Introduction to Nuclear Radiation

Presented By:

The Palladino Company, Inc.

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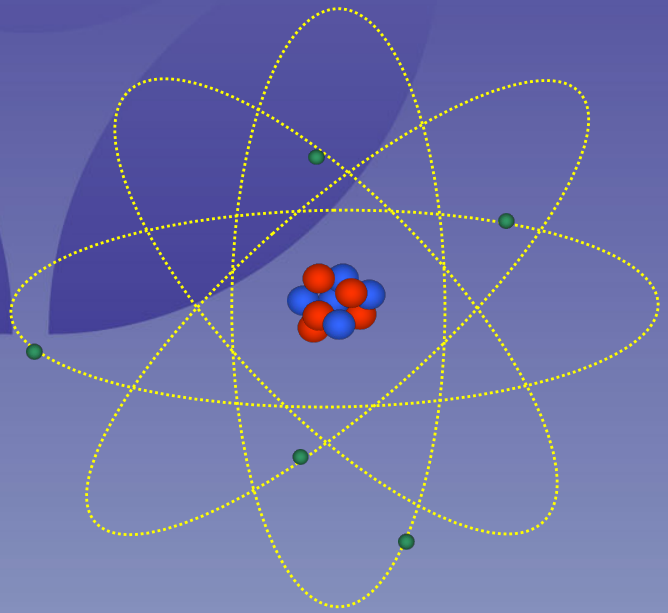
Course Agenda

- Characteristics
- Measurement
- Action Levels
- Health Effects
- Protection Methods
- Radioactive Sources
- Instruments
- Incident Procedures
- Decontamination

Characteristics of Radiation

Sooo what is nuclear radiation anyway?



Radioactivity

- Materials that release nuclear ionizing radiation are **Radioactive**

- Three primary types of nuclear ionizing radiation
  - Alpha
  - Beta
  - Gamma

Alpha Radiation α

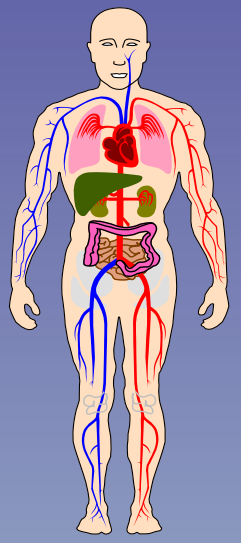
- 2 protons and 2 neutrons from the nucleus

- Travels 1 to 2 inches in air
- Stopped by paper or skin

- Large amount of energy released in short distance

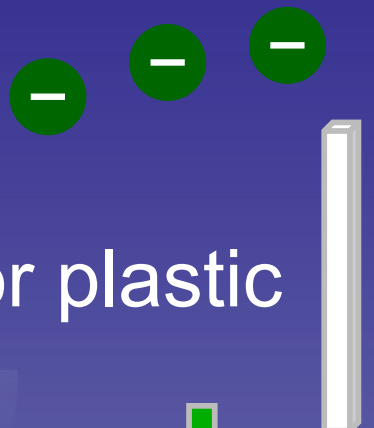
- Not an external hazard (except for eyes)

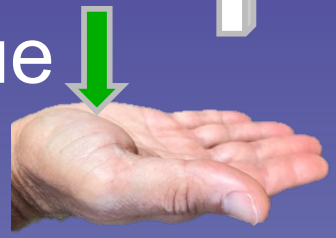
- Serious internal hazard
- Common symbol is the Greek letter for A = α

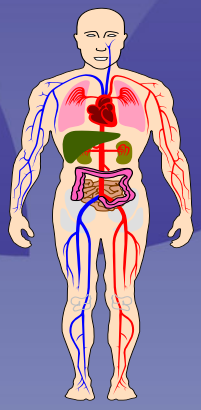


Beta Radiation β

- Electrons from the nucleus ($n \rightarrow p^+ + e^-$)
- Travel up to 10 feet in air
- Stopped by a sheet of aluminum or plastic
- Travel up to 1/4 inch into animal tissue
- High external hazard
- Internal hazard
- Common symbol is the Greek letter for B = β





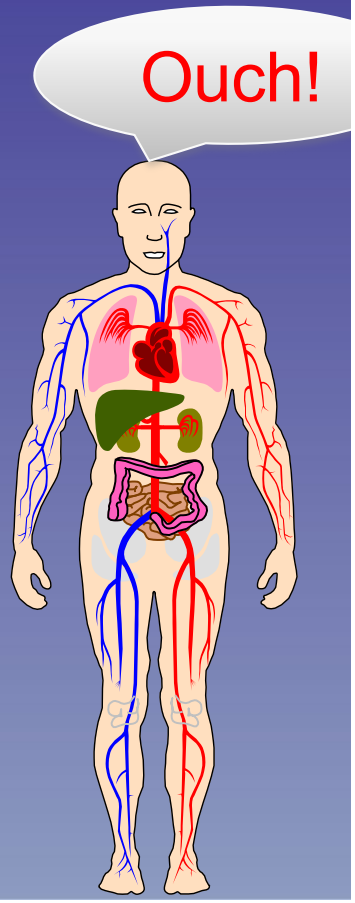


Gamma Radiation γ

- Electromagnetic energy released from the nucleus
- Travels 100s of feet in air

- Stopped by 3 feet of concrete or 1 foot of lead

- Greatest external hazard
- Internal hazard
- Common symbol is the Greek letter for G = γ



Activity

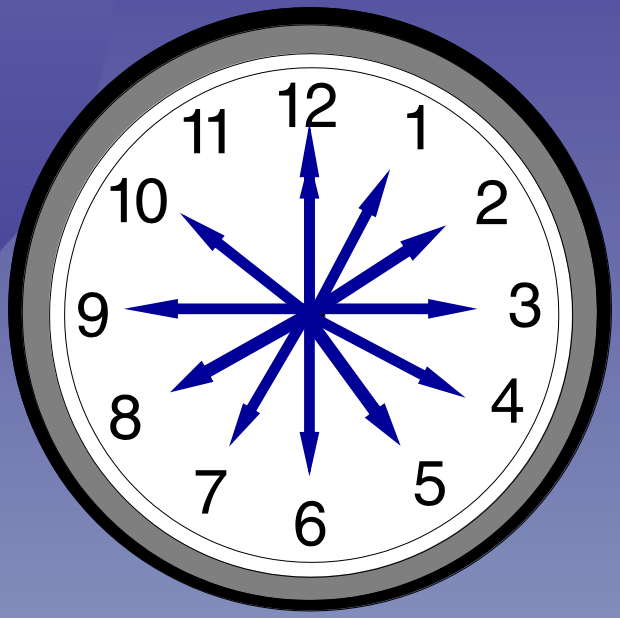
- **Curies (Ci)** = radioactivity of material
  - 1 Ci = 37 billion disintegrations per second (dps)
- **Becquerel (Bq)** is international unit
  - 1 Bq = 1 dps
- 1 Ci = 37 billion Bq
- Example: 1 µCi Cs-137 check source = 37,000 dps

