

# **Incorporated Radionuclides: Health Effects, Dosimetry, Decorporation & NRA**

by

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***“Learning from Plutonium  
and Uranium Workers”***

# The Poisoning of Alexander Litvinenko (London, UK)



- On 1 November 2006, Alexander Litvinenko (former FSB and KGB agent) suddenly fell ill and was hospitalized.
- He died three weeks later, becoming the first confirmed victim of lethal polonium-210-induced acute radiation syndrome.

# TV/Press 'Radiation' Hysteria – UK & Worldwide

## Experts: Radiation Risk from Spy Death Minimal (Unless You're a Spy)

Since investigators discovered traces of radiation on three British Airways jets yesterday and expanded their search today, **the public health scare caused by the radiation poisoning of an ex-Russian spy in London has exploded into a mini-hysteria**—one that experts say is largely **overblown**.

By Simon Cooper

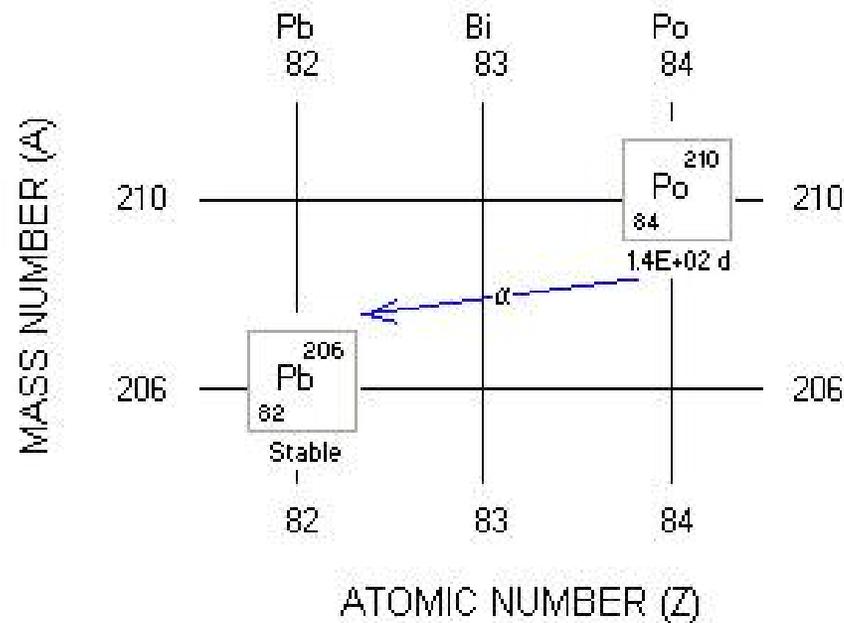
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**PopularMechanics.com, Nov. 30** — Since investigators discovered traces of [radiation](#) on three British Airways jets yesterday and expanded their search today, the public health scare caused by the radiation poisoning of an ex-Russian spy in London has exploded into a mini-hysteria—one that experts say is largely overblown.

At least 2500 airline passengers have contacted British Airways over concern about exposure to polonium 210—the radioactive poison that killed the spy, Alexander Litvinenko—adding to the more than 1700 Londoners who've called the U.K. Health Protection Agency's emergency line out of fear that they'd been exposed to polonium while visiting some of the same sites Litvinenko had. British authorities are closely examining at least 12 locations where radiation has been detected, some of which Litvinenko visited, and yesterday British Airways grounded three of its airliners.



# Radioactive Decay of $^{210}\text{Po}$



Decay products of Po-210 (MeV)

Alpha		Beta		Electron		Positron		Photon	
Energy	Yield	Energy	Yield	Energy	Yield	Energy	Yield	Energy	Yield
5.30E+00	1.00E+00			7.14E-01	8.59E-08			8.02E-01	1.06E-05
				7.86E-01	1.25E-08				
				7.87E-01	4.79E-09				
				7.89E-01	1.41E-09				
				7.99E-01	4.30E-09				
				8.02E-01	1.63E-09				
				5.83E-02	1.67E-09				
				8.16E-03	3.10E-08				
				1.08E-02	2.03E-08				
				2.92E-03	1.28E-07				

# History of Radon (and Uranium) – beginning 1470<sup>1</sup>

- The occupational story starts in a region known as the Erzgebirge, the “Ore Mountains”. The two principle towns of interest are Schneeberg on the German side of the mountains and Jachymov on the Czech Side.
- Mining first started in Schneeberg in the early 1400’s and in Jachymov in 1516 after the discovery of rich veins of silver.
- After the discovery of uranium in 1789 by Martin Klaproth, pitchblende was then mined, primarily at Jachymov. This pitchblende may have contained about 1% uranium. The uranium was at that time used for coloring wood, leather, pottery glazes and glass.
- The miners of these very early years paid a heavy price for their labors. A quote from **Agricola’s publication “De Re Metallica”** gives us a feel for the conditions in the mines and the miners fate, “the dust has corrosive qualities, it eats away the lungs and implants consumption in the body... Women are found who have married seven husbands, all of whom have this terrible consumption [which] has carried off to a premature death.” The miners themselves called this disease “Bergsucht” or “Mountain Sickness.” The miners attributed it to sub-terrestrial dwarfs.



<sup>1</sup>Taken from [http://www.ohioradonpro.com/Radon\\_History.html](http://www.ohioradonpro.com/Radon_History.html).

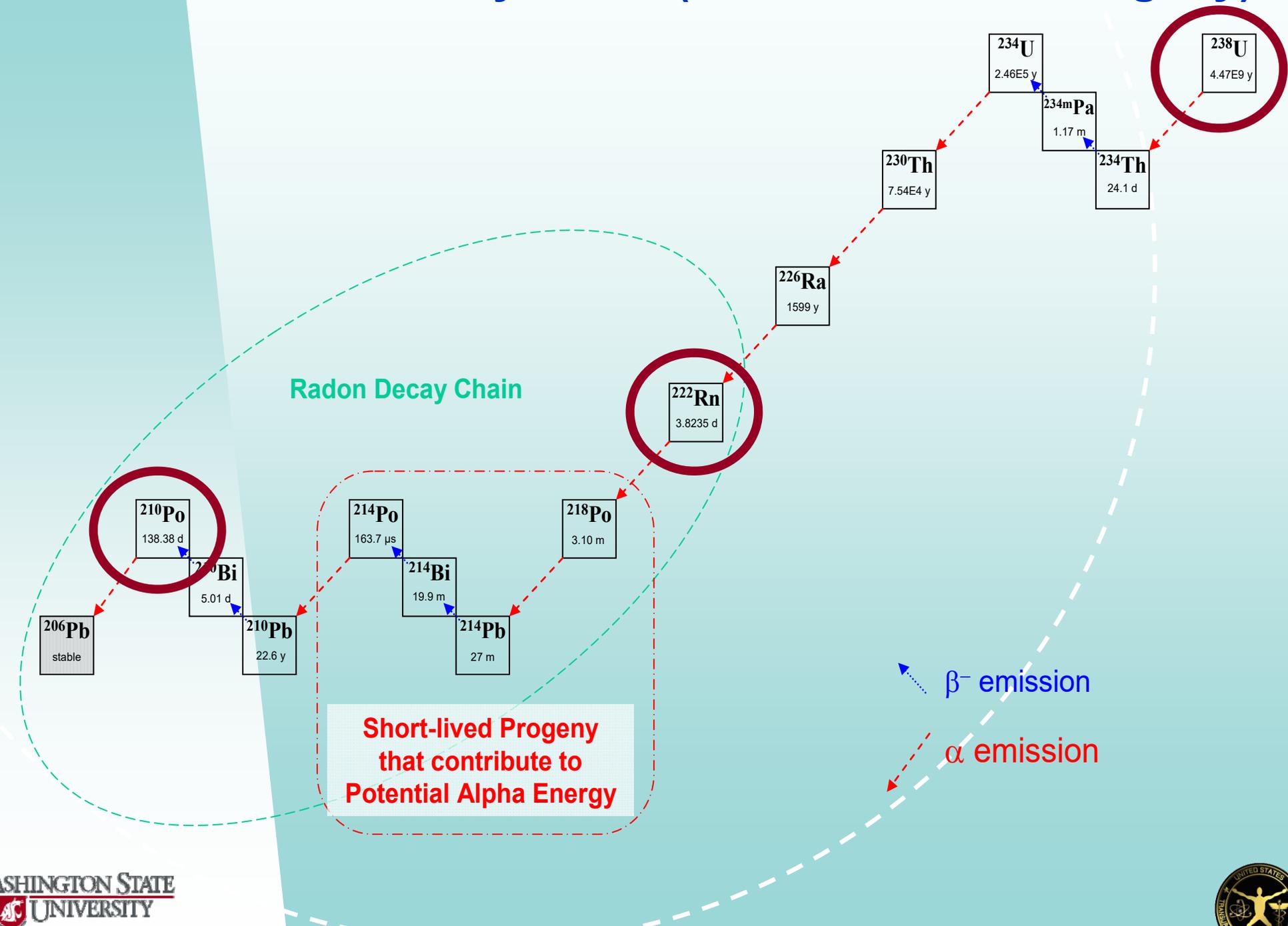
# History of Lung Cancer and Radon<sup>1</sup>

- We must follow a long and winding road to go from the “Mountain Sickness” of the Erzgebirge to the **progeny-induced** lung cancer of today.
- Paracelsus (1493-1541) a contemporary of Agricola, and a physician himself, postulated the inhalation of metallic vapors .... ‘which settle on the lung...’.
- Understanding the ‘cause’ of this sickness took 400 y – and 4 significant discoveries; **first** was the discovery of x-rays in 1895 by W.C. Roentgen, **then** radioactivity in 1896 by Henri Becquerel, **third** the discovery of radium in 1898 by M. and P. Curie, and **finally** the discovery of radon by Friedrich Ernst Dorn in 1900, initially called “radium emanation” and not to be called radon until 1923.
- In 1879 Harting and Hesse by use of “clinical and anatomical research” proved that the “Mountain Sickness” of the Schneeberg miners was actually a **malignant tumor of the lung**.
- These authors stated that from the period 1869 to 1877 **about 75% of all deaths among miners of Schneeberg were due to lung cancer**. Though this number is probably unreliable, it can be contrasted with the autopsy findings in 1878 from the Institute of Pathology at the University of Dresden where malignant tumors of the lung only accounted for 1% of all cancers. **Lung cancer was a very rare disease 150 years ago**.

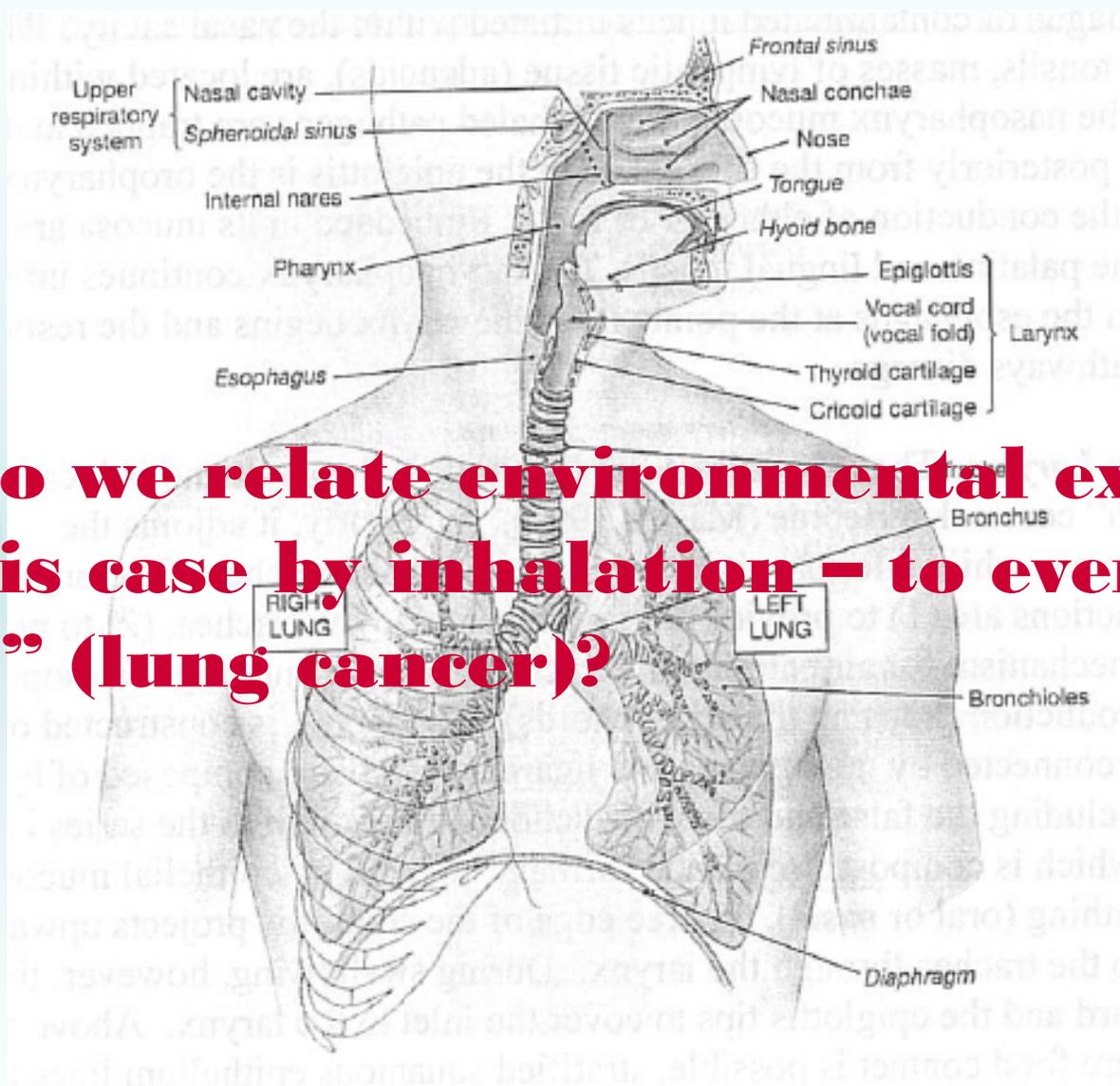
<sup>1</sup>Taken from [http://www.ohioradonpro.com/Radon\\_History.html](http://www.ohioradonpro.com/Radon_History.html).



