LOVELACE
BIOMEDICAL

Cutaneous Radiation Injuries Created with Different Radiation Sources

WM Weber

06 May 2019

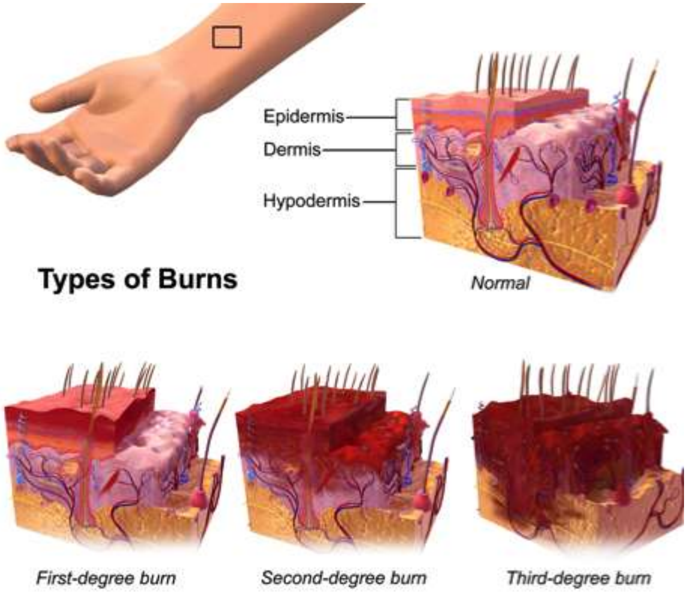
Sunburns – The Simple Example

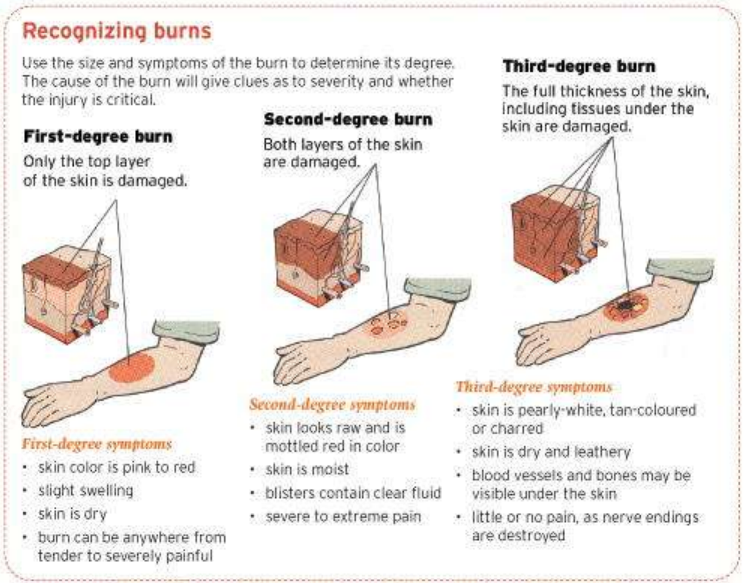

First degree - Erythema


Second degree - Blistering

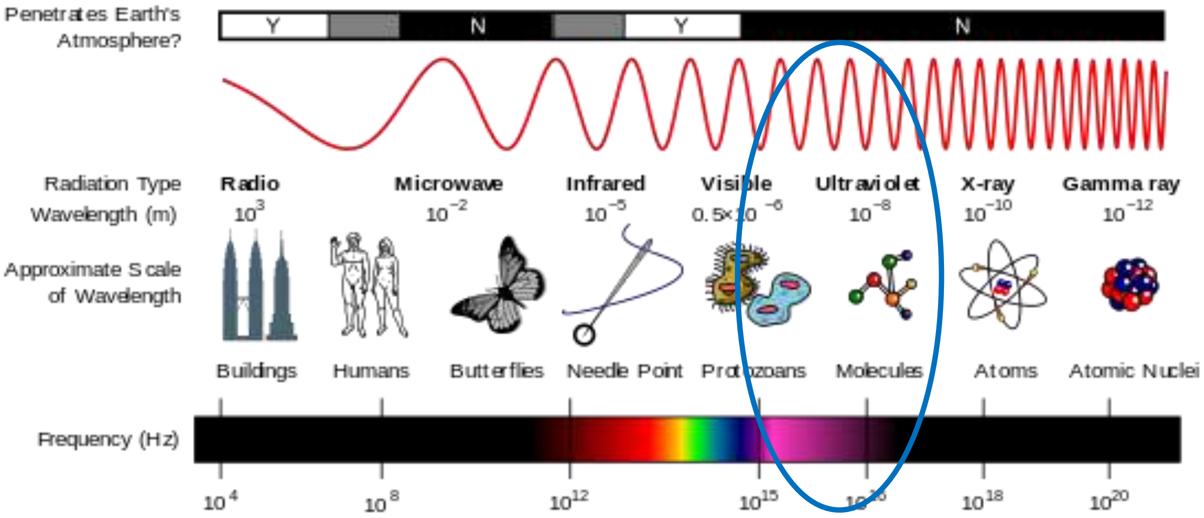

Third degree - Necrosis

Dermal Damage Severity





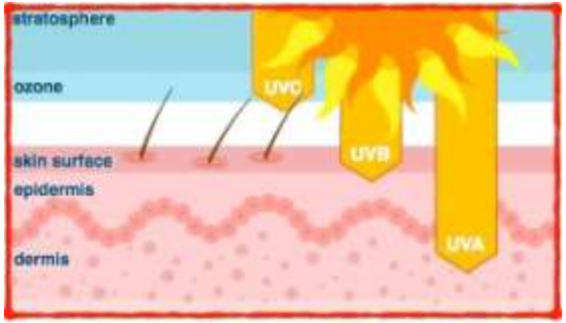
Photons

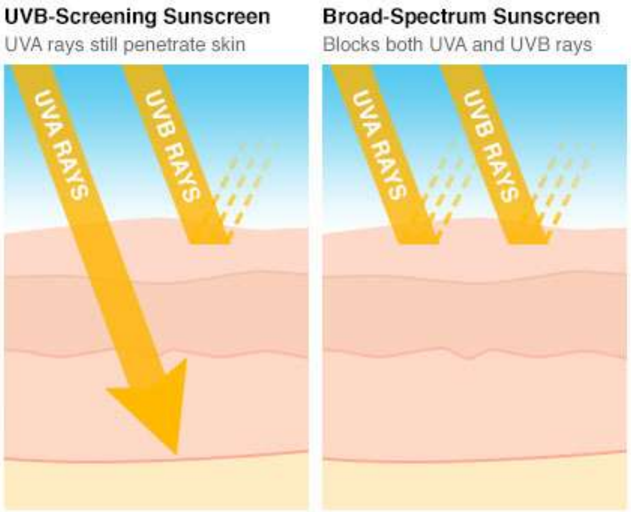

Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Radio
10^3
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Approximate Scale of Wavelength