Half-Life ($T_{1/2}$)

- **Half-Life ($T_{1/2}$)** = time for radioactivity to decrease in half
- 7 to 10 half-lives until material is near background
- Example: if half-life is 1 hour, then activity remaining after 10 hours is

0.1%

Half Lives = 10

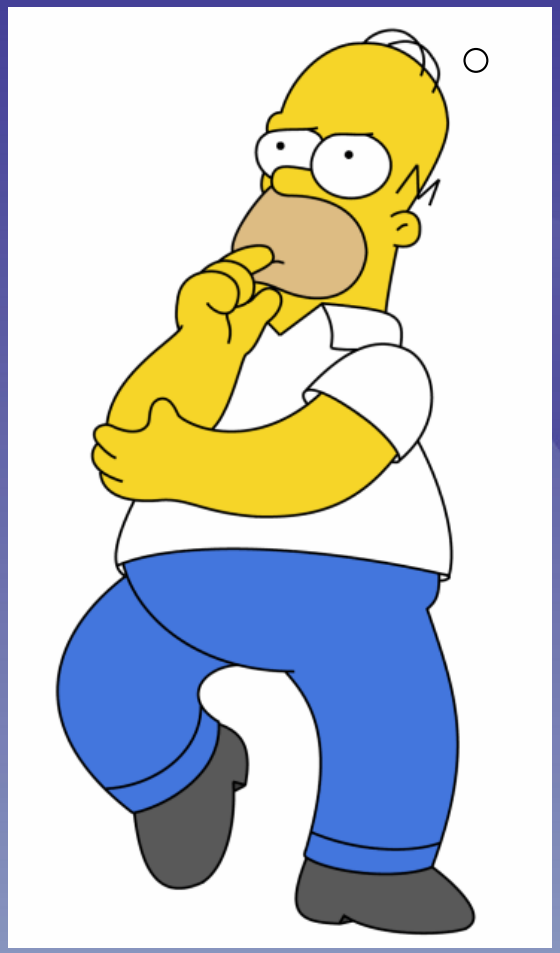


Comparison Of Half-Lives

Radioactive Material	Half-Life
U-238	4.5 billion years (depleted U)
C-14	5,730 years (carbon dating)
I-131	8 days (treat thyroid cancer)
Tc-99m	6 hours (medical imaging)
Pu-232	35 minutes (no uses)
Sr-77	9 seconds (no uses)
Po-212	0.298 microsec (no uses)

Shorter half-life = higher activity

Roentgen, rem, micro, milli,
dose, dose rate...
What's the difference?



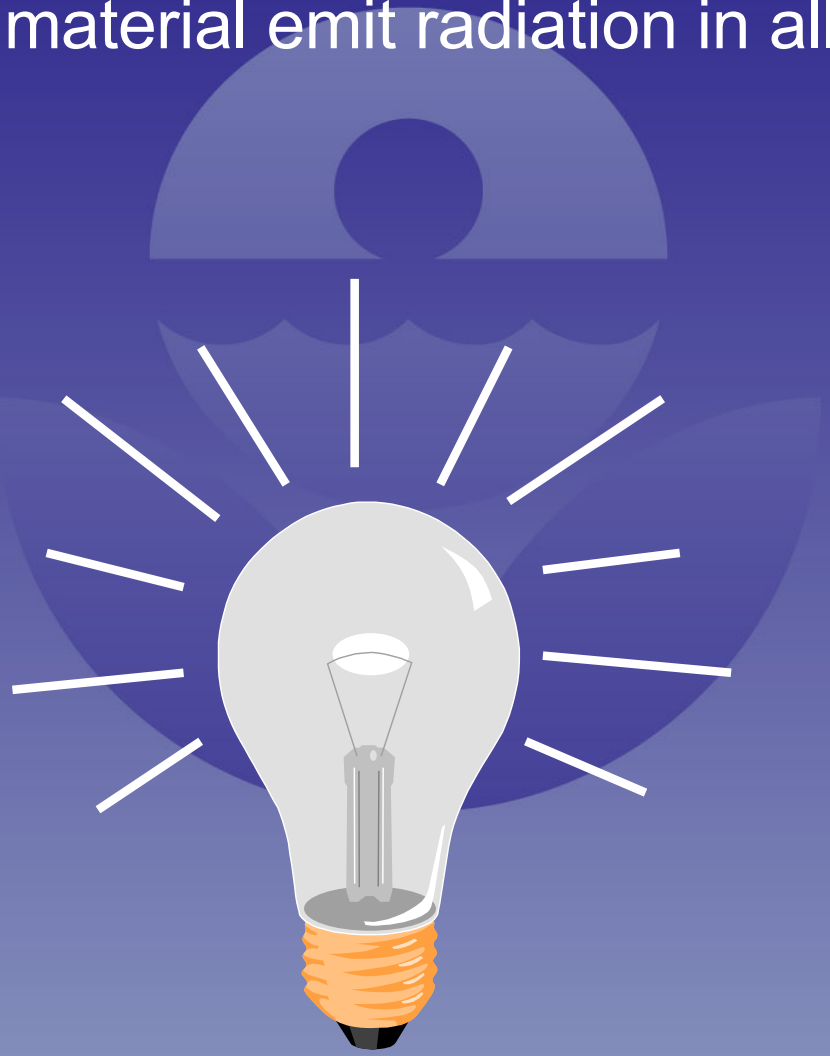
Units of Measurement

Units

Unit	Symbol	Name	Number
Tera	T	trillion	1,000,000,000,000
Giga	G	billion	1,000,000,000
Mega	M	million	1,000,000
kilo	k	thousand	1,000
—	—	one	1
milli	m	thousandth	1/1,000
micro	μ	millionth	1/1,000,000
nano	n	billionth	1/1,000,000,000
pico	p	trillionth	1/1,000,000,000

Radioactive Point Source

Radioactive material emit radiation in all directions



Radiation Measurement

- **Counts per minute (cpm)** = radiation measured by a detector
- cpm ≠ activity (Ci or Bq)
- cpm ≠ exposure (uR)

Roentgen (R)

- **Roentgen** (ran-'kin) – primary health and safety detector

- Some instruments measure in
  - ▶ **milliroentgen per hour (mR/hr)**
  - ▶ **microroentgen per hour (μR/hr)**