# Natural Uranium Decay Chain (Radon & Radon Progeny)



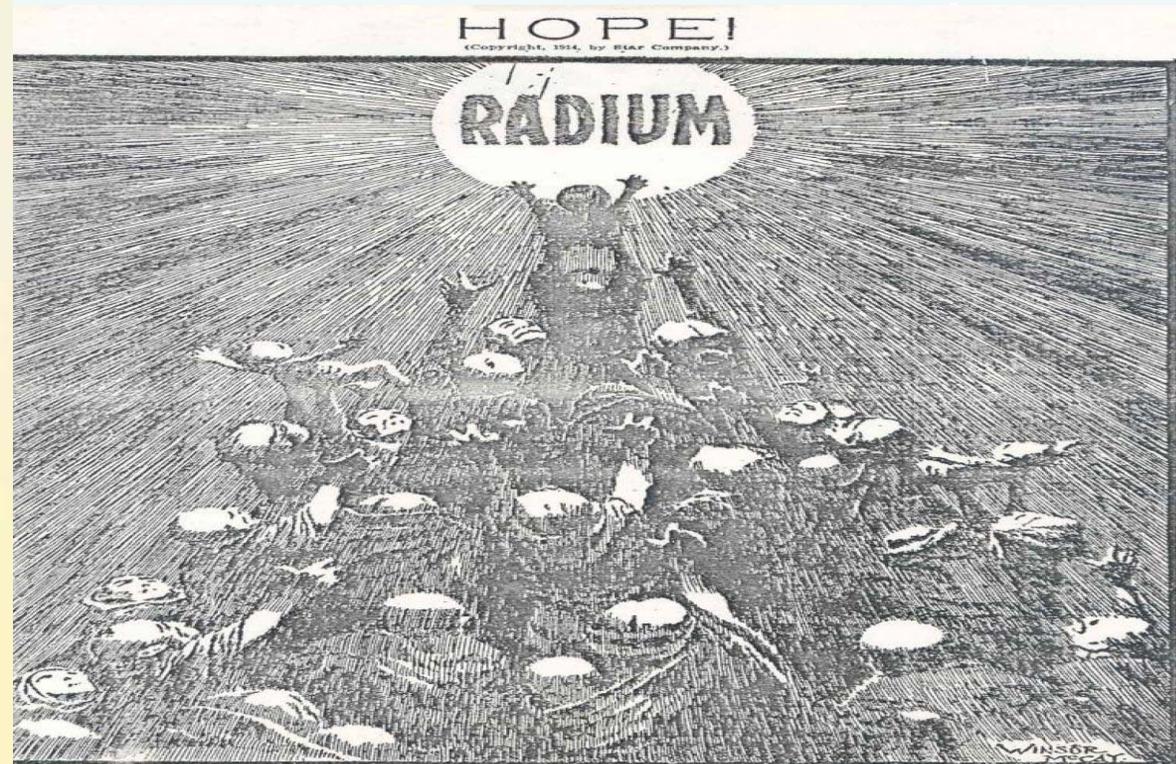
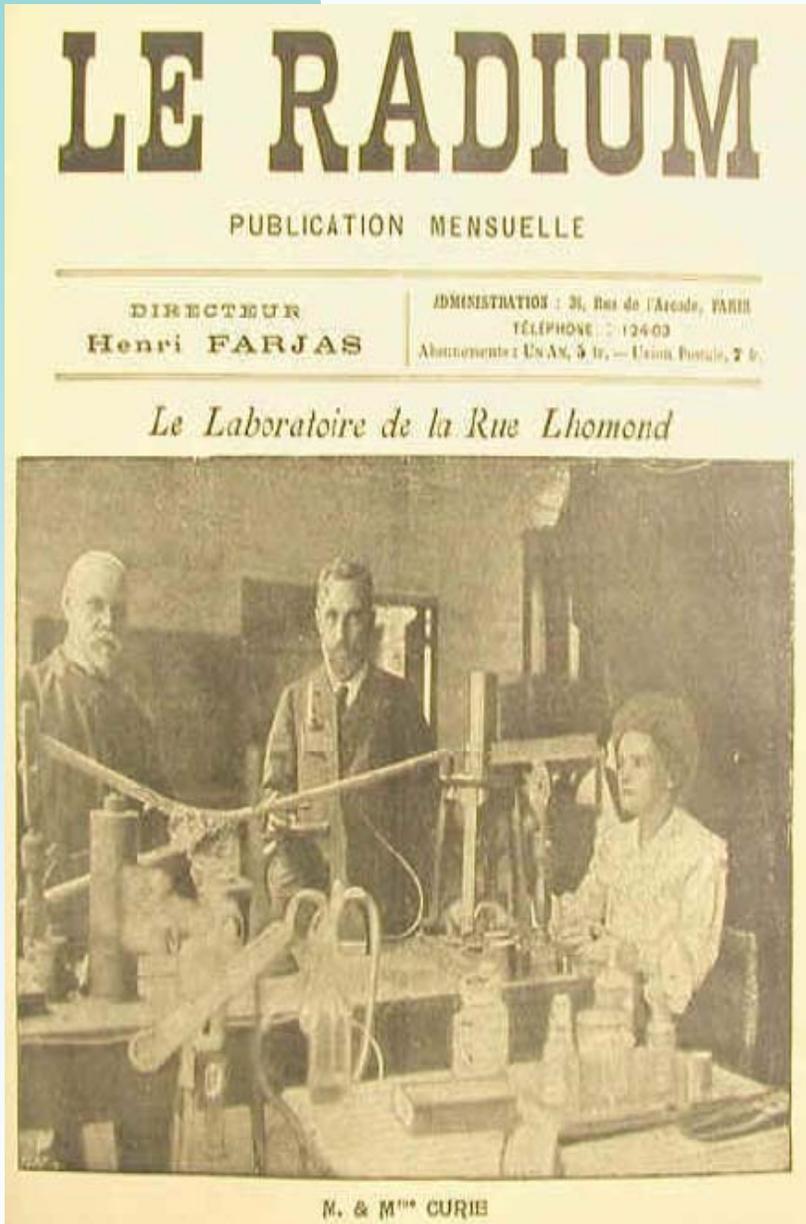
# Anatomy of the Respiratory Tract<sup>1</sup>



**How do we relate environmental exposure - in this case by inhalation - to eventual “effect” (lung cancer)?**

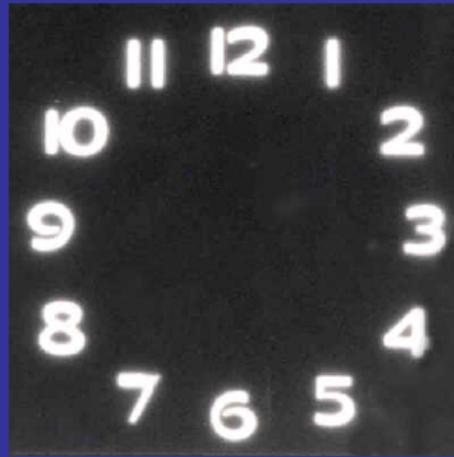
<sup>1</sup>Taken from “Practical Applications of Internal Dosimetry” (Ed. W.E. Bolch). Madison, Wisconsin: Medical Physics Publishing (2002).

# Radium – Discovered by the Curies (1897)



**Soon 'hyped' as the HOPE to cure all cancer!**

# Radium – The Universal “Elixir” (and Consumer Product)



**FIND IT *in the DARK!***

**Radi-Glo**  
PATENT APPLIED FOR

**GENUINE RADIUM RAY  
"SPOTTER" BUTTON**

NEED NEVER BE EXPOSED TO LIGHT FOR RECHARGE



**INSTRUCTIONS:** For example, on light switches, simply remove one plate screw, center one Radi-Glo button over opening (countersunk side toward you) and replace the screw. Radi-Glo buttons can be glued, sewn, stapled, screwed or attached to hundreds of objects and places for instant visibility in darkness. Scotch tape or other adhesive may be used.

**LIFETIME USE • APPLY ANYWHERE  
LIGHT SWITCHES • STAIRS • DARKROOM**  
(SEE OVER)



# Then Came “Radium Jaw”



**“The Saga of the Radium Dial Painters”**: The first occupational **internal dose** study cohort!

Taken from “Radium in Humans: A Review of U.S. Studies”. Rowland R.E. ANL/ER-3.  
(Available at <http://www.ustur.wsu.edu/Radium/files/RainHumans.pdf>).

# Radium Health Effects

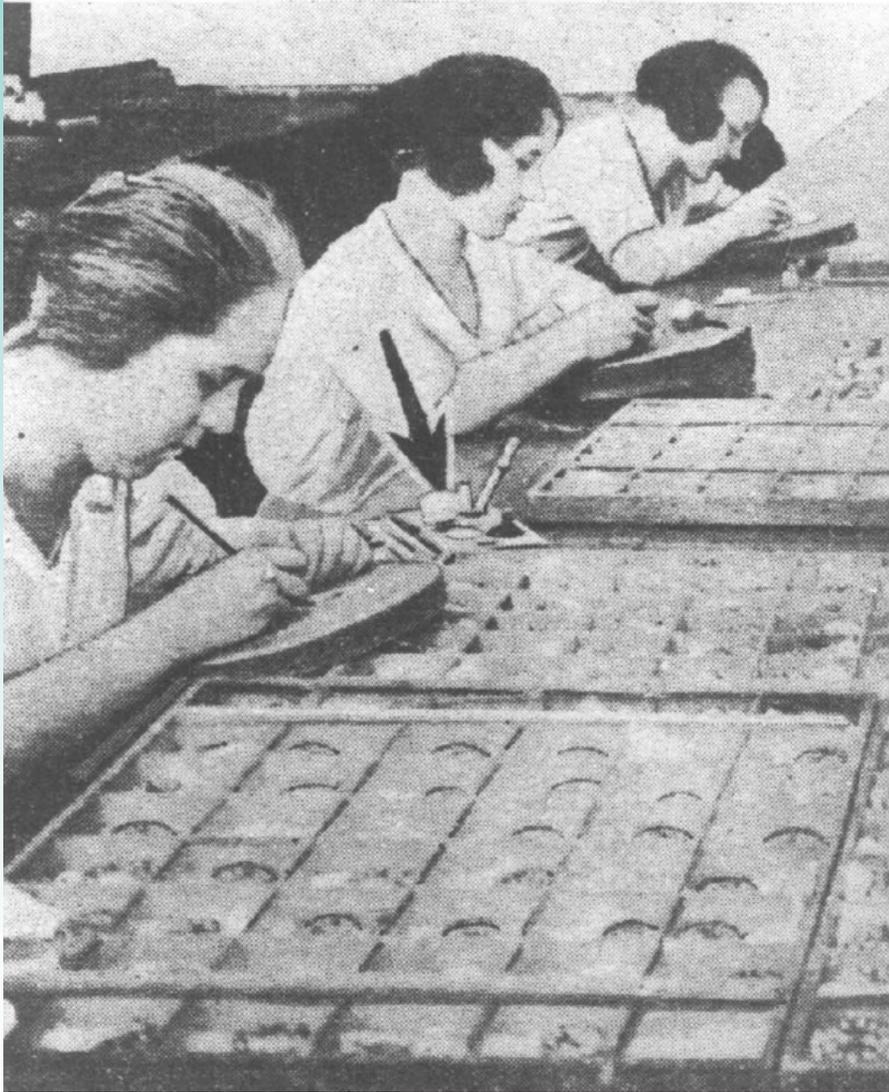
- **First noted by Dr. Theodore Blum, a NJ dentist in the early 1920's.**
- **“Radium jaw” analogous to “phossy jaw”.**
- **Quantified by Dr. Harrison Martland, pathologist in Orange, NJ.**
- **Numerous trials and stories on the “girls doomed to die” in the late 1920's.**

# Radium – First Symptom Severe Bone Necrosis



# “Radium Workers at Deadly Task”

Radium Workers at Deadly Ta



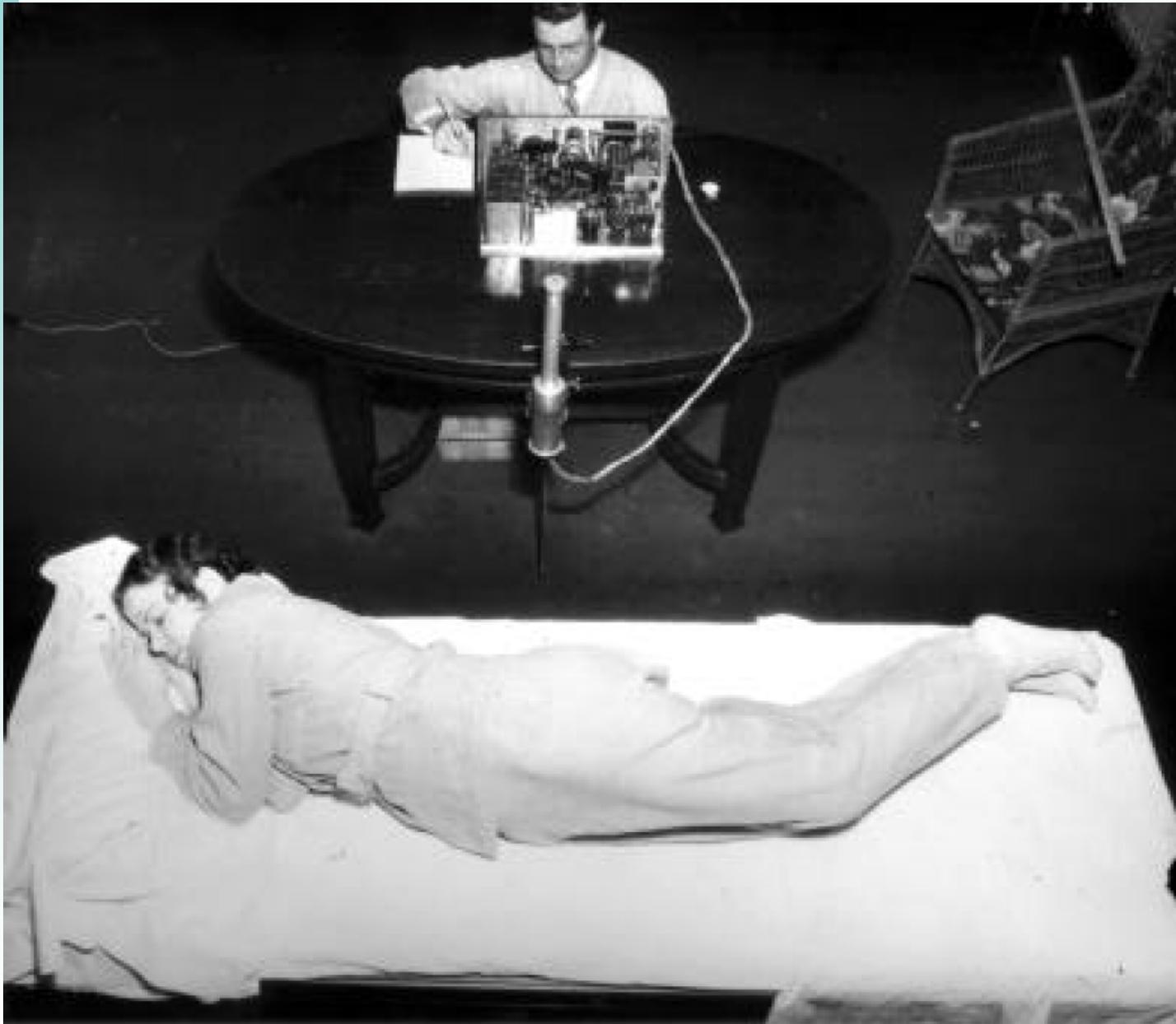
# A Simple Safety Standard

- Don't eat the paint!
- “Brush-tipping” was forbidden as an unsafe labor practice by the U.S. Department of Labor (in 1929).
- No dial workers from the 1930's on had significant intakes of radium – but were followed up because of external gamma exposure.

# 1930's "Dosimetry" Studies of Radium Dial Painters – Dr. Robley Evans (MIT)



# Earliest Measurements of $^{226}\text{Ra}$ Body Burden (Evans, MIT)



## High Sensitivity Measurement of Body Burden (Argonne National Laboratory, ANL – 1970's)



Inside the whole-body counter in Argonne's Center for Human Radiobiology, a patient is ready for a measurement of gamma rays emitted from her body. From: Rowland, R. E. "Radium in Humans: A Review of U.S. Studies," ANL/ER-3 (1994).

# Origin of “Exposure Standards” for Internal Contamination - U.S. National Bureau of Standards (1941)

The concept that radiation should have its own exposure standards grew from early radiobiological effects on humans working with the new radiation energy sources. The first official exposure standard for a radionuclide in the body was established for  $^{226}\text{Ra}$  at a level of  $0.1 \mu\text{Ci}$ , by a task group assembled by the U.S. National Bureau of Standards in 1941. On the basis of the average radiation dose to the skeleton from deposited radium, a “practical threshold” dose of 10 Gy was established many decades ago by the pioneer of the work contained in this book, Dr. Robley Evans, then at the Massachusetts Institute of Technology. It was Evans who, through appearances before the Atomic Energy Commission and congressional committees, spearheaded the establishment of the Center for Human Radiobiology at Argonne National Laboratory in 1968.

