Dosimetry: Radiation Protection to Health Effects

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USTUR

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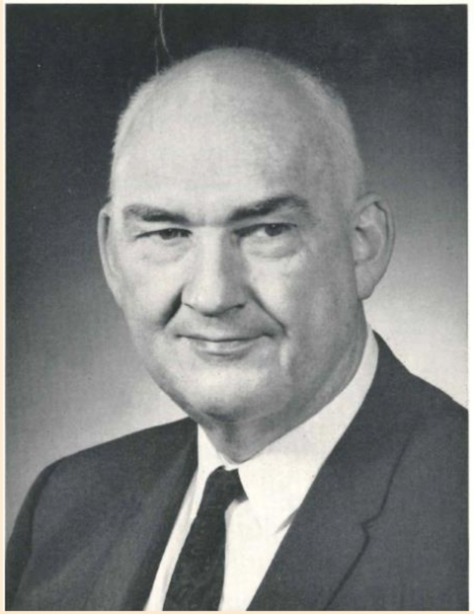
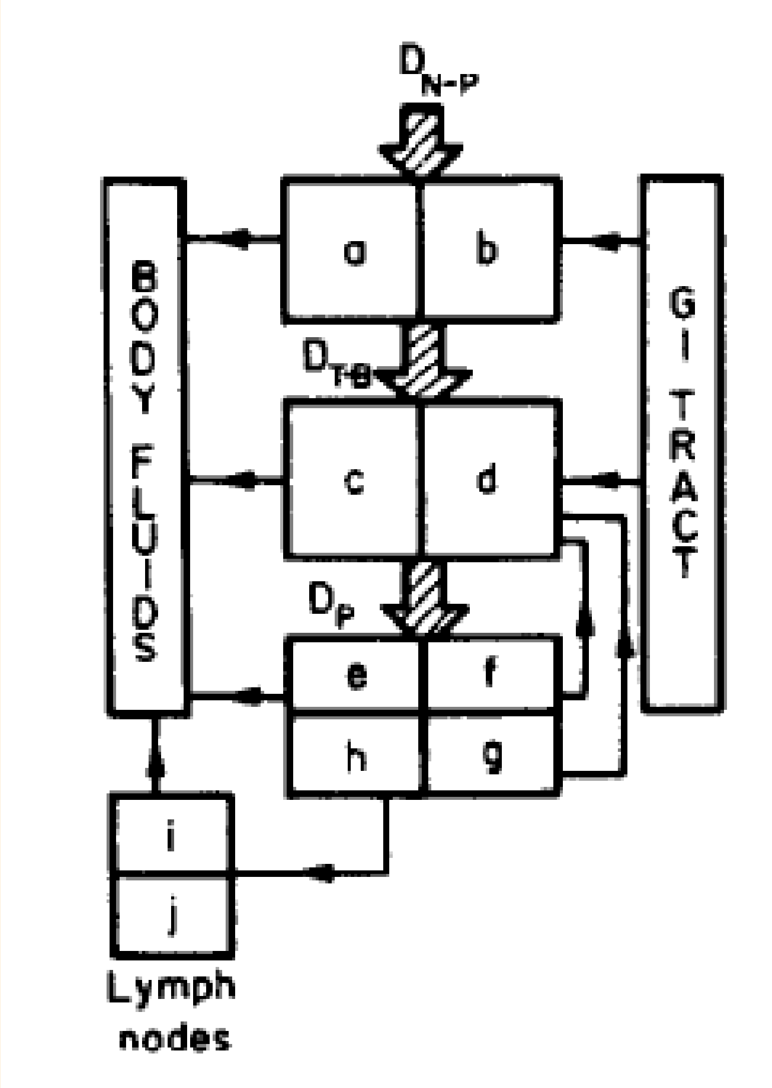
Internal Dosimetry

