



NC Department of Health and Human Services

Toxicological Assessment of Uranium and other Radionuclides in Groundwater

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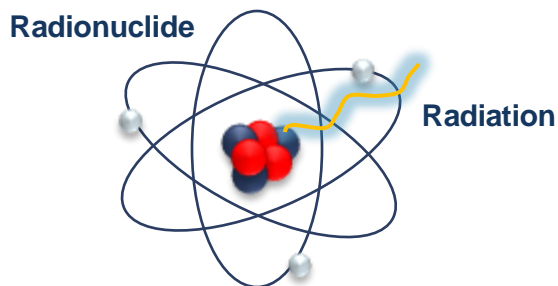
Presentation Outline

- **Radionuclides**
 - What are they?
 - What is the concern?

- **Toxicology of Radionuclides**
 - Mechanisms Toxicity
 - Absorption, Distribution, Metabolism, and Excretion

What is a radionuclide?

- Atoms with unstable nucleus due to excess energy.

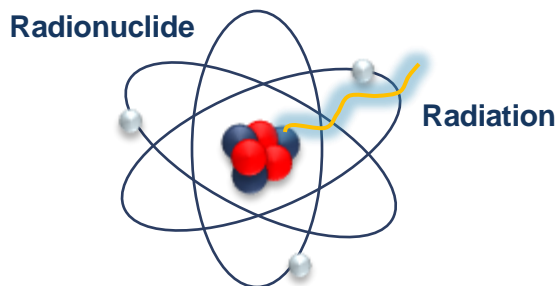


- In order to become stable, the nucleus releases energy, in the form of radiation.

Source: <https://www.epa.gov/radiation/radiation-basics>

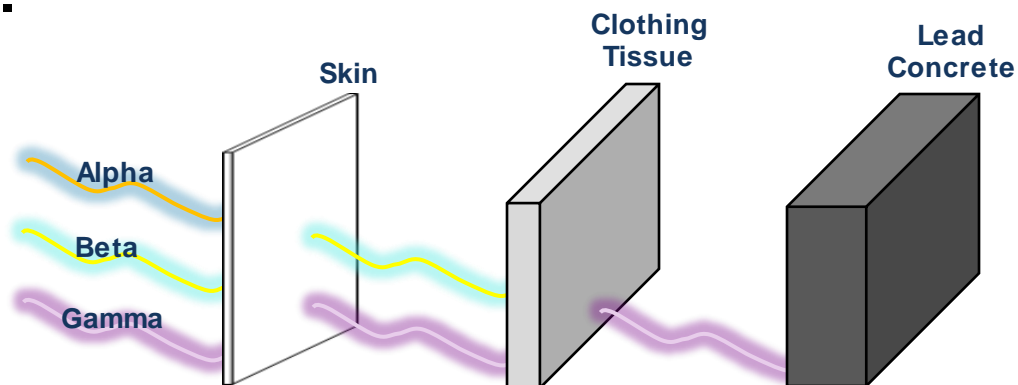
What is a radionuclide?

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- In order to become stable, the nucleus releases energy, in the form of radiation.

- Radiation can be in the form of alpha, beta or gamma emissions.



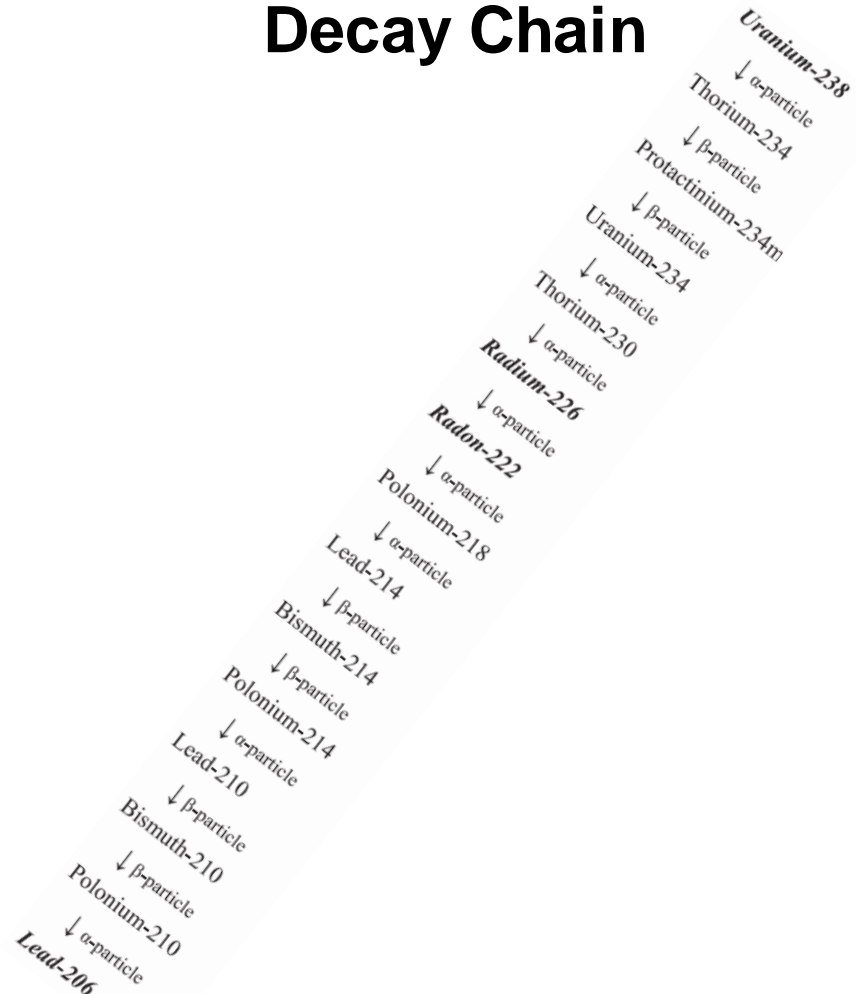
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What is a radionuclide?