# The Center for Human Radiobiology (CHR) Project - Argonne National Laboratory (1968 – 1993)

- Total population (est.) 6,000
  - Names 5,000
  - Located 3,500
  - Measured 2,500
- (includes some deceased cases)

# The Center for Human Radiobiology (CHR) Project

## Entry at First Exposure

<u>Radium measured</u>	<u>Yes</u>	<u>No</u>
Number	759	476
Mean start date	1922.7	1922.1
Mean start age	19.0	21.5
Deaths:		
With Ra tumor	47	27
Other observed	188	267
Other expected	308	152
Obs./Exp.	0.61	1.76

# Malignancies Observed in CHR Radium Dial Painter Cohort

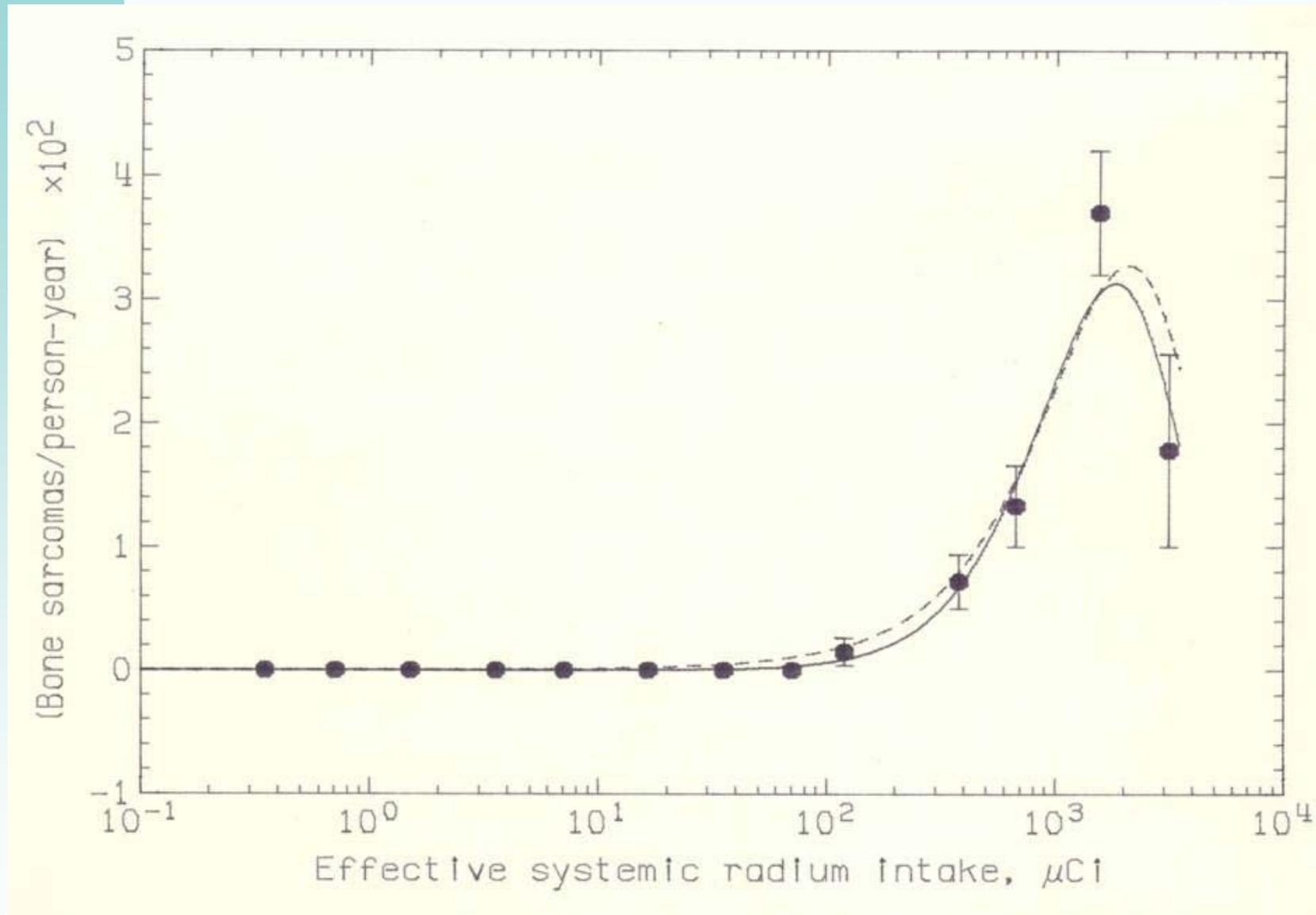
- Bone tumors:
  - Osteosarcomas
  - Chondrosarcomas
  - Giant cell tumors
- Head Carcinomas:
  - Sinuses
  - Mastoids
- Nothing Else!
  - No excess leukemias
  - No other excess solid tumors

# Bone Tumor Incidence

<u>Ra intake, <math>\mu</math>Ci</u>	<u>Cases</u>	<u>Bone tumors</u>
More than 2500	16	4
1000 -- 2499	22	15
500 -- 999	18	8
250 -- 499	32	9
100 -- 249	27	2
<b>Less than 100</b>	<b>644</b>	<b>0</b>

**100  $\mu$ Ci = 3.7 MBq (3.7 Million Bq)!**

# Bone Sarcoma Death-Rate in Radium Dial Painters vs. $^{226}\text{Ra}$ Intake



# Radium Standard – NBS (1941)

- No health effects noted in radium DPs with retained Ra-226 < 1.0  $\mu\text{Ci}$
- Throw in a safety factor of 10
- **Maximum Permissible Body Burden (MPBB) for Ra-226 = 0.1  $\mu\text{Ci}$**

Toohy, R. E. Available at

<http://www.ustur.wsu.edu/Radium/files/SagaOfRaDPs.pdf>

# Application of “Radium Standard” for Incorporated Plutonium – Manhattan Project

- Robley ratios:

Pu toxicity in man/Ra toxicity in man =

Pu toxicity in dog/Ra toxicity in dog

- Dog studies:

- ANL-E, Utah, UC Davis, ITRI, Colorado State, Hanford

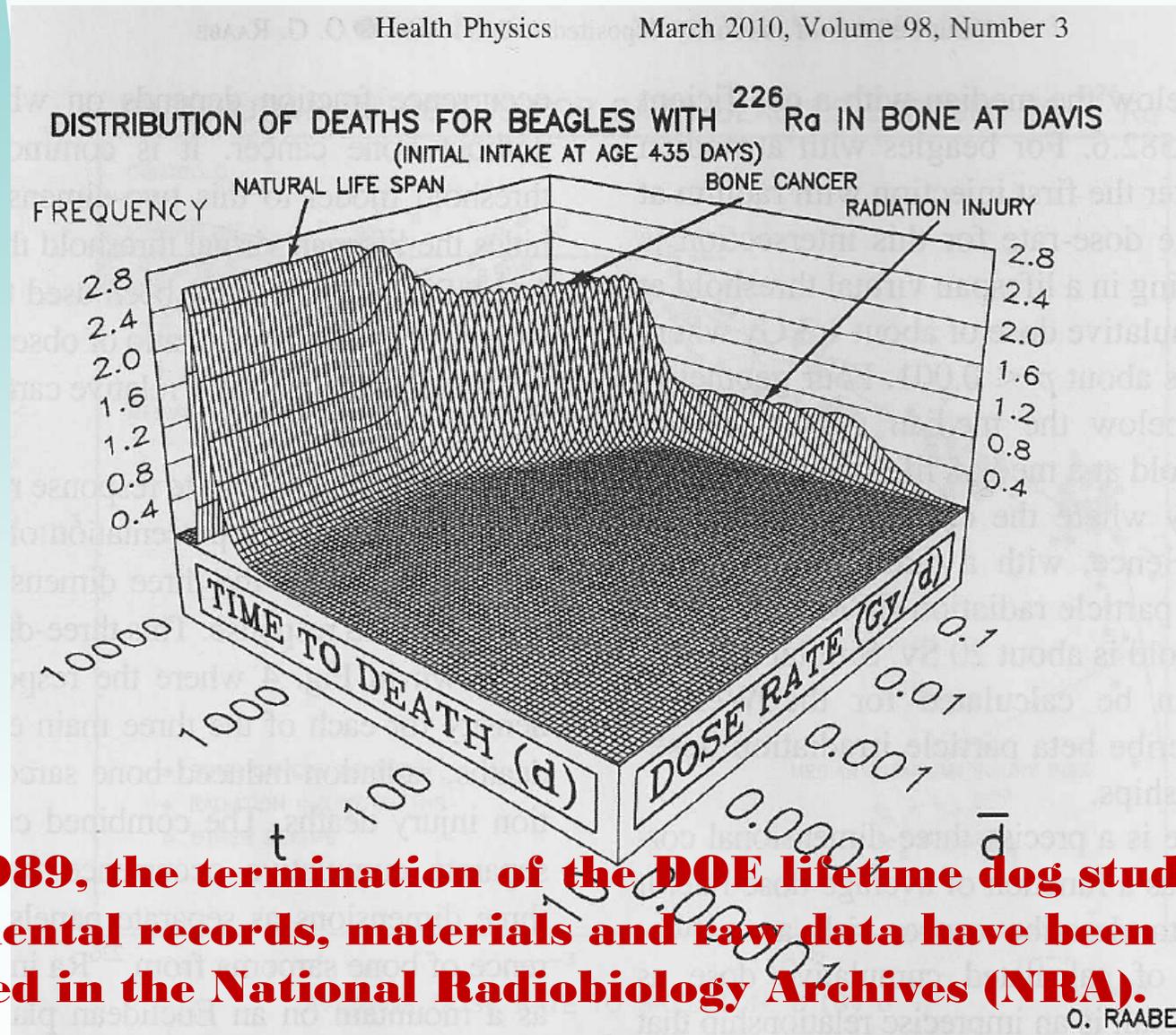
# Manhattan Project - U.S. Plutonium Standard

- Total alpha energy per decay of parent:
  - Ra-226 = 12 MeV
  - Pu-239 = 5 MeV about a factor of 2.
- All Pu alpha energy deposited on bone surface, most Ra energy deposited in bone volume, about a factor of 5.
- **100 nCi x 2/5 = 40 nCi (MPBB for Pu- $\alpha$ ).**

Toohy, R. E. Available at

<http://www.ustur.wsu.edu/Radium/files/SagaOfRaDPs.pdf>

# Lifetime Studies of Effects of Internal Emitters in Dogs – the USAEC/ERDA/DOE “Legacy” Investment



**Since 1989, the termination of the DOE lifetime dog studies, the experimental records, materials and raw data have been preserved in the National Radiobiology Archives (NRA).**

# USDOE's National Radiobiological Archives (NRA)

- Maintained “off campus” by WSU’s College of Pharmacy (COP)
  - COP-funded laboratory facility (Richland Airport, Richland, WA)
  - Currently no USDOE grant support
  - Research student investment from PNNL (LDRD-funded).



**Laboratory records, tissue blocks, pathology slides and searchable database from USAEC/ERDA/DOE's lifetime studies of internal emitter toxicity in dogs**

# Information About the NRA on the Web

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## National Radiobiology Archives

by Charles R. Watson

### Introduction

The U.S. National Radiobiology Archives (NRA) is an archival program that was started in 1989 to collect, organize, and catalog data, laboratory notebooks, and animal tissue specimens from government (i.e. DOE and its predecessor agencies) sponsored radiobiology life-span studies performed at various National Laboratories and universities since the 1940's. These archived records and specimens that are stored and maintained in a centralized facility and are available for additional future research or analyses.

The NRA is part of a greater international program that includes the European Radiobiology Archives (ERA) and the Japanese Radiobiology Archives (JRA)<sup>1</sup>. Dr. Chuck Watson (NRA Database Consultant) served as the U.S. representative on the ERA Advisory Board. The board is overseeing the development of an internet version of the ERA to be called ERA-PRO. This activity is funded by European Community and managed by the German Federal Office for Radiation Protection.

[ERA Advisory Board »](#)  
[ERA-PRO »](#)

**Radiobiological Studies**



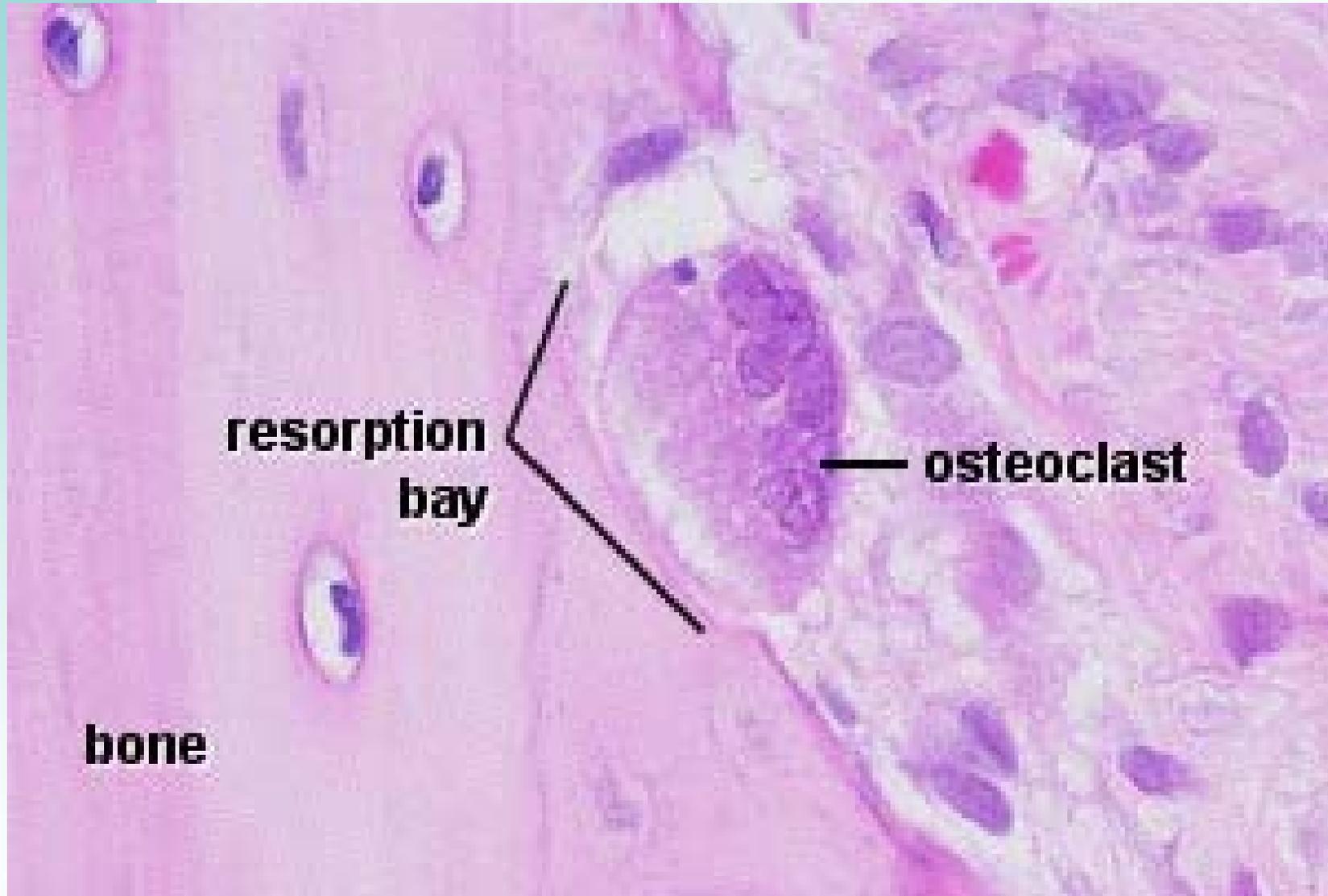
**The NRA houses paraffin embedded tissue blocks, histopathology slides, and clinical notes for various animal life-span studies performed at National Laboratories and universities.**

