

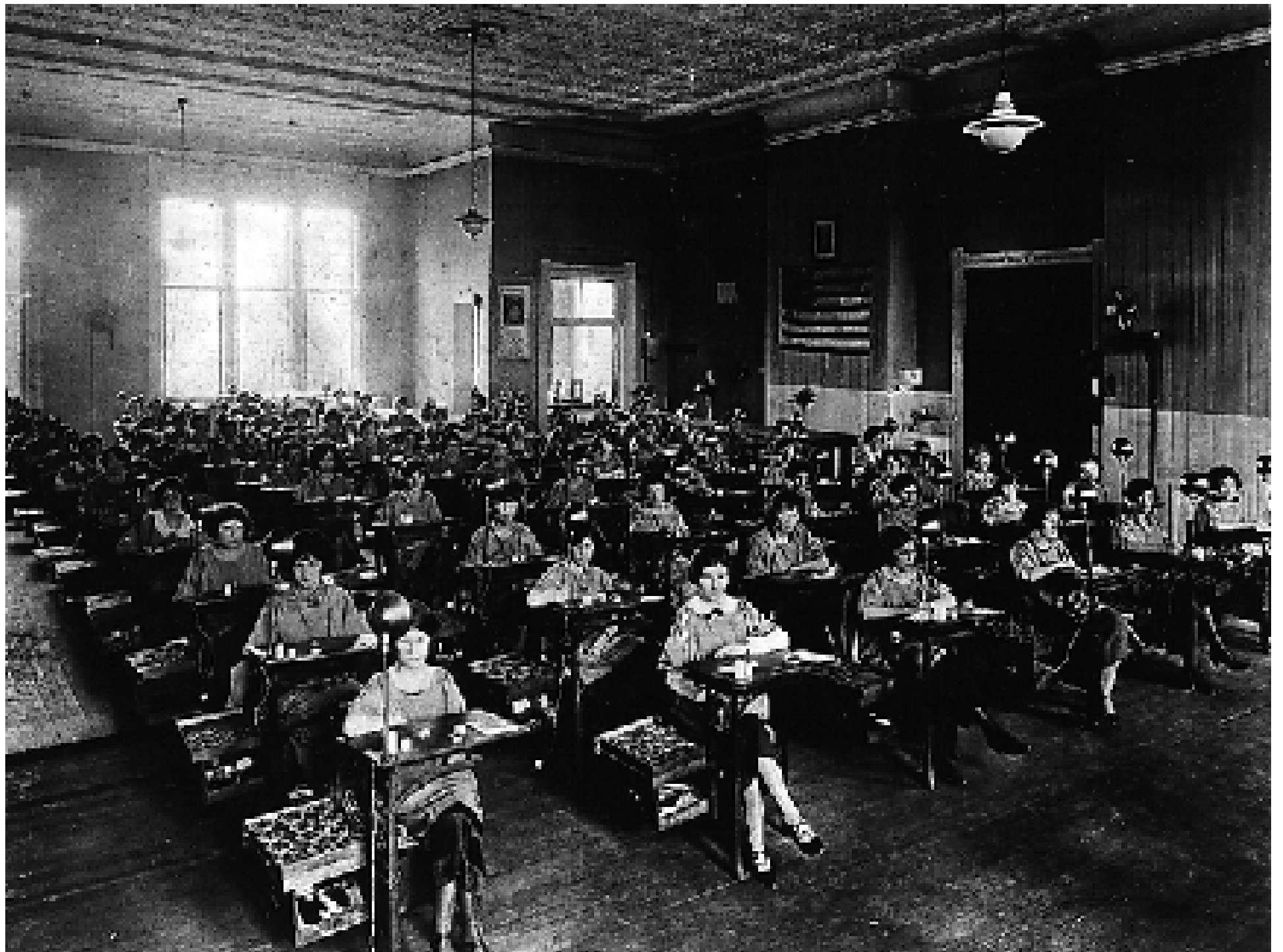


OAK RIDGE INSTITUTE
FOR SCIENCE AND EDUCATION

Skeletal Dose Estimates for Radium Dial Workers

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Dose Estimates to What, Exactly?