- Exposure rate is like a speedometer

- Roentgen ≠ radiation dose to people

Roentgen Equivalent Man (rem)

- Rem = amount of damage to human tissue
  - 1 R ≈ 1 rem (gamma or beta only)
  - 1 R ≈ 20 rem (alpha **internal exposure**)

- 1 rem = 0.01 **Sievert (Sv)** - International units
  - 100 rem = 1 Sv
  - 100 mrem = 1 mSv

- Rem is like an odometer

- Rem = total damage to people

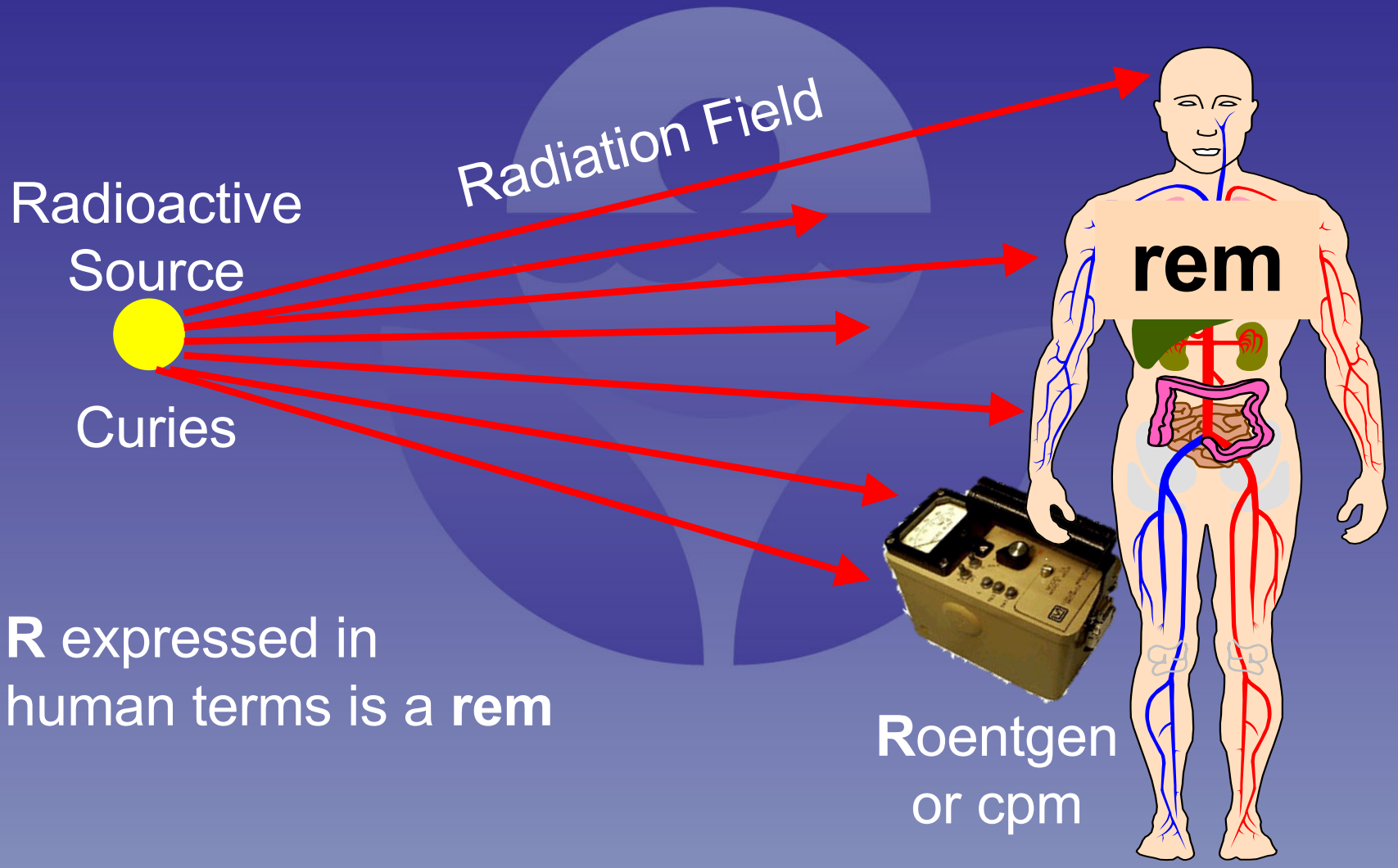
Units Mnemonic

μR = OK

mR = Maybe

R = Rethink

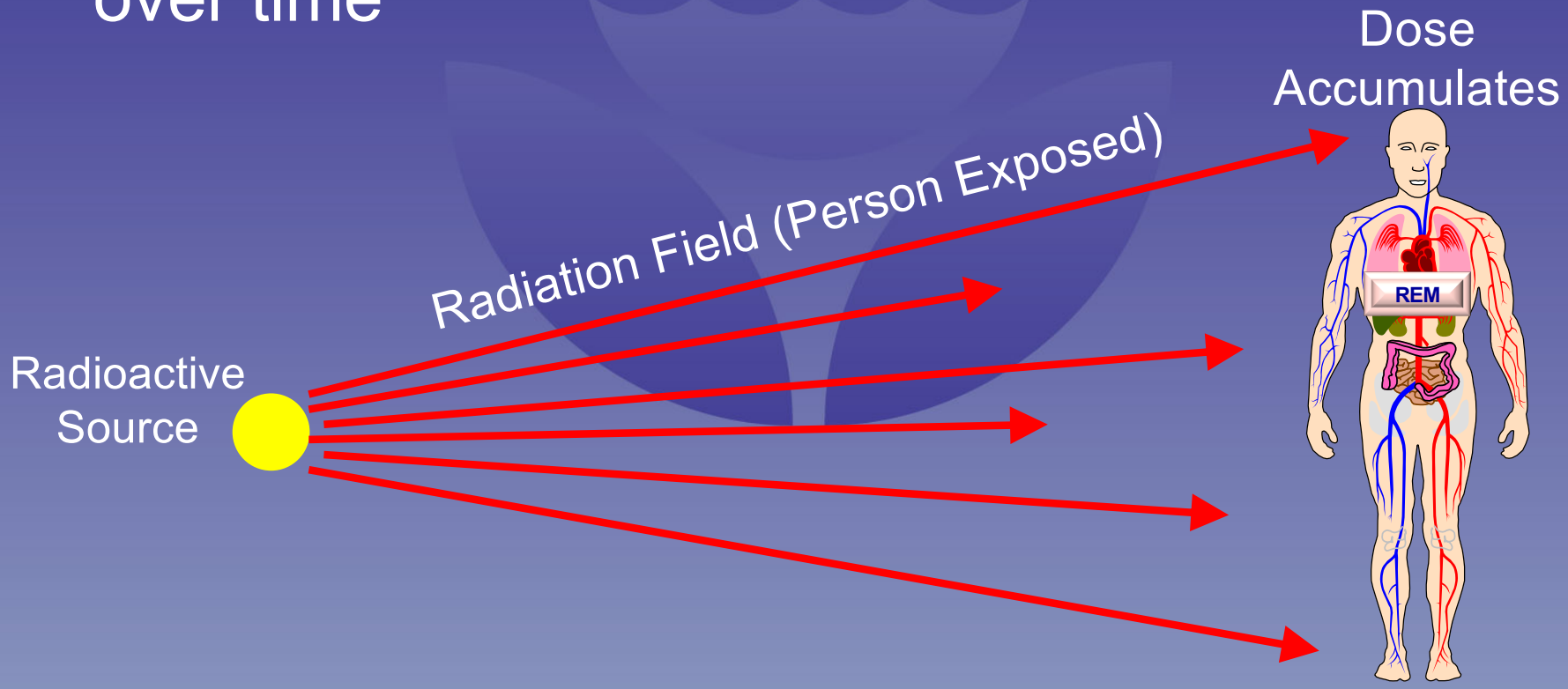
Measurement Illustrated



R expressed in human terms is a **rem**

Exposure and Dose

- Exposure = radiation interacting with your body
- Dose = damage to your tissue from exposure over time

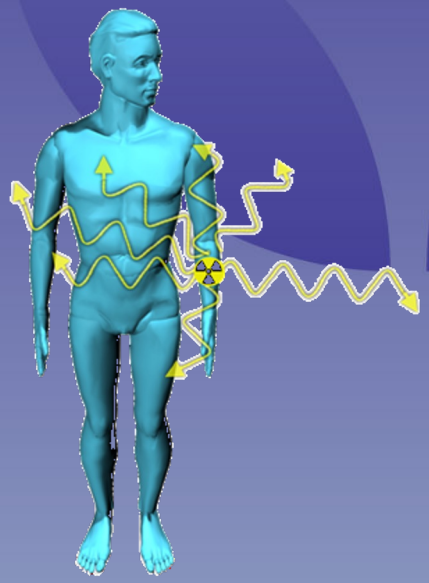


Exposure Misconception

- You can not "become radioactive" or "glow" if exposed to radiation! (Sorry)

- You are contaminated if a radioactive material is *on* (external) or *in* (internal) your body

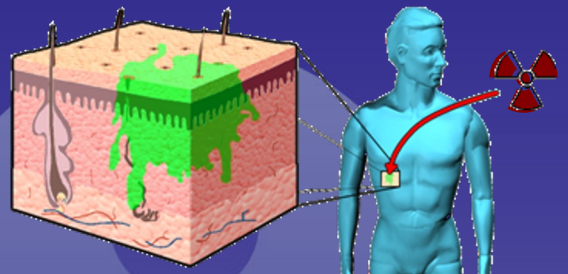
External



Internal

Internal Contamination

Inhalation



Absorption

Ingestion

Injection

Action Levels

How much is too much?

H&S Action Levels

- Dose = 5 rem/yr

  Reference: Nuclear Regulatory Commission (NRC) 10 CFR 20.1201 for licensees and Federal OSHA 29 CFR 1910.1096(b)(1) for general workers

