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# URANIUM CONTENT, DISTRIBUTION, AND BIOKINETICS IN HUMAN BODY: USTUR STUDIES

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Maia Avtandilashvili and Sergey Y. Tolmachev

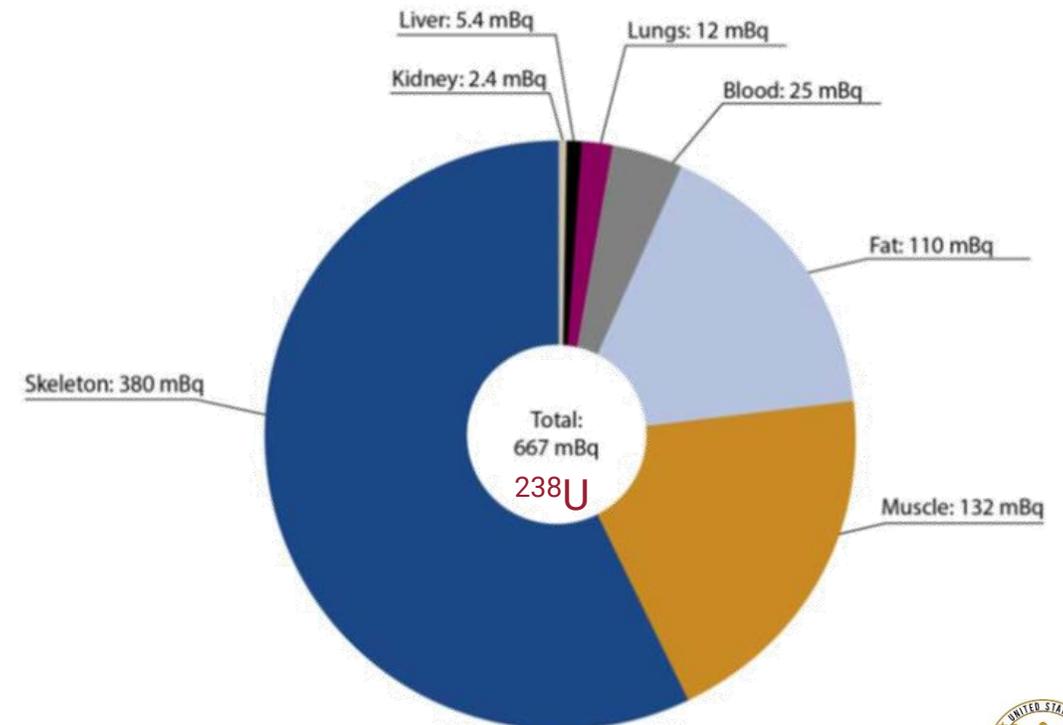
United States Transuranium and Uranium Registries  
College of Pharmacy and Pharmaceutical Sciences  
Washington State University, Richland, WA, USA



*"Learning from Plutonium and Uranium Workers"*

# Uranium: Environmental Exposure

- Main route of natural uranium intake: ingestion (diet)
- ICRP Reference Man<sup>a</sup>
  - ✓ Total body content: 90  $\mu\text{g}$
  - ✓ Skeleton content: 59  $\mu\text{g}$
  - ✓ Daily intake: 1.9  $\mu\text{g d}^{-1}$
- UNSCEAR<sup>b</sup>
  - ✓ Total body content: 54  $\mu\text{g}$
  - ✓ Skeleton content: 31  $\mu\text{g}$
  - ✓ Average intake rate: 1.5  $\mu\text{g d}^{-1}$