- As a calcium analogue, radium is bone volume seeker
- Because of the short range of alpha particles in tissues, they contribute almost all the dose to the skeleton; internal gamma dose is negligible in comparison
- Mean skeletal dose = total alpha energy absorbed/7 kg
- But most of that mass is bone mineral (hydroxyapatite), and biologically inert
- ICRP now uses “bone surfaces” a 10- μ m-thick layer of tissue, with a total mass of 120 g.
- Dose is of course a function of time post intake

“Dose” Parameters used in Radium Studies

- Terminal body burden
- Cumulative skeletal rads
- Initial systemic “intake” (really “uptake”, and time-invariant)
= $\mu\text{Ci } ^{226}\text{Ra} + 2.5 \times \mu\text{Ci } ^{228}\text{Ra}$
- Average skeletal dose rate, Gy d^{-1}
- All needed to be calculated from bioassay measurements, usually many (> 40) years after exposure

Retention Equations

1955: Norris function:

$$R(t) = 0.54 R(0) t^{-0.52}$$

Based on measured retention in patients at Elgin (IL) State Hospital injected with ^{226}Ra for treatment of schizophrenia

However, some question as to the exact injected amounts

$$R(50 \text{ y}) = 0.35\%$$

Retention Equations, con't

1973: ICRP 20 Alkaline Earth Retention Model

(Ca, Sr, Ba, Ra)

$$R = (1 - p)e^{-mt} + p\varepsilon^b(t + \varepsilon)^{-b}[\beta e^{-r\lambda t} + (1 - \beta) e^{-\sigma r\lambda t}]$$

$$R(50y) = 0.9\%$$

1982: Schlenker modified 5 parameters in the ICRP 20 model for retention in soft tissue

$$R(50y) = 0.2\%$$

Retention Equations, con't

1993: Rowland furthered modified the ICRP 20 model, changing the value of λ (the apposition and resorption rate in compact bone) from 1.5% to the originally proposed 2.5%

$$R(50y) = 0.1\%$$

ICRP-30 models (NUREG 4884):

