

Radiation: Units of Measure and Health Effects

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Units of Measure

- Traditional Unit

$$1 \text{ curie (Ci)} = 3.7 \times 10^{10} \text{ dps}$$

$$= 2.2 \times 10^{12} \text{ dpm}$$

- Subunits

$$1 \text{ microcurie } (\mu\text{Ci}) = 1 \times 10^{-6} \text{ Ci}$$

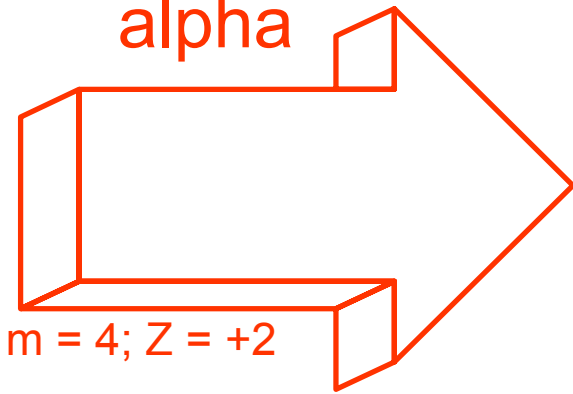
$$1 \text{ picocurie } (\text{pCi}) = 1 \times 10^{-12} \text{ Ci}$$

- International System (SI)

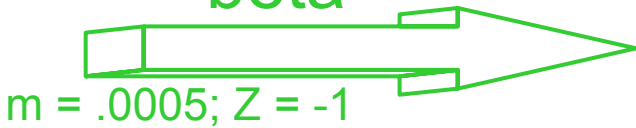
$$1 \text{ becquerel (Bq)} = 1 \text{ dps}$$

Ionization Density

alpha

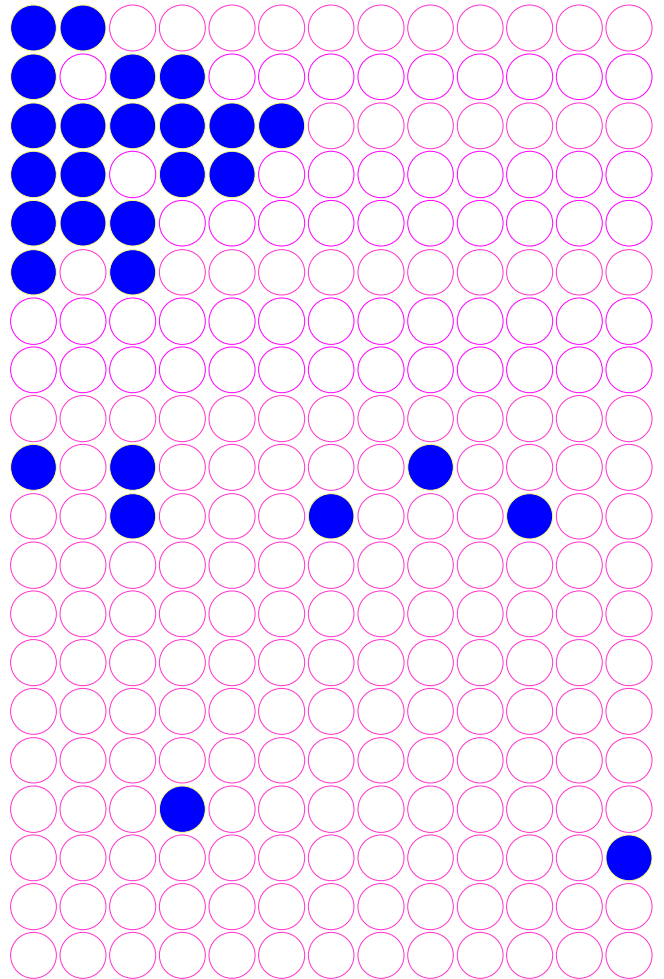
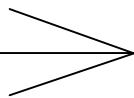


beta



gamma

$m = 0; Z = 0$



m = atomic mass units (amu)

Z = electric charge units

● = ionizations

roentgen (R):

An amount of x- or gamma radiation that causes 1 esu (electrostatic unit) of charges due to ionization in 1 cc of air.

Absorbed Dose

The rad (r) [or Gray (Gy)]

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The Roentgen (R) describes the radiation field (the agent); but,
The rad (r) describes the effect in a medium.

$$1 \text{ rad} = 100 \text{ ergs/gm}$$

100 ergs of energy released
per gram of medium

- a. applies to any medium (including air)
- b. applies to any type of radiation (not just photons)

$$\text{The Gray (Gy)} = 100 \text{ rad (r)}$$

The rad is a medium-dependent quantity, and is very useful as an estimate of the effect of radiation in, say, tissue. However, it does not take into account the relative biological effects of different types of radiation.