- Dose rate = 2 mR/hr

  Reference: Industry standard and NRC 10 CFR 20.1301(a)(2) for licensees

- Contamination = 2 times background

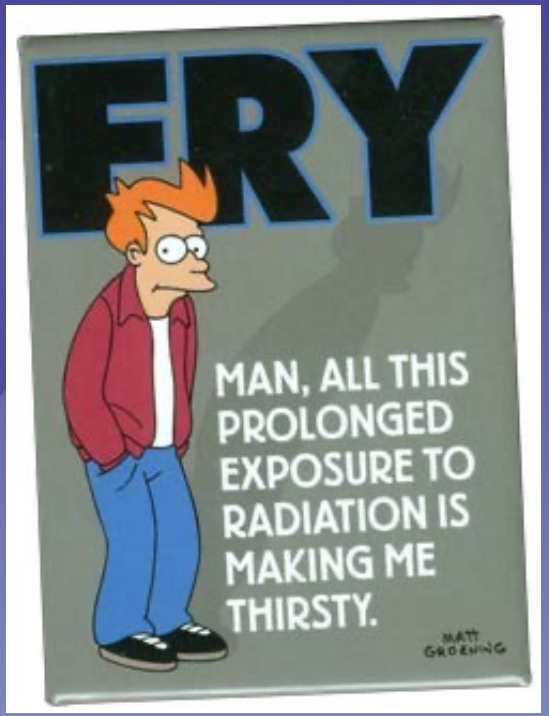
  Reference: Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, EPA 400-R-92-001, May 1992

Emergency Dose Limits

- Emergency worker whole body dose limits (EPA-recommendation)
  - 5 rem = All activities
  - 10 rem = Protecting valuable property
  - 25 rem = Lifesaving or protection of large populations
  - >25 rem = Lifesaving or protection of large populations on voluntary basis only

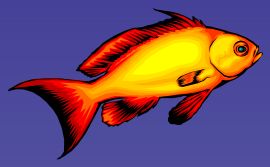
Radiation Health Effects

Dude, check out my radiation tan!



Effects on Organisms

Organism	LD50/30* (rem)
M. Radiodurans	100,000s
Cockroach	10,000s
Goldfish	2,300
Tortoise	1,500
Alligator	1,000
Rabbit	800
Cow	500
Dog	350
Human (without medical treatment)	350
Human (with medical treatment)	500
Superman	1



*LD50/30 = Dose that kills 50% of the population within 30 days

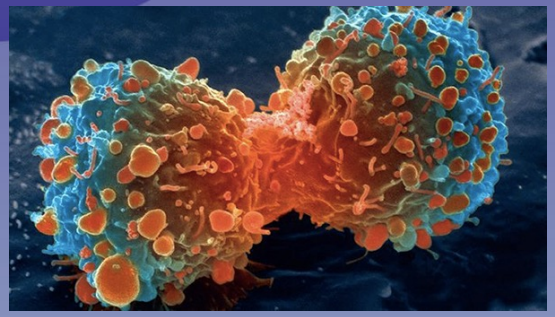
Health Effects from Radiation Exposure

- Somatic - Early or late physical effects
  - Blood count reduced
  - Hair loss
  - Sterility
  - Cancer
- Genetic - Damage to genetic reproductive cells
- Teratogenic - Damage to fetus
  - Reduced birth weight
  - Small head size
  - Leukemia

