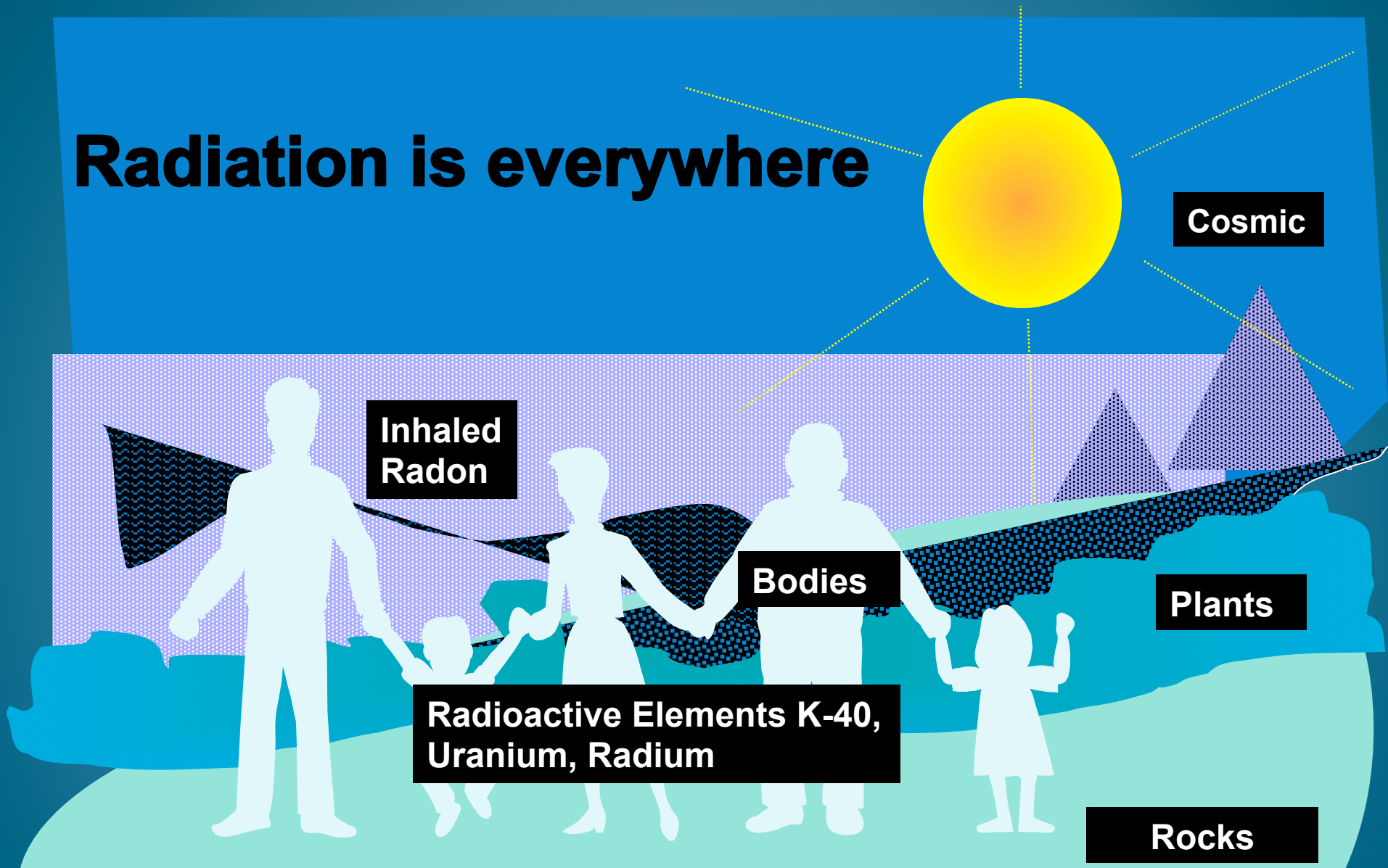
Radiation is everywhere

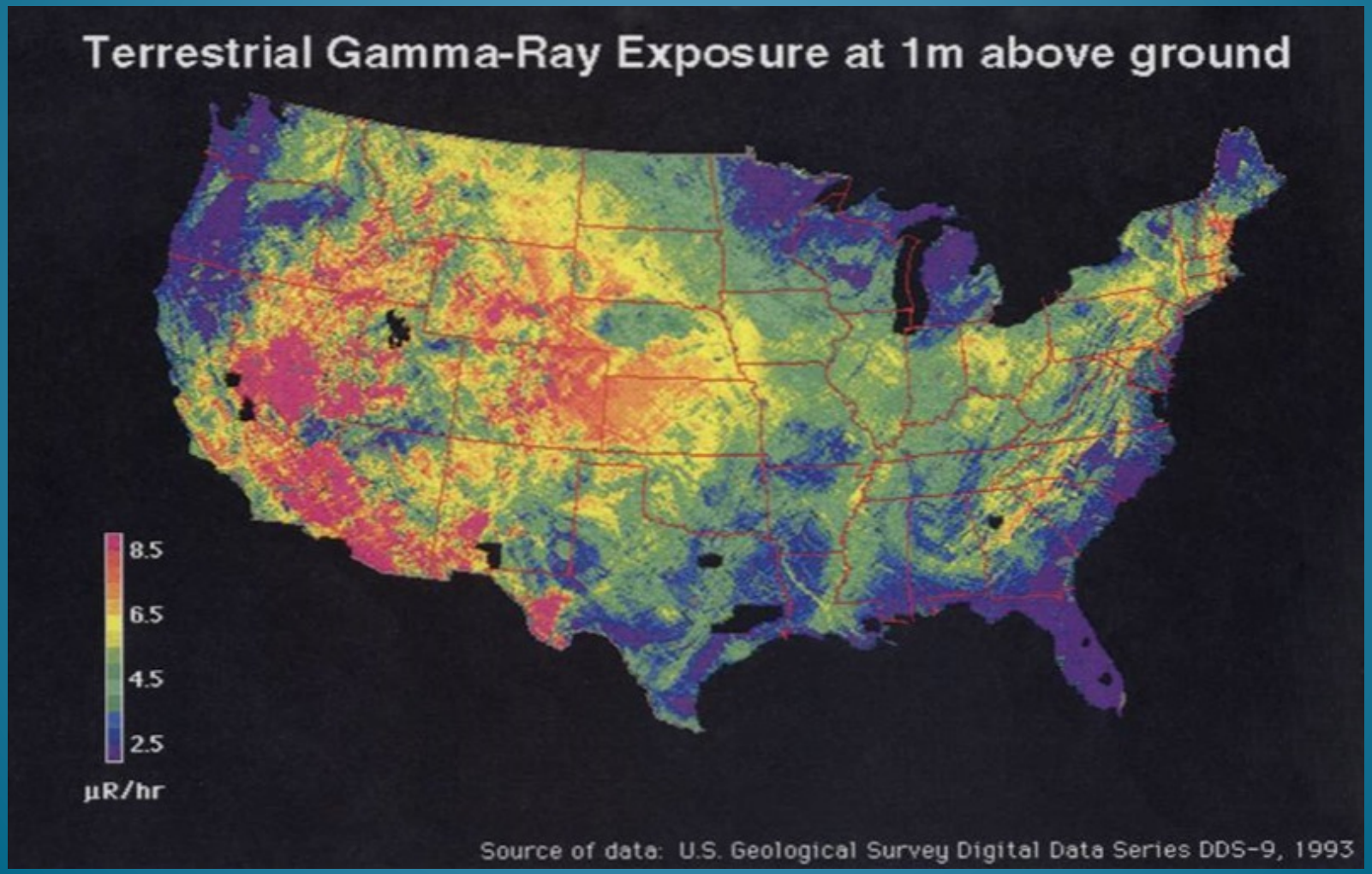