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}


Energy

Dermal Interaction

- So what does that mean when it comes to sunburns?





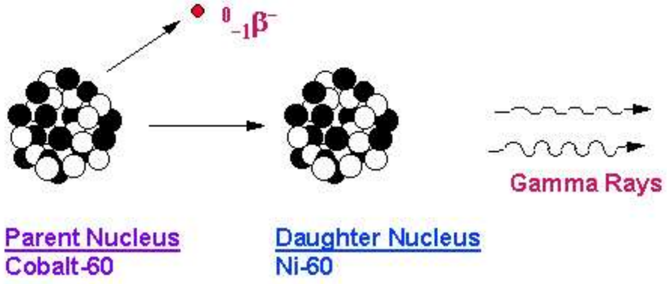
- Ozone blocks some UV
- Wear broad-spectrum sunscreen

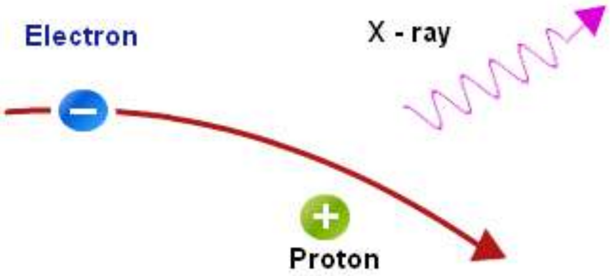
Radiation Protection

- So to reduce **radiation** injury to the dermis, we should simply apply sunscreen and limit our time around the radiation source?
  - Yes – for sunburns
    - Ozone and sunscreen block the relevant wavelengths for radiation induced injury
  - Not true for all types of radiation
    - Photons
    - Particles

What about for Co-60 or Cs-137?