Available at <http://www.ustur.wsu.edu/NRA/radioarchive.html>

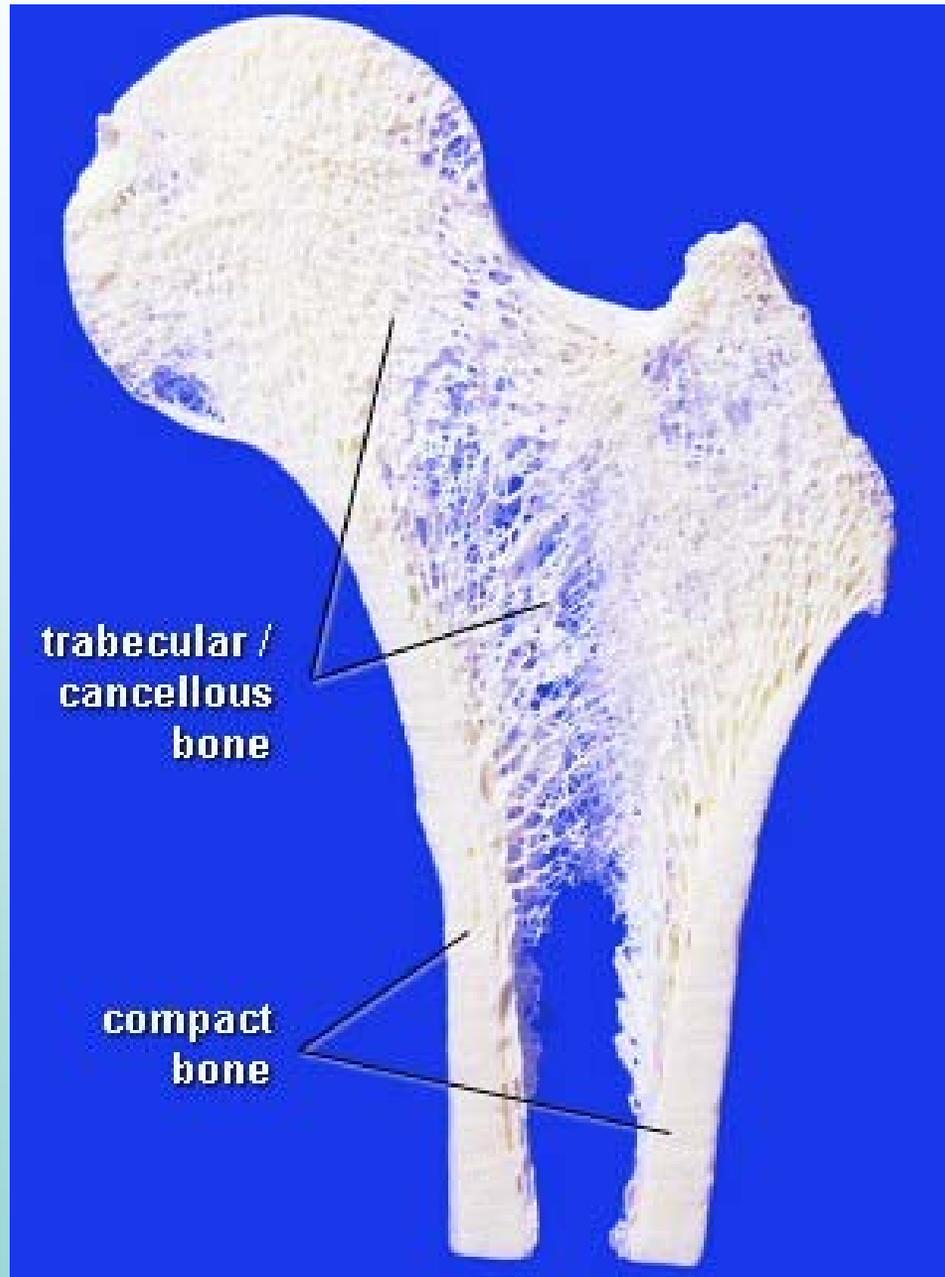
# Internal Contamination is Very Different from External Exposure!

- External exposure **ends** when source (or person) is removed.
- Internally deposited radionuclides “**go on giving**” – when they are retained in body organs, i.e., they **commit** the individual having the **intake** to **future dose**.
- **Amount of future dose depends on:**
  - Amount of exposure (intake)
  - Amount of uptake into the blood – lung/wound/ingestion models
  - Amount of uptake (and retention) by body organs/tissues – systemic “metabolic” or “biokinetic” models
  - Number of radioactive transformations in “source” organs
  - Amount of dose absorbed by “target” organs.

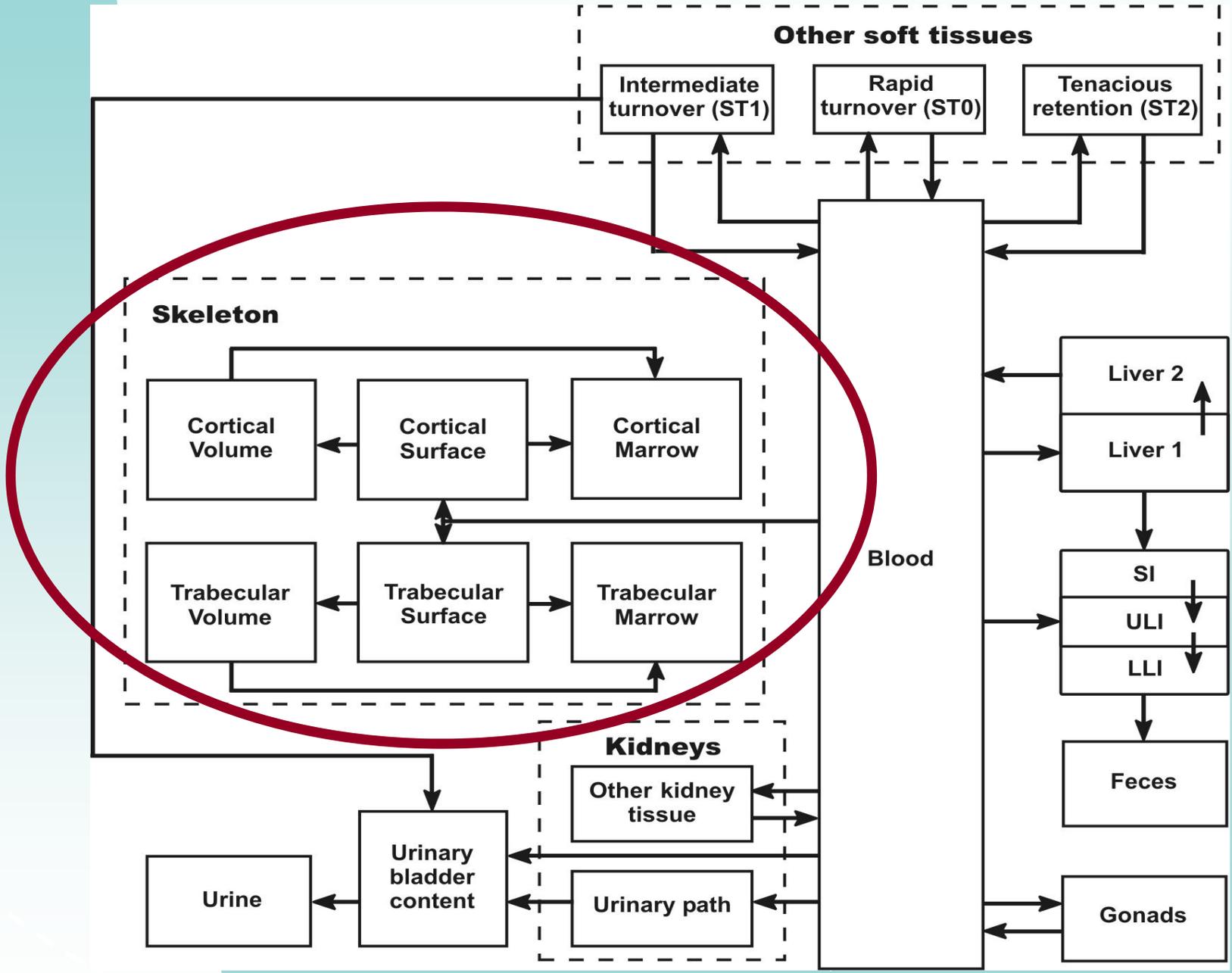
# Cellular Histology of Bone Surface and Bone Marrow



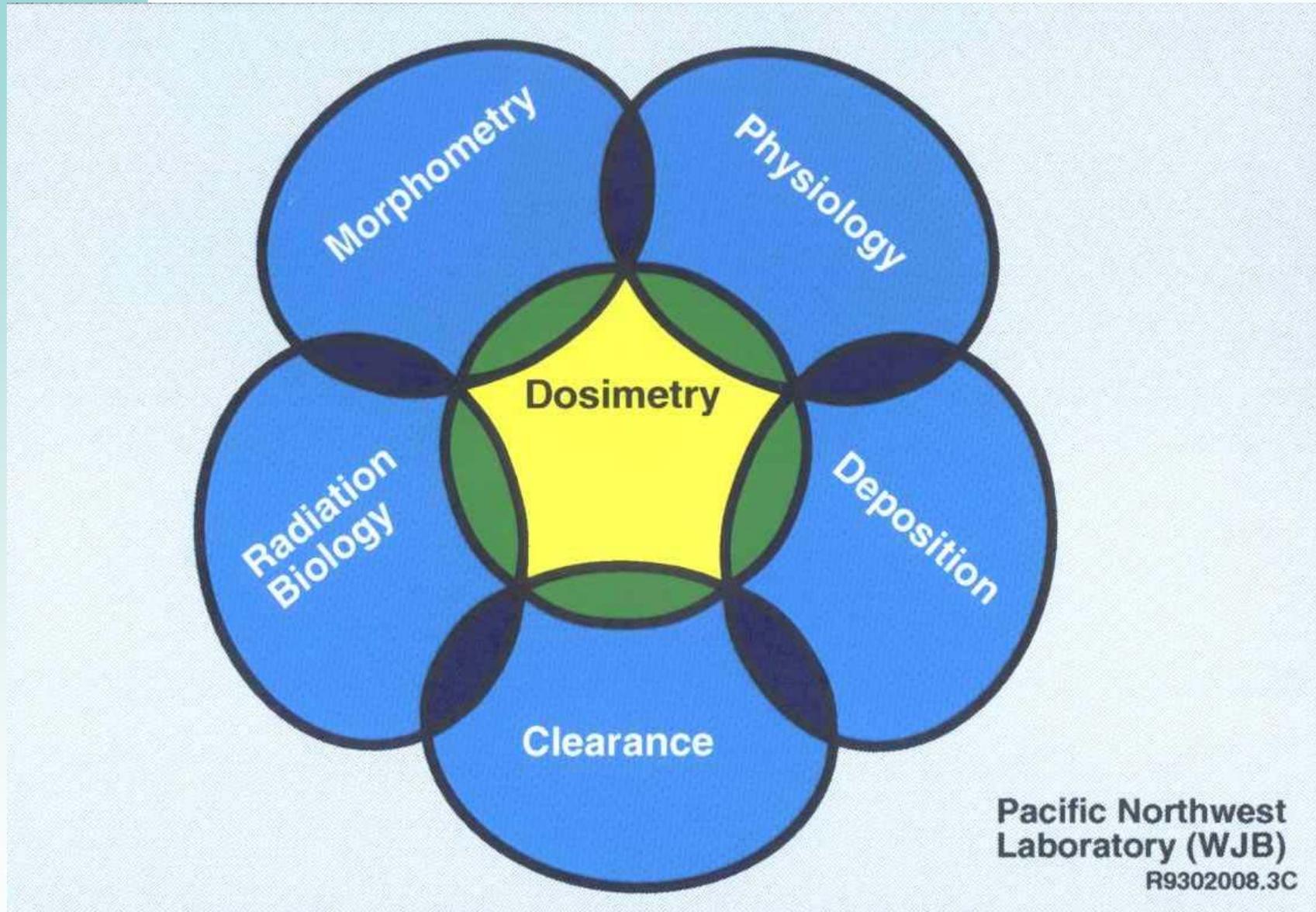
# Functional Structure of Bone



# ICRP67 Systemic Model for Pu – Skeletal Biokinetics



# Elements of the ICRP66 Respiratory Tract Model (HRTM,1994)



# ICRP Specifications (1984) for the HRTM

- Useful for calculating both *intake limits*, i.e., *dose coefficients*, and *assessing exposures* to radioactive particles, gases and vapors.
- Calculate *tissue average doses* in defined regions of the respiratory tract.
- Calculated doses applicable to *ICRP tissue weighted dosimetry system*.

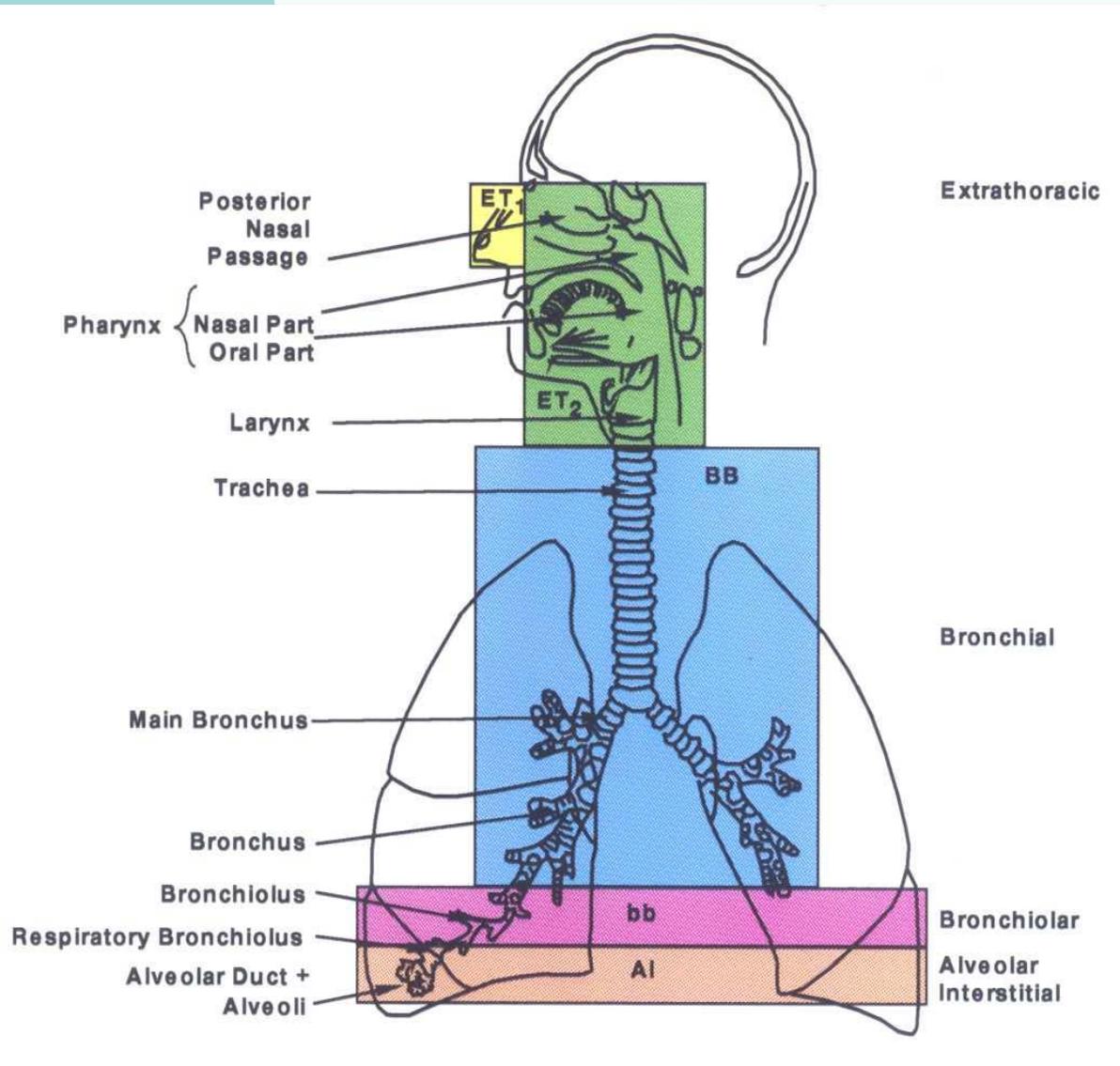


# Features of the Final HRTM – Adopted by ICRP in Publication 66 (1994)

- Based on premise that *large differences* in both *radiation sensitivity* and *absorbed doses* require the calculation of *specific tissue doses* rather than *average “lung” dose*.
- Specified for the *reference worker* and *members of the public* – but applicable (with some modified parameter values) to all *members of the world population*.
- Can be adjusted to account for influence of *smoking, air pollutants and diseases*.