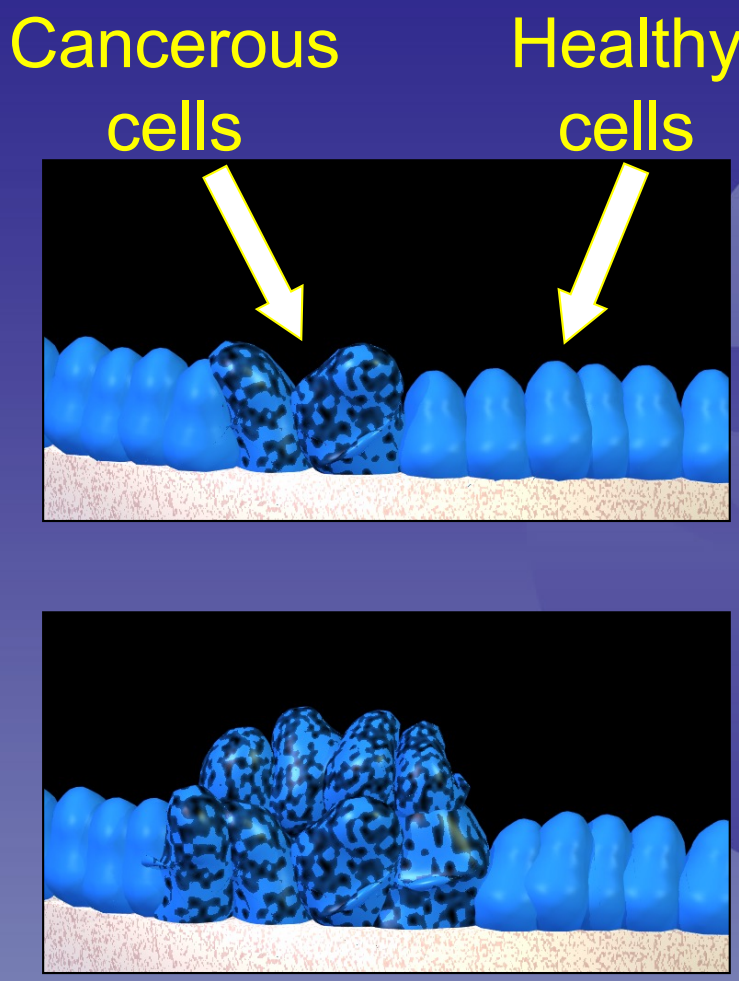
Somatic Effects

Delayed Somatic Effects

- Shortening of life span
- Cataracts (100 rems)
- Sterility (200 - 400 rems)
- Cancer (>10 rems)



Radiation Carcinogenesis



- Can occur at 10+ rem
- Documented at 100+ rem
- Tumor development is 5 - 20 years
- Most frequent in the blood system, thyroid, bone, and skin

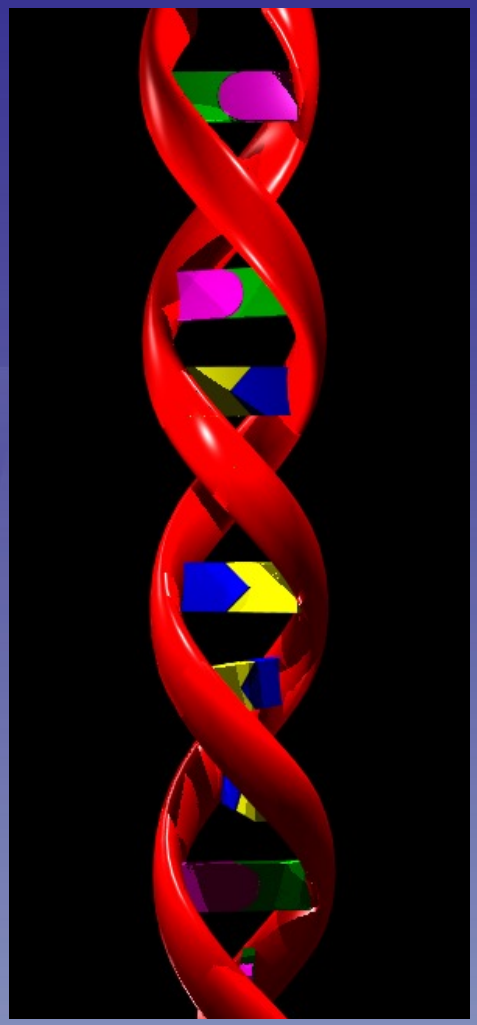
Cancer Statistics

Exposure	Chance of Dying from Cancer
Background	20%
1 rem	20.07%
10 rem	20.7%
100 rem	27%

Reference: National Cancer Institute and Biological Effects of Ionizing Radiation (BEIR V)

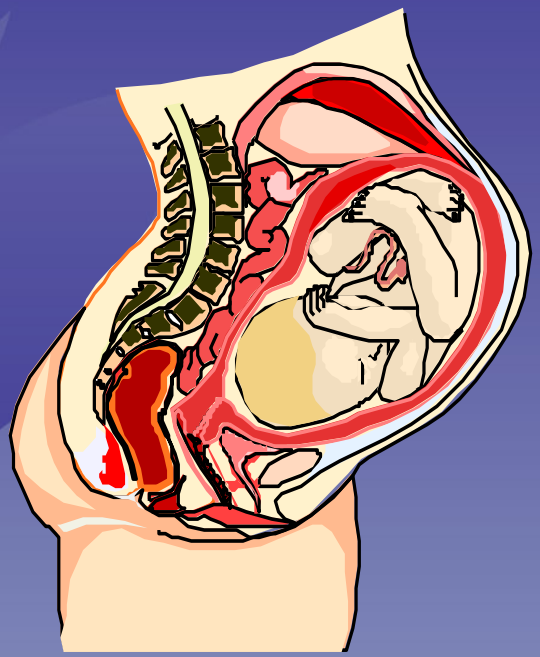
Genetic Effects

- Radiation is a mutagen
- Damage to reproductive cells that pass to children
- Has not been observed



Teratogenic Effects

- Embryo/fetus affected at over 20 rems
  - Reduced birth weight
  - Small head size
  - Childhood leukemia