$$R(50y)^* = 0.15\%$$

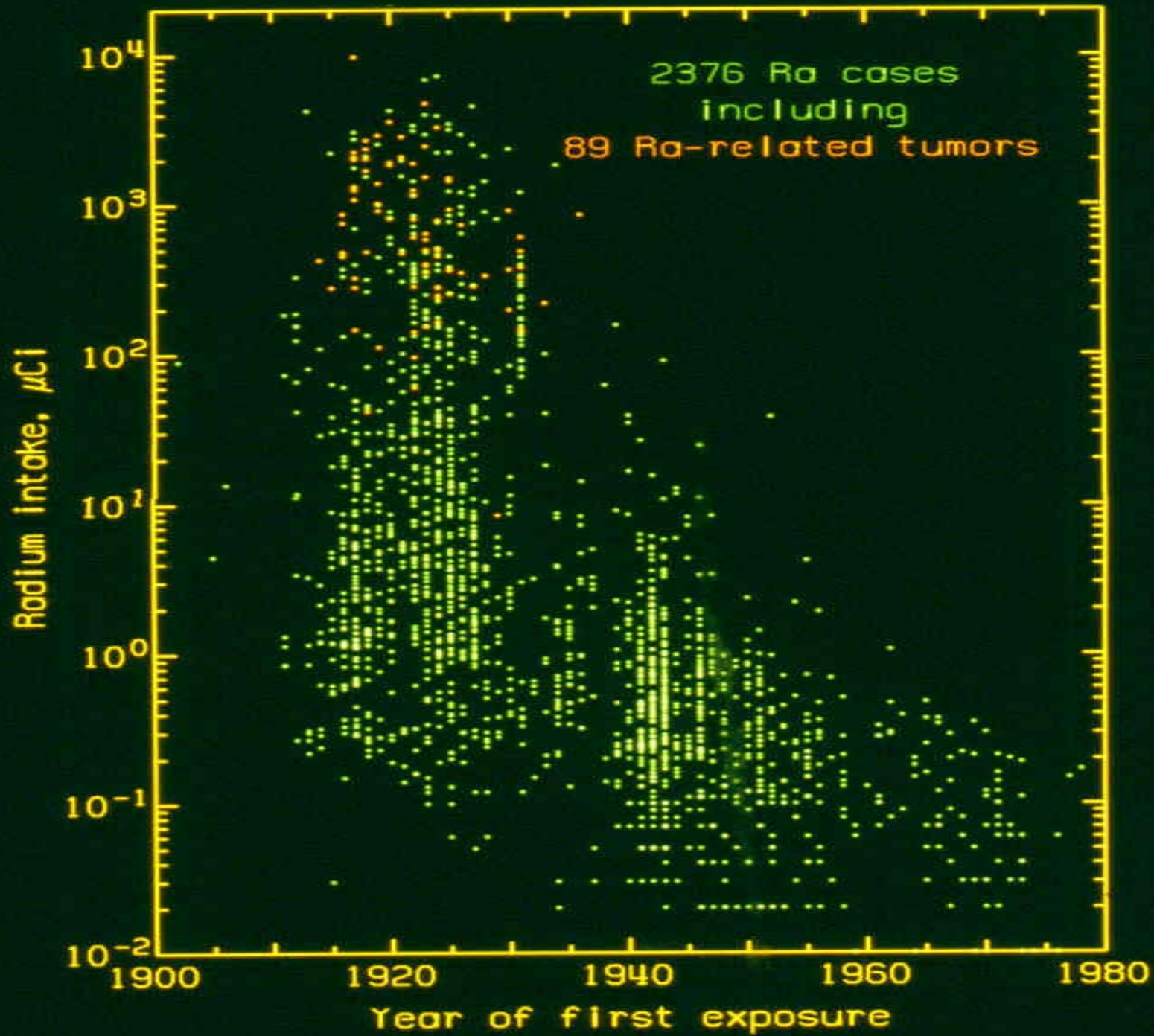
ICRP-78 models: $R(50y)^* = 0.5\%$

* Corrected for $f_1 = 0.2$

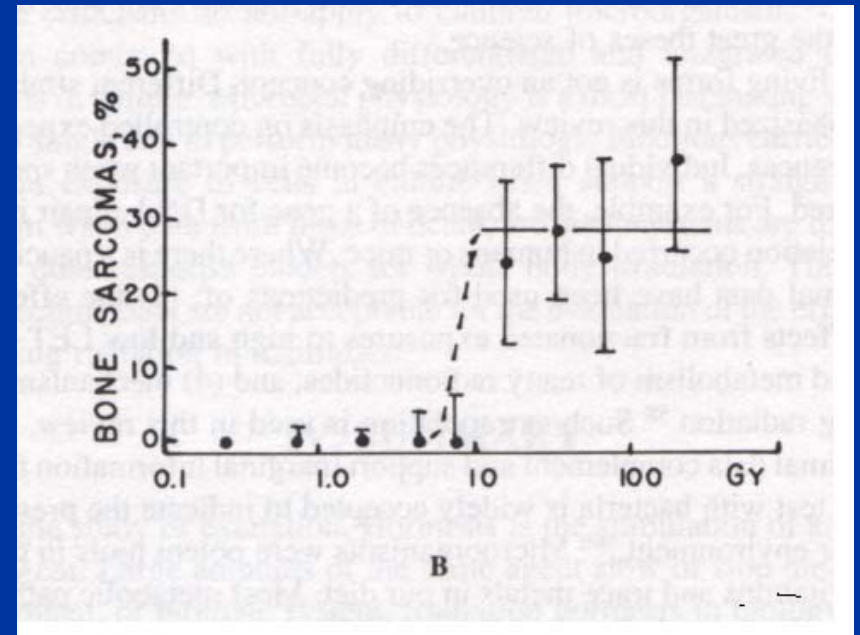
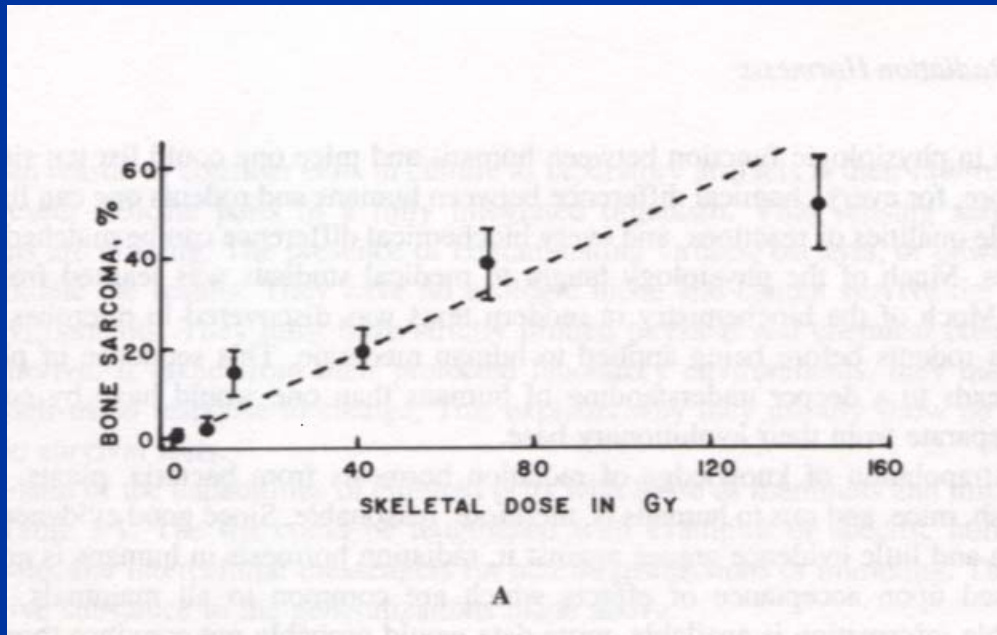
Dose Coefficients for ^{226}Ra

- Lloyd (1981) proposed that endosteal dose = 45% of mean skeletal dose, so with Rowland's model, $\text{DC} = 7.5 \times 10^{-6}$ (Sv Bq^{-1} uptake)
- ICRP 30 $\text{DC}^* = 3.4 \times 10^{-5}$ (Sv Bq^{-1} uptake)
- ICRP 78 $\text{DC}^{*\dagger} = 1.4 \times 10^{-4}$ (Sv Bq^{-1} uptake)

- *Corrected for $f_1 = 0.2$
- †Corrected for $w_{\text{bs}} = 0.01$



Bone sarcoma incidence in radium dial painters (same data, different axes)



Linear scale

Log scale

Professor Evans' Advice:

“A little contemplation saves a lot of calculation”

The Atomic Nucleus (1955), p. 499

Evan's Proposed Radium Standard

- No health effects noted in radium DPs with retained $^{226}\text{Ra} < 1.0 \mu\text{Ci}$
- Throw in a safety factor of 10
- MPBB for $^{226}\text{Ra} = 0.1 \mu\text{Ci}$
- MPBB for ^{239}Pu :
Total α energy $^{226}\text{Ra} = 12 \text{ MeV}$; $^{239}\text{Pu} = 5 \text{ MeV}$; bone surface vs. bone volume distribution: $100 \text{ nCi} \times 2/5 = 40 \text{ nCi}$

For more information

- <http://www.orau.org/ptp/collection/radioluminescent/radioluminescent.htm>
 - This site has photos of radioluminescent items in the PTP historical collection and some excellent articles on the paint and the painters
- http://www.rerowland.com/dial_painters.htm
- Radium in Humans: a Review of U.S. Studies. R. E. Rowland, ANL/ER-3, 1994
- “Deadly Glow” Ross Mullner, Univ. of Chicago Press