Common in Groundwater

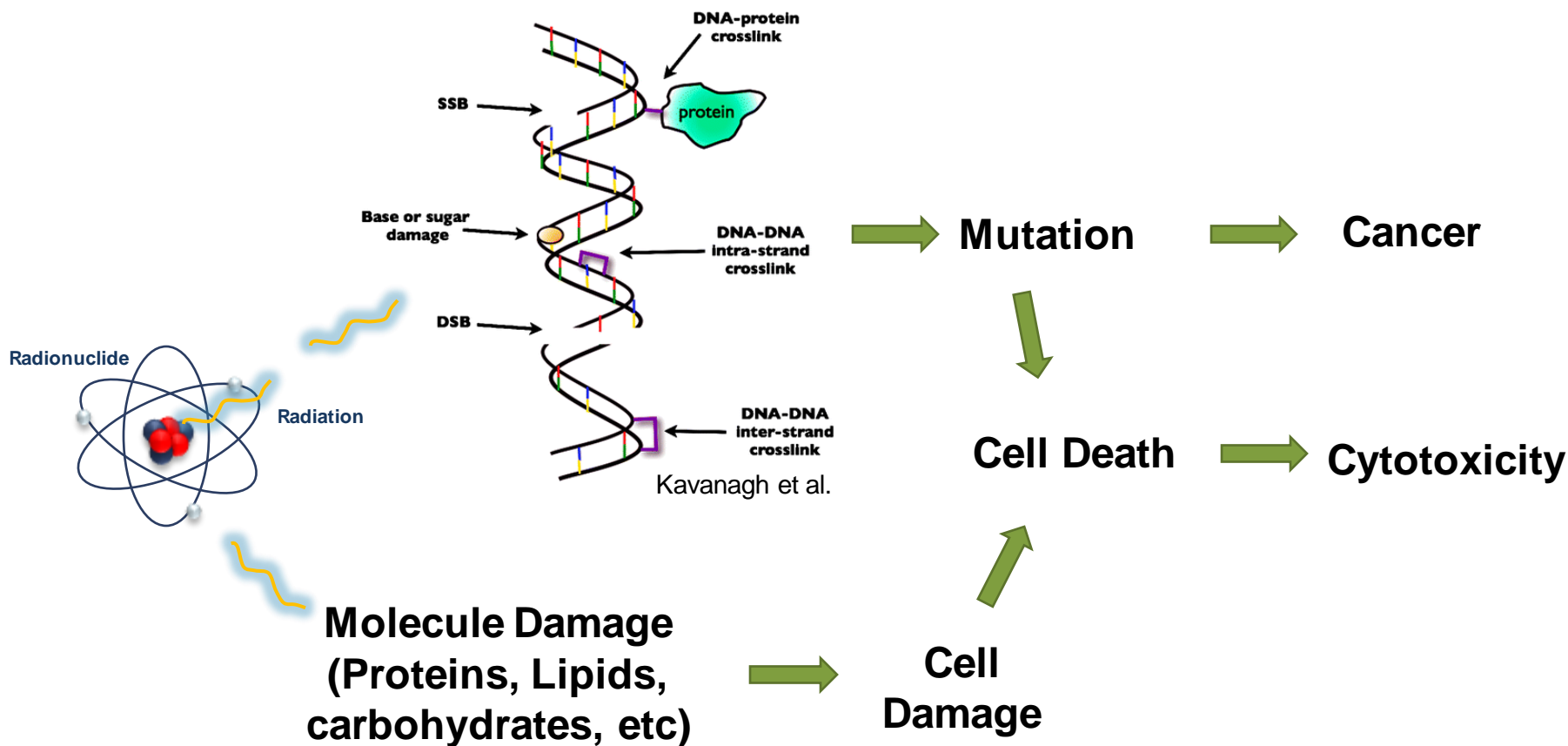
- Uranium
 - Ur 238 (98% of natural U)
- Radium
 - Ra 226 and 228
- Radon
 - Rn 222

Decay Chain



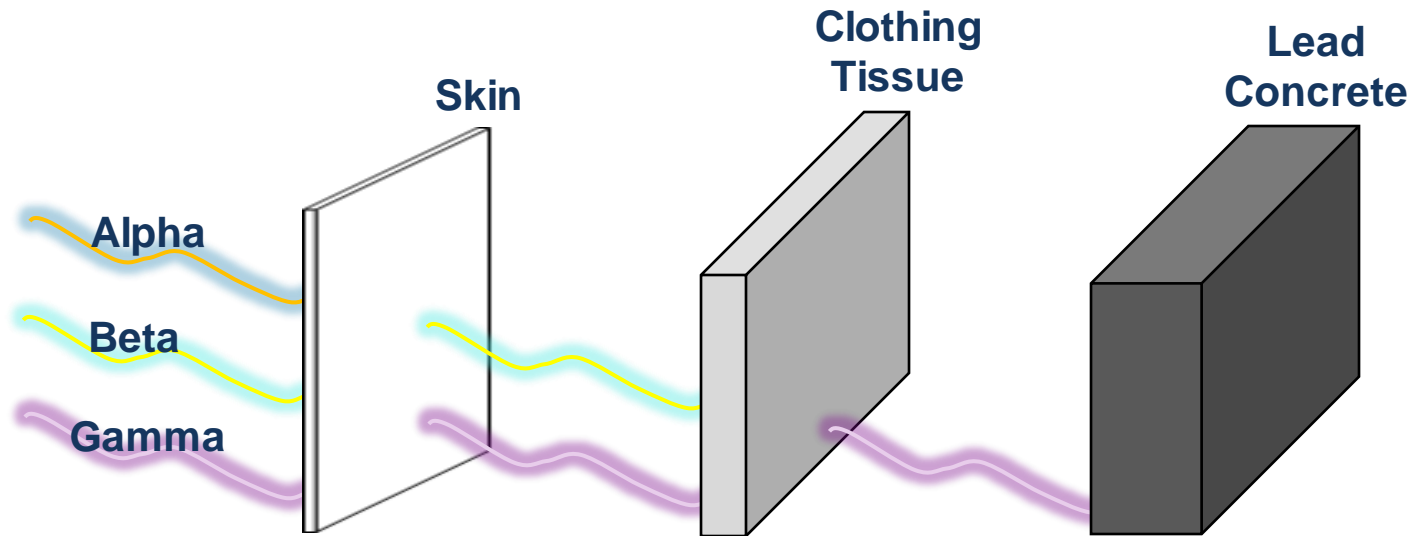
Source: IARC Radiation Volume 100D <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D.pdf>