- They are also photons (gamma-emitters), so sunscreen should work, right?
  - Wrong, the have different energies
- Combinations of beta and gamma





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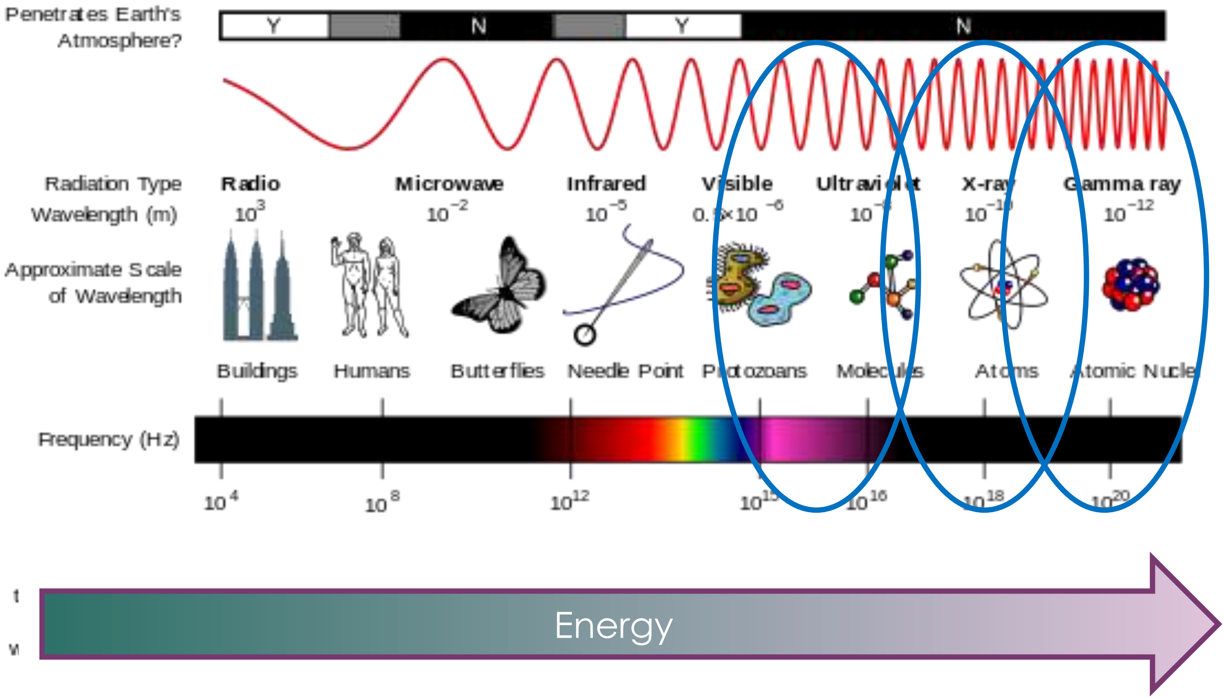