# 1. Anatomical Regions of the Respiratory Tract



- Extrathoracic

- $ET_1$
- $ET_2$

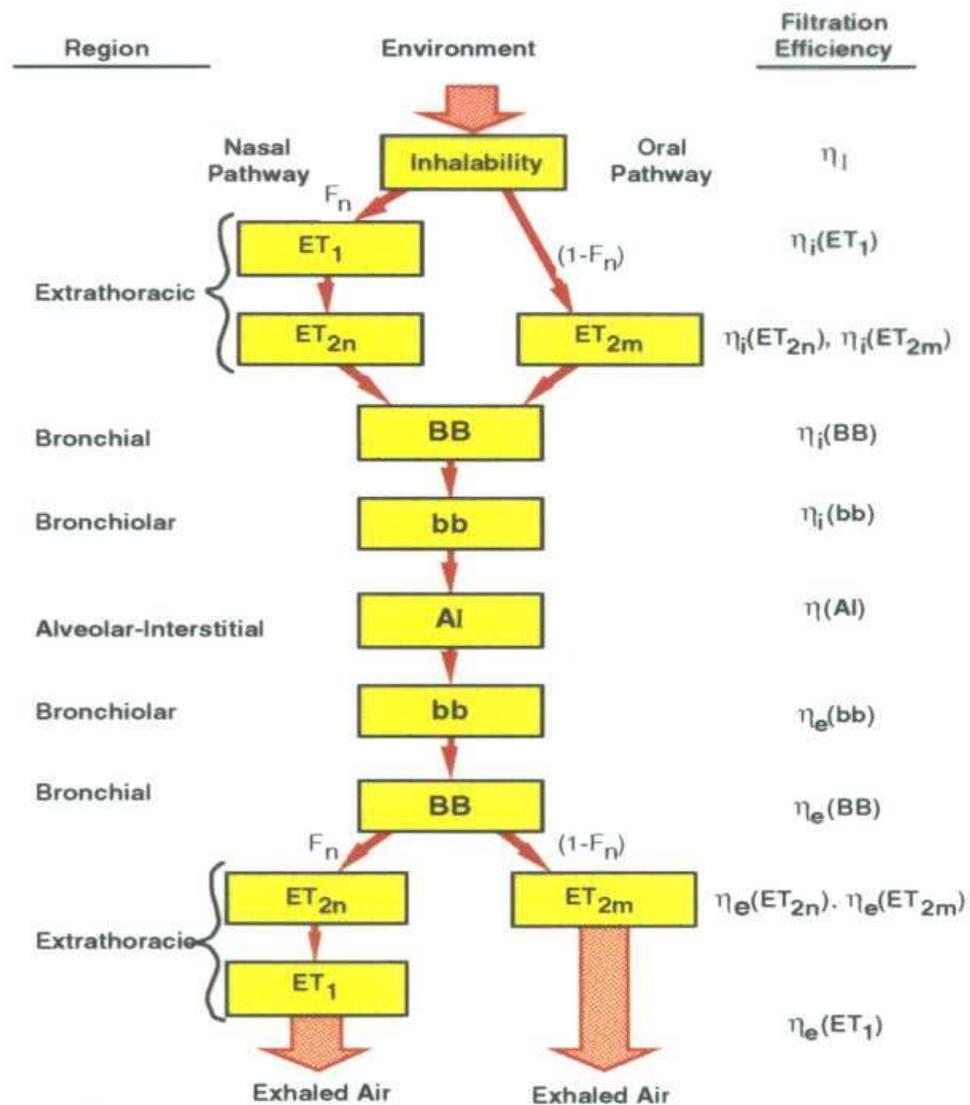
- Thoracic

- Bronchial (BB) including Trachea;
- Bronchiolar (bb);
- Alveolar-Interstitial (AI).

## 2. Deposition Model

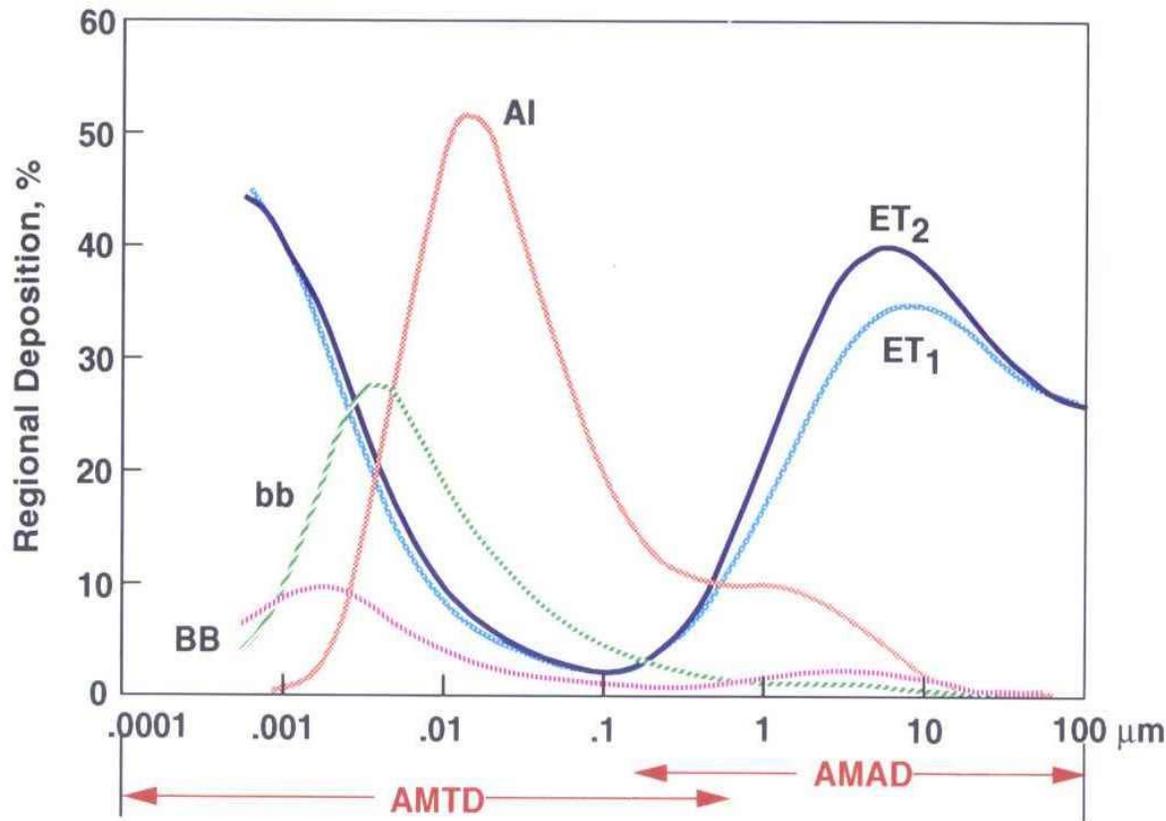
- Evaluates *fractional deposition* of an aerosol in each region of the respiratory tract.
- Considers *all possible aerosols*:
  - 0.0006  $\mu\text{m}$  AMTD to 100  $\mu\text{m}$  AMAD.
- Considers *inhalability* of large particles.
- Considers *breathing habit* – *nose/mouth* breathers.
- Considers *gender and age-dependence* of respiratory tract deposition.
- Gives *reference values* of regional deposition for Caucasians:
  - Man, woman, 15-y-old boy and girl, children age 10 y or 5y, and infants age 1 y or 3 mo.
  - For sleep, rest, light exercise, heavy exercise.

# Empirical Representation of the Filtration Efficiency of Each Region of the Respiratory Tract



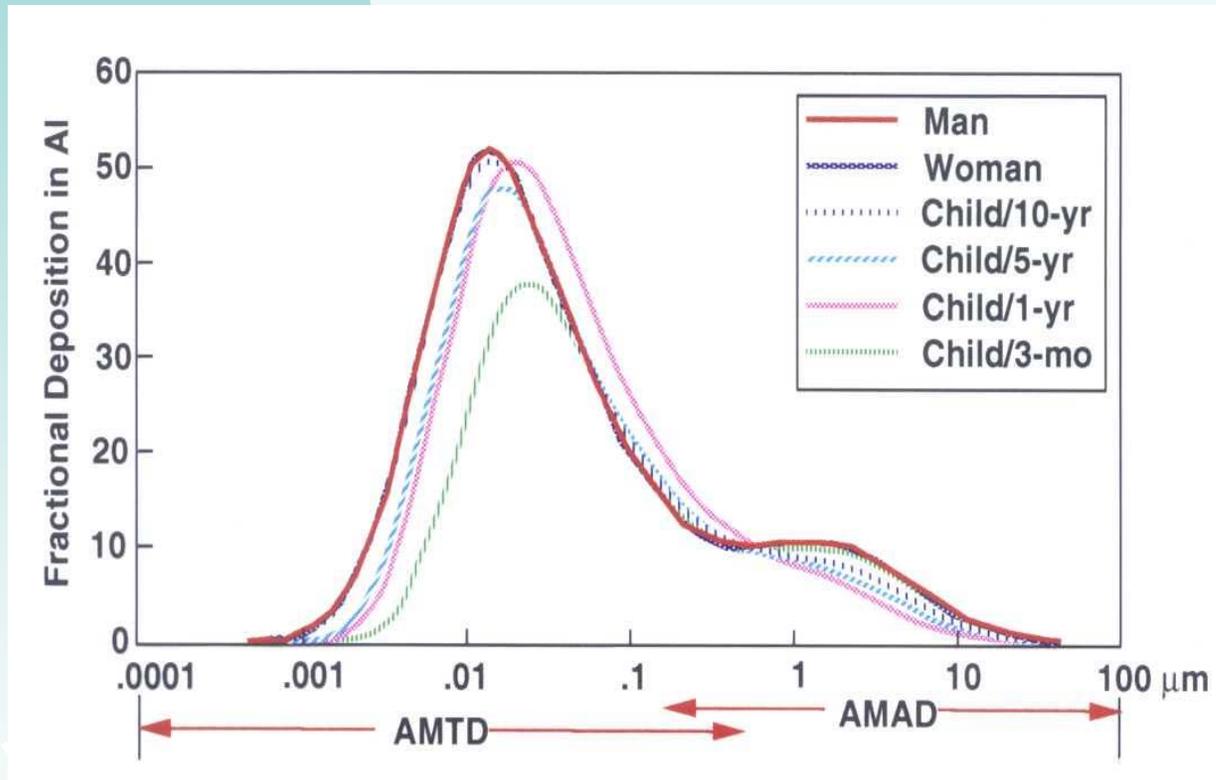
- Consider as transport through a series of filters.
- Deposition tracked separately on *inhalation* and *exhalation*.
- Represents “steady-state” (multiple breath) deposition.
- Model **fitted** to results of full **theoretical calculation** of gas and particle transport in cyclic breathing.
- Model **validated** by comparison with **published experimental data**.

# Fractional Deposition in Each Region of the Respiratory Tract – Reference Worker



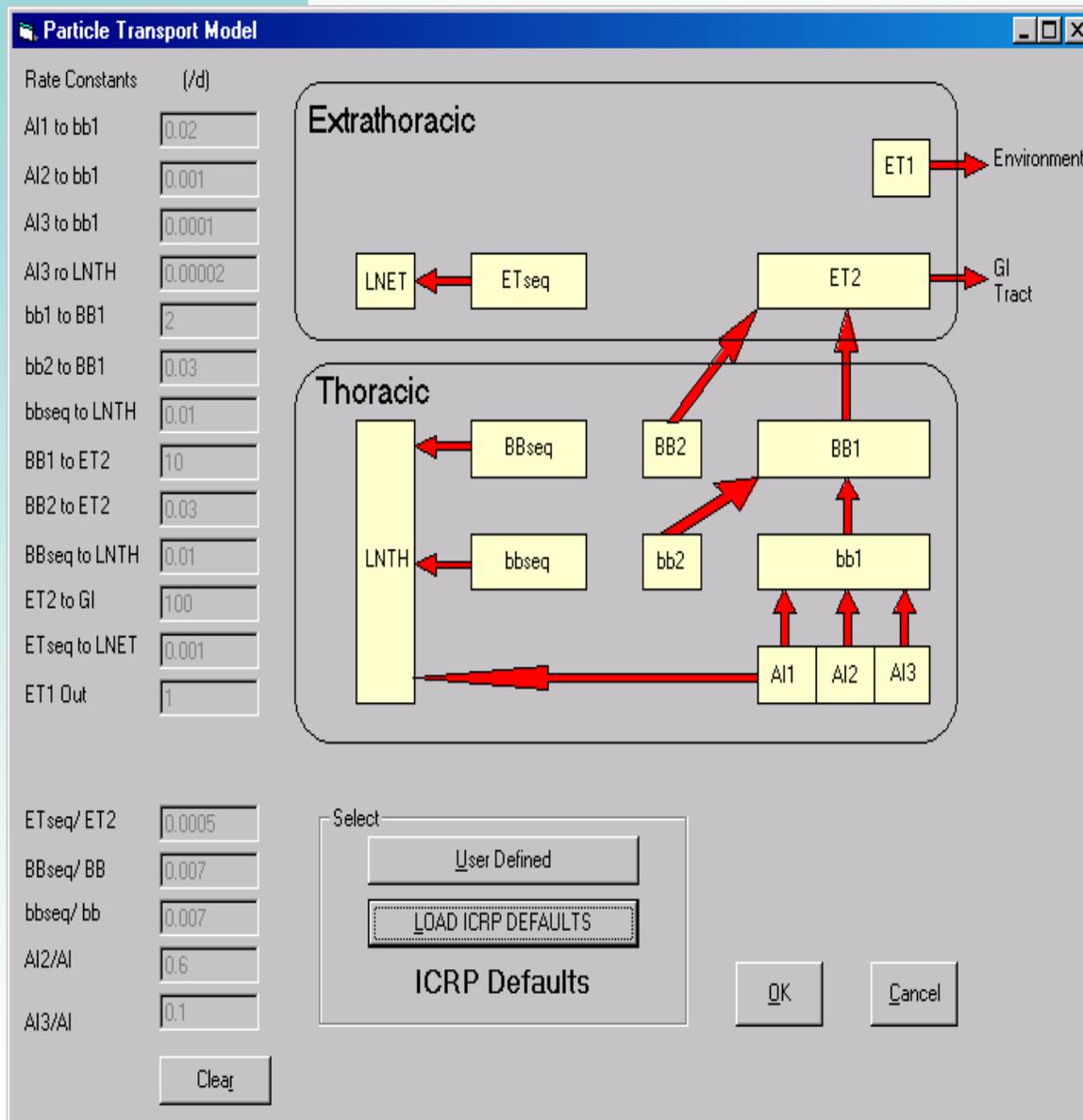
- For large-size aerosols, deposition is reduced by low *inhalability*.
- All regions exhibit *by-modal* deposition efficiency vs. aerosol size – inertial processes deposit large particles, diffusion deposits small particles.
- For intermediate-size particles, “wash-in” over several breaths *significantly increases AI* deposition.
- For *extremely small* particles (< 1 nm), total deposition approaches 100%.

# Gender/Age-Dependence of Fractional Deposition in the Alveolar-Interstitial (AI) Region – Outdoor Exposure



- *Very little difference* in the AI deposition fraction between **man, woman, and 10-y-old**.
- For **children** (3-mo to 5-y-old), and aerosols of  $0.5 \mu\text{m} < \text{AMAD} < 50 \mu\text{m}$ , the AI deposition fraction is *substantially lower*.
- For **children** (3-mo to 5-y-old), the AI deposition fraction is *substantially lower* for ultra-fine aerosols ( $1\text{-nm} < \text{AMTD} < 20 \text{ nm}$ ).