1 rad = 0.87 R For air

1 rad = 0.98 R For soft tissue



Dose Equivalent

[rem or Seivert (Sv)]

- * Gamma rays have a much different biological effect than alpha particles
- * The Dose Equivalent modifies the absorbed dose (rad) by the relative biological effectiveness (or, Quality Factor, QF) of the radiation

<u>Radiation</u>	<u>QF</u>
γ -rays X-rays β above .03 MeV	1
β less than .03 MeV	1.7
Neutrons (thermal)	2
Neutrons (fast) Protons	10
Alpha particles Heavy charged particles	20

$$\text{rem} = \text{rad} \times \text{QF}$$

Gamma

Beta

Alpha

R	1	xxxxxxxxxxxxxxxxxxxx
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rad	1	1	1
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rem	1	1 - 1.7	20
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$$\text{The ede} = \Sigma (\text{rem} \times \text{WF})$$

(Summed over all organs)

Effective Dose Equivalent [rem or Sv]

G. L. Gels

Relates internal and external doses by means of "organ weighting factors" for internally deposited radionuclides

External Radiation:

The effective dose equivalent (ede) includes all total body radiation from external sources

Internal Radiation:

For internally deposited radionuclides, the ede is the sum of the dose equivalent (rem) to each organ times the organ weighting factor

Organ Weighting Factors:

<u>Organ</u>	<u>W.F.</u>	<u>Organ</u>	<u>W.F.</u>
Gonads	.25	Thyroid	.03
Breast	.15	Bone Surface	.03
Lung	.12	Remainder	.30
Red Marrow	.12		

Organ Weighting Factors

Weighting Factors

<u>Organ</u>	<u>ICRP 26</u>	<u>NCRP 91</u>	<u>ICRP 60 & NCRP 116</u>
Gonads	0.25	0.25	0.20
Red Marrow	0.12	0.12	0.12
Colon			0.12
Lung	0.12	0.12	0.12
Stomach			0.12
Bladder			0.05
Breast	0.15	0.15	0.05
Liver			0.05
Esophagus			0.05
Thyroid	0.03	0.03	0.05
Skin		0.01	0.01
Bone Surface	0.03	0.03	0.01
Remainder	0.30	0.30	0.05