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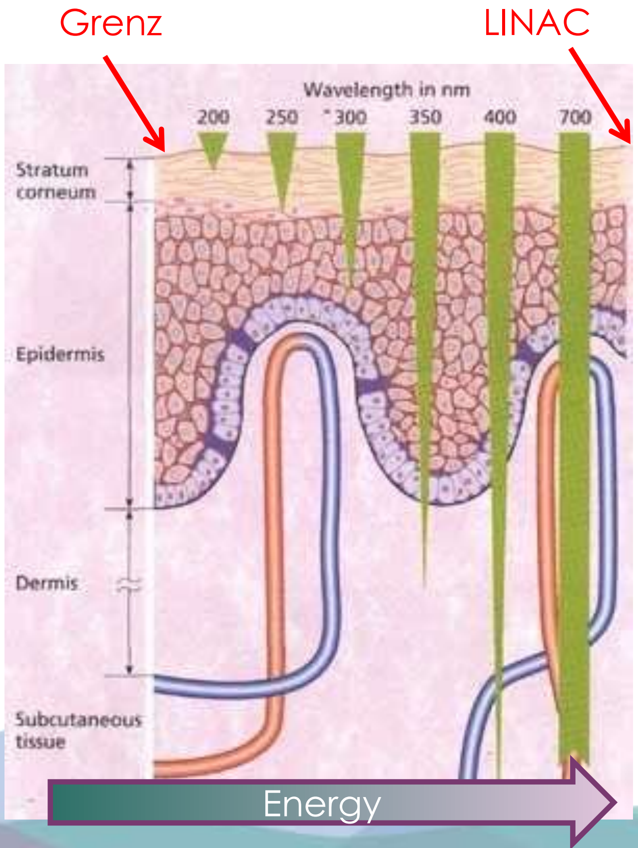
Needle Point
Frequency (Hz)
Energy

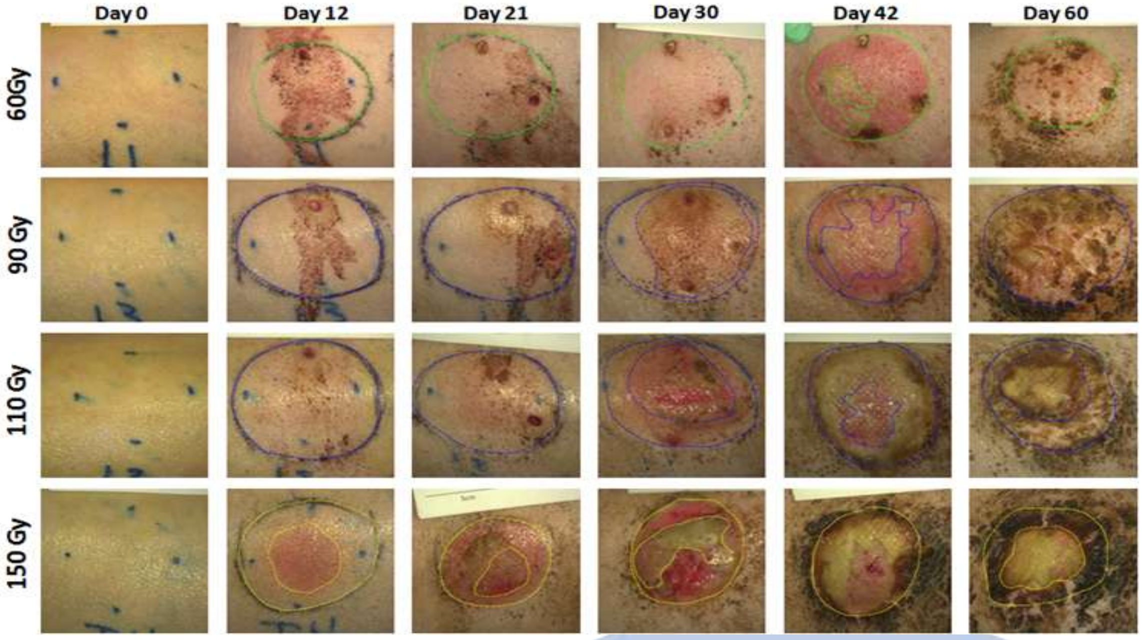
Photon Penetration into Tissue

- Lovelace radiation generating instruments with high and low energies
  - Grenz – 20 kV (~10^{-7} m)
  - RT250 – 250 kV (~10^{-8} m)
  - LINAC – 6 MV (~10^{-9} m)
- Low energy
  - long wavelengths
  - low penetration
- High energy
  - Short wavelengths
  - high penetration



