Absorbed Dose (rad) | Roentgen Equivalent Man (rem) |
| Photon ionization in air (exposure) | Amount of energy deposited in unit mass of medium | Biological effect of energy deposited by radiation in system |
| 2.58E-4 C/kg | SI unit: Gray (Gy) = 100 rad Gray = J/kg | SI Unit: Sievert (Sv) = 100 rem Sv = Rad*QF |

Where:

C = Coloumbs
J = Joules
QF = Quality Factor

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## How To Use Various Units of Measurement

| Units Describing Radiation Field | | |
|---|---|---|
| Exposure | Contamination | Occupational Dose |
| Roentgen (R) | dpm/mCi/Bq | Roentgen Equivalent Man (rem) |

- Use Roentgen (R) when describing an exposure in air or mR/h for exposure rate in air.
  - "Exposure" measures how much radiation is present in air.
  - Measured with an ion chamber or a GM ratemeter.
  - Used for daily surveys or release measurements.
- Use rem or Sievert (Sv) when describing the "occupational dose," or biological effect to the human body as a system.
  - These units are used to communicate risk in terms of cancer induction probability.
  - Note, the US still recognizes the rem (1 Sv = 100 rem).
  - This is the unit you will see on your dosimetry or occupational badge report.

*These units are not interchangeable.

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