The TOTAL effective dose equivalent
tede

Equals the internal dose (ede)
plus

The external dose equivalent

The COMMITTED effective dose equivalent
cede

Includes dose in future years from
radionuclides incorporated in the
body

Field Rule of Thumb

For Gamma and most Beta radiation,

$$\text{roentgen} = \text{rad} = \text{rem}$$

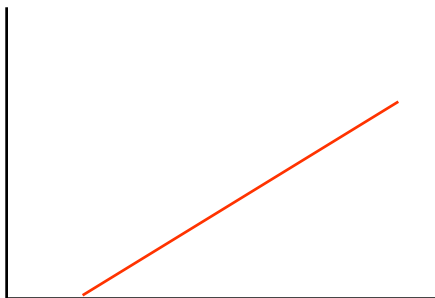
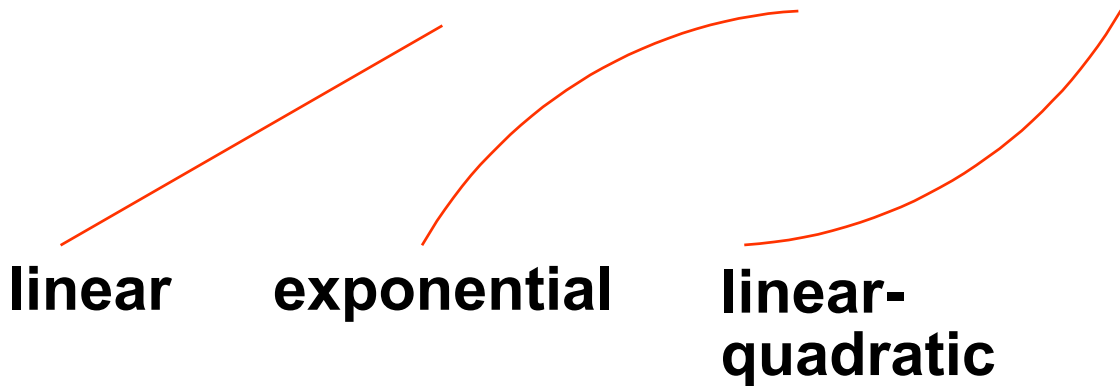
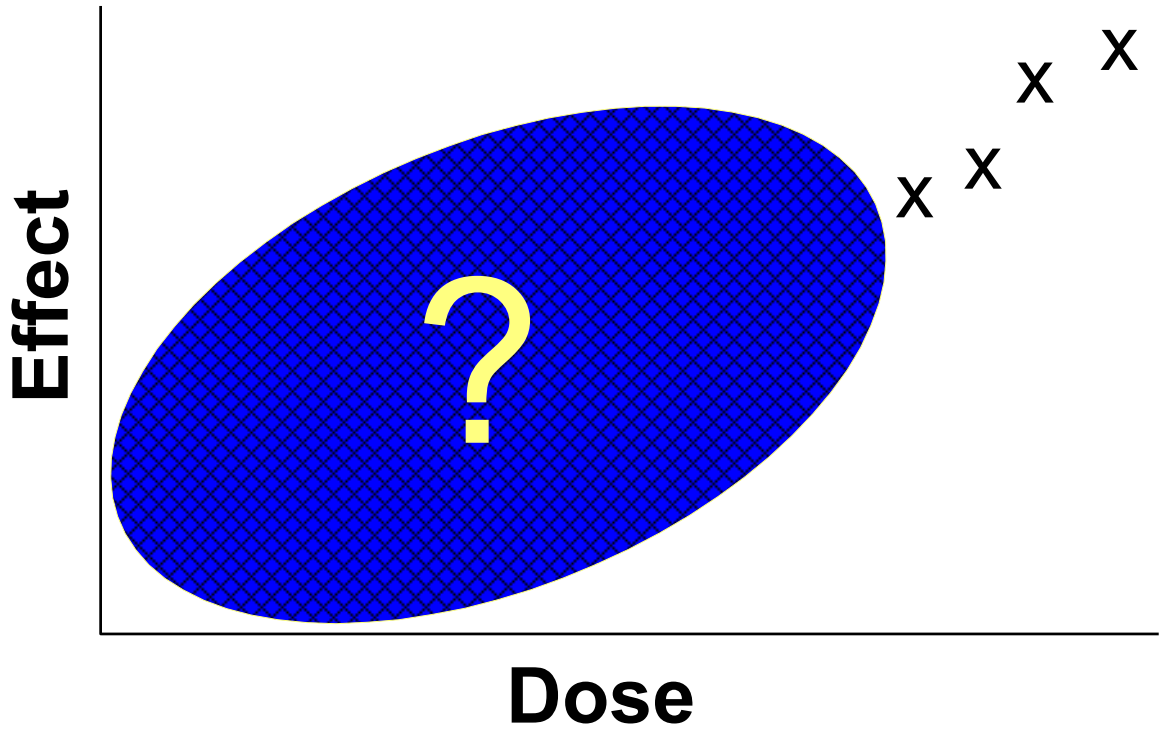
For Alpha,

$$\text{rem} = 20 \times \text{rad}$$

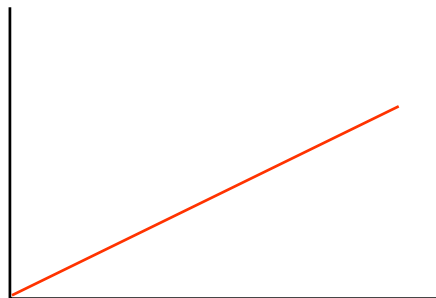
Health Effects

- Early radiographers
 - Burns
 - Amputations
 - Death
- Dial Painters
 - Bone cancer
- Atomic Bomb Victims
 - Blast deaths
 - Acute radiation fatalities
- Uranium Miners
 - Lung cancer