MPS Focus is on Tissue Dose

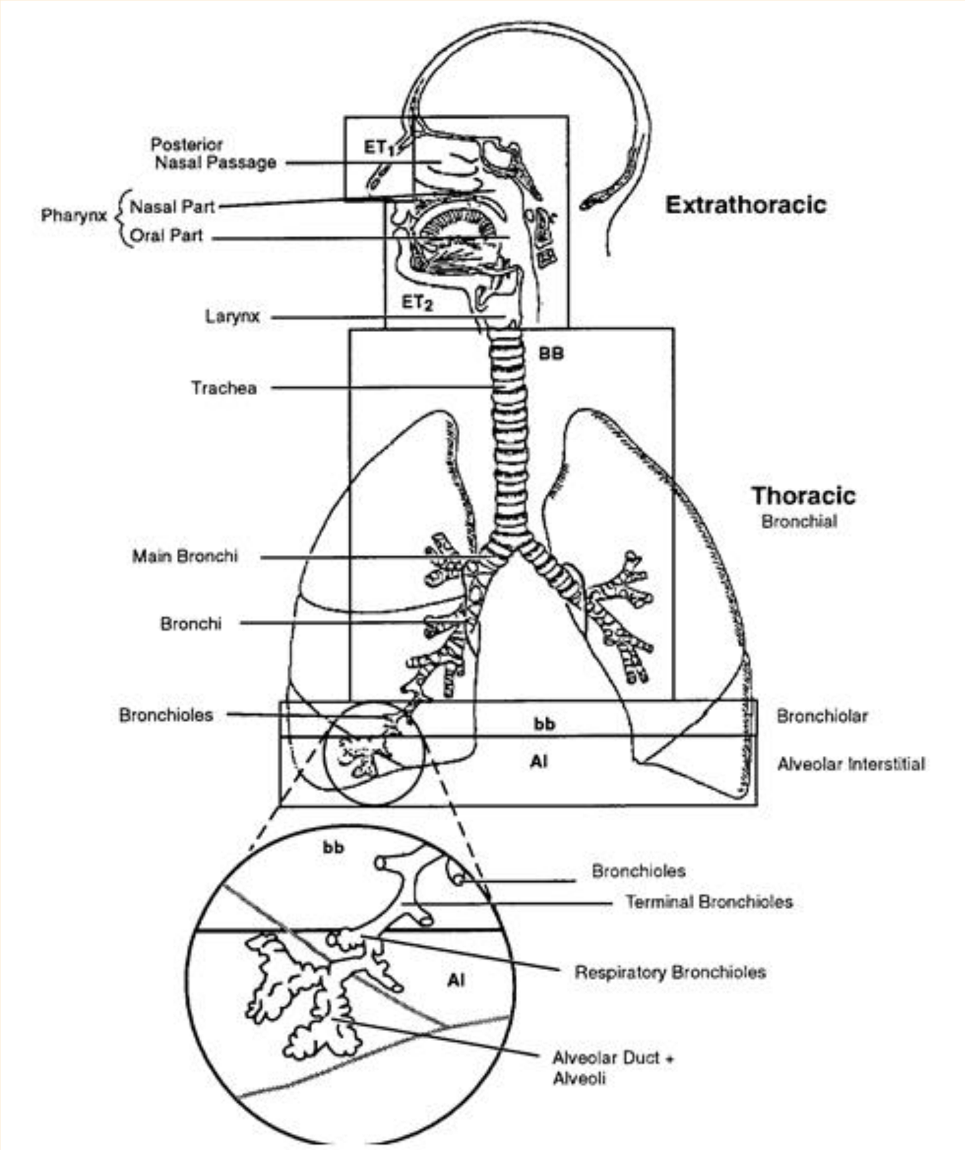
External Dosimetry

Lung Model: ICRP 30 (1982)



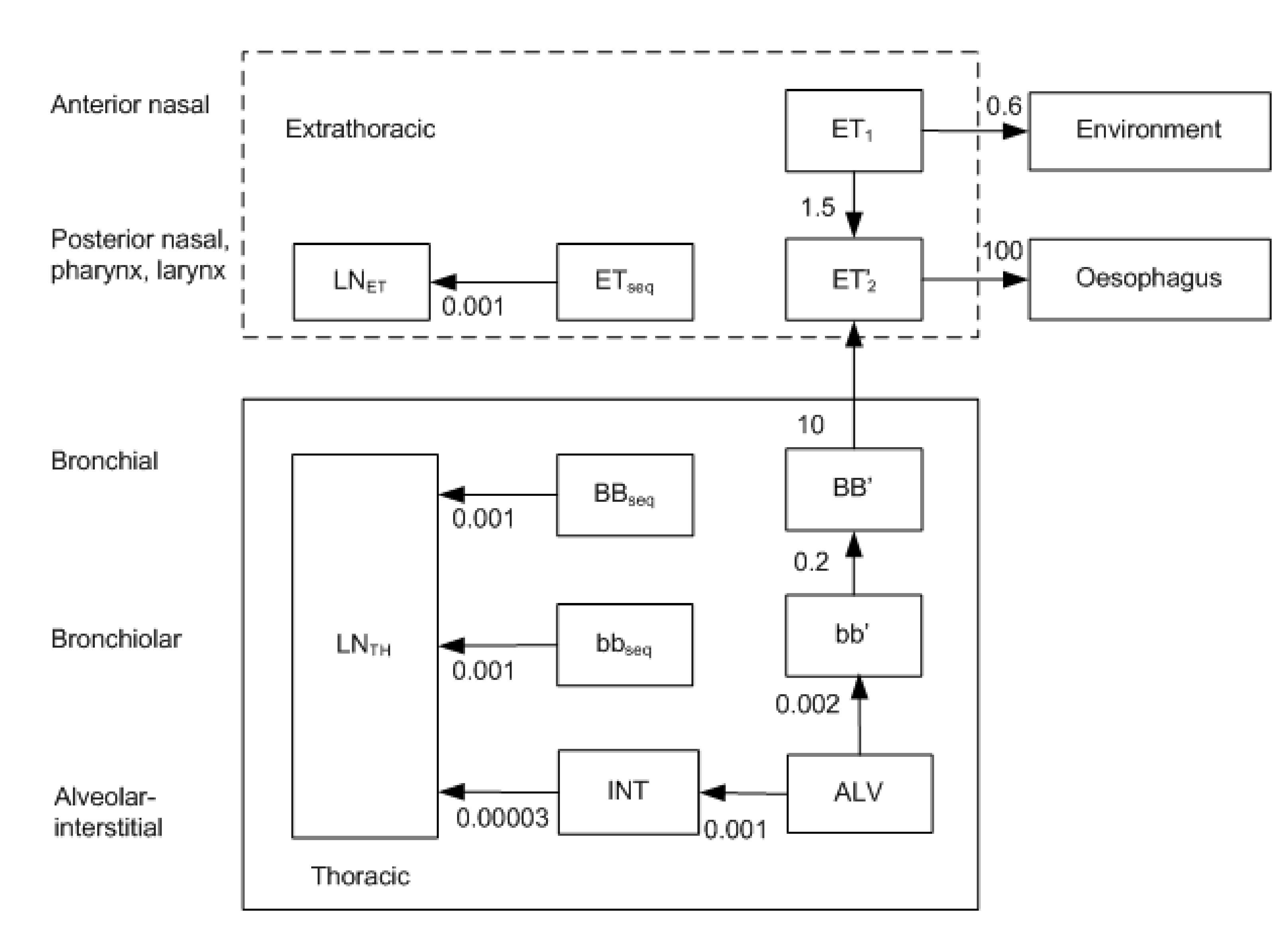


Human Respiratory Tract Model: ICRP 66 (1994)