Mechanism of Toxicity



Source: ATSDR Toxicological Profile for Ionizing Radiation

Toxicity Depends on where they end up



Toxicity Depends on ADME

- **Absorption** – how much and where it enters the body
- **Distribution** – where it goes
- **Metabolism** – does it change
- **Excretion** – how does it leave the body



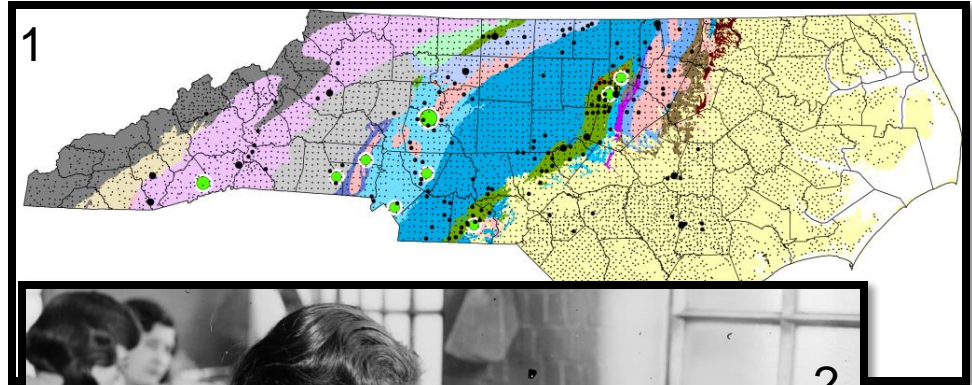
Source: 1) US Nuclear Regulatory Commission



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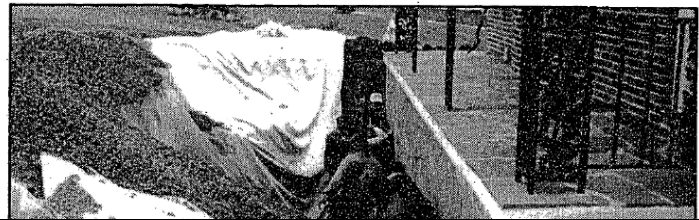


The Radon Raiders: Turning Perils Into Profits 3

Companies seek a bonanza in testing. After all, there may be 75 million customers.

By DAVID BERREBY

ments for all kinds of things," said Mr. Watras, a construction engineer. "There was even a company that made this thing you attach to your toilet that was supposed to make the radon go away with every flush." As the news spread in early 1985 — and homes with high levels of radon were found elsewhere in Pennsylvania, New Jersey and other states — other bogus operators leaped in with "radon tests" that consisted of gussied-up mayonnaise jars. One New Hampshire sharpie went around offering elderly people a "radon remover" that had to be replaced every