Dose-Effect Relationship



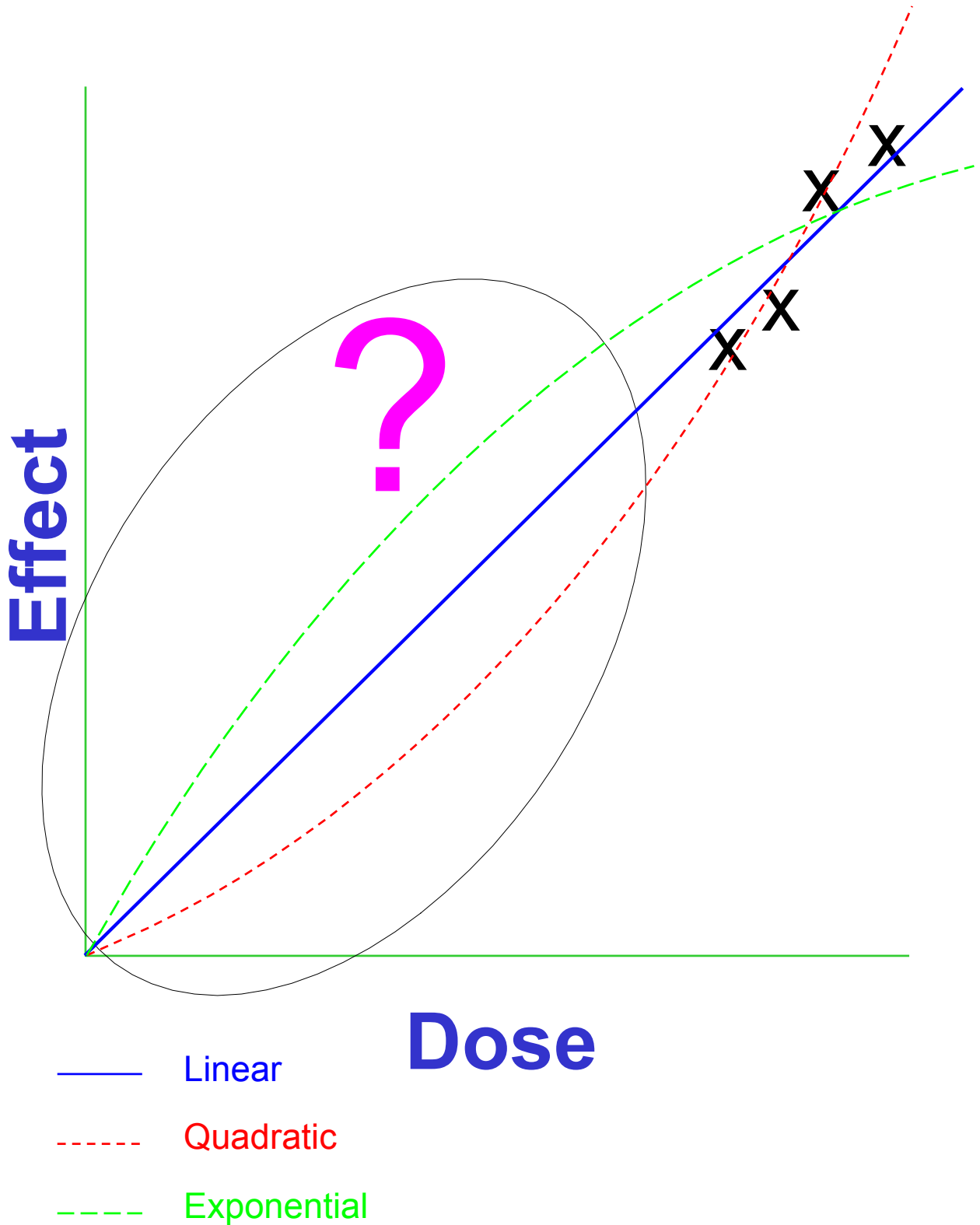
**linear-
threshold**



**linear-
no threshold**

Dose-Effect Relationship

No-Threshold Hypothesis



Sources of Ionizing Radiation Exposure: Average Annual Effective Dose Equivalent (ede, H_E) in U.S.

		H_E in millirem/yr (ROUNDED TOTALS)		PERCENT
Natural Sources:		Sub-Group Total		
Cosmic	27	100	100	
Cosmogenic	1			
Terrestrial	28			
Internal	39			
			100	
Radon	200	200	300	83
Occupational:			0.9	0.2
Nuclear Fuel Cycle:			0.05	0.01
Consumer Products:			9	2
Misc. Environmental Sources:			0.06	0.01
			310	
Medical:				
Diagnostic X-rays	39	50	360	15
Nuclear Medicine	14			

* Estimated Number of People Exposed:
 Occupational: 0.9 Million
 Consumer Products: 120 Million
 Misc. Env. Sources: 25 Million

Acute Radiation Health Effects

- Below 25 – 50 rem — -no noticeable effects
- Above 25 – 50 rem — -decrease in WBC count
- ~ 100 rem — -TD_{L0} mild radiation sickness
- ~ 200 rem — -LD_{L0} possible death
- 450(+) rem — -LD_{50/30} 50% die in 30 days
- 600(+) rem — -LD₉₉ 99% die
- 700(+) rem — LD₁₀₀ 100% lethal

Fatal Radiation

Haemopoietic Syndrome: < 1000 rad

Gastro-Intestinal Syndrome: $\sim 1000 - 5000$ rad

Central Nervous System: > 5000 rad

Occupational Exposure Limits -- EPA

Radiation Workers:

Those enrolled in the Radiation Safety and Health Protection Program -- expected to receive exposure to ionizing radiation above normal background

Administrative Control Level (ACL) of
500 mrem per 12 month period
[also protective of pregnant females
and the fetus].

Action Reference Level (ARL) of 50 mrem per
quarter (3 month period)

Units

roentgen (R) Exposure

rad Absorbed Dose

rem de dose equivalent
 ede effective de
 tede total effective de
 cede committed effective de

curie (Ci)

millicurie (mCi)

microcurie (μ Ci)

nanocurie (nCi)

picocurie (pCi)

femtocurie (fCi)

becquerel (Bq)

kilobecquerel (kBq)

megabecquerel (MBq)

terabecquerel (TBq)