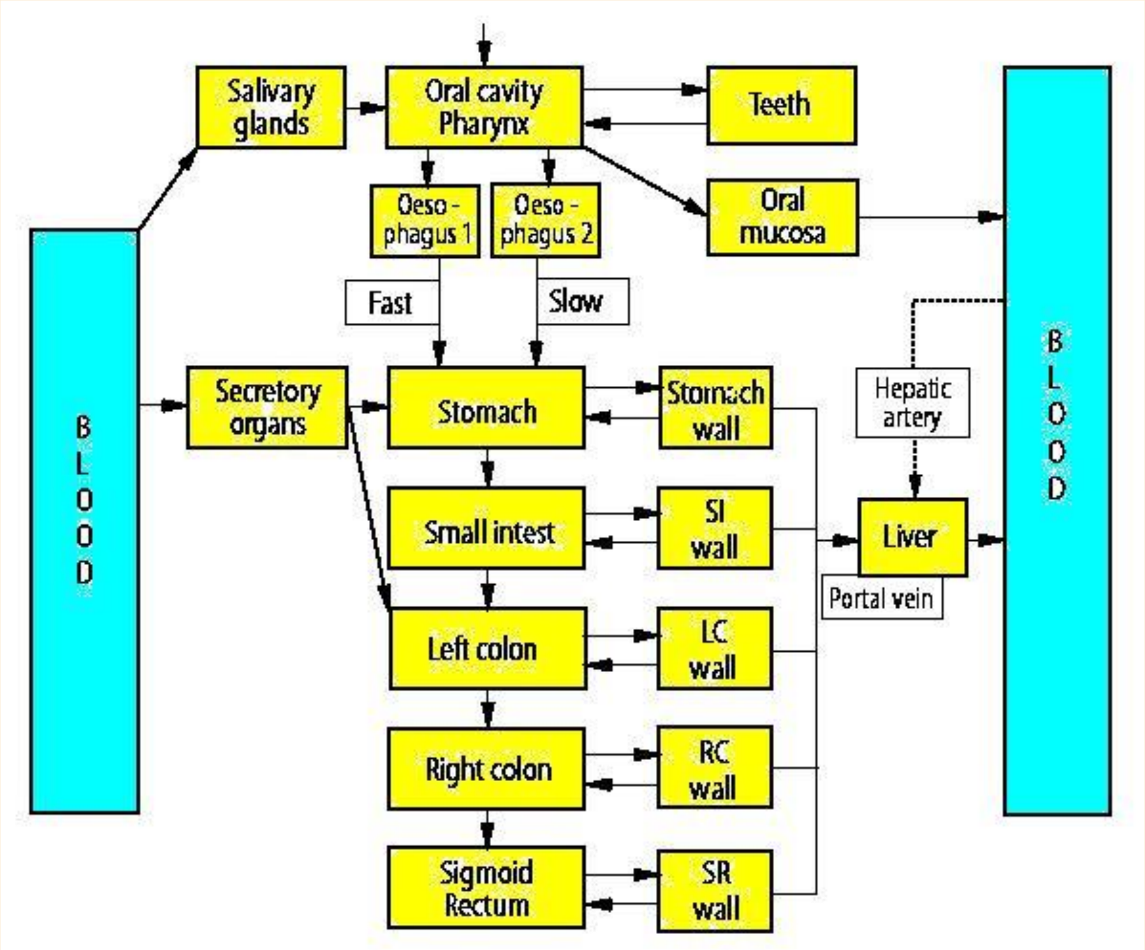


Bill Bair ICRP 66

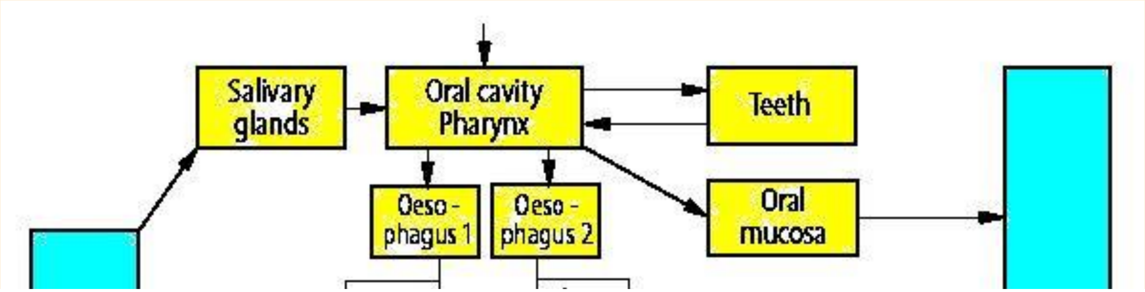
Revised HRTM: ICRP 130 (2015)



Human Alimentary Tract Model: ICRP 100 (2006)