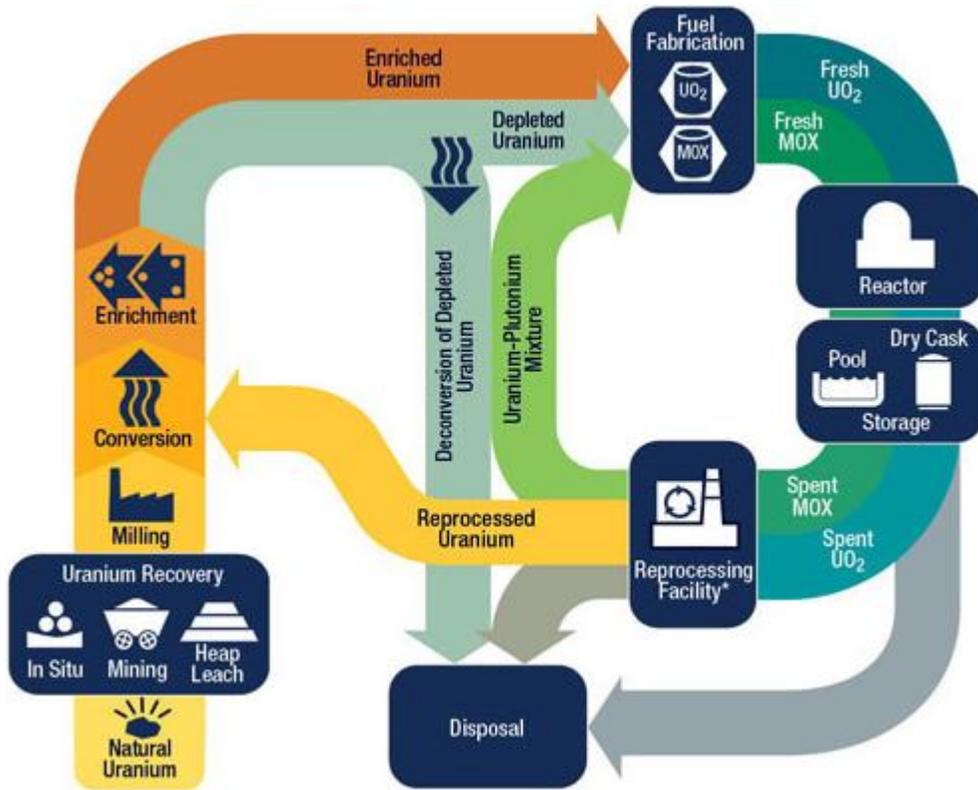


<sup>a</sup> ICRP Publication 23, 1975

<sup>b</sup> UNSCEAR Report 2016, Annex D

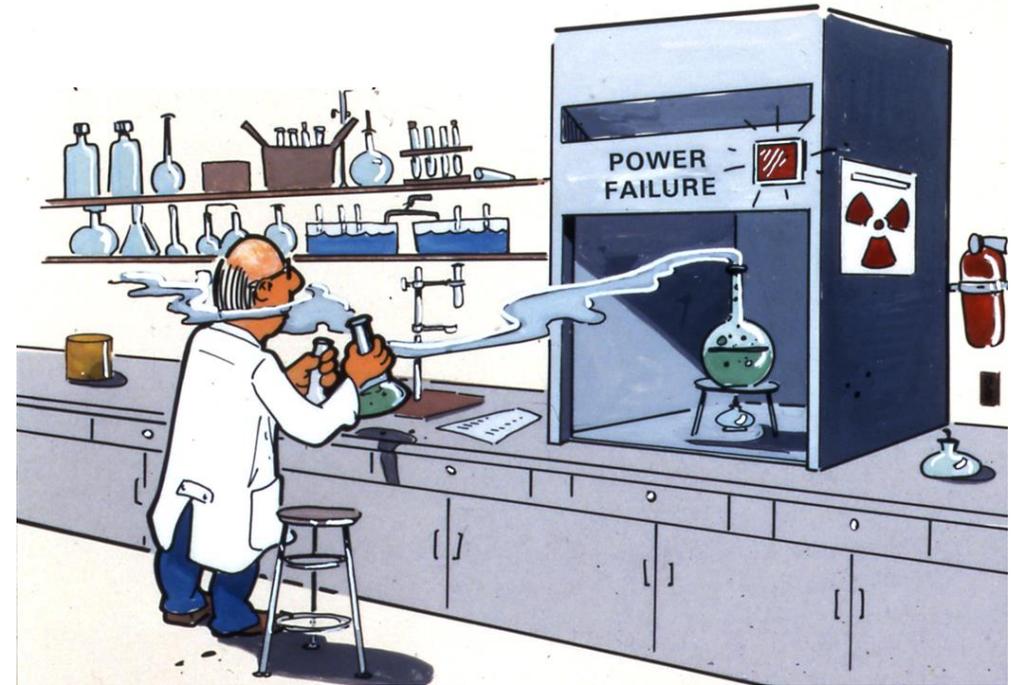


# Uranium: Occupational Exposure



<https://www.nrc.gov/images/materials/fuel-cycle-fac/nuclear-fuel-cycle-02.jpg>

Main route of intake: Inhalation



Courtesy of Eugene Carbaugh



# United States Transuranium and Uranium Registries

- Established by U.S. Atomic Energy Commission in 1968
- Since 1992, operated by Washington State University as a research grant funded by U.S. Department of Energy (DOE) Office of Domestic and International Health Studies (EHSS-13)
- Studies **biokinetics** and **tissue dosimetry** of uranium and transuranium elements in occupationally exposed individuals
- Voluntary tissue donors (posthumous)

**whole- (49) and/or partial-body (319) donations**

Autopsy

Tissue  
collection

Radiochemical  
analysis

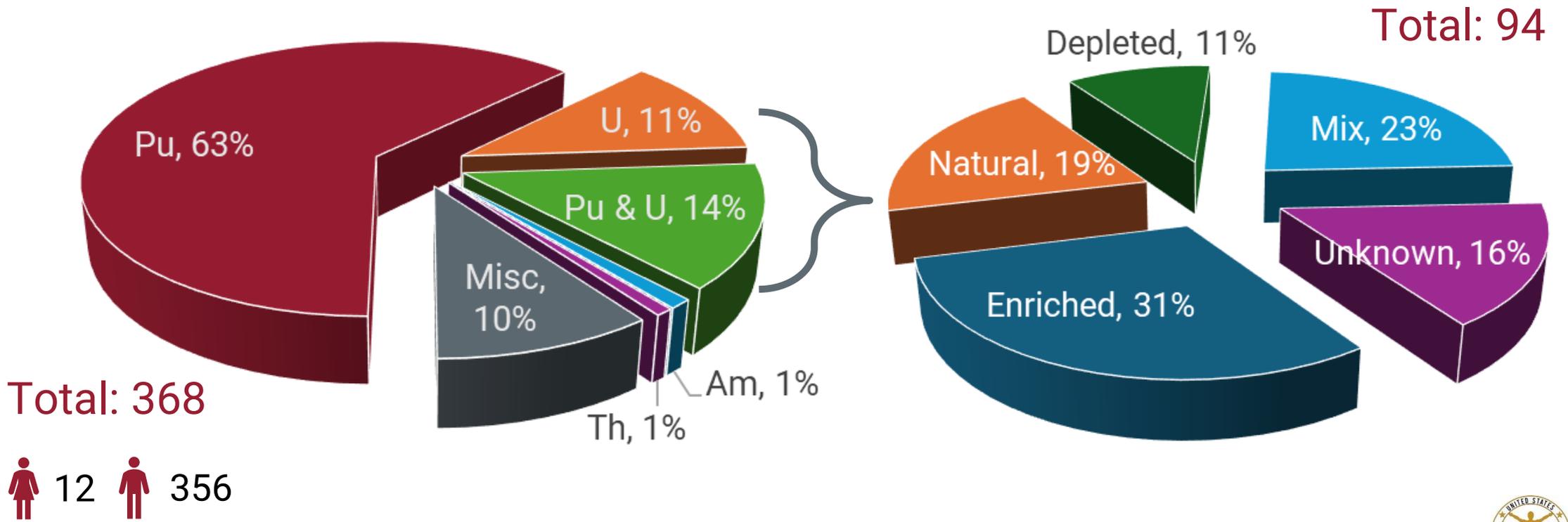
Biokinetic  
modeling

# Uranium at the USTUR

- 94 USTUR tissue donors with exposure to uranium
  - ✓ 49 cases with U as primary nuclide
- Worksites: URW, FER, OAK, PAD, NFS, LOS, HAN, ROC
- Wide range of U materials with different enrichment levels