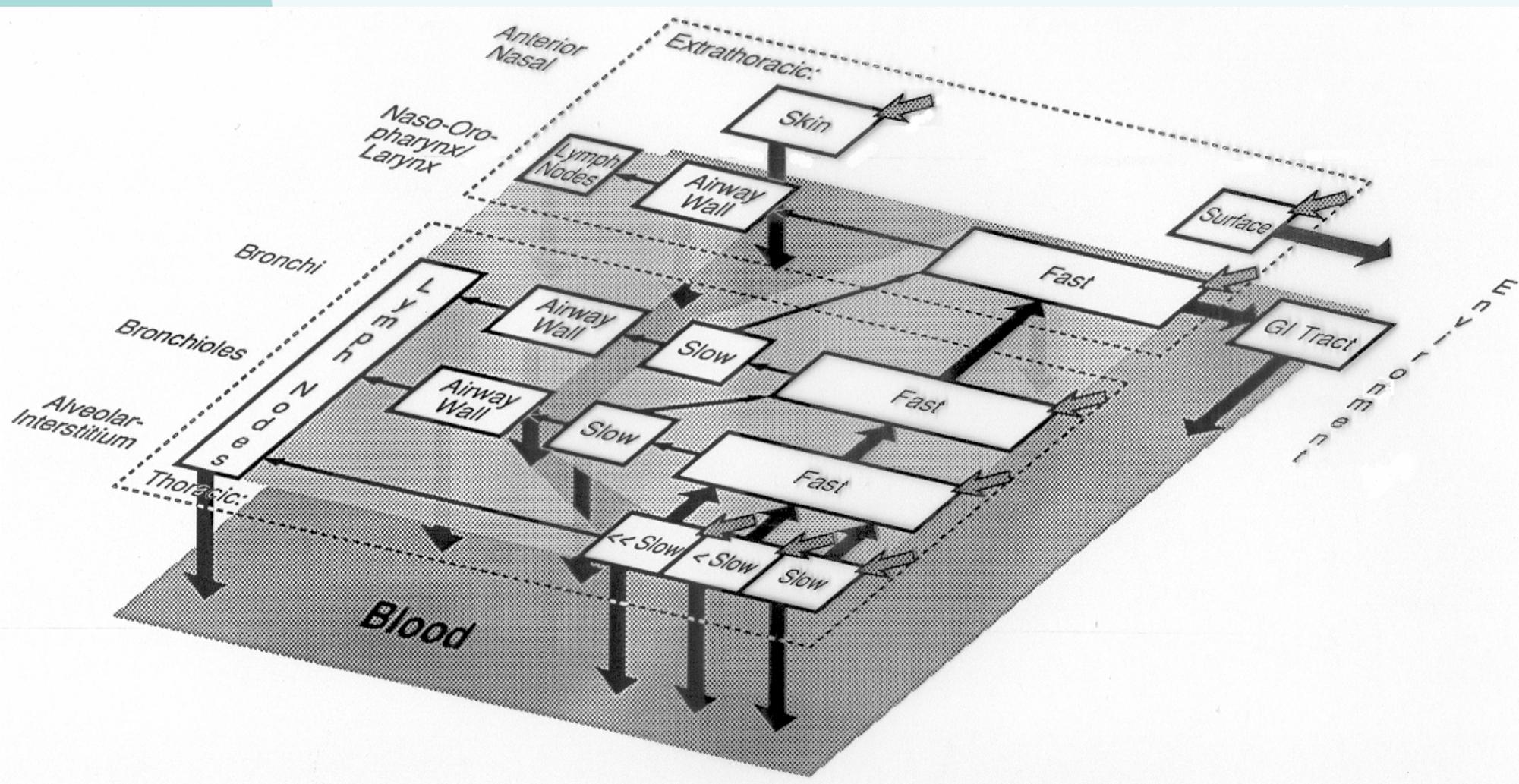
# 3. Mechanical (Particle) Transport Model



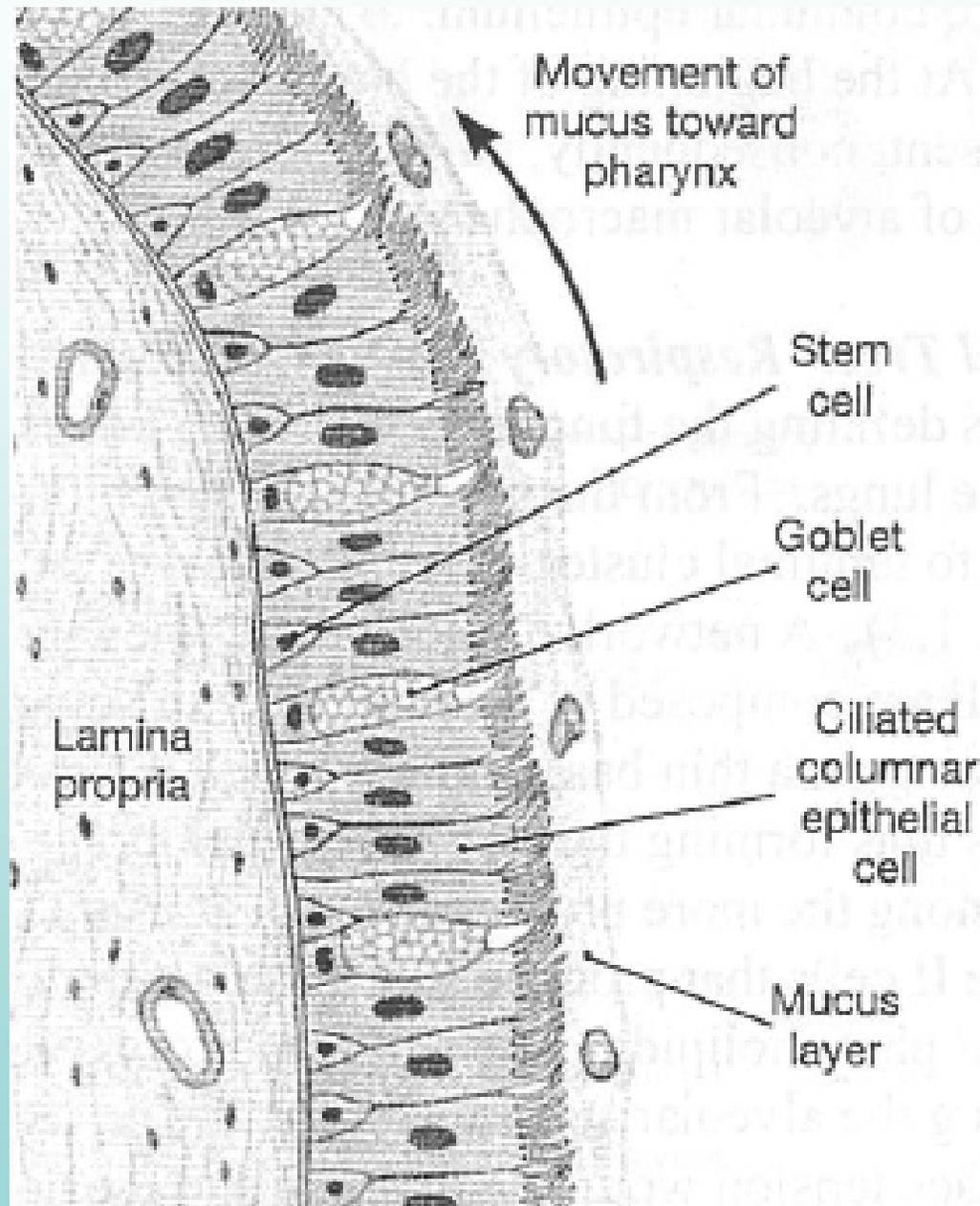
- Material deposited in each region (ET<sub>2</sub>, BB, bb, and AI) is *fractionated* between available clearance pathways.
- Material is cleared from each fractionated compartment at a *constant rate*.

# Competition Between Particle Clearance and Absorption: Key Feature of HRTM

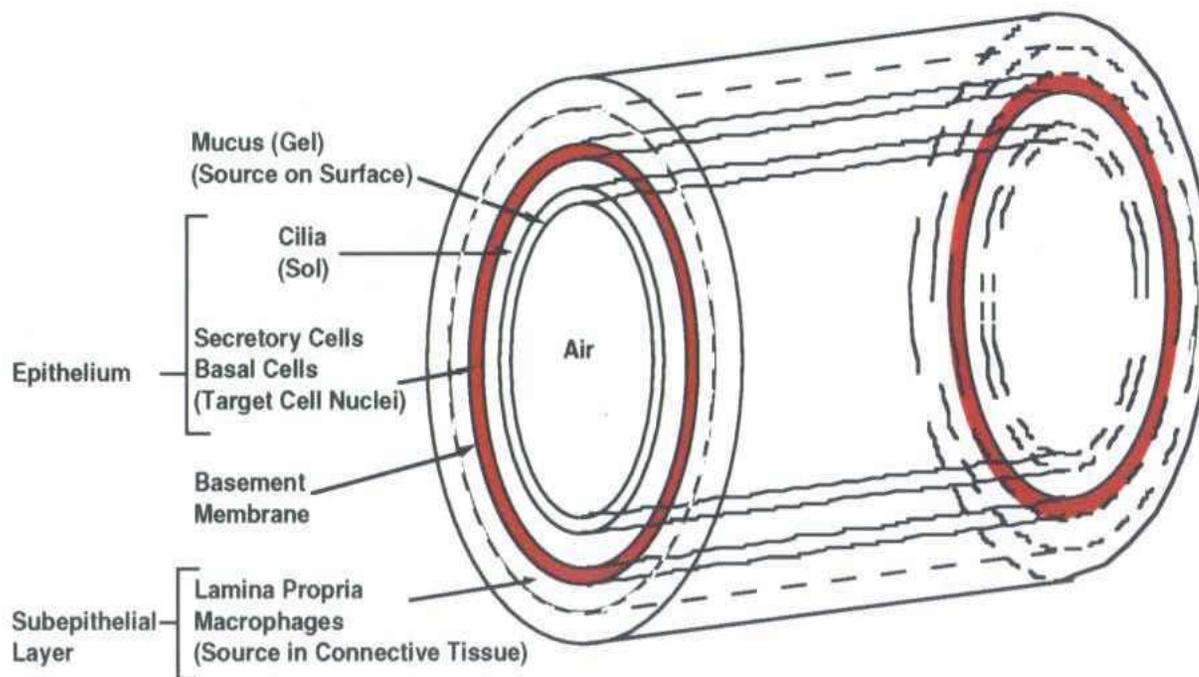
- Particle clearance and absorption treated as *competing rates* – *not* as independent “compartments” (as in ICRP 30 lung model).



# Cellular Anatomy of Tracheal Epithelium

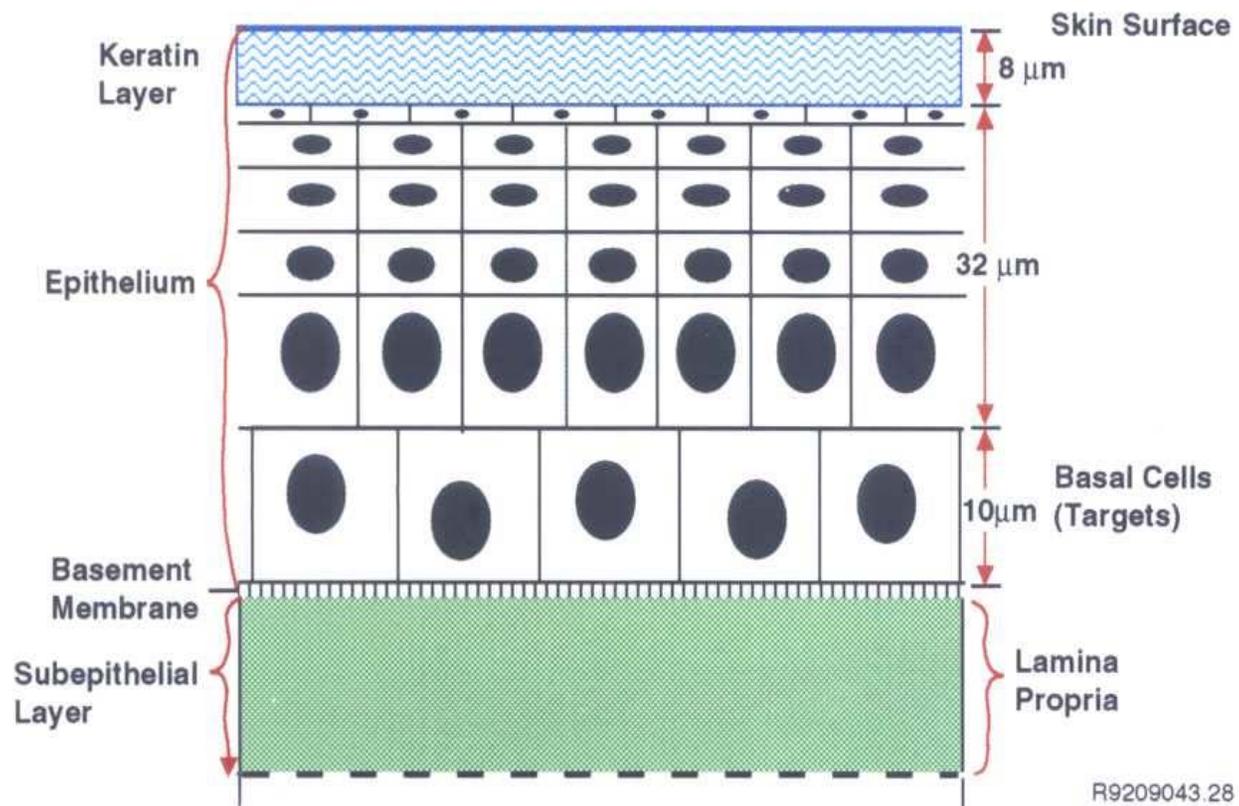


## 4. Morphometry: Model of Source and Target Geometry for Airway Dosimetry



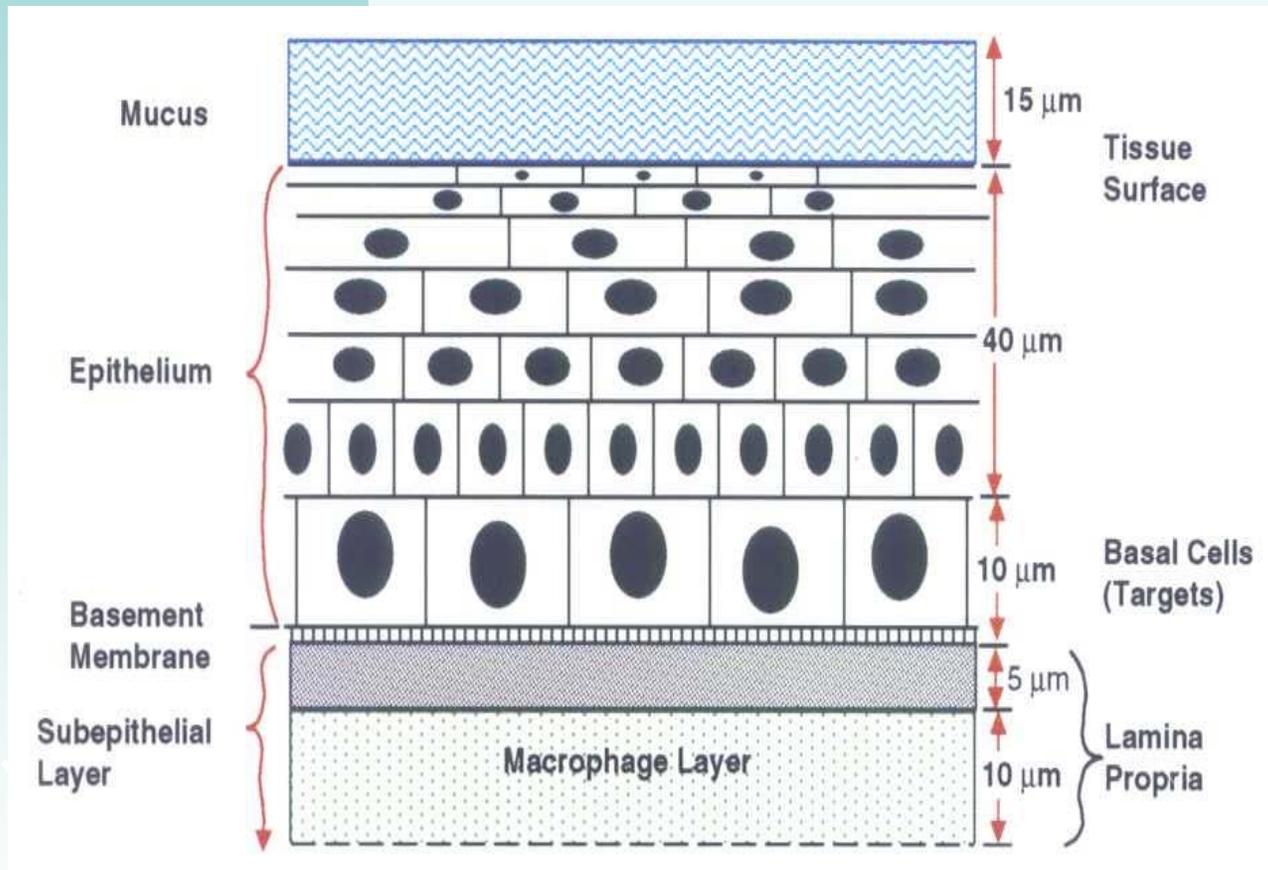
- Used for both **alpha** and **beta** particle dosimetry.
- Represent airway as hollow (air-filled) cylinder.
- Cylinder is infinitely long – c.f. particle range (in air).
- Used for ET<sub>1</sub>, ET<sub>2</sub>, BB and bb regions – with appropriate airway caliber.
- **Sources** – and **targets** – are part of **thick wall**.