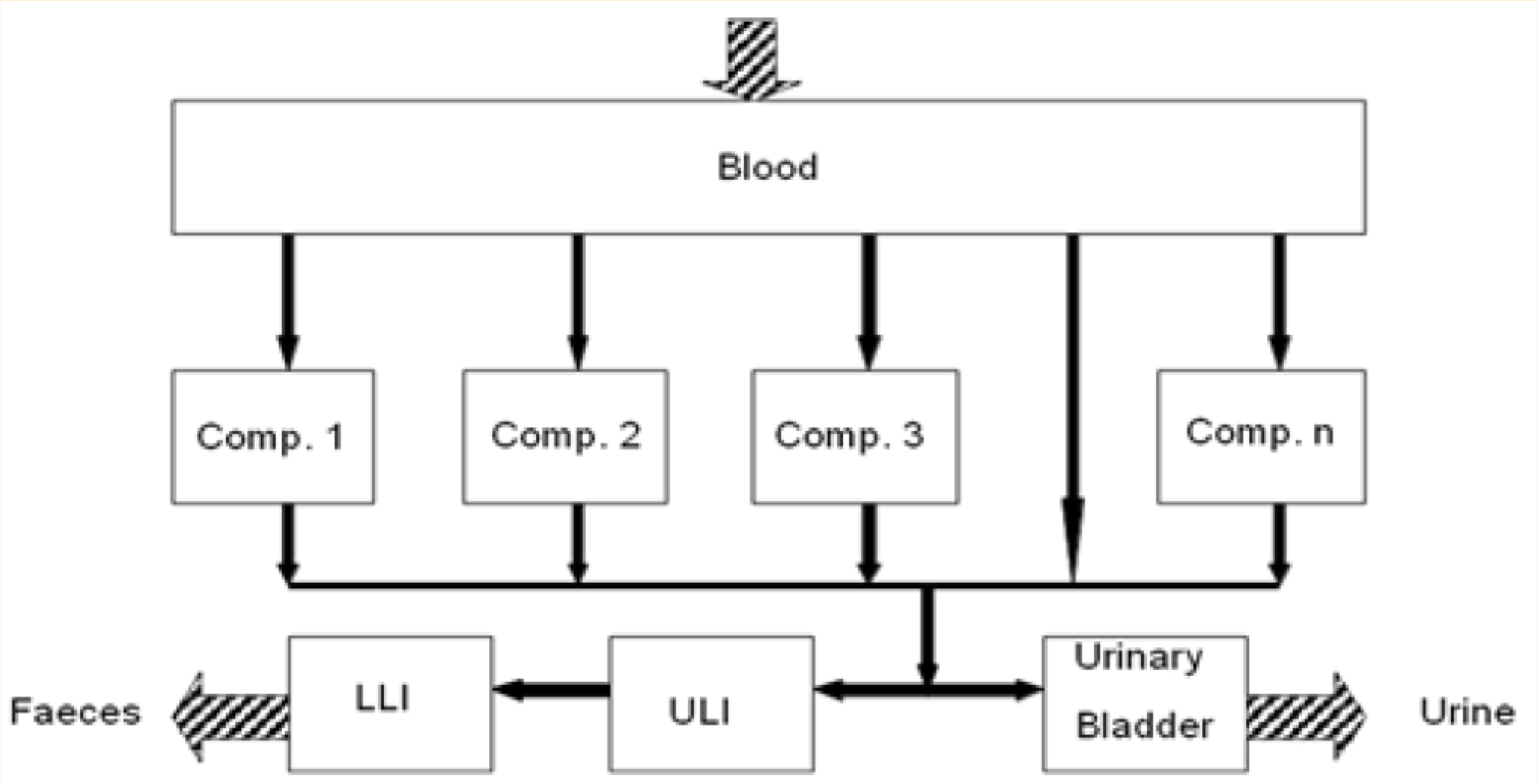
Human Alimentary Tract Model: ICRP 100 (2006)



HATM transfer coefficients (d^{-1}) for reference worker

From	To	Transfer coefficient (d^{-1})
Oral cavity contents	Oesophagus Fast	6480
Oral cavity contents	Oesophagus slow	720
Oesophagus Fast	Stomach contents	12300
Oesophagus Slow	Stomach contents	2160
Stomach contents	Small intestine contents	20.57
Small intestine contents	Right colon contents	6
Right colon contents	Left colon contents	2
Left colon contents	Rectosigmoid contents	2
Rectosigmoid contents	Faeces	2