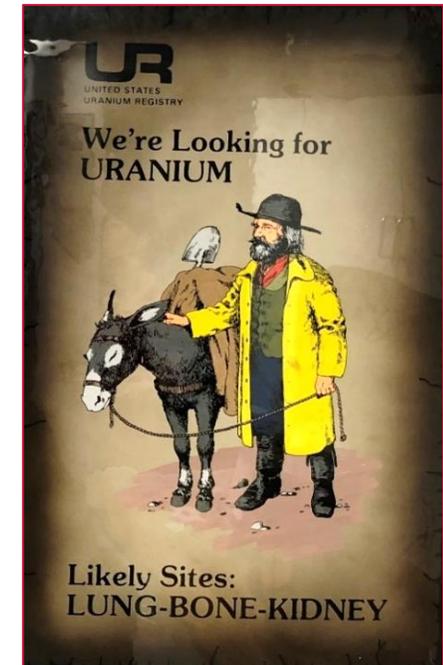
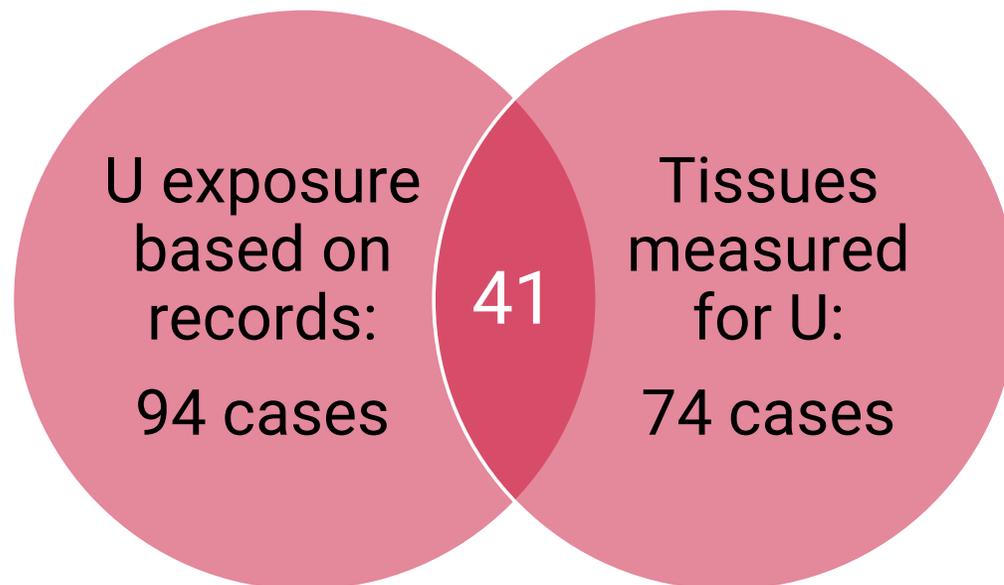
<https://en.wikipedia.org>



# Uranium Tissue Radiochemical Analysis

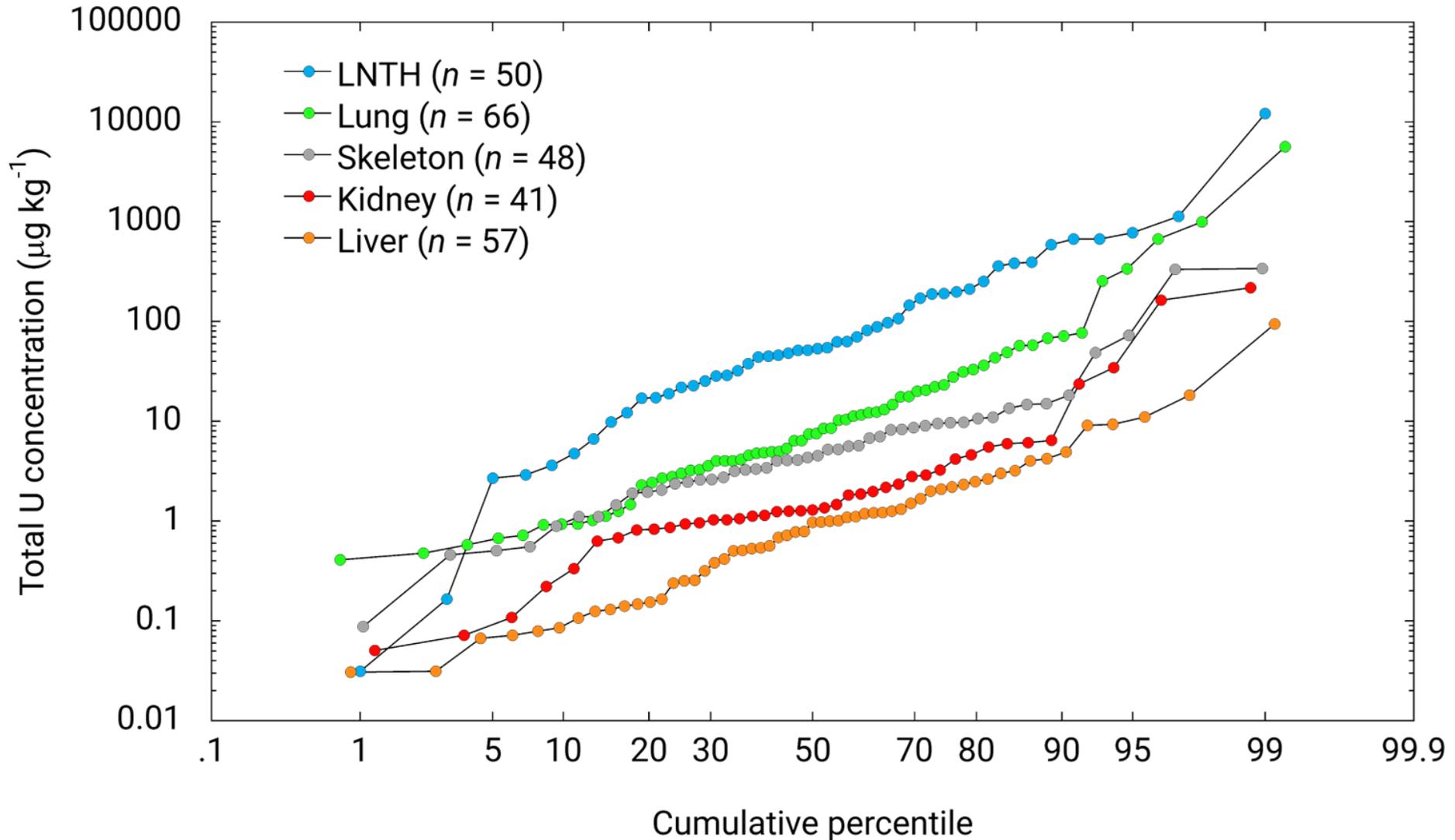
Soft tissue and bone samples from 74 USTUR donors measured using:

- Alpha spectrometry (AS)
- Kinetic phosphorescence analysis (KPA)
- Inductively-coupled plasma mass spectrometry (ICP-MS)