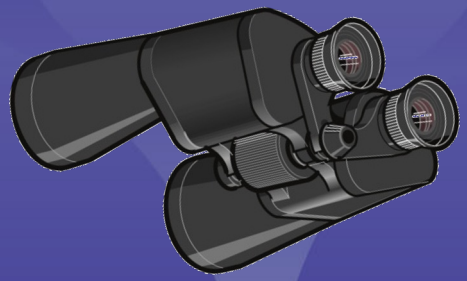


Radiation Protection

Radiation Protection Methods

- Time

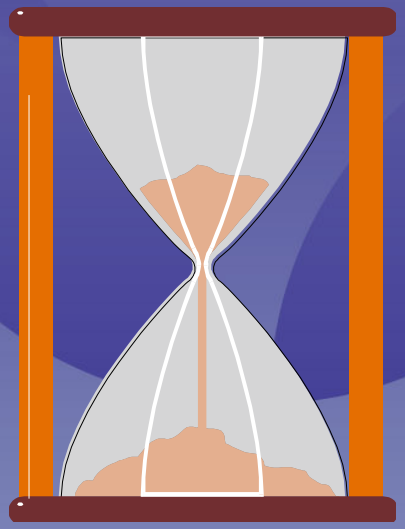
- Distance



- Shielding

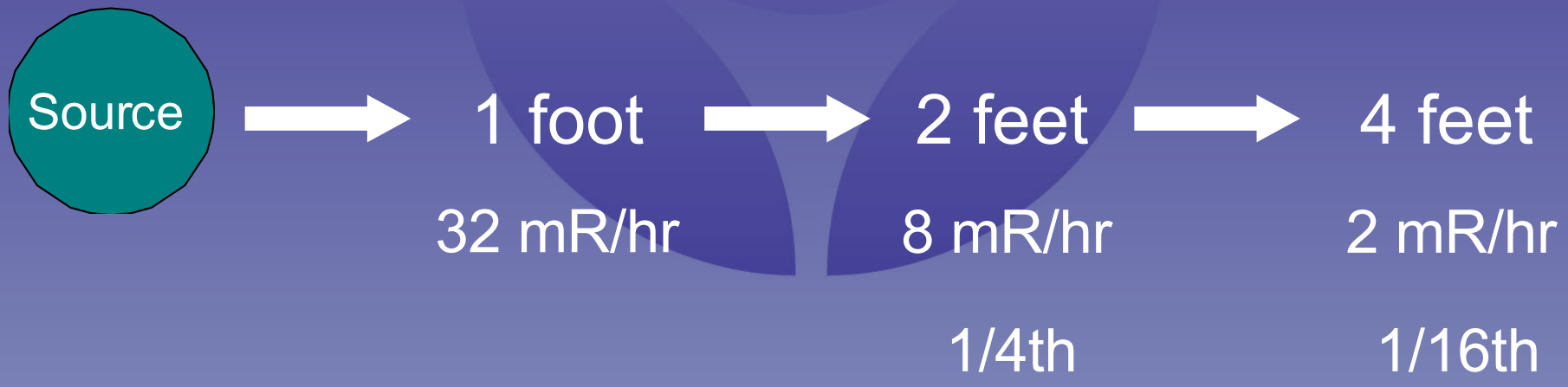
Time

Decrease time → Decrease Exposure



Distance

- Increase distance → Decrease exposure
- Double distance → Quarter exposure rate



Shielding

- Increase shielding → Decrease exposure
  - Concrete walls and lead shielding
  - Personal Protective Equipment (alpha and beta only)
  - Drums, plywood, vehicles, natural terrain (hills, trees, rocks) or any dense object

Water Wall

Personal Protective Equipment

- Typical PPE stops Alpha and some Beta
  - Tyvex suit and gloves for dermal protection from contamination
  - Respirator for inhalation protection (APR or SCBA)
    - Contaminated dust or smoke
    - Radioactive powders

- Street clothing or turnouts protective of Alpha and some Beta
- No PPE is fully protective of gamma or neutrons
- Dispose of contaminated PPE as rad waste if greater than 2 times background

Dosimeter: Canberra UltraRadiac

- Detector: gamma (neutrons optional)
- Built to military specs
- Dose Range: 0.1 µR to 999 R
- Dose Rate Range: 1 µR/hr to 500 R/hr
- Alarms adjustable (vibrating alarm option)
- Liquid Crystal Display with backlight
- Standard AAA Batteries
- $630 with vibrator mode - Canberra (800) 243-3955

TLD Badge

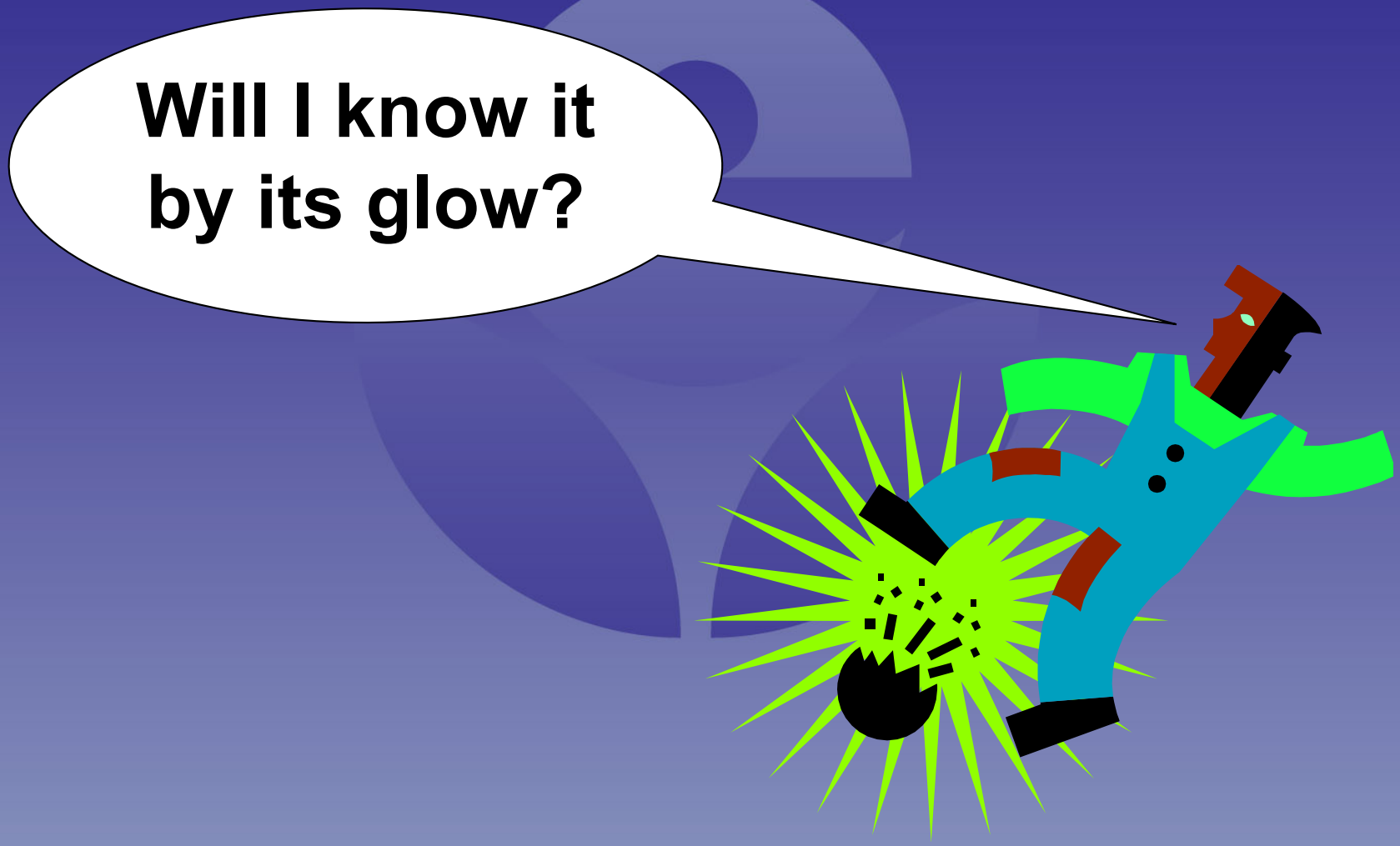
- Legal occupational documentation for licensed facility
- Cumulative Dose to beta (high energy only), gamma, and X-rays
- Sensitivity 1 mrem to 1,000 rem
- Analyzed by laboratory