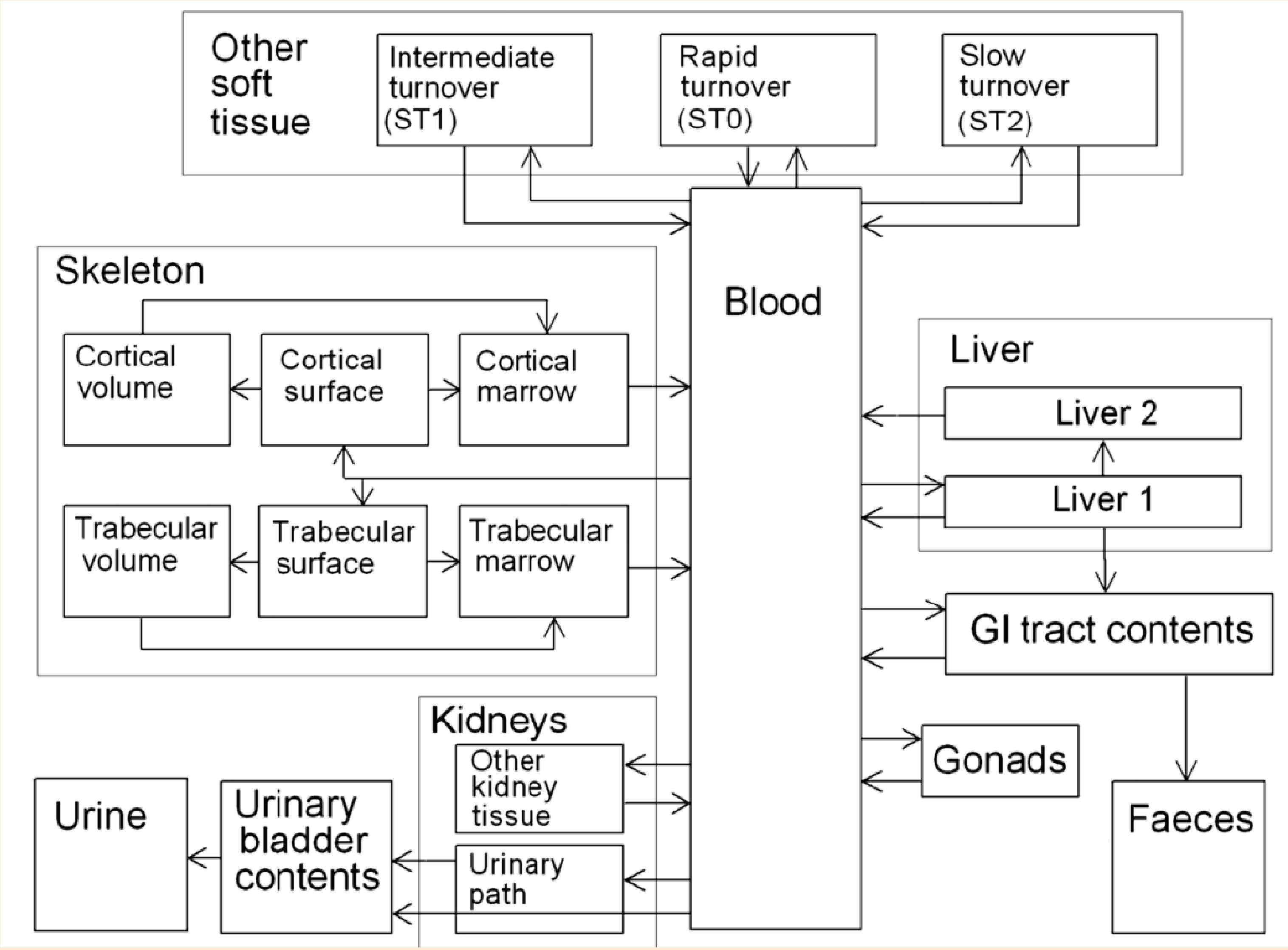
Systemic Biokinetics: ICRP 68 (1994)