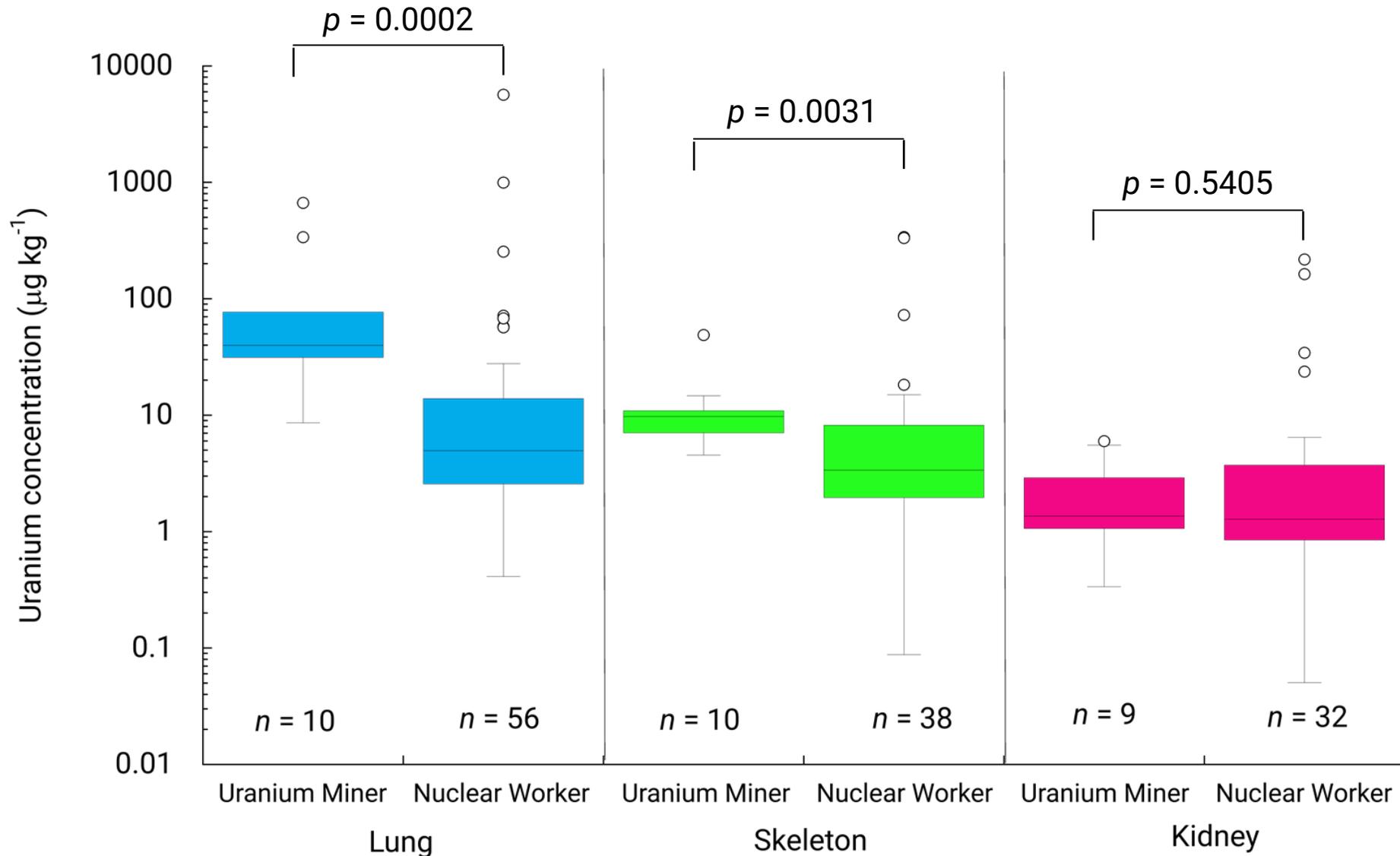


# Uranium in Occupationally Exposed Humans





# Uranium Miners vs. Nuclear Workers



# Uranium in Human Body: USTUR Studies

- Uranium organ content and distribution in six whole-body tissue donors

Paper

**URANIUM DEPOSITION AND RETENTION IN A USTUR WHOLE BODY CASE**

J. J. Russell\* and R. L. Kathren†

*Abstract*—This report describes a whole body donation from a person with a documented occupational intake of uranium, USTUR Case 10, an infarct operator at the Berlin Academy, identifying a new metallic element, which he named uranium after the planet Uranus, which

Paper

**NATURAL URANIUM TISSUE CONTENT OF THREE CAUCASIAN MALES**

Ronald L. Kathren and Sergei Y. Tolmachev\*

*Abstract*—Uranium content and concentrations were measured in the tissues of three Caucasian male whole-body donors to the U.S. Transuranium at other than from important information to verify or refine Reference Man data and various biokinetic models and validate protection

Radiation and Environmental Biophysics  
https://doi.org/10.1007/s00411-023-01053-0

**RESEARCH**

**Long-term retention and distribution of highly enriched uranium in an occupationally exposed female**

Sergey Y. Tolmachev<sup>1</sup> · Maia Avtandilashvili<sup>1</sup>

Received: 5 June 2023 / Accepted: 8 December 2023

JAAS

Dynamic Article Links ▶

Cite this: *J. Anal. At. Spectrom.*, 2011, **26**, 2524  
www.rsc.org/jaas

**TECHNICAL NOTE**

**Measurement of uranium isotopes in human tissue samples by TIMS**

Chunsheng Li,<sup>a</sup> Nancy Elliot,<sup>b</sup> Sergei Tolmachev,<sup>c</sup> Stacey McCord,<sup>c</sup> Tom Shultz,<sup>b</sup> Youqing Shi<sup>b</sup> and Gary H. Kramer<sup>d</sup>

Received 5th August 2010  
DOI: 10.1039/c1ja1023

TECHNICAL NOTE

www.rsc.org/jaas | Journal of Analytical Atomic Spectrometry

**Measurement of <sup>236</sup>U in human tissue samples using solid phase extraction coupled to ICP-MS**

Chunsheng Li,<sup>a</sup> Karima Benkhedda,<sup>a</sup> Sergei Tolmachev,<sup>b</sup> Lisa Carty,<sup>c</sup> Raymond Ko,<sup>c</sup> Deborah Moir,<sup>d</sup> Jack Cornett<sup>d</sup> and Gary Kramer<sup>d</sup>

Received 13th November 2009, Accepted 26th January 2010  
First published as an Advance Article on the web 5th February 2010  
DOI: 10.1039/b923909j

Proc. Radiochim. Acta 1, 173–181 (2011) / DOI 10.1524/rpr.2011.0032  
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**The US Transuranium and Uranium Registries: forty years' experience and new directions in the analysis of actinides in human tissues**