Lovelace Swine Radiation Burns

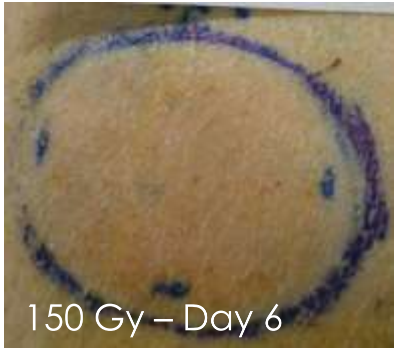
- Grenz – Irradiated with up to 150 Gy



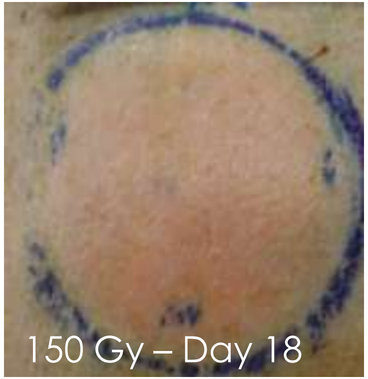
- Followed out to 60 days

Lovelace Swine Radiation Burns

- RT250 - Irradiated with up to 150 Gy


150 Gy – Day 6


150 Gy – Day 12


150 Gy – Day 18

Gy – Day 12 (Grenz)

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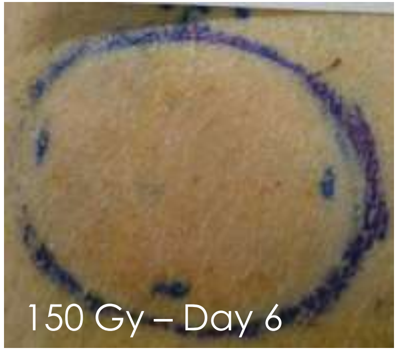
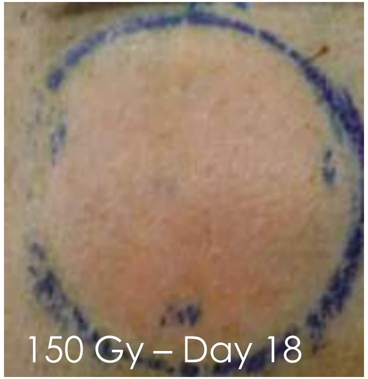

150 Gy – Day 6


150 Gy – Day 12


150 Gy – Day 18

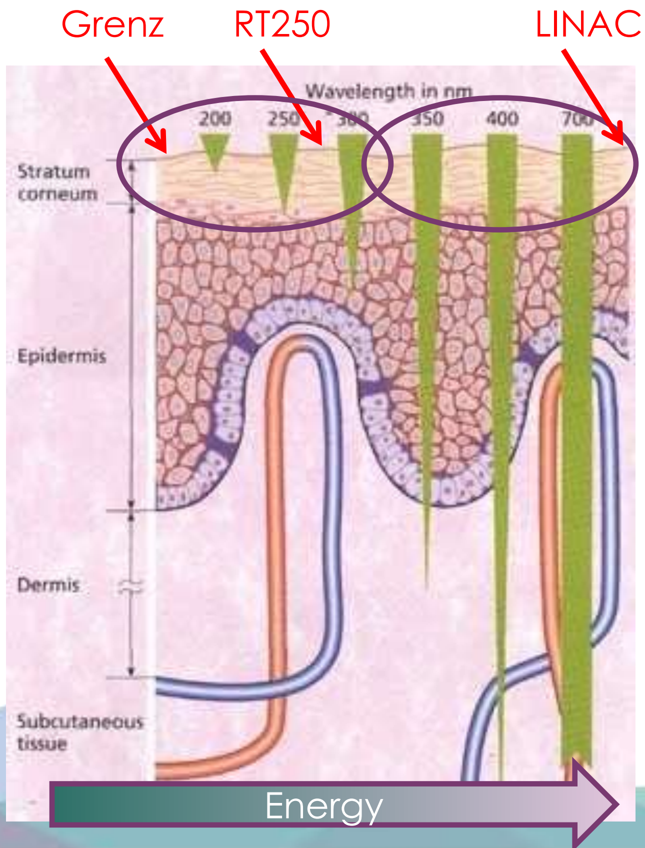

150 Gy – Day 12 (Grenz)

- RT250 – both ani hanized as moribund by Dc

Depth Dose

- In both cases animals received a relatively soft x-ray
  - Most of the dose was to the surface
- LINAC resulted in animals euthanized within 9 days
  - Dermal wounds had not formed