We live in a sea of radiation…

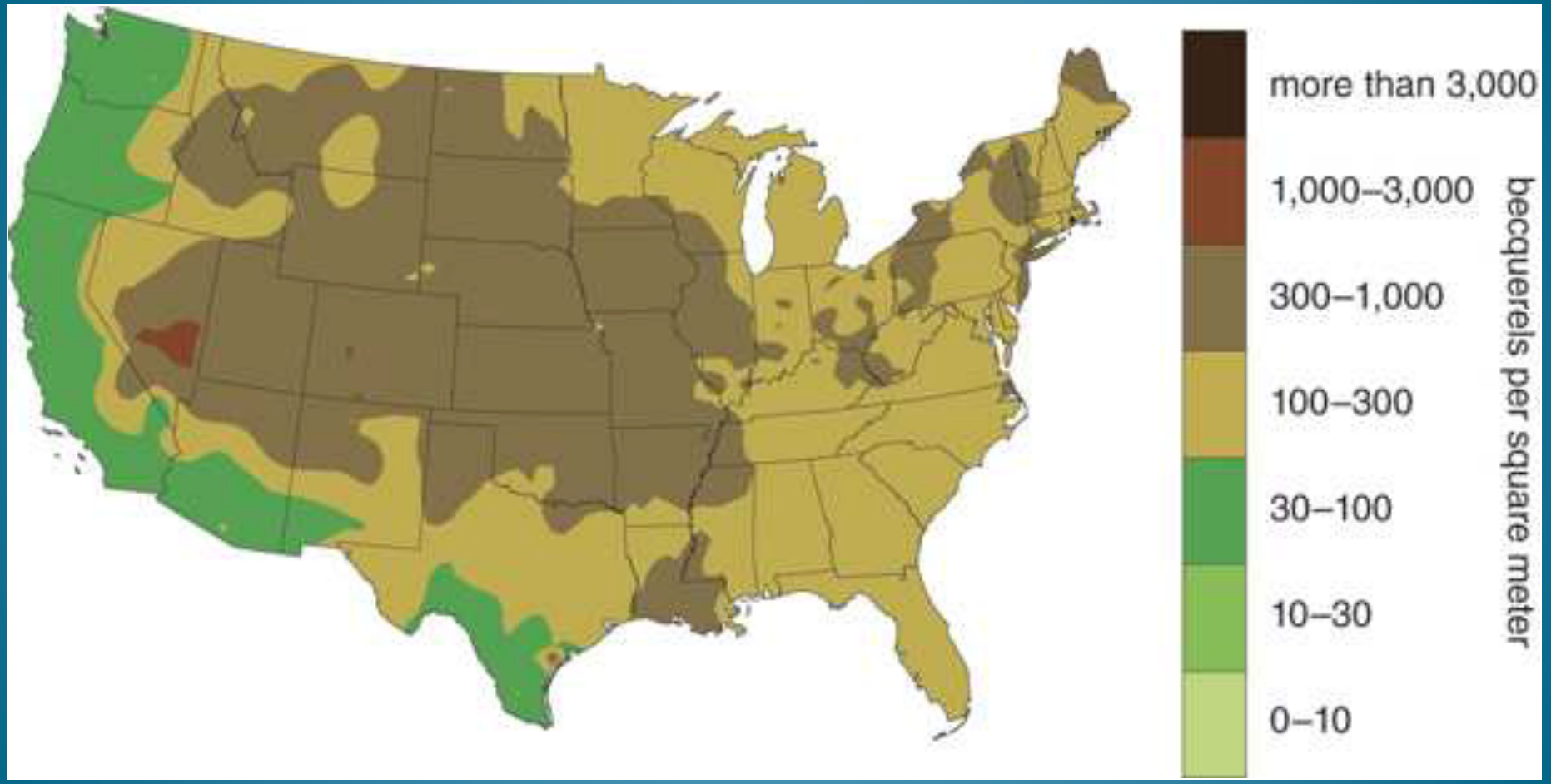
The question is: How much?

- **Compared to what?**
  - Fallout vs Natural Background
  - Fallout vs Nuclear power
  - Fallout vs Nuclear Accidents
  - Fallout vs Medical Exposures