# Model of Target Cell Nuclei in the Nasal Vestibule (Anterior Nares – ET<sub>1</sub> Region)



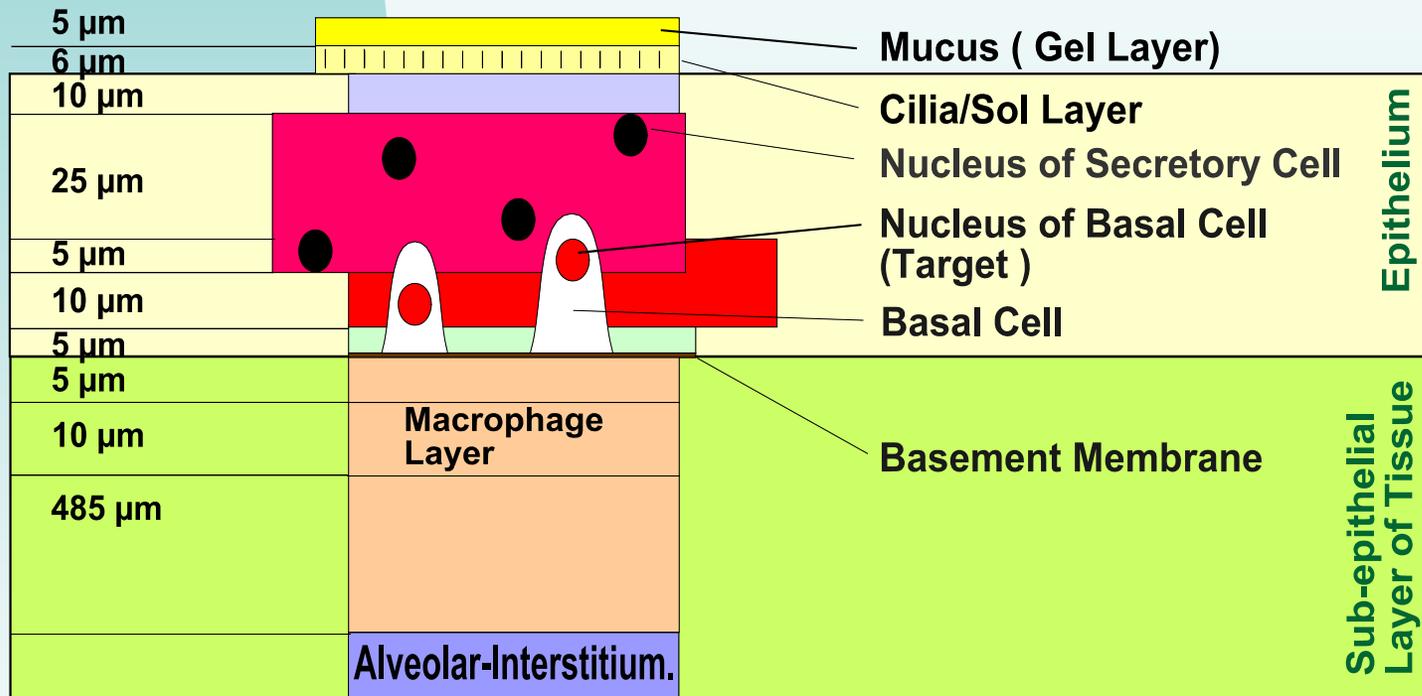
- **No mucus.**
- **Covered by skin.**
- **Skin is 8-μm thick – impervious keratin layer.**
- **Sources: thin layer – on skin surface.**
- **Target: basal cell nuclei.**
- **10-μm-thick layer – at 40-μm depth.**

# Model of Target Cell Nuclei in the Naso-oro-pharynx and Larynx (ET<sub>2</sub> Region)



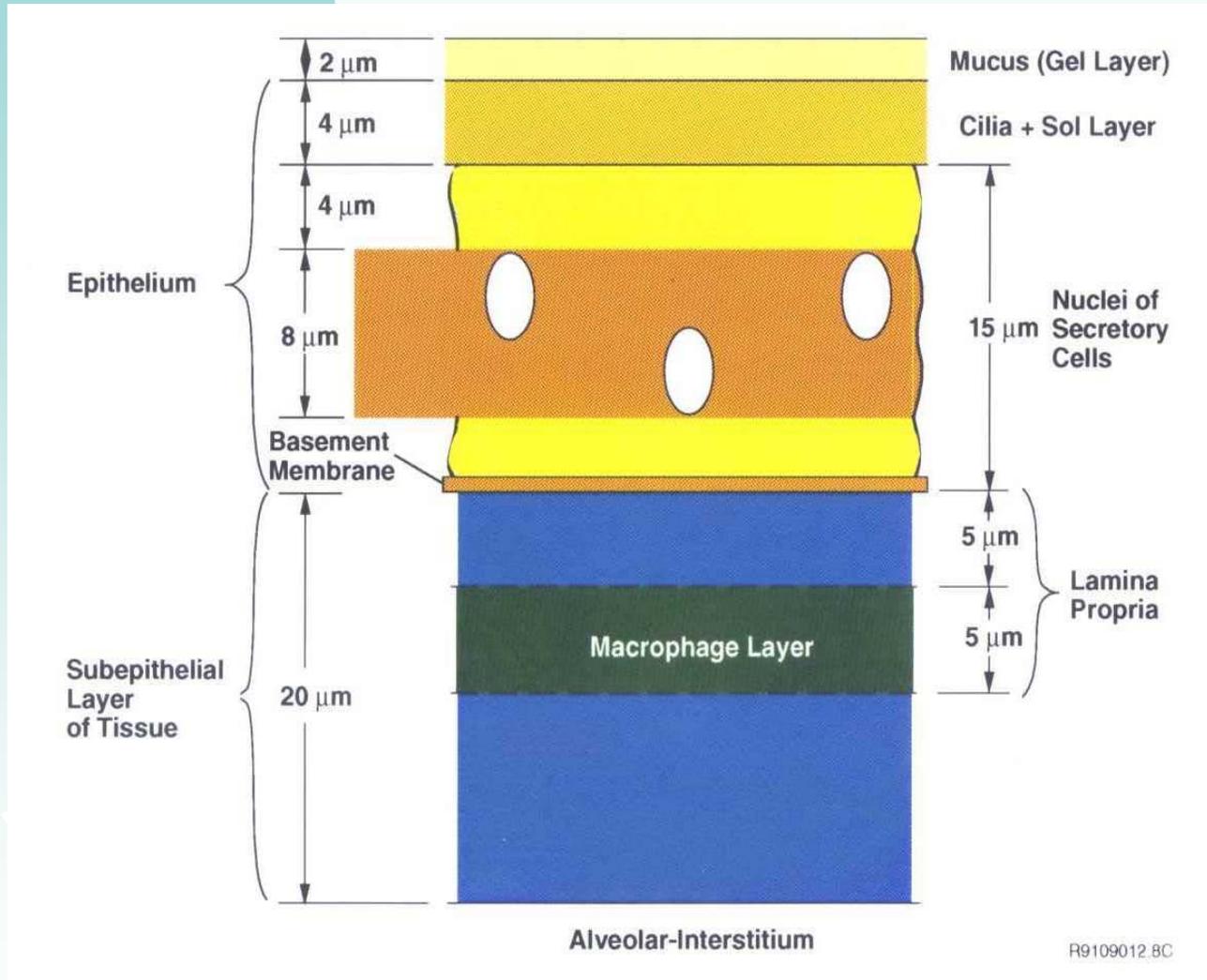
- **15-μm-thick mucous layer.**
- **Sources:** mucus, epithelium, macrophages.
- **Target:** basal cell nuclei -
  - 10-μm-thick layer – at 40-μm depth.

# Model of Target Cell Nuclei in the Bronchi



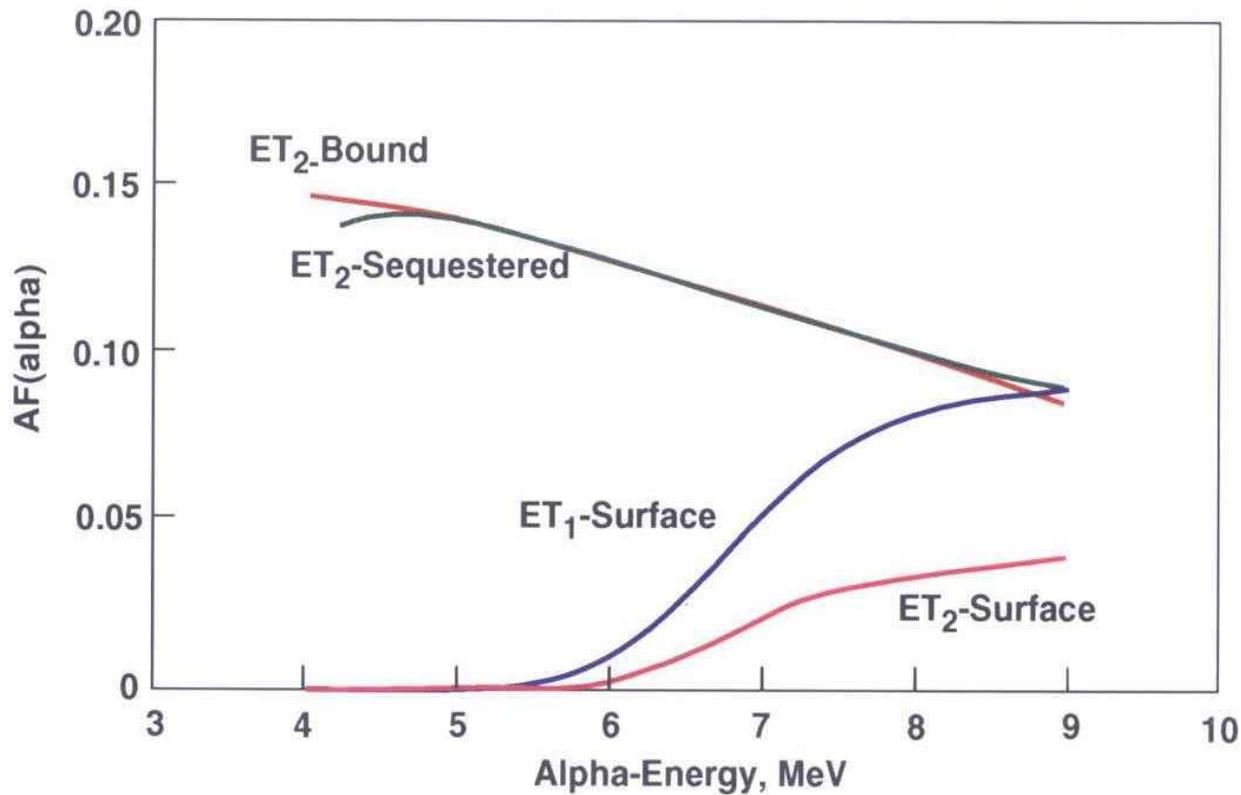
- Thick **mucous layer** (5 + 6 μm).
- **Targets:** Both **basal** and **secretory** cells.
- **Secretory cell nuclei** between 10- and 40-μm deep.
- **Basal cell nuclei** between 35- and 50-μm deep.
- **Sources:** Gel, Sol, Epithelium, Macrophage Layer.
- **Total wall thickness** is 555 μm – includes very thick (500-μm sub-epithelial tissue).

# Model of Target Cell Nuclei in the Bronchioles



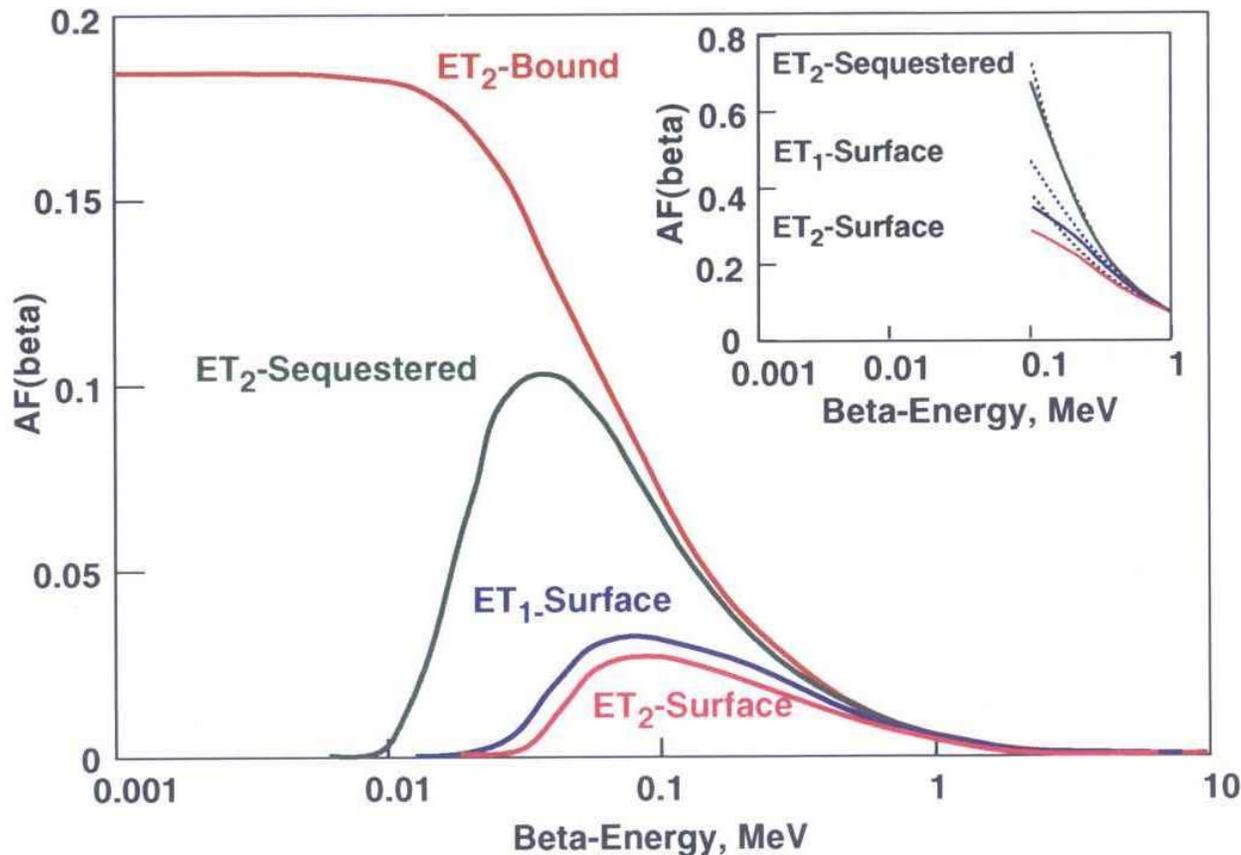
- Thin **mucous layer** (2 + 4  $\mu\text{m}$ ).
- **Target:** Secretory cell.
- Nuclei between 4- $\mu\text{m}$  and 12- $\mu\text{m}$  deep.
- **Sources:** Gel, Sol, Epithelium, Macrophage Layer.
- Total wall thickness is 35  $\mu\text{m}$  – including 20- $\mu\text{m}$  sub-epithelial tissue.
- Thin enough for substantial **cross-fire** (alpha & beta) from alveolar-interstitium.