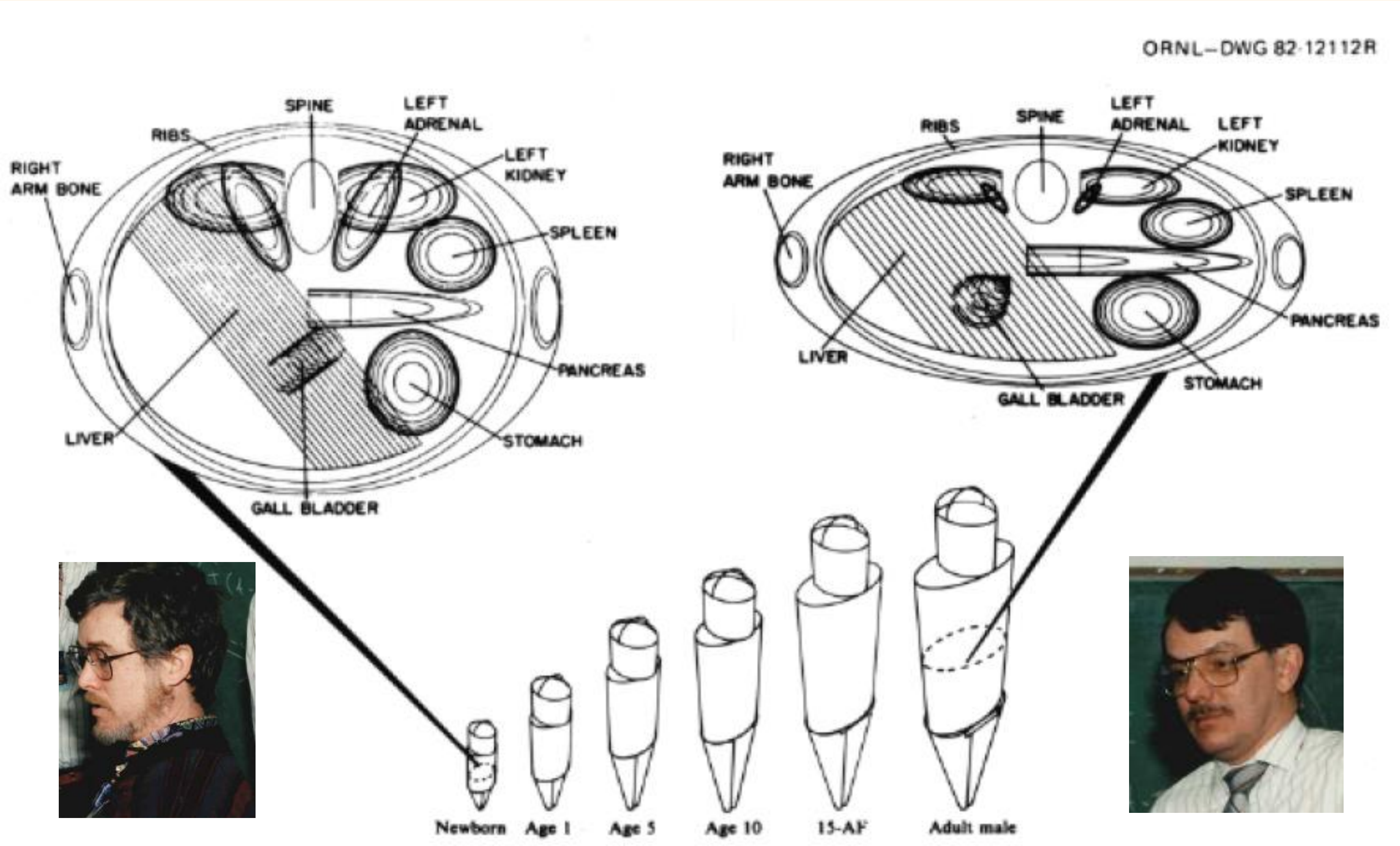
Systemic Biokinetics Models

- Behavior following introduction to blood
- ORNL effort lead by Rich Leggett
- Developed using
  - Radionuclide specific studies in man
  - Physiological information
  - Information on member of chemical family
  - Information on animal studies
- Models predict distribution in body for:
  - Organ/tissue dose estimates
  - Interpretation of bioassay measurements

Systemic Biokinetics (Actinides): ICRP 130 (2015)



Anatomical Model (Phantom)



Computational Phantoms: ICRP 110 (2009)

Main Characteristics of adult Reference Computational Phantoms		
Property	Male	Female
Height (m)	1.76	1.63
Mass (kg)	73	60
Number tissue voxels	1,946,375	3,886,020
Voxel volume (mm^3)	36.54	15.25
Voxel in-plane resolution (mm)	2.137	1.775
Number of slices	222	348

Internal Emitter Absorbed Dose: ICRP 130 (2015)

Biokinetics: $A_{i,j}(t)$ is the activity of decay chain member *i* in compartment *j* at *t* in a system of *M* biokinetic compartments is

$$\frac{\mathrm{d}\,A_{i,j}(t)}{\mathrm{d}\,t} = \sum_{\substack{k=1\\k\neq j}}^{M} A_{i,k}\lambda_{i,k\rightarrow j} - A_{i,j}\sum_{\substack{k=1\\k\neq j}}^{M}\lambda_{i,j\rightarrow k} - A_{i,j}\lambda_i^{\mathrm{P}} + \sum_{n=1}^{i-1} A_{n,j}\beta_{n,i}\lambda_n^{\mathrm{P}}$$

Absorbed dose, $D(r_\mathrm{T})$ is integral of $\dot{D}(r_\mathrm{T})$

$$\dot{D}(r_T \leftarrow r_S) = A(r_S)\frac{1}{M(r_T)}\sum_i Y_i\, E_i\, AF(r_T \leftarrow r_S, E_i)$$

if no time-dependence in *AF* then

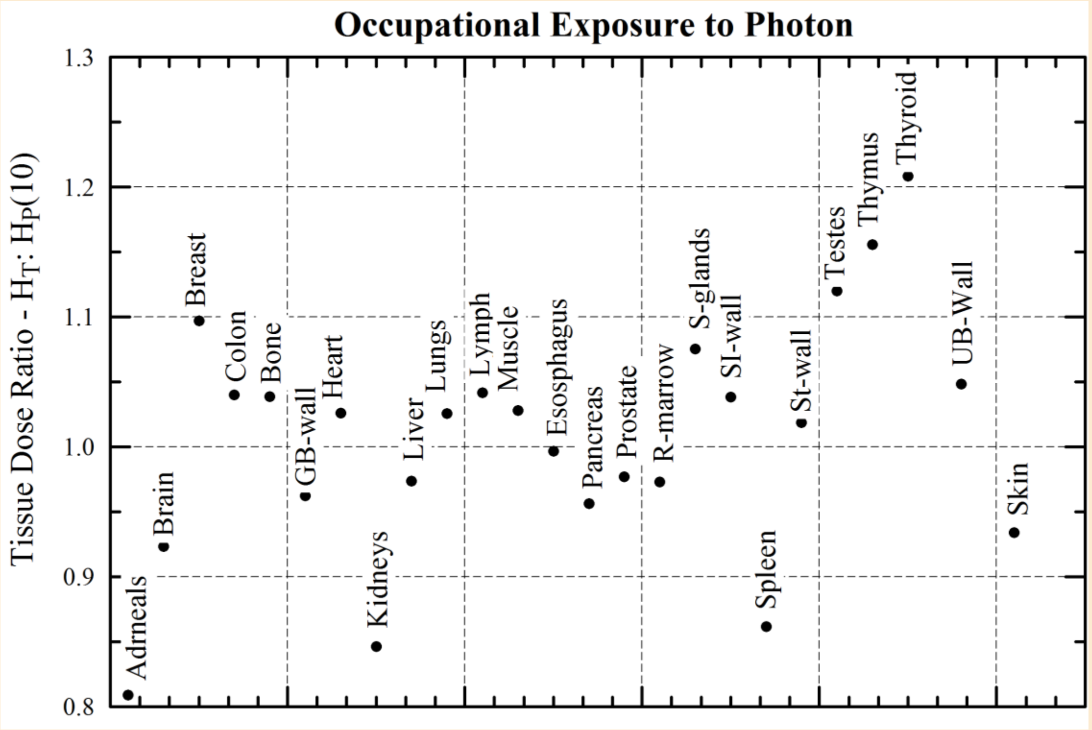
$$D(r_T \leftarrow r_S) = \tilde{A}(r_S)\frac{1}{M(r_T)}\sum_i Y_i\, E_i\, AF(r_T \leftarrow r_S, E_i)$$

where $\tilde{A}(r_S) = \int_0^\tau A(r_S)dt$ and τ is the commitment period.