Nominal energy	Depth of maximum dose (cm)	Skin dose (%)
240 kV(p)	Surface	100
Cobalt-60	0.500	50
6 MeV	1.500	35
10 MeV	2.500	25
18 MeV	3.000	15

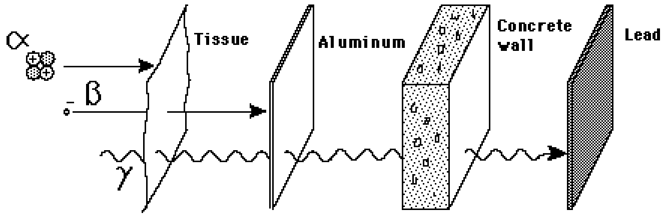


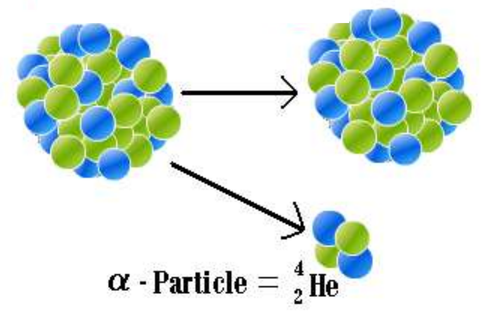
Photon Summary

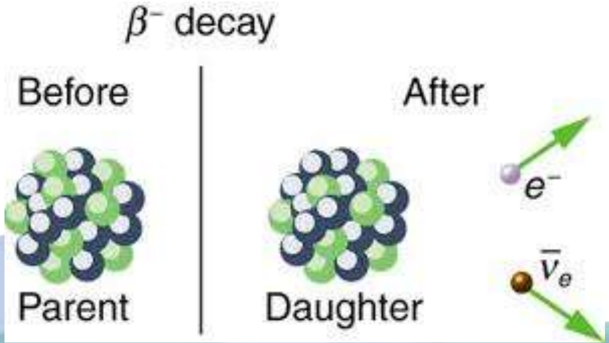
- High energy photons readily penetrate the dermis with only partial deposition in the upper layers of the skin
- Low energy photons do not readily penetrate the dermis with maximal deposition in the upper layers of the skin
- High levels of photons are needed to create a significant radiation wound
  - Low energy are "better" because they do not penetrate deeply causing "other types" of radiation injury
- Lovelace studies utilized pure photon exposures

Particle Radiation

- Photons are different wavelengths of energy
- Particles have a physical mass
  - Alpha particles
    - Helium nuclei
  - Beta particles
    - Electrons





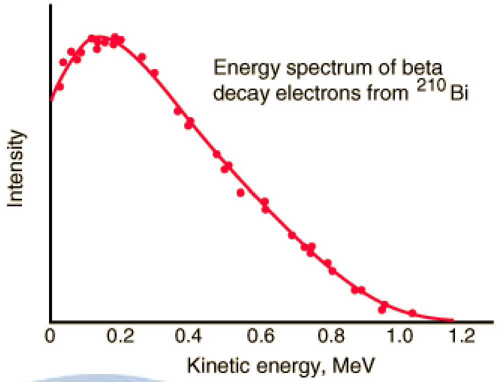


Alpha Wounds

- Not likely to result in moderate to deep wounds (full thickness)
  - Particles do not penetrate past the very top layer of the skin
    - Protects the under lying tissues from injury
  - Low every, low travel lengths
- Very dangerous if internal
  - Ingestion, open wound, inhalation