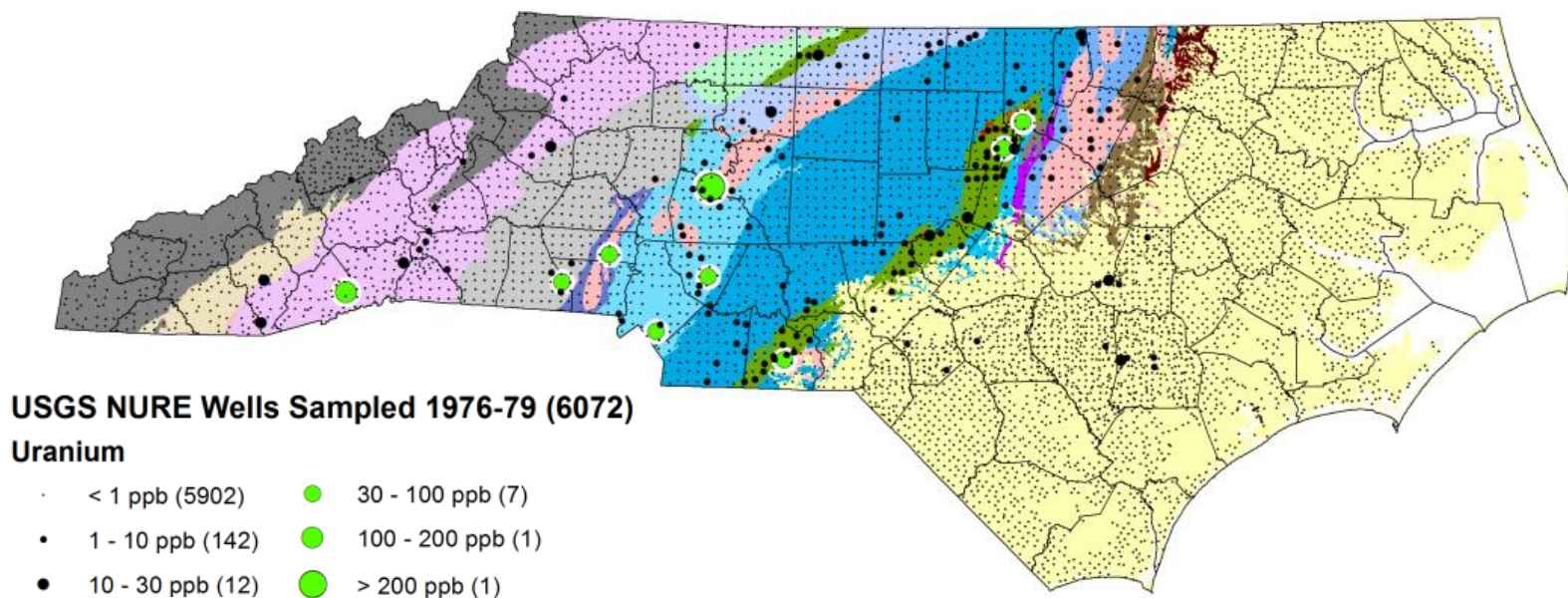


Bureau of Environmental Protection. Nonetheless, state and the E.P.A. are voluntary quality-control systems requiring certification and inspection. New Jersey and Pennsylvania rules in place in the country, life will be difficult for the less experienced. "Eventually, the

Source: 1) USGS NURE, 2) Daily Herald archives, 3) New York Times

Common in Groundwater

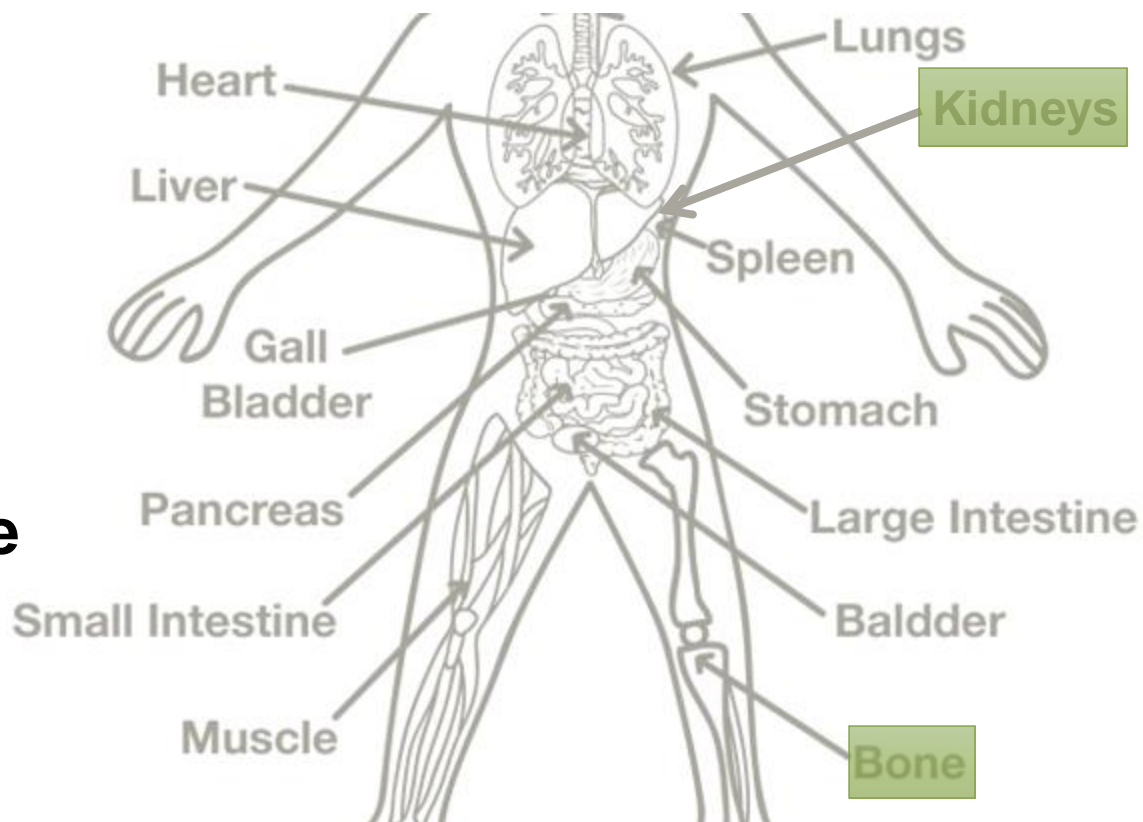
- Uranium
 - Ur 238 (98% of natural U)



Source: U.S. Geological Survey, 2004, National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance data: U.S. Geological Survey, Denver, CO.

Uranium – ADME - Ingestion

- **Absorption - <5%**
- **Distribution**
 - Bone and kidney
- **Metabolism – None**
- **Excretion**
 - Majority in feces