Thanks Daniel J. Strom

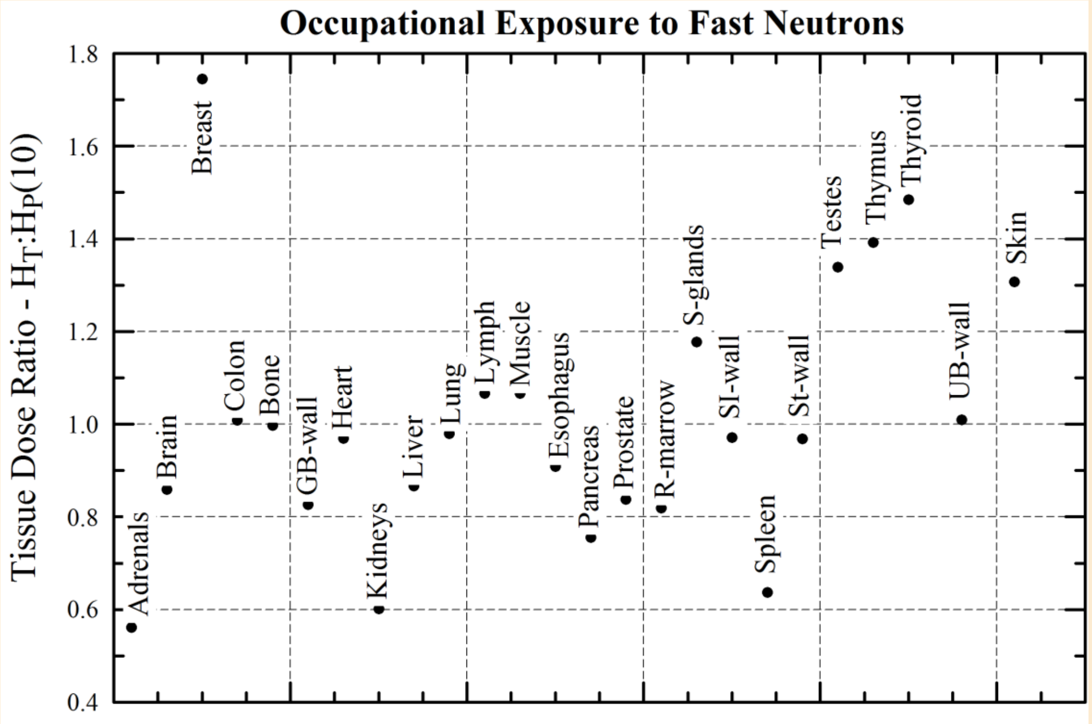
Absorbed Dose – LANL Photon Irradiation

- Irradiation geometry – 50% AP plus 50% ROT
- Assume down-scattered energy spectra of Cs-137/Ba-137m
- ICRP 116 coefficients (2010)
- Assume badge reading represents the whole body dose or $H_p(10)$
- Derive $H_T/H_p(10)$ ratio and apply to badge readings



Absorbed Dose – LANL Fast Neutrons

- Irradiation geometry – 50% AP plus 50% ROT
- Assume Watt spontaneous fission neutron spectra for Pu-238
- ICRP 116 coefficients (2010)
- Assume badge reading represents the whole body dose or $H_p(10)$
- Derive $H_T/H_p(10)$ ratio and apply to badge readings



Reflection on MPS

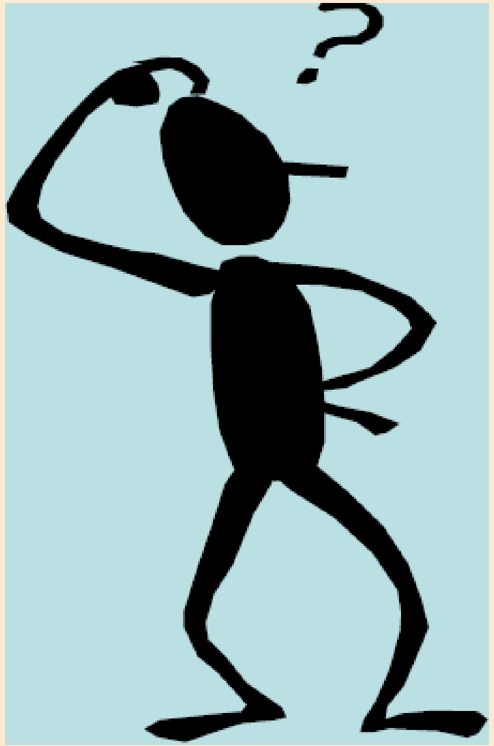
What have we learned?