## 5. Dosimetry Model: Absorbed Fractions for Alpha Emissions in the Extrathoracic Region



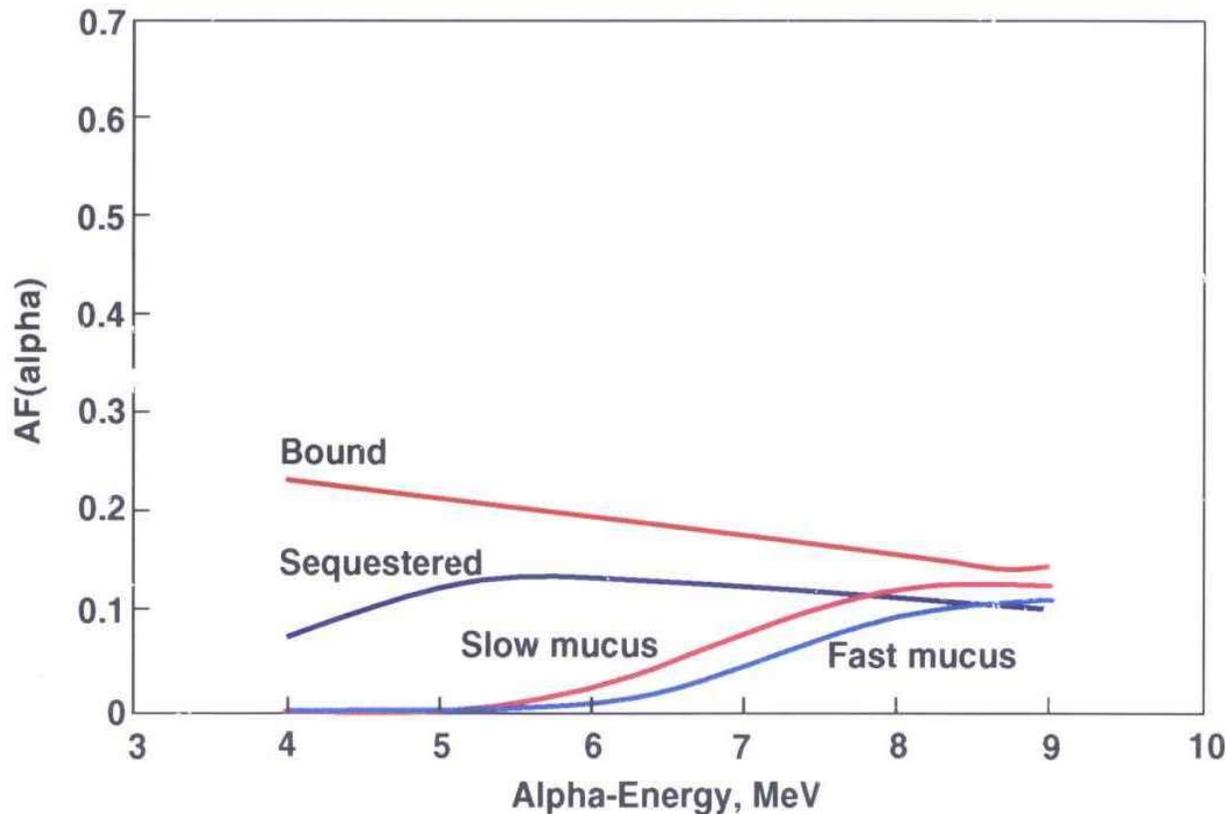
- **ET<sub>1</sub>-Surface:**  $AF(\alpha) = 0$  for  $E_\alpha \leq 5.8$  MeV.
- **ET<sub>2</sub>-Surface:**  $AF(\alpha) = 0$  for  $E_\alpha \leq 5.4$  MeV.
- **ET<sub>2</sub>-Sequestered and Bound:**  $AF(\alpha)$  decreases with  $E_\alpha$  – value is similar for both sources.

# Absorbed Fractions for Beta and Positron Emissions in the Extrathoracic Region



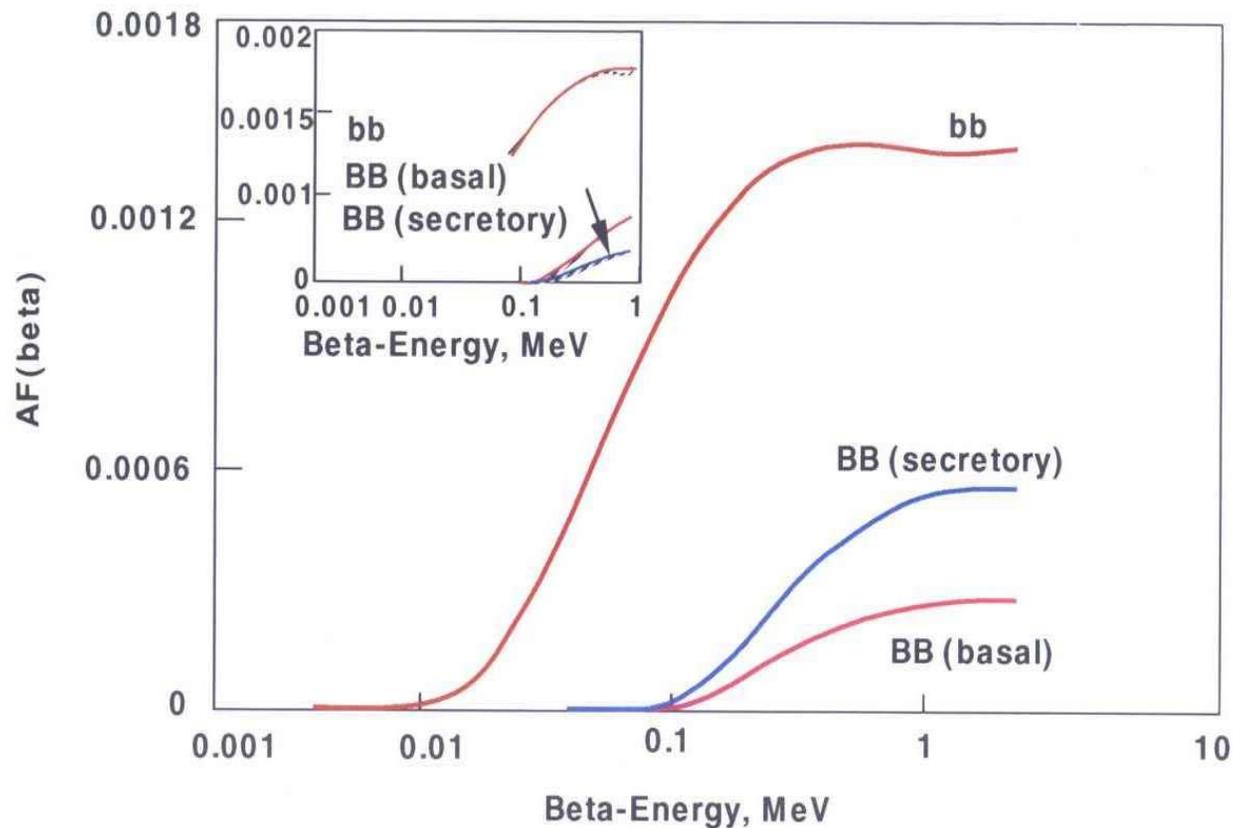
- **ET<sub>1</sub>-Surface:**  $AF(\beta) = 0$  for  $E_{\beta} \leq 20$  keV.
- **ET<sub>2</sub>-Surface:**  $AF(\beta) = 0$  for  $E_{\beta} \leq 30$  keV.
- **ET<sub>2</sub>-Sequestered:**  $AF(\beta) = 0$  for  $E_{\beta} \leq 9$  keV.
- **ET<sub>2</sub>-Bound:** For low energy betas,  $AF(\beta)$  tends to volumetric fraction.
- **All Sources at High Energy:**  $AF(\beta)$  converges for  $E_{\beta} \geq 800$  keV.

# Absorbed Fractions for Basal Cell Targets from Alpha Emissions in the Bronchi



- **Fast Mucus:**  $AF(\alpha) = 0$  for  $E_\alpha \leq 5.3$  MeV.
- **Slow Mucus:**  $AF(\alpha) = 0$  for  $E_\alpha \leq 5.3$  MeV.
- **Sequestered:**  $AF(\alpha)$  is maximum for  $E_\alpha \approx 5.3$  MeV.
- **Bound:**  $AF(\alpha)$  decreases with  $E_\alpha$ .
- **Mucus and Bound:**  $AF(\alpha)$  tends to converge for very high  $E_\alpha$ .

# Absorbed Fractions for Cellular Targets in the Bronchi and Bronchioles from Beta and Positron Emissions in the Alveolar-Interstitium



- **Bronchiolar Secretory Cells:**  $AF(\beta) = 0$  for  $E_\beta \approx 7$  keV.  $AF(\beta)$  is maximum for  $E_\beta \approx 500$  keV.
- **Bronchial Secretory Cells:**  $AF(\beta) = 0$  for  $E_\beta \approx 80$  keV.  $AF(\beta)$  is maximum for  $E_\beta \approx 2$  MeV.
- **Bronchial Basal Cells:**  $AF(\beta) = 0$  for  $E_\beta \approx 100$  keV.  $AF(\beta)$  is maximum for  $E_\beta \approx 2$  MeV.

# Standard ICRP Internal Dosimetry System

- **1979 - ICRP Publication 30**

“Limits for Intakes of Radionuclides by Workers”

- **Reference Worker** - adult male.
- **Dose coefficient** - *committed* equivalent dose in organ T resulting from intake I:

$$H_T(\tau) = \int_{t_0}^{t_0 + \tau} H'_T(t) dt \quad \dots\dots\dots (4)$$

$$H_T(\tau) = I h_T(\tau) \quad \dots\dots\dots (5)$$

$$h_T = \sum_S \sum_j U_{S,j} SEE(T \leftarrow S)_j \quad \dots\dots\dots (6)$$

$$SEE(T \leftarrow S) = \sum_R \frac{E_R Y_R w_R AF(T \leftarrow S)_R}{m_T} \quad \dots\dots\dots (7)$$

## 6. Summation of Risk from Regional Doses

$$H_T(ET) = H_{T,ET_1} A_{ET_1} + H_{T,ET_2} A_{ET_2} + H_{T,LN_{ET}} A_{LN_{ET}}$$

$$H_T(TH) = H_{T,BB} A_{BB} + H_{T,bb} A_{bb} + H_{T,AI} A_{AI} + H_{T,LN_{TH}} A_{LN_{TH}}$$

Region	Risk Apportionment Factor, A
ET <sub>1</sub>	0.001
ET <sub>2</sub>	0.998
LN <sub>ET</sub>	0.001
BB	0.333
bb	0.333
AI	0.333
LN <sub>TH</sub>	0.001

# Practical Implementation of ICRP Models – Bioassay Analysis and Dose Assessment

**IMBA**  
Professional  
*Plus*

Ver 4.1.2  
Now 64 bit compatible

Health Protection Agency

By Alan Birchall & Tony James

# IMBA Professional Plus Suite – Ongoing Development

**Main Screen**

File Edit Parameters Calculations Tools Advanced Help

Open Save New Quick Save Load Load Report Help IDEAS

Ver 4.1 Add-Ons: 12 No file opened No file appended Current ICRP Future ICRP

**IMBA Professional Plus Academic Edition**

**Intake Scenario**

**Intake Regimes**

Clear All Intake Regimes Enter Number of Intake Regimes (1-10) 1

**IR 1**

Route:  Inhalation  Ingestion  Injection  Wound  Vapor

Mode:  Acute  Chronic

Start Time (d) 0

**Units**

Specify Time As:  Date  Time (d) since 1/1/1980

Intake:  Bq  dpm  pCi  mg

Dose:  Sv  rem  mSv  mrem

**Intake (IR 1)**

0 Bq

**Indicator Nuclide**

Select Radionuclide

Number of Associated Radionuclides: 0

Half Life: Unknown d

**Associated Radionuclides**

None Selected

**Model Parameters**

These Model Parameters Apply to All IRs

**Respiratory Tract**

Deposition Vapor Wound Bioassay

Particle Transport Absorption GI-Tract Biokinetics

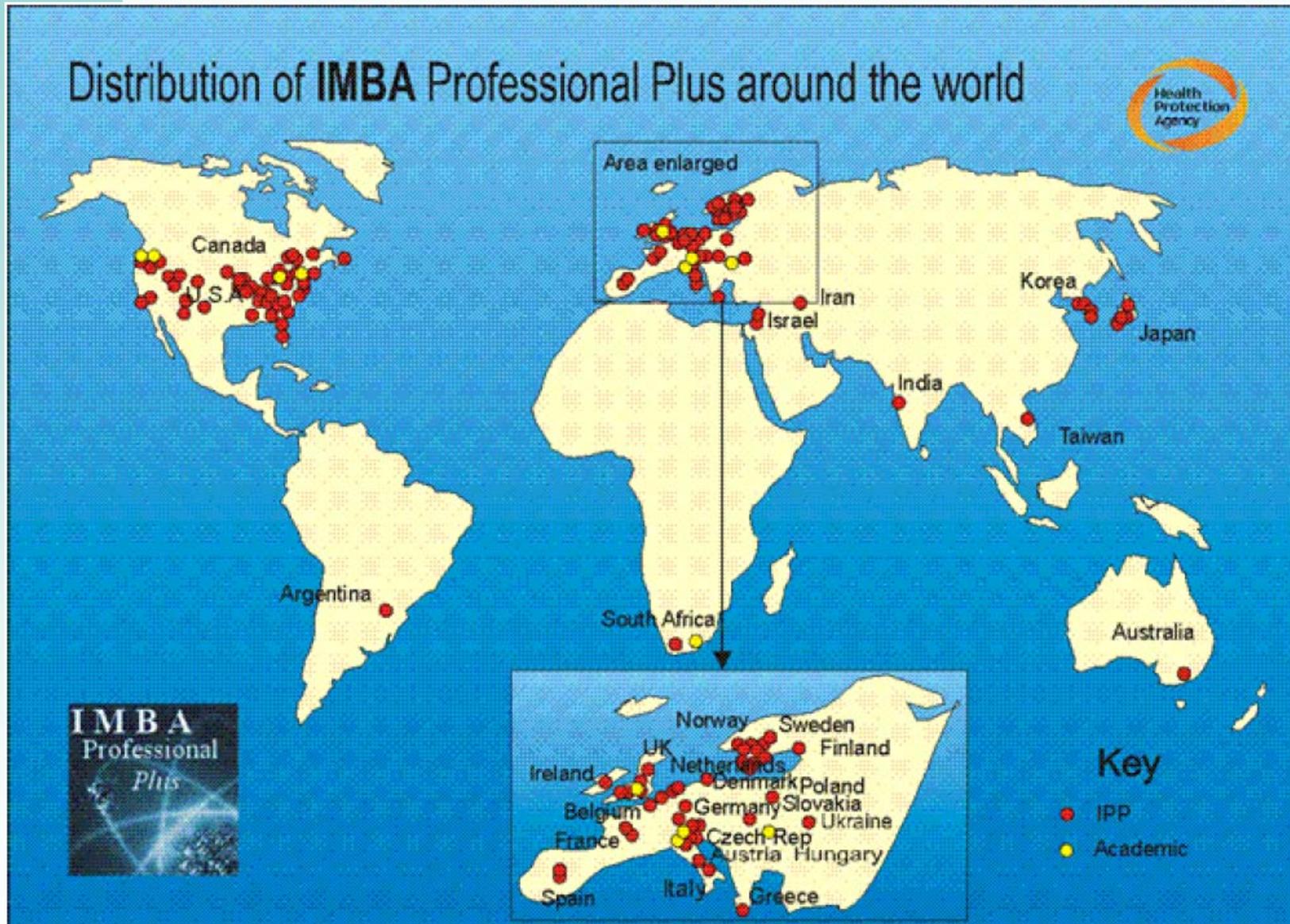
**Calculations**

Bioassay Calculations

Dose Calculations

All IRs Absorption: Not Specified Part Tran: Not Specified GI-Tract: Not Specified f1= Biokinetics: Not Specified Deposition: Not Specified AMAD: 0 µm Wound: Not Specified

# Global Implementation (and Standardization)



# “Care Package” – Specially for ES/RP 416/516 Students!

- CD-ROM with:

- “User Manual” for IMBA Expert™ OCAS/ORAU-Edition (IX4)
- “Technical Basis” for IMBA Expert™ OCAS/ORAU-Edition (IX4)
- “Biokinetic and dosimetric modelling in the estimation of risks from internal emitters”, Harrison J. J. Radiol. Prot. 29:A81-A105 (2009)
- “Health Risks of Radon and Other Internally Deposited Alpha-emitters – BEIR IV”, Washington, DC: National Academy Press (1988)
- “The anatomical and physiological bases for internal dosimetry”, Bolch W.E., In *Practical Applications of Internal Dosimetry*. Madison, Wisconsin: Medical Physics Publishing (2002)
- “Radium in Humans: A Review of U.S. Studies”, Rowland R.E. ANL/ER-3 (1994).



# Radionuclide Decorporation

**Will discuss this on Thursday 4<sup>th</sup> – in  
“Actinide Biokinetics, Dosimetry and  
Health Outcomes in Former Nuclear  
Workers: The USTUR.”**