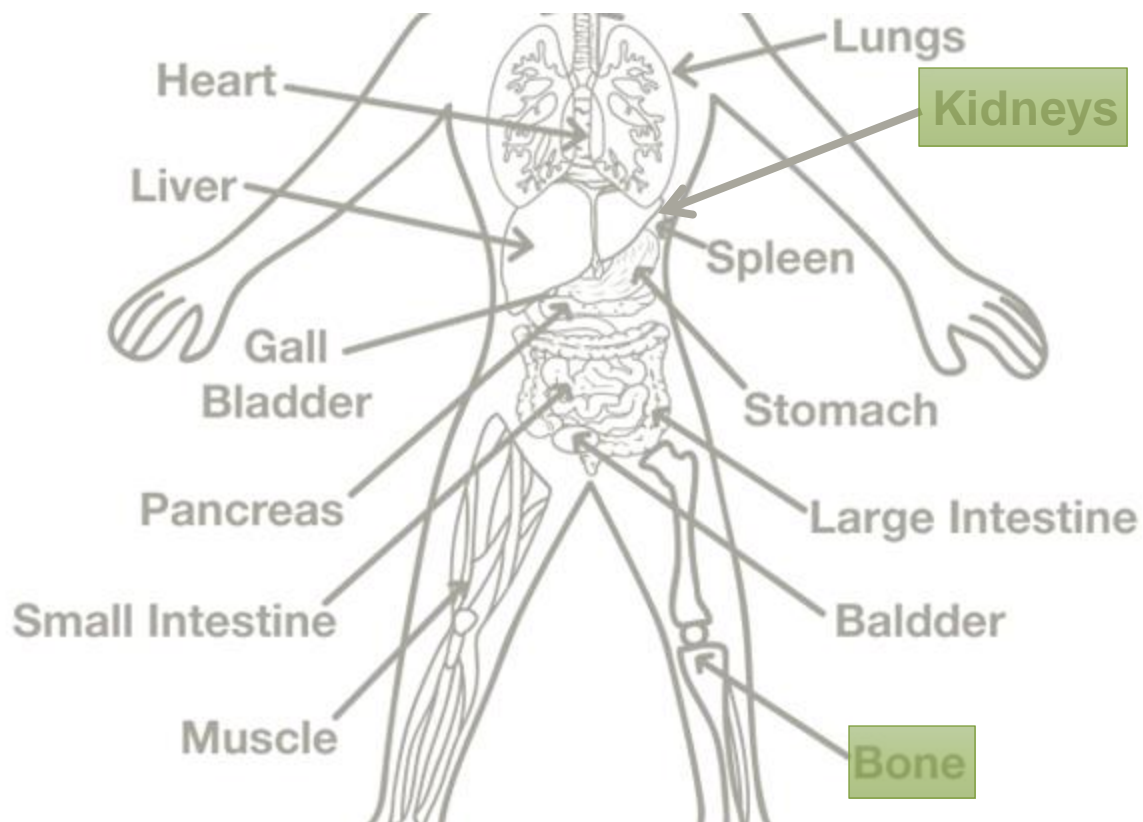


Half-Life = 4.5 billion years

Source: ATSDR Toxicological Profile for Uranium; Body (https://coloringtop.com/sites/default/files/17_1674.jpg)

Uranium – ADME - Ingestion

- Mimics calcium
- Majority stored on the surface of bones
- Released from bones
- Circulates in blood and filtered by kidney

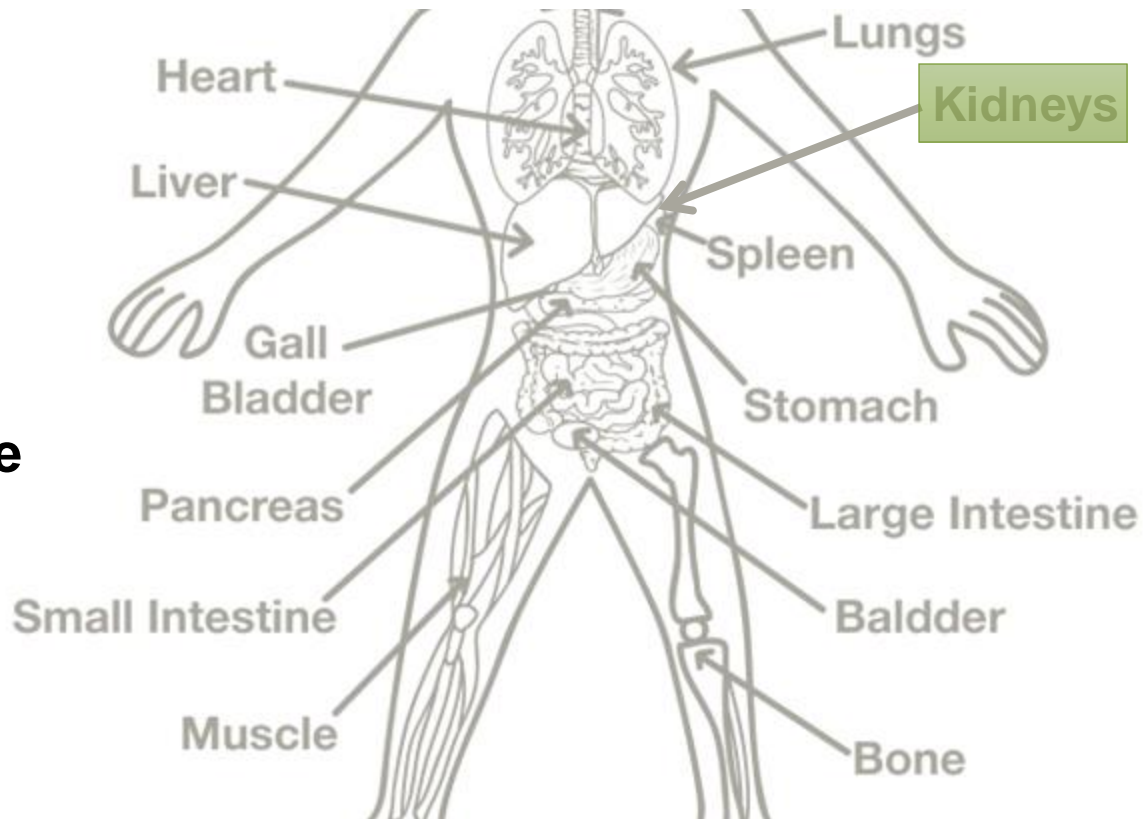


Half-Life = 4.5 billion years

Source: ATSDR Toxicological Profile for Uranium; Body (https://coloringtop.com/sites/default/files/17_1674.jpg)

