Electromagnetic Interaction

Non-Ionizing Case

Coherence Scatter
Path can be deflected
→ Photon has lost energy, but
the atom is otherwise unchanged
(“braking”)

Bremsstrahlung radiation
→ Interaction w/ nucleus
Compton Scatter

\[ p_{(\text{Compton})} \propto \text{tissue } e^- \text{ density} \]

\[ \text{not the atoms in the tissue} \]

\[ \text{lost energy is sufficient to eject} \]

\[ \text{a valence } e^- \text{! (Compton } e^-) \]

\[ \text{\Rightarrow photon has lost energy AND we've} \]

\[ \text{got a free } e^- \text{ on the loose} \]

\[ \text{\Rightarrow low energy, but...} \]

\[ \text{\Rightarrow lower energy photons will lead to low contrast} \]

\[ \text{in images ... poor diagnostic value...} \]
\( \text{Density for } H_2O \rightarrow 3.8 \times 10^{26} \text{ e}^-/\text{kg} \)

\( \text{bone } \rightarrow 3.2 \times 10^{26} \text{ e}^-/\text{kg} \)

.: Compton photons are effectively same intensity (of beam) from all tissues \( \rightarrow \) no contrast

At high incident energies, Compton interactions will be dominant source of radiation interaction \( \rightarrow \) most received signal has no clinical value.
Photoelectric Effect → the photon is absorbed!

- The incident photon is usually absorbed by an $e^-$, resulting in ejection of the $e^-$ [ionization] and subsequent characteristic radiation as other $e^-$ fill holes.
Likelihood of photoelectric effect

\[ P(PE) \propto \frac{Z_{\text{eff}}^4}{(h\nu)^3} \]

- H: 1
- C: 0
- Air: 7.8
- H₂O: 7.5
- Muscle: 7.0
- Fat: 6.5
- Bone: 12.3 - 20

incident energy

\( P(PE) \)
Biological Effects of Imaging

Ionizing Radiation

- $E \geq 13.6 \text{ eV}$

* $1 \text{ eV} = 1.6 \cdot 10^{-19} \text{ J}$

Radiation is measured by

- Sievert (Sv) = $1 \text{ Sv/kg}$
- Gray (Gy) = $1 \text{ Gy/kg}$

“Stochastic” risk

“Deposition” risk
DNA where we have greatest concern

1 Gy of absorbed exposure

\[ \Rightarrow 1 \times 10^6 \text{ Gy DNA damage} \]

\[ \begin{align*}
\text{Loss of function} & \quad \text{Enzymatic Repair} \\
\text{or reprogramming} & \\
\text{Tissue R Cell} & \\
\text{Death} & \quad \text{Correct Repair} \\
\end{align*} \]

Cancer \leftarrow Neoplastic Transformation

Small- and large-scale mutations \rightarrow Could become heritable

A.O.K.
Dose → Sv or Gy

Effective Dose (H)

→ Sv 1 Sv ~ 5.5% chance of cancer

⇒ Weighted sum over all exposed tissues

⇒ Tissue-specific measure

Committed Effective Dose \((H_{eff}(t))\) = Sum of the product of committed equivalent dose and tissue weighting factors ... integrated over a given period of exposure.
\[ H_r(t) = \int W_r D_r(t) \, dt \]

dose to the particular tissue

...equivalent dose \rightarrow \text{rate of radiation exposure following the INTAKE of the material}

\textbf{Committed Dose} \Rightarrow \text{measure of stochastic health risk}

\& \text{Internal source: committed dose} = \text{equivalent dose} \quad \text{where the equivalent dose is taken as applied uniformly to the whole body from an external source} \ldots \text{same as effective dose as applied to the tissue near/within internal source.}