U.S Dose Rates from Natural Background

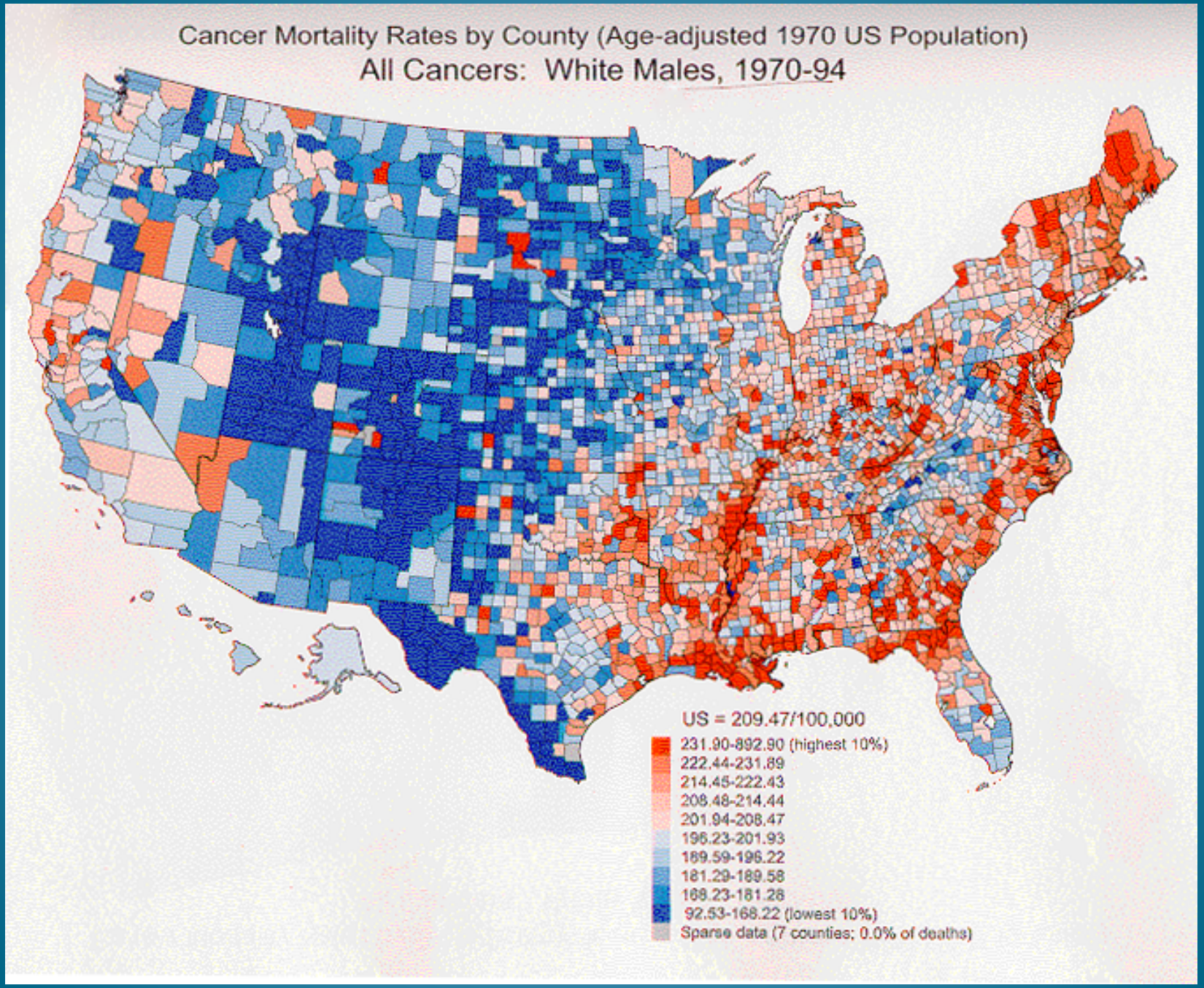


Nevada Test Fallout



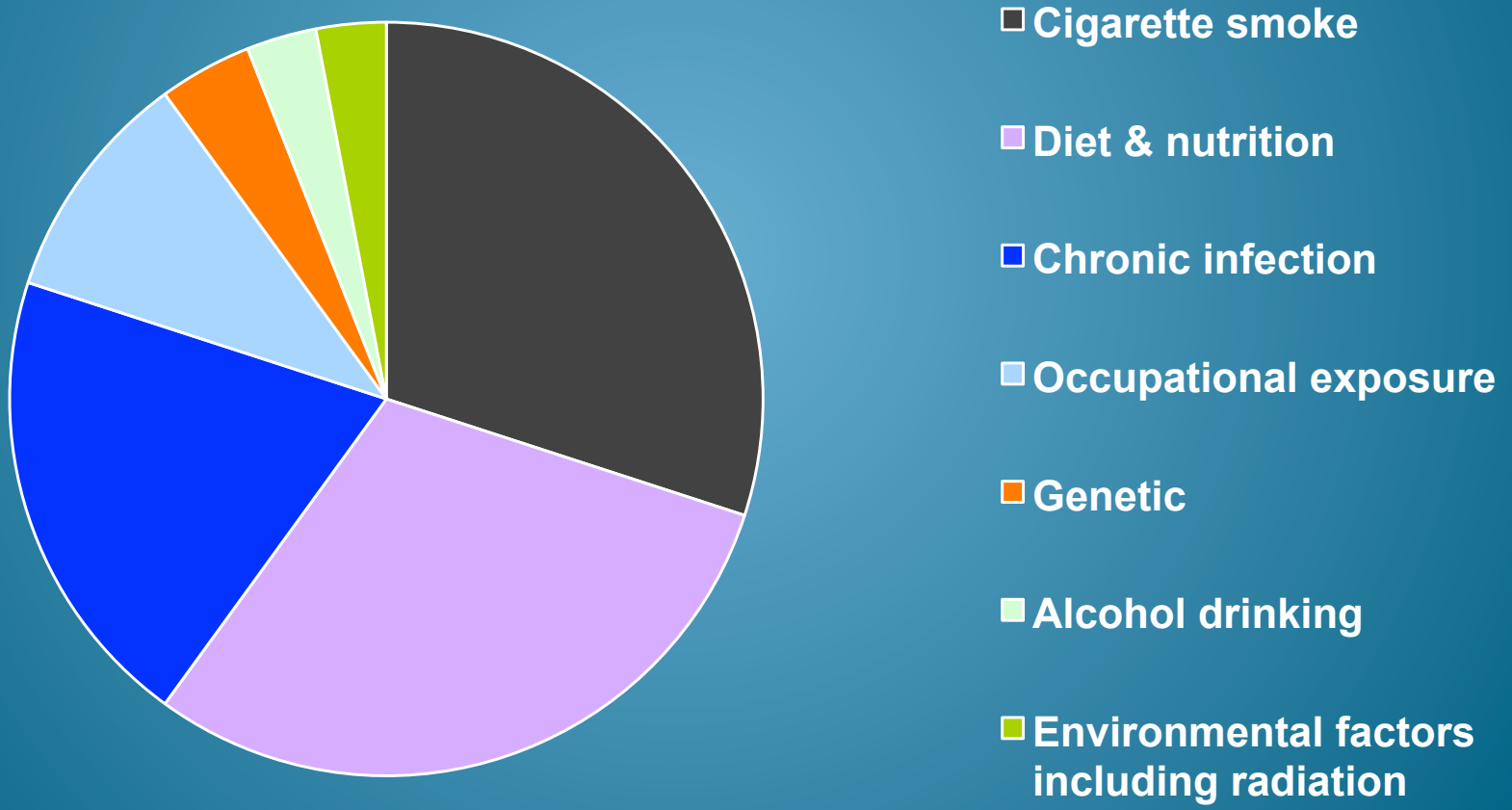
Cesium-137 deposition density resulting from the cumulative effect of the Nevada tests generally decreases with distance from the test site in the direction of the prevailing wind across North America, although isolated locations received significant deposition as a result of rainfall.

Simon et al. 2006


Cancer Mortality Rates by County (Age-adjusted 1970 US Population)
All Cancers: White Males, 1970-94
US = 209.47/100,000
231.90-892.90 (highest 10%)
222.44-231.89
214.45-222.43
208.48-214.44
201.94-208.47
196.23-201.93
189.59-196.22
181.29-189.58
168.23-181.28
92.53-168.22 (lowest 10%)
Sparse data (7 counties; 0.0% of deaths)