By S. Y. Tolmachev<sup>1,\*</sup>, M. E. Ketterer<sup>2</sup>, D. Hare<sup>3</sup>, P. Doble<sup>3</sup> and A. C. James<sup>1</sup>

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<sup>2</sup> Northern Arizona University, Department of Chemistry and Biochemistry, Box 5698, Flagstaff, AZ 86011, USA



# Studied Whole-Body Cases

USTUR Case	Occupational: Inhalation			Environmental: Ingestion		
	1028 <sup>a</sup>	1002 <sup>a,b</sup>	1031 <sup>a,c</sup>	0213 <sup>a,d</sup>	0242 <sup>a,d</sup>	0425 <sup>a,d</sup>
Sex	F	M	M	M	M	M
Age at death, y	86	83	87	68	77	83
Smoking	Yes	No	No	No	Yes	Yes
U intake:						
Mode	Acute+chronic	Chronic	Acute	Chronic	Chronic	Chronic
Composition	HEU	NU	LEU	NU	NU	NU
Compound	U <sub>3</sub> O <sub>8</sub>	Oxide	UF <sub>6</sub>			
Post-intake, y	31	20	65			
Whole-body U, µg	40.3±2.5	373.8±14.5	94.7±3.9	62.1±0.4	61.6±0.4	108.5±1.4

<sup>a</sup> Tolmachev SY, Avtandilashvili M. Long-term retention and distribution of highly enriched uranium in an occupationally exposed female. *Radiation and Environmental Biophysics* 63(1): 109-123; 2024.

<sup>b</sup> Russell JJ, Kathren RL. Uranium deposition and retention in a USTUR whole body case. *Health Physics* 86(3): 273-284; 2004

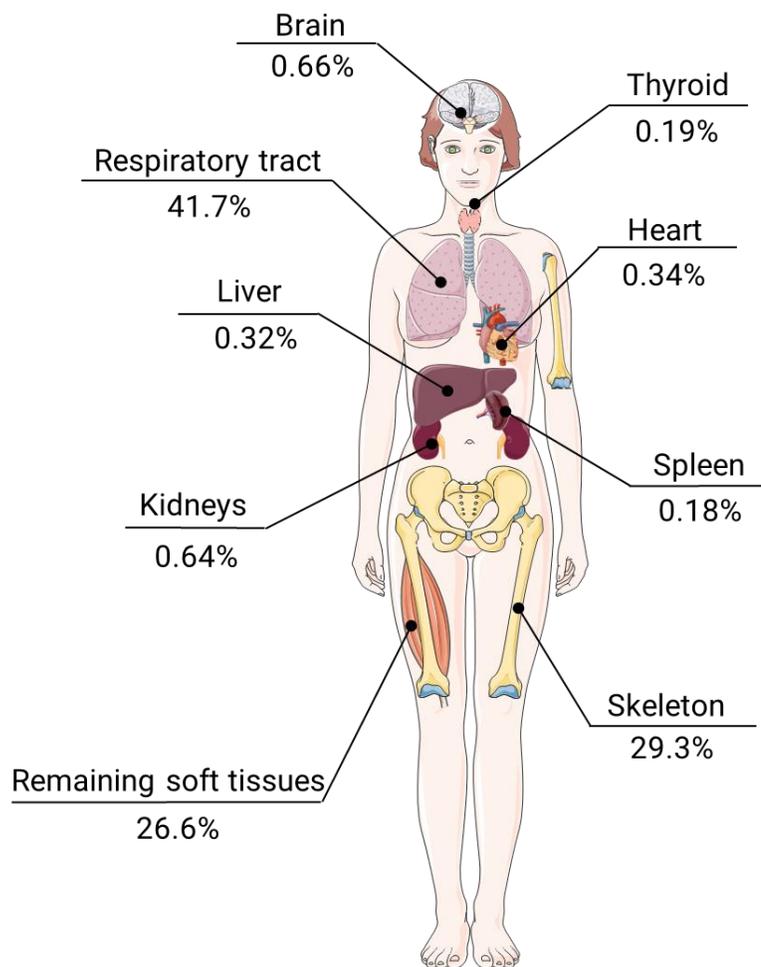
<sup>c</sup> Avtandilashvili M, Puncher M, McComish SL, Tolmachev SY. US Transuranium and Uranium Registries case study on accidental exposure to uranium hexafluoride. *Journal of Radiological Protection* 35(1): 129-151; 2015.

<sup>d</sup> Kathren RL, Tolmachev SY. Natural uranium tissue content of three Caucasian males. *Health Physics* 109(3): 187-197; 2015.