Uranium - Toxicity - Ingestion

- **Exerts toxicity on tubules of kidney**
 - Evidence from occupational exposure studies
 - Animal studies
 - General public case studies are inconsistent
- **Carcinogenicity is theoretical**



Half-Life = 4.5 billion years

Uranium - Regulation

US Environmental Protection Agency Standards

Maximum Contaminant Level (enforceable)	Maximum Contaminant Level Goal (non-enforceable)
30 µg/L	0 µg/L
~45 pCi/L	0 pCi/L

Cancer Risk

- Approximately 1 in 10,000 people

Source: US EPA (https://www.epa.gov/sites/production/files/2015-09/documents/risk_neal_nelson.pdf)

Common in Groundwater

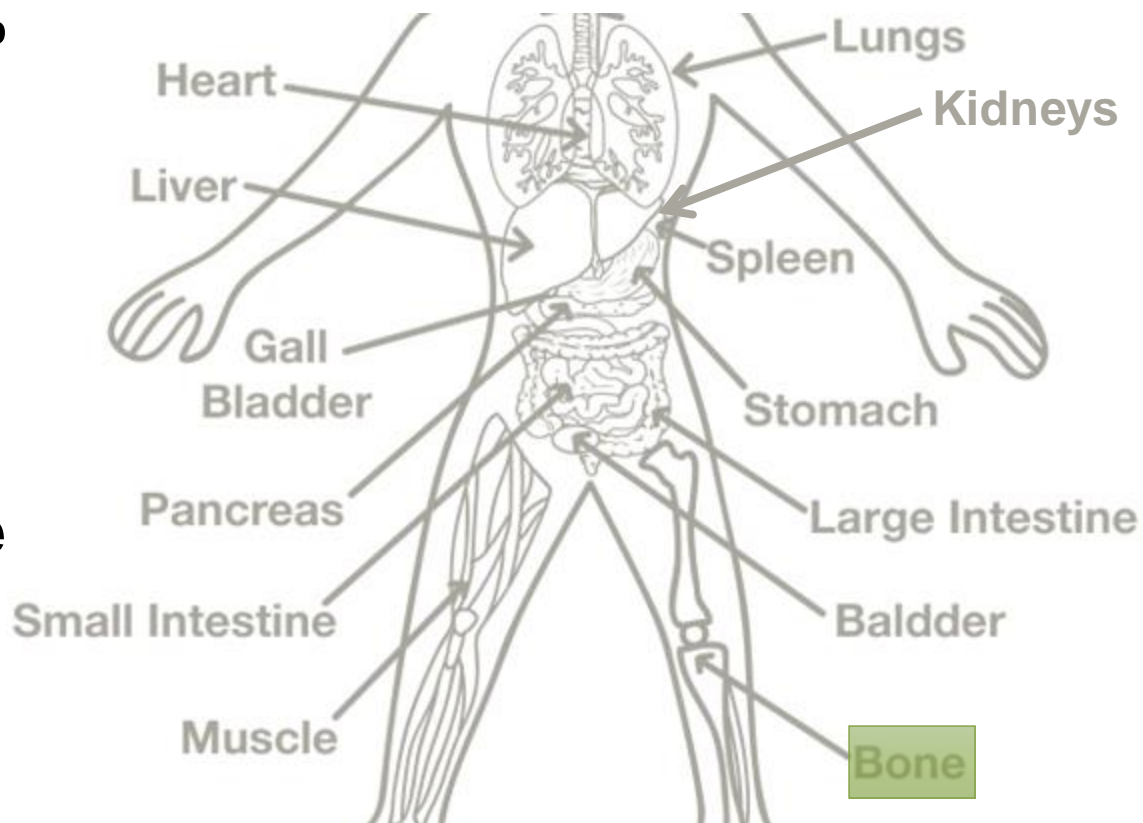
- Uranium
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- Radium
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Source: Daily Herald archives

Radium - ADME - Ingestion

- **Absorption - ~20%**
- **Distribution**
 - Bone
- **Metabolism - None**
- **Excretion**
 - Majority in feces