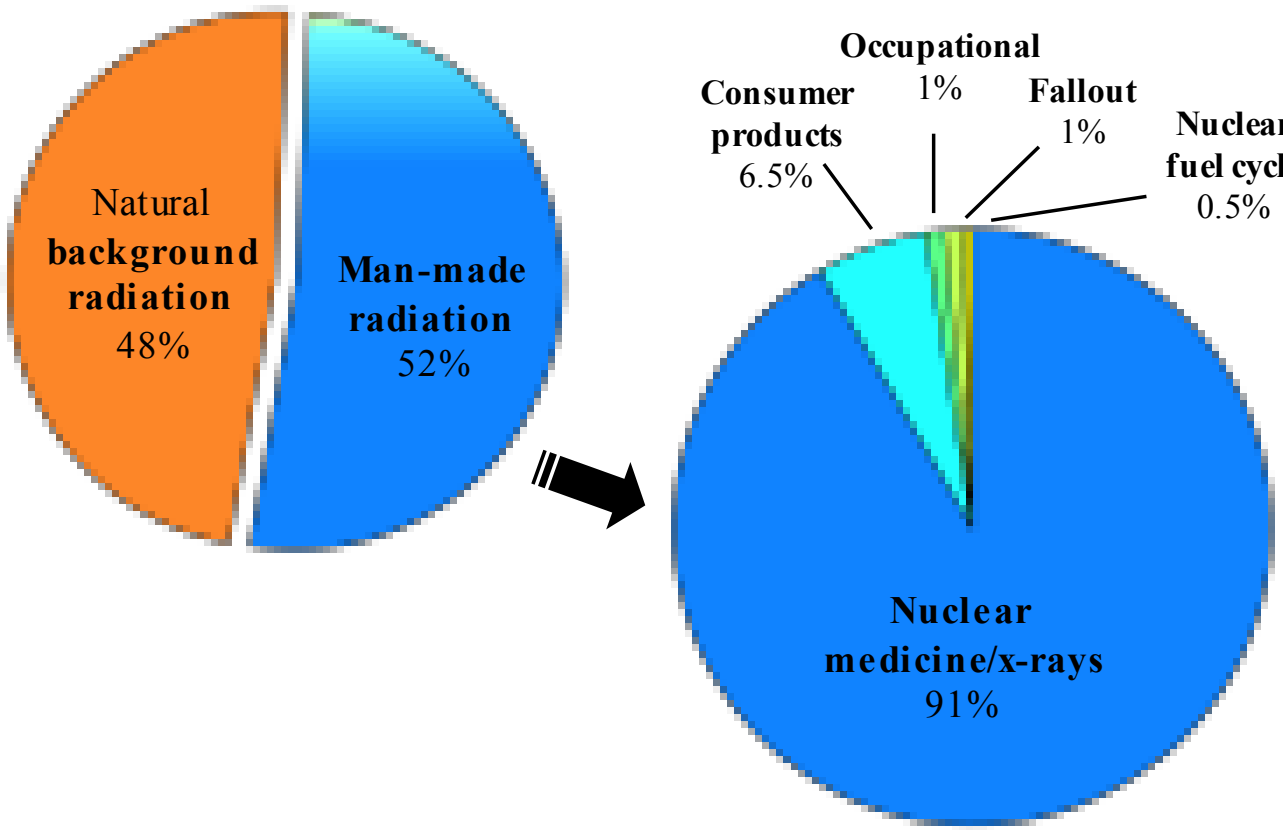
What causes Cancer?

Radiation is not a big hitter!!!



WHO

What Radiation Exposures can we Modify?



Summary

- We **live in a sea of radiation** and always have.
- Radiation is a **poor mutagen and Carcinogen**.
- Low dose responses seem to be **protective** and high dose responses damaging, thus **the body responds differently to high and low doses**.
- Cancer risks using LNTH are **conservative**.

Ionizing Radiation
Dose Ranges
(Rem)

acute exposure = all at once; chronic = hours, days, years

Cancer Radiotherapy
total doses to tumor

Whole body, acute: G-I destruction; lung damage; cognitive dysfunction (death certain in 5 to 12 days)*

Whole body, acute: cerebral/ vascular breakdown (death in 0-5 days)*

6 — 0 — 2000 — 4000 — 6000 — 8000 — 10,000 rem

Total Body Irradiation (TBI) Therapy

Acute Radiation Syndromes

Life Span Study (A-bomb survivor epidemiology)

Whole body, acute: circulating blood cell death; moderate G-I damage (death probable 2-3 wks)*

Whole body, acute: marked G-I and bone marrow damage (death probable in 1-2 wks)*

Charged particle event (Solar flare) dose on moon, no shielding

Estimated dose for 3-yr Mars mission (current shielding)

5 — 0 — 200 — 400 — 600 — 800 — 1,000 rem

Early, transient skin erythema (2-24 hr onset)

Temporary epilation (3 wk onset)

Main erythema reaction (10 day onset)

Permanent epilation (3 wk onset)

Human LD_{50} range acute exposure no medical intervention*

Human LD_{50} range acute exposure with medical intervention

*Note: Whole body acute prognoses assume no medical intervention (G-I = gastrointestinal)