Dose Management

- As Low As Reasonably Achievable (ALARA)
  - Basis for radiation protection programs
  - Limit dose as much as possible

- Strategies for reducing dose
  - Limit amount of exposure time
  - Increase distance from source
  - Shield source materials
  - Rotate entry team with new team
  - Reduce number of entry team members
  - Use dosimeters
  - Start with lower dose limits and increase, if needed

Radioactive Sources



Background Radiation

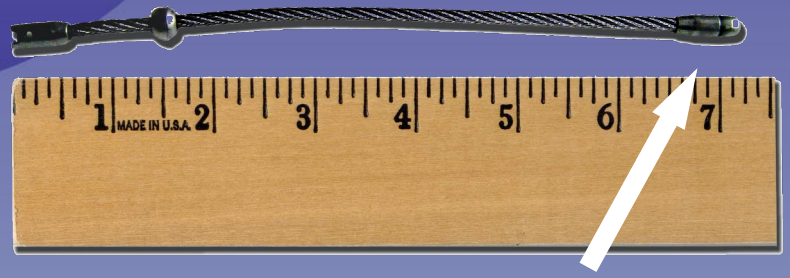
Source of Radiation	mrem/year
Natural Background Radon	200
Natural Background Other	100
Medical	50
Consumer Products	10
Nuclear Fuel Cycle and Occupational Exposure	1
Total	361

Industrial Sources

Pharmaceuticals

Industrial
(radiography camera)

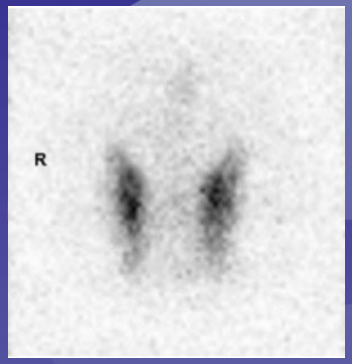
Field Instruments
(nuclear density gauge)



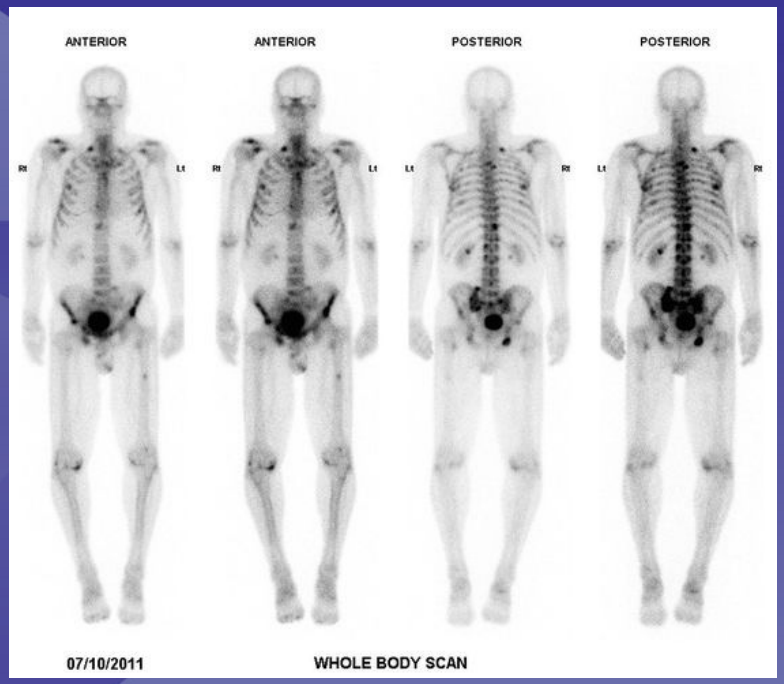
Radiography
Source

Medical Radioactive Materials

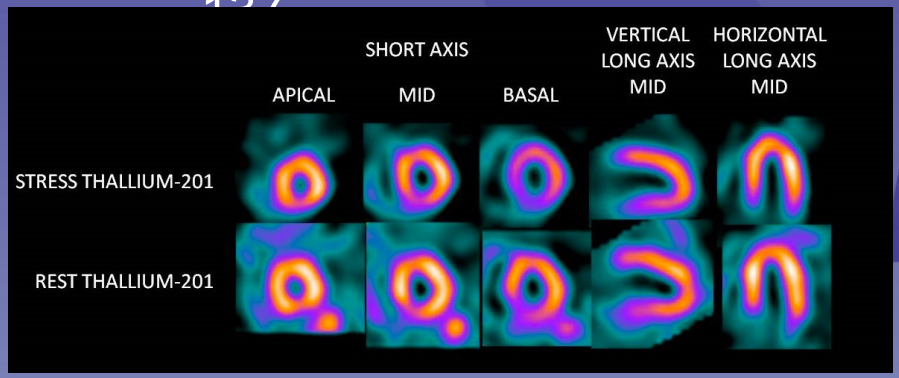
Cancer Treatment
cobalt-60 or cesium-



Thyroid Imaging
iodine-131



Bone Test: technetium-99m



Heart Stress Test: thallium-201

Commercial Radioactive Materials

- Smoke detectors (battery operated): americium-241

- Fiestaware: uranium-238

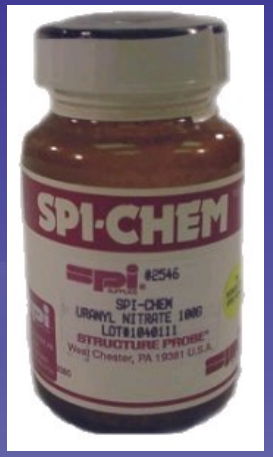
- Old glow-in-the dark watches, clocks, dials: radium-226