Rocketdyne nuclear facility

Mound nuclear facility

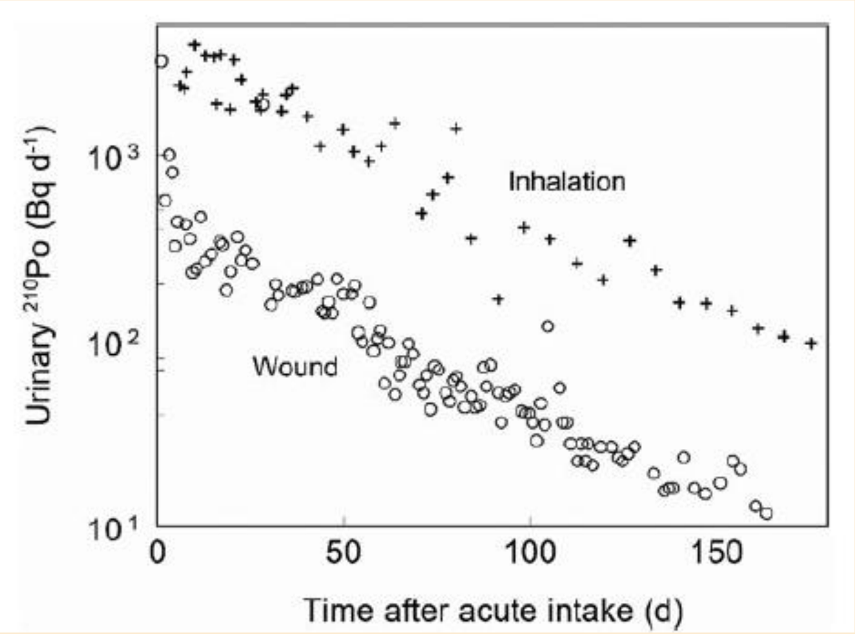
Mallinckrodt Chemical works

LANL, work in progress



Observation

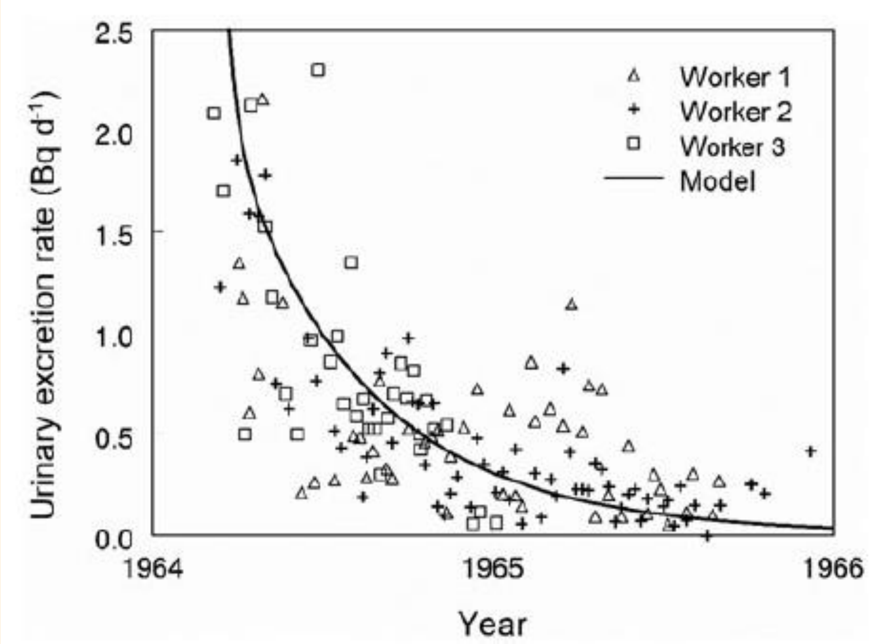
- Much effort needs to be devoted to:
  - Developing feasible exposure scenarios
    - Time pattern of intake/exposure
    - Mode of intake
    - Form of material inhaled
    - Energies of external radiation field

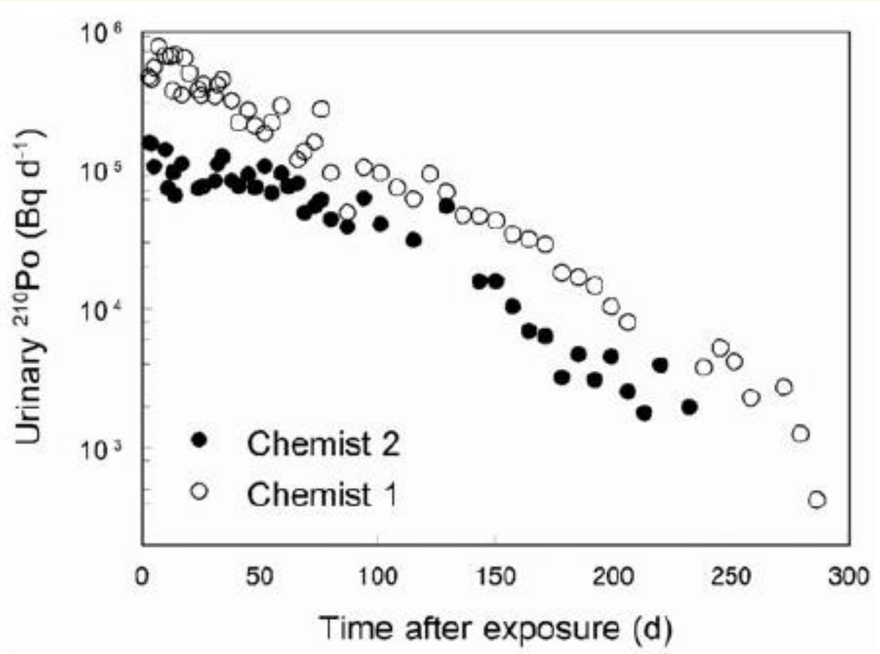


Similar urinary excretion pattern by Mound workers following inhalation intake and wound.

Observation

Coworker data should be used to assign exposure scenarios or dose estimates to workers with missing exposure data if, and only if, these is compelling evidence of similar exposure.





Left three Rocketdyne works acutely exposure in an incident, on right two Mound chemist exposed in same incident.

Observation

- Dose estimates derived solely from air monitoring data should be treated as highly uncertain values.
- For intakes known or assumed to be via inhalation, the uncertainty in the lung dose typically is much greater than the uncertainty in the dose to systemic tissues, when dose estimates are based on urinary excretion data.
- Lung dose estimates often can be improved through development of site-specific, respiratory absorption parameter values.

Final Comment

Computer and technological advances have been a significant driver of changes in prospective and retrospective radiation dosimetry.

My current desktop computer is over an order of magnitude faster than the IBM 370 Model 195 upon which we did the ICRP 30 calculations.

Thanks for your attention.