Beta Wounds

- Will result in wounds
  - Particles deposit their energy in the first several layers resulting in compared to photons
- But…
  - Spectrum of energy
  - Damage at deeper depths
  - Results in complex wounds



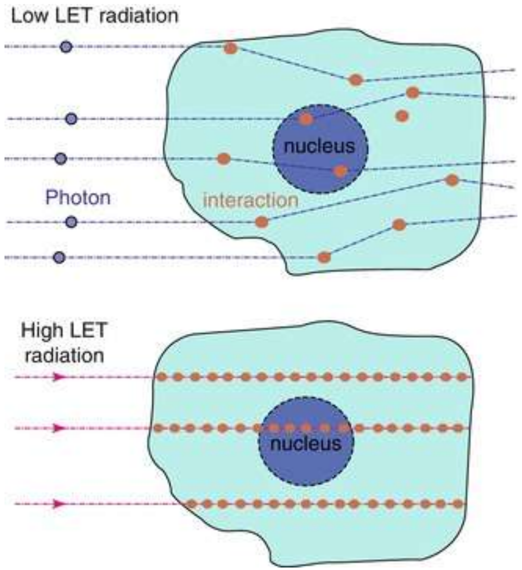
Beta Wounds

- Because particles are present, lower doses than photons are needed

2–6 Gy	transient erythema 2–24 h
3–5 Gy	dry desquamation in 3–6 weeks
3–4 Gy	temporary epilation in 3 weeks
10–15 Gy	erythema 18–20 days
15–20 Gy	moist desquamation
25 Gy	ulceration with slow healing
30–50 Gy	blistering, necrosis in 3 weeks
100 Gy	blistering, necrosis in 1–3 weeks

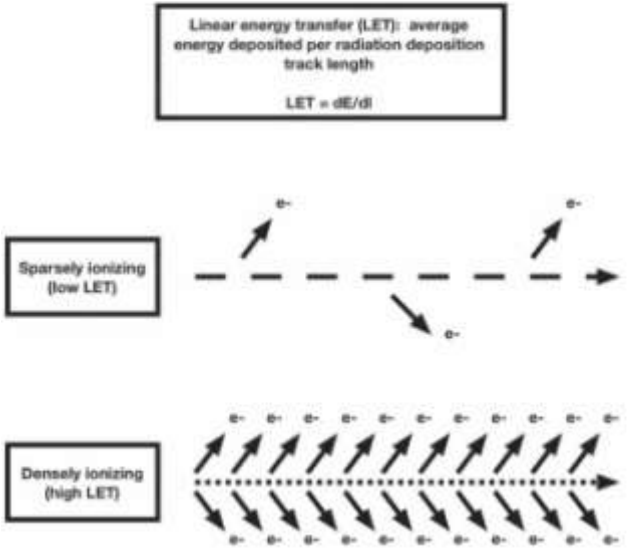
Linear Energy Transfer (LET)

- Amount of energy a particle transfers to material (skin) per unit distance
  - Comes down to the energy of decay
- High LET – low penetration
  - All energy deposited in a short distance
- Low LET – high penetration
- Not directly transferable to gamma rays
- LET explains why injury in not always proportional to dose



Particle Summary

- Alpha particles are mono-energetic
  - low in energy with a high LET
- Beta particles are poly-energetic
  - Continuous energy spectrum
  - Some high LET, some low LET



Summary

- Know your source
  - Pure gamma rays will require a large dose to create a dermal wound
    - High energy will penetrate and result in secondary radiation effects
    - Low energy will result in mostly superficial dermal wounds
  - Alpha particles are less likely to result in dermal wound
  - Beta particles are the biggest concern
    - Penetration at all dermal levels depending on the energy
    - Lower doses can result in dermal injuries similar to high gamma doses
  - Isotopes with multiple routes of decay (beta and gamma) will result in wounds from both types of radiation
    - Beta will be more pronounced due to dermal interactions

Summary (cont.)

- Understand your model
  - What are you trying to accomplish?
    - Full thickness – needs a higher energy OR a higher total dose
    - Partial thickness – needs a lower energy OR a lower total dose
    - Combined injury – radiation + other types of injury

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Thank You

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