- No salt: potassium-40

Commercial Radioactive Materials

- Exit signs (non-electrical powered): tritium

- Photographic processes: uranium (uranium-238) nitrate



- Gas lantern mantles: thorium-228 and thorium-232

Discrete versus Dispersed Source

- Discrete sources
  - Intact sealed source
  - Intact vial of liquid

- Dispersed sources
  - Contaminated soil
  - Spilled liquid
  - Smoke from burning radioactive material

Radiation Instruments

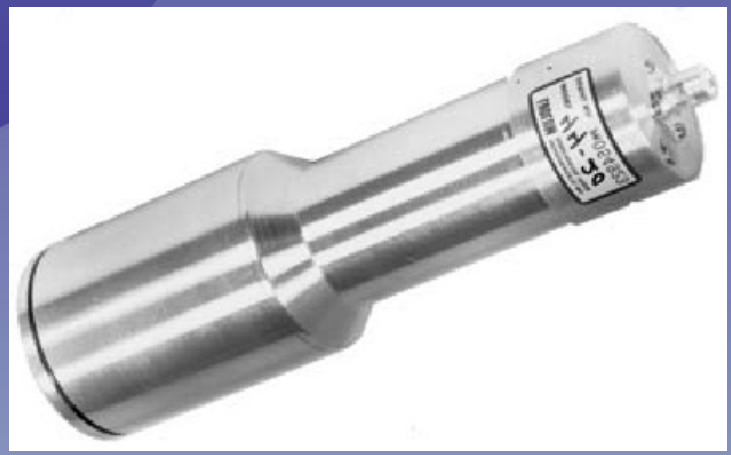
What on earth does THAT probe do?

Pancake Geiger-Mueller (GM) Detector

- Detects alpha, beta, gamma, X-ray
- Use for to locate contamination (esp. decon frisk)
- Pros
  - Detects all types of radiation
- Cons
  - Can't discriminate between radiation types
  - Low gamma detection efficiency
- **Calibrate in cpm NOT µR/hr**

NaI Scintillation Detector

- NaI detects gamma and X-ray
- Pros
  - Highly efficient
  - Durable
- Cons
  - Works only for gamma and X-rays
- Calibrate
  - µR/hr for exposure rate or surveys
  - cpm for surveys



Ion Chamber Detector

- Gas filled chamber
- Detects gamma, X-ray, high energy beta (with a beta window)
- Pros
  - Accurate exposure rate
- Cons
  - Not sensitive to low energy radiation
  - More delicate

Gamma Spectroscopy

- Identify the radioisotope

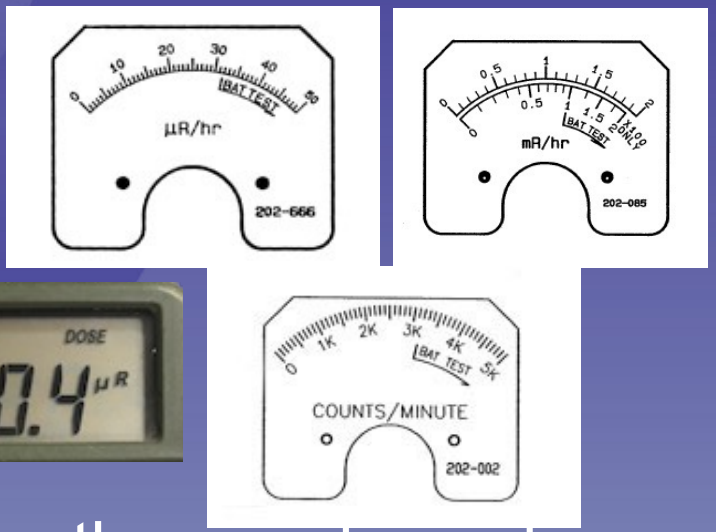
- Instruments can give wrong information! Operators should have significant experience.

Meter Components

- Analog or digital dial
- Fast/slow (response time)
- Light on/off
- Head phone input
- Audio on/off and divide
- Timer start and duration (scaler)
- Detector selector
- Battery check
- Reset
- Internal and/or external detector

Instrument Readings

- Understand the reading on your instruments
- Units
  - µR/hr = microroentgen per hour
  - mR/hr = milliroentgen per hour
  - µR = microroentgen
  - mR = milliroentgen
  - cpm = counts per minute
  - c/m = counts per minute
  - kc/m = kilocounts per minutes or thousand counts per minute (1000 times the reading)



Incident Procedures

Tag, you're it!

HAZWOPER Regulations

- **29CFR1910.120(h)(2)** Initial entry

- Upon initial entry, representative air monitoring shall be conducted to identify any IDLH condition, exposure over permissible exposure limits or published exposure levels, **exposure over a radioactive material's dose limits** or other dangerous condition such as the presence of flammable atmospheres or oxygen-deficient environments.

Basic Entry Procedures

1. Record background for each instrument & zero dosimeter
2. Wear PPE with (sometimes) a respirator
3. Make work zones based on action levels
4. Find sources and contamination

Work Zones

- Controls are same as any hazmat incident
- Typical zone delineation:
  - Hot zone = 2 mR/hr
  - Decontamination reduction zone = twice background
  - Cold (support) zone = background

Decontamination

I've been slimed!

Decontamination Solutions

- People
  - Soap and water
  - Wet wipe or towel
  - No aggressive scrubbing!

- Equipment
  - Soap and water
  - Scrubbing Bubbles®
  - Spray ‘n Wash®
  - Dilute nitric acid for metals

Frisk for Contamination

- Use pancake detector/probe (Geiger-Muller)
- Detector held 1/4” from person/object
- Move detector no faster than 1”/sec
- Takes 30 – 40 min to frisk a person 100%
- Focus on:
  - Hands
  - Feet
  - Face
  - Thighs
  - Butt

CDC Radiological Decon for Patients

"Radiation decontamination should not interfere with medical care of patients with life threatening injuries or illness."

"The right thing to do…[with a contaminated patient with a life threatening condition]…is to admit them to the Emergency department for immediate care."

Reference: *Interim Guidelines for Hospital Response to Mass Casualties from a Radiological Incident*, Centers for Disease Control and Prevention, Department of Health and Human Services, December 2003

Questions?