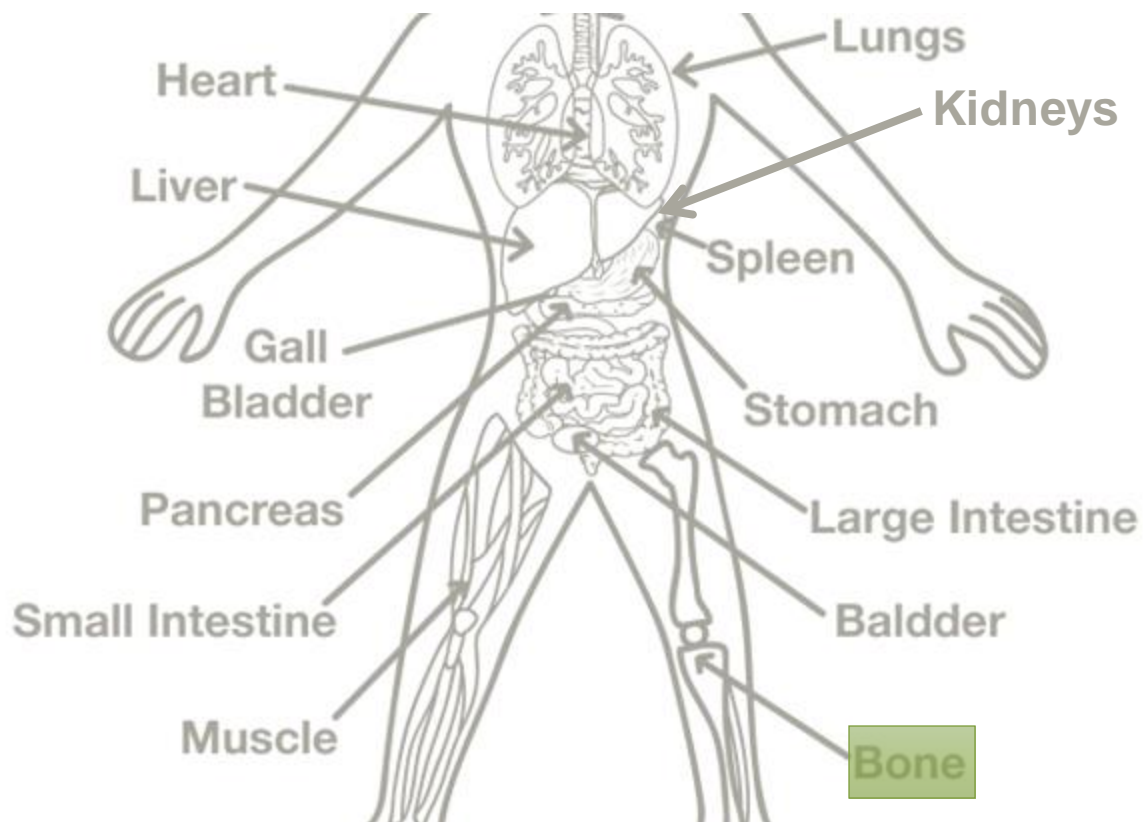


Half-Life = 5.8 to 1,600 years

Source: ATSDR Toxicological Profile for Radium; Body (https://coloringtop.com/sites/default/files/17_1674.jpg)

Radium - Toxicity - Ingestion

- Mimics calcium
- Stored in bone matrix
- Exerts radioactivity in bones



Half-Life = 5.8 to 1,600 years

Source: ATSDR Toxicological Profile for Radium; Body (https://coloringtop.com/sites/default/files/17_1674.jpg)

Radium - Regulation

US Environmental Protection Agency Standards

Maximum Contaminant Level (enforceable)	Maximum Contaminant Level Goal (non-enforceable)
5 pCi/L	0 pCi/L

Cancer Risk

- 0.5 – 2.1 in 10,000 people
- 5 to 210 in 100,000 people

Source: US EPA (https://www.epa.gov/sites/production/files/2015-09/documents/risk_neal_nelson.pdf)

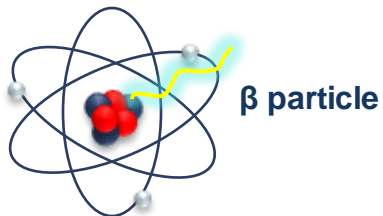
Radiation Particle

US Environmental Protection Agency Standards



Maximum Contaminant Level Goal (non-enforceable)	Maximum Contaminant Level (enforceable)
0 pCi/L	15 pCi/L

Cancer Risk - 1 in 20,000 people



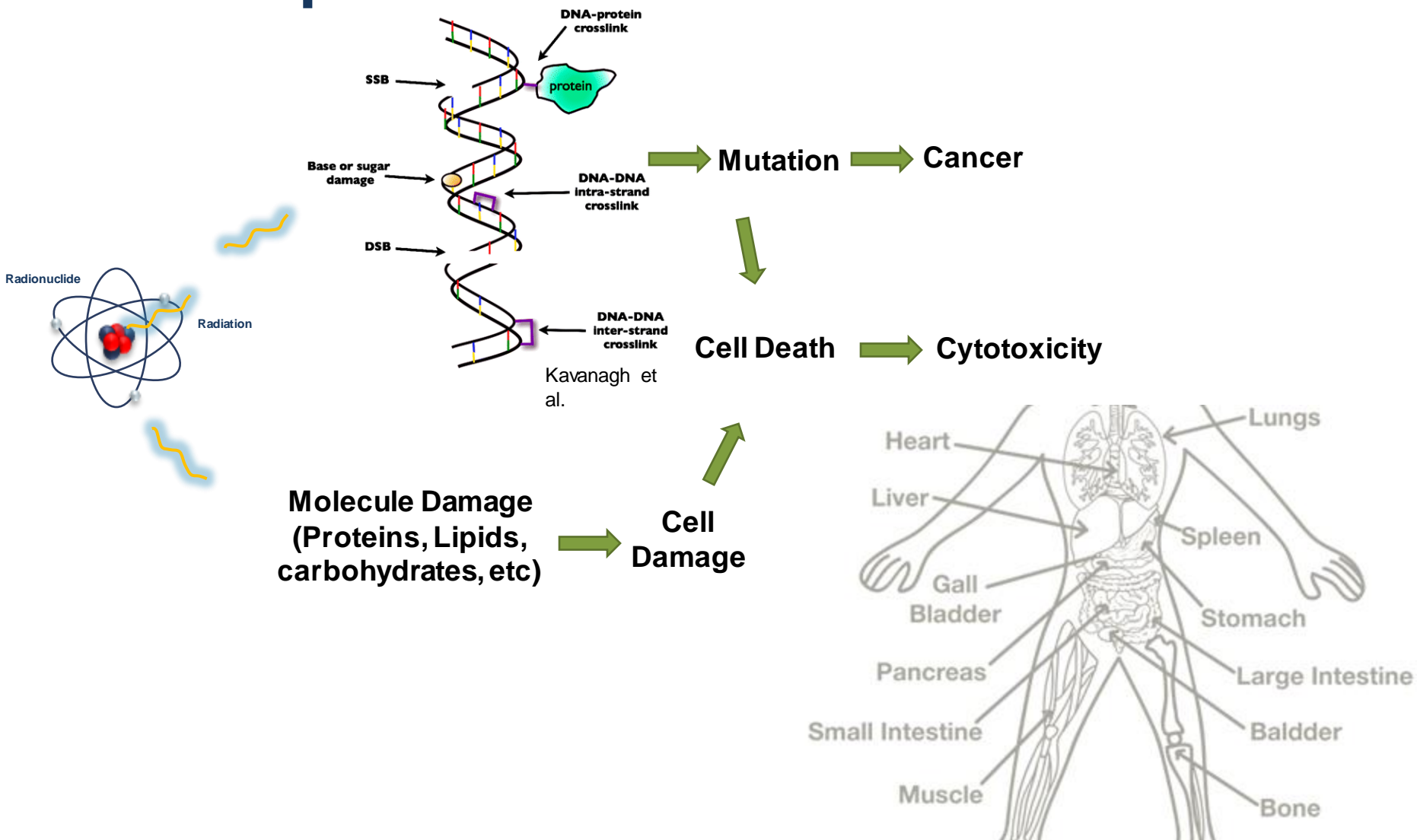
0 mrem/y	15 mrem/y
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Action Level: 50 pCi/L