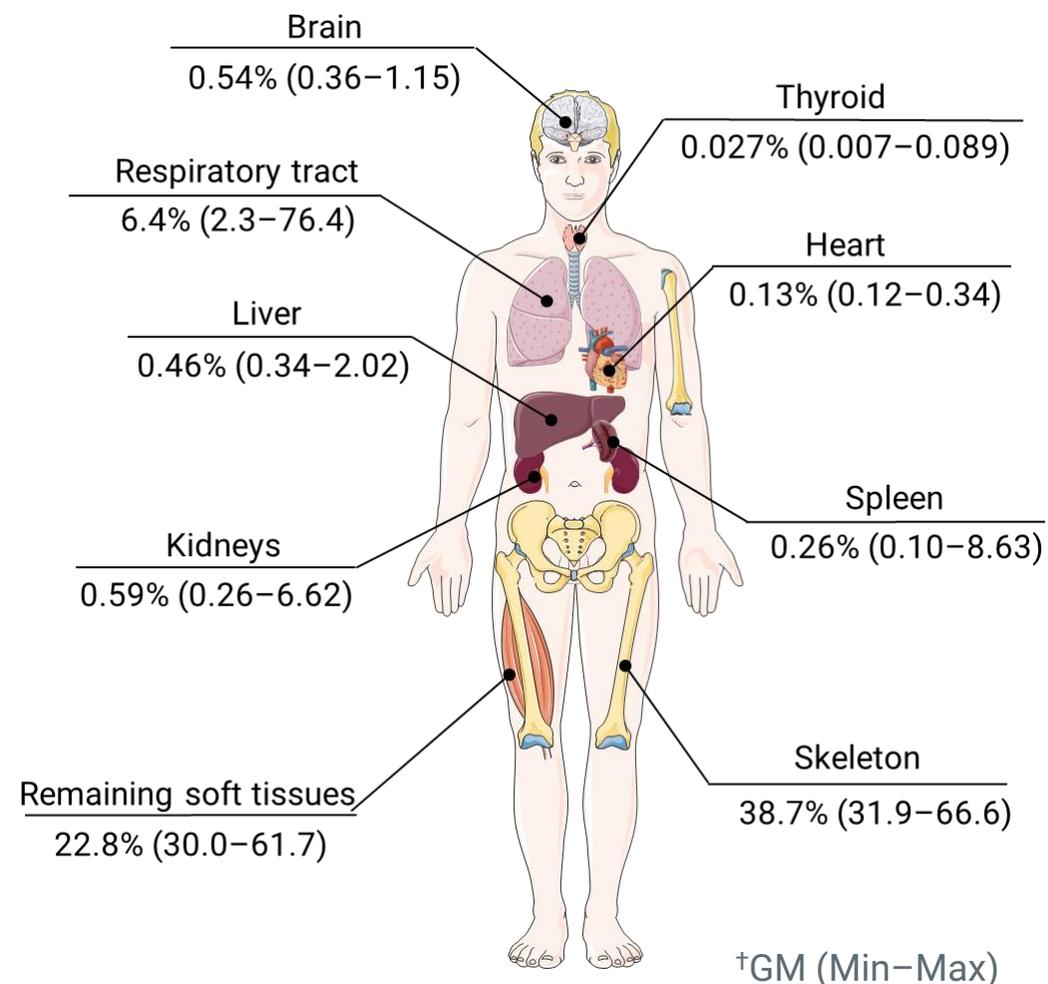


# Uranium Distribution in Human Body

Female (*n* = 1)



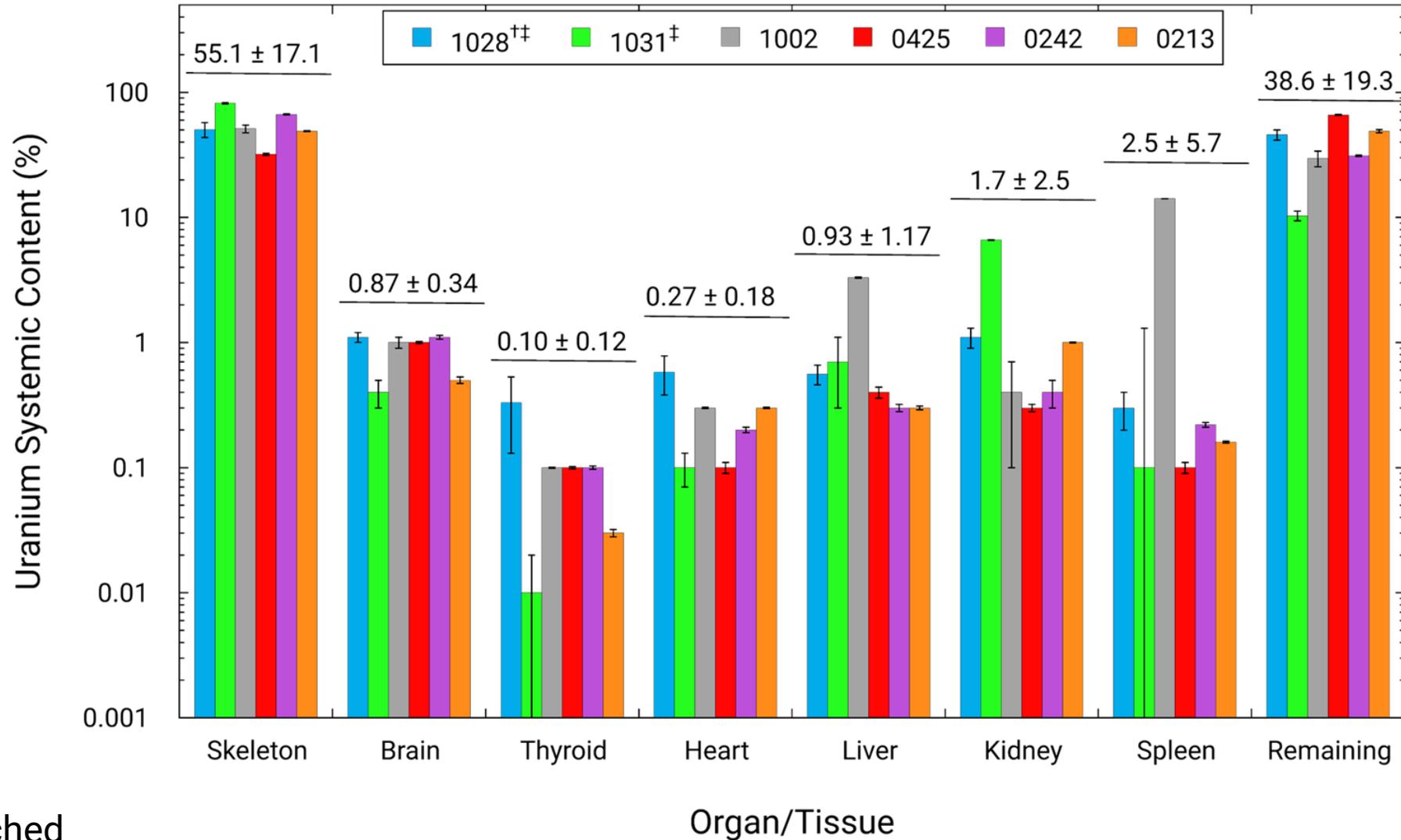
Males (*n* = 5)



†GM (Min–Max)