Office of Science
U.S. DEPARTMENT OF ENERGY

Cancer Epidemiology

Evidence for small increases in human cancer above 10 rem acute exposure or 20 rem chronic exposure

4 — 0 — 10 — 20 — 30 — 40 — 50 — 60 — 70 — 80 — 90 — 100 rem

Typical mission doses on International Space Station (ISS)

Ramsar, Iran high natural bkg/yr

DHS emergency guideline to save a life: 25 rem

Interplanetary Space natural bkg/yr

DOE Low Dose Program

3 — E F M I N J K G H L — 0 — 1 — 2 — 3 — 4 — 5 — 6 — 7 — 8 — 9 — 10 rem

Kerala coast, India high natural bkg/yr

DHS emergency guideline for public relocation: 2 rem/yr (20 mSv/yr)

Guarapari, Brazil high natural bkg/yr

DOE, NRC dose limit for workers: 5 rem/yr (50 mSv/yr)

Typical added annual dose for commercial airline flight crews

Medical Diagnostics (A-O)
see chart >>

2 — A B C D E F — 0 — 100 — 200 — 300 — 400 — 500 — 600 — 700 — 800 — 900 — 1,000 mrem (1 rem)

Natural background, USA average ≈ 310 mrem/yr (includes radon)

Yangjiang, China high natural bkg/yr

Airport x-ray whole body scanner: 0.007 mrem/scan

(Limit = 25 mrem/yr ≈ 4000 scans/yr)

DOE facility releases

Regulations & Guidelines

1 — A B — 0 — 10 — 20 — 30 — 40 — 50 — 60 — 70 — 80 — 90 — 100 mrem

Round-trip Los Angeles – New York (≈ 3.7 mrem)

EPA dose limit public drinking water systems: 4 mrem/yr

EPA dose limit from release in air: 10 mrem/yr

NRC cleanup criteria for site decommissioning / unrestricted use: 25 mrem/yr

DOE, NRC dose limit for the public: 100 mrem/yr (1 mSv/yr) (ICRP, NCRP)

Medical Diagnostics rads
(Estimated maximum organ dose)

X-ray films	
A – Chest (PA & Lat)	0.014
B – Dental Panoramic	0.07
C – Lumbar-Sacral Spine	0.2 – 0.3
D – Mammogram	0.2 – 0.4
Radiotracer Imaging	
E – Heart Stress (Tc-99m)	0.6 – 1.2
F – Bone (Tc-99m)	0.4 – 1.5
G – Dual Isotope Stress Test	4.0 – 4.5
H – PET: F-18 FDG (bladder)	5.5 – 8
CT Scans (X-ray) (multiple scan average dose)	
I – Chest	2 – 3
J – Head	3 – 5
K – Abdominal	2.2 – 6
L – Full Body	5 – 10
Fluoroscopy /Procedures	
M – Barium Contrast G.I.	1 – 2.2
N – Cardiac Catheterization	1.2 – 4
O – TIPS Procedure	40 – 140

(TIPS: Transjugular Intrahepatic Porto-systemic Shunt)

LD_{50} = Lethal Dose to 50% (whole body dose that results in lethality to 50% of exposed individuals in 30-60 days)

Dose Equivalent: 100 rem = 1 Sievert = (absorbed dose x radiation quality)
Absorbed Dose: 100 rad = 1 Gray
1 rem ≈ 1 rad for x- and gamma-rays
(" ≈ " stands for "approximately equal to")

NOTE: This chart was constructed with the intention of providing a simple, user-friendly, "order-of-magnitude" reference for radiation exposures of interest to scientists, managers, and the general public. In that spirit, most quantities are expressed as "dose equivalent" in the more commonly used radiation protection units, the rem and Sievert. Medical diagnostics are expressed as estimated maximum organ dose; as they are not in "effective dose" they do not imply an estimation of risk (no tissue weighting). Dose limits are in effective dose, but for most radiation types and energies the difference is numerically not significant within this context. It is acknowledged that the decision to use these units is a simplification, and does not address everyone's needs. (NRC = Nuclear Regulatory Commission; EPA = Environmental Protection Agency; DHS = Department of Homeland Security)
Disclaimer: Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or

Chart compiled by NF Metting, Office of Science, DOE/BER. "Orders of Magnitude" revised June 2010
http://www.lowdose.energy.gov/

Source: Office of Biological and Environmental Research (BER), Office of Science, U.S. Department of Energy