Cancer Risk - 1 in 20,000 people

Source: US EPA (https://www.epa.gov/sites/production/files/2015-09/documents/risk_neal_nelson.pdf)

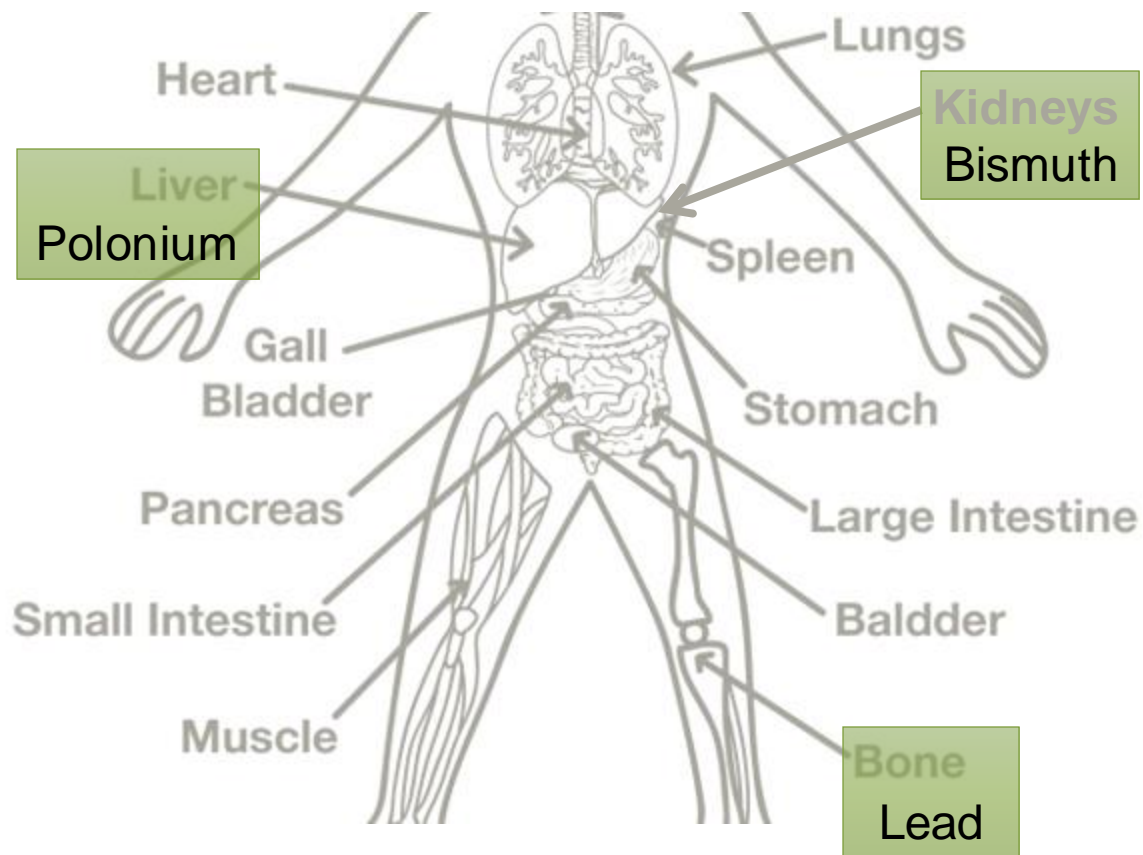
Absorption and Distribution



Source: ATSDR Toxicological Profile for Ionizing Radiation

Radionuclide Decay Chain

Radionuclide	Half-life
Uranium-238	4,468,000,000 years
↓ α-particle	
Thorium-234	24.1 days
↓ β-particle	
Protactinium-234m	1.17 minutes
↓ β-particle	
Uranium-234	2,444,500 years
↓ α-particle	
Thorium-230	75,400 years
↓ α-particle	
Radium-226	1,600 years
↓ α-particle	
Radon-222	3.82 days
↓ α-particle	
Polonium-218	3.11 minutes
↓ α-particle	
Lead-214	26.8 minutes
↓ β-particle	
Bismuth-214	19.9 minutes
↓ β-particle	
Polonium-214	0.000163 seconds
↓ α-particle	
Lead-210	22.3 years
↓ β-particle	
Bismuth-210	5.01 days
↓ β-particle	
Polonium-210	138 days
↓ α-particle	
Lead-206	Stable



Source: IARC Radiation Volume 100D

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“There was even a company that made this thing that you attached to your toilet that was supposed to make the radon go away with every flush.”

Source: New York Times

To be continued...



Questions?

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