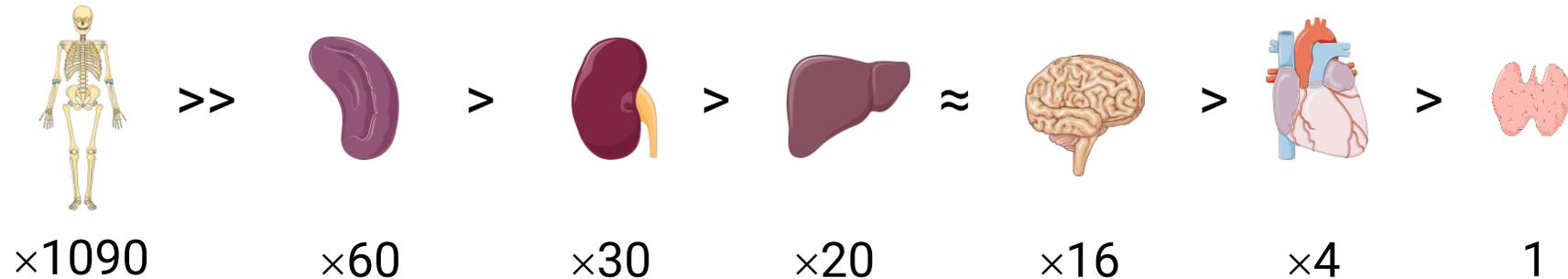
# Uranium Systemic Distribution



# Systemic Organ Content Distribution Pattern

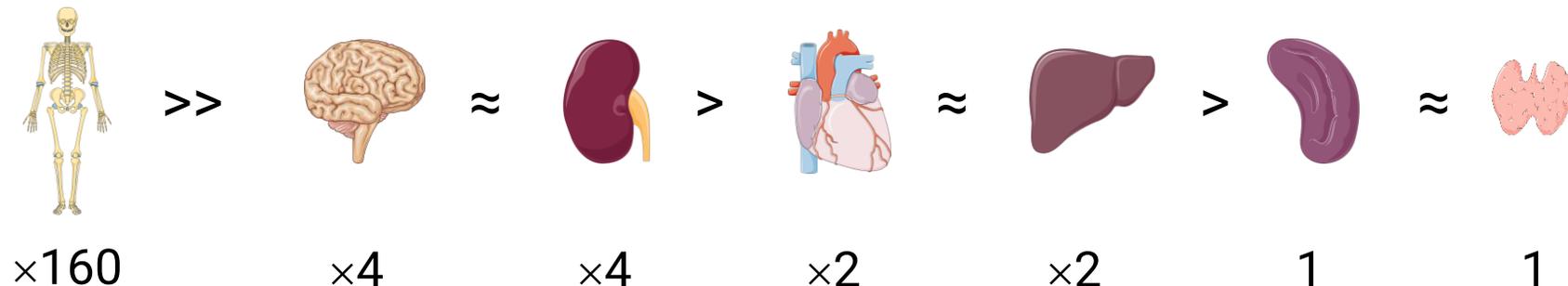
Males ( $n = 5$ ):

skeleton >> spleen > kidneys > liver  $\approx$  brain > heart > thyroid



Female ( $n = 1$ ):

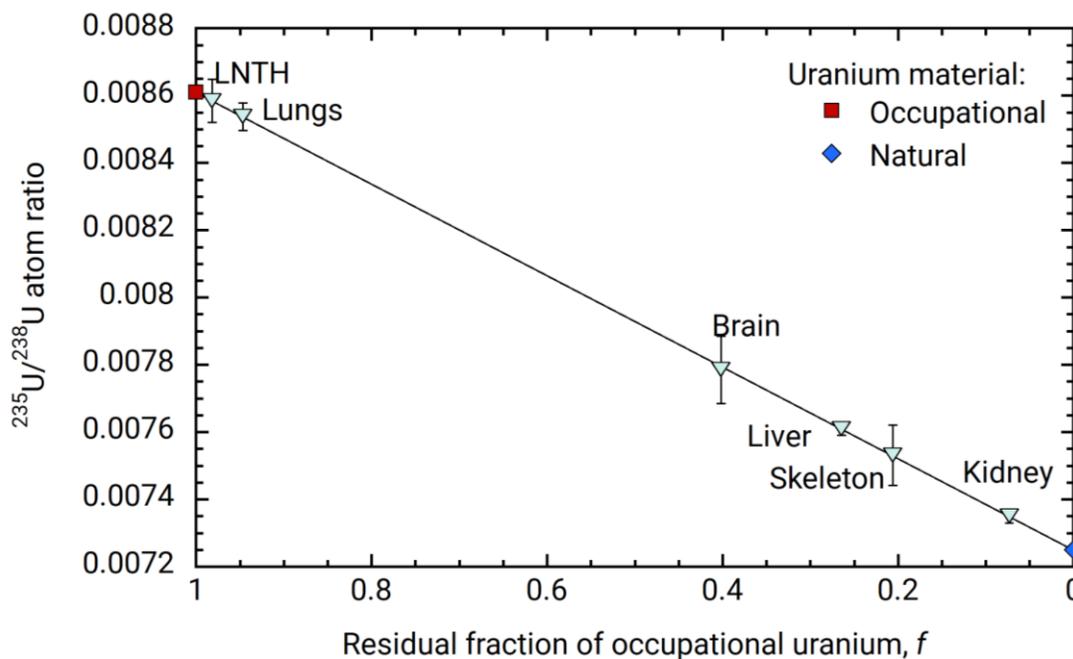
skeleton >> brain  $\approx$  kidneys > heart  $\approx$  liver > spleen  $\approx$  thyroid



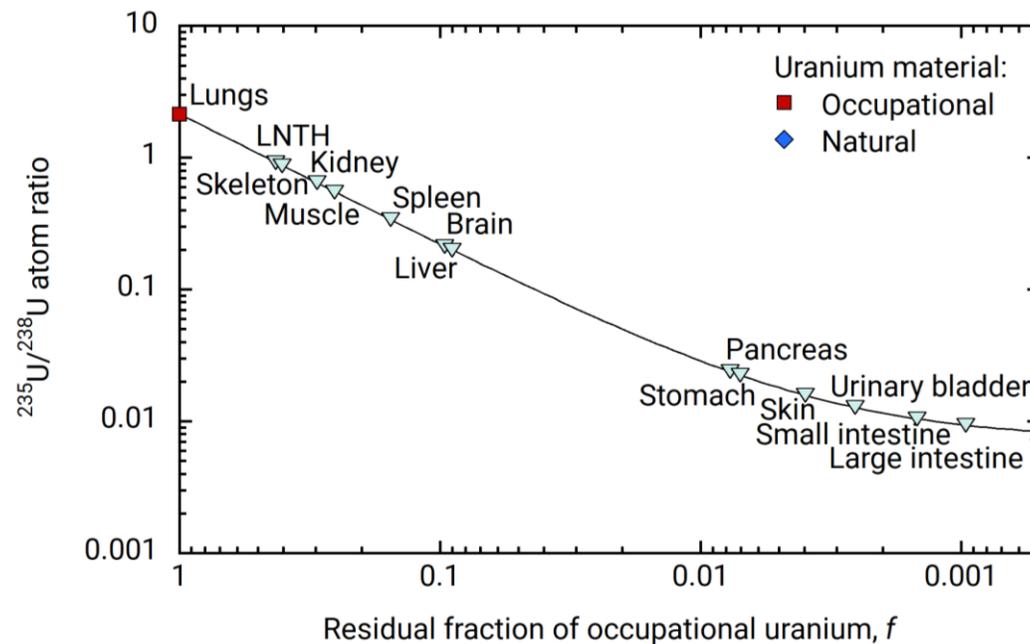
# Retention of Occupational Uranium in Human Organs

Binary mixing equation: 
$$f = \frac{R_{Tissue} - R_{NU}}{R_{Material} - R_{NU}}$$

Case 1031: Low (0.86%) enriched  $UH_6$



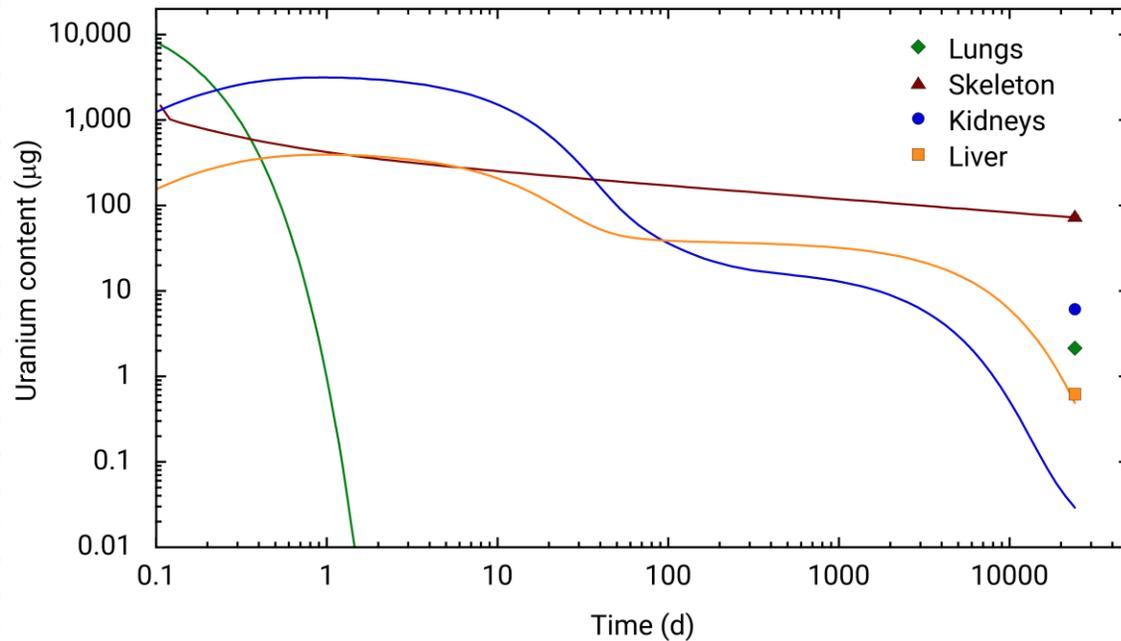
Case 1028: Highly enriched  $U_3O_8$



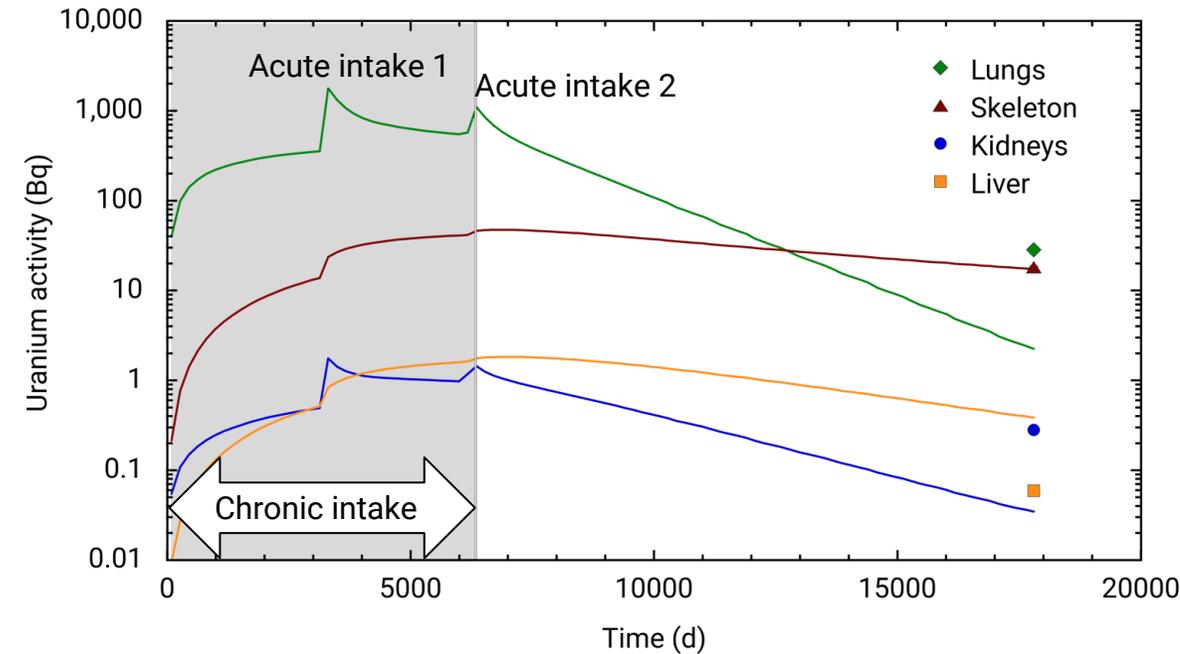


# Testing ICRP Model Predictions

## Acute inhalation of UF<sub>6</sub>



## Chronic and acute inhalation of U<sub>3</sub>O<sub>8</sub>



Avtandilashvili M, Puncher M, McComish SL, Tolmachev SY. US Transuranium and Uranium Registries case study on accidental exposure to uranium hexafluoride. *Journal of Radiological Protection* 35(1): 129-151; 2015.

Avtandilashvili M, Tolmachev SY. Forty-eight-year follow-up of a female worker exposed to highly enriched uranium via chronic and acute inhalation. *Radiation and Environmental Biophysics* 63(1): 81-95; 2024.



# Summary and Take-Home Message

- USTUR: unique resource of data to study uranium in human body
- Uranium concentrations in lung and skeleton significantly higher for uranium miners compared to nuclear workers ( $p=0.0002$  and  $p=0.0031$ ). No significant difference found for kidney ( $p=0.5405$ )
- Uranium whole body distribution published for one female and five males
- No significant difference found in systemic uranium retention for female and males
- USTUR data used to develop, validate and improve biokinetic models for radiation protection



# QUESTIONS?



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