# The Health Implications of Combined Exposure to Multiple Sources of Iodine-131


**F. Owen Hoffman, Ph.D.**

***SENES*** **Oak Ridge, Inc.**
**Center for Risk Analysis**
**102 Donner Dr.**
**Oak Ridge, TN 37830**

**Ph: 865.483.6111 Fax: 865.481.0060**
**e-mail: senesor@senes.com**

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# The evaluation of health risk requires an estimate of the dose to the thyroid gland

- **The radiation dose is a measure of amount of energy produced from radioactive decay that is absorbed by a unit mass of tissue**
  - **Old unit is the**
    **rad = 100 ergs per gram tissue**
  - **New SI unit is the**
    **gray (Gy) = 1 Joule per kg tissue**

  **1 rad = 0.01 Gy or 1 cGy**

# The Health Risk from Iodine-131 Exposure

- **At very high doses (>2,000 to 10,000 cGy), ablation of the thyroid occurs**
  - Leading to hypothyroidism and the need for hormone replacement
  - Observed in a few children on Rongelap Is. in 1954 who were exposed to fallout from shot Bravo
- **At lower doses (<100 cGy), the main concern is thyroid cancer and other neoplasms (new growths)**
  - The risk is greatest for females exposed in childhood
  - The frequency of occult thyroid cancer is three to four times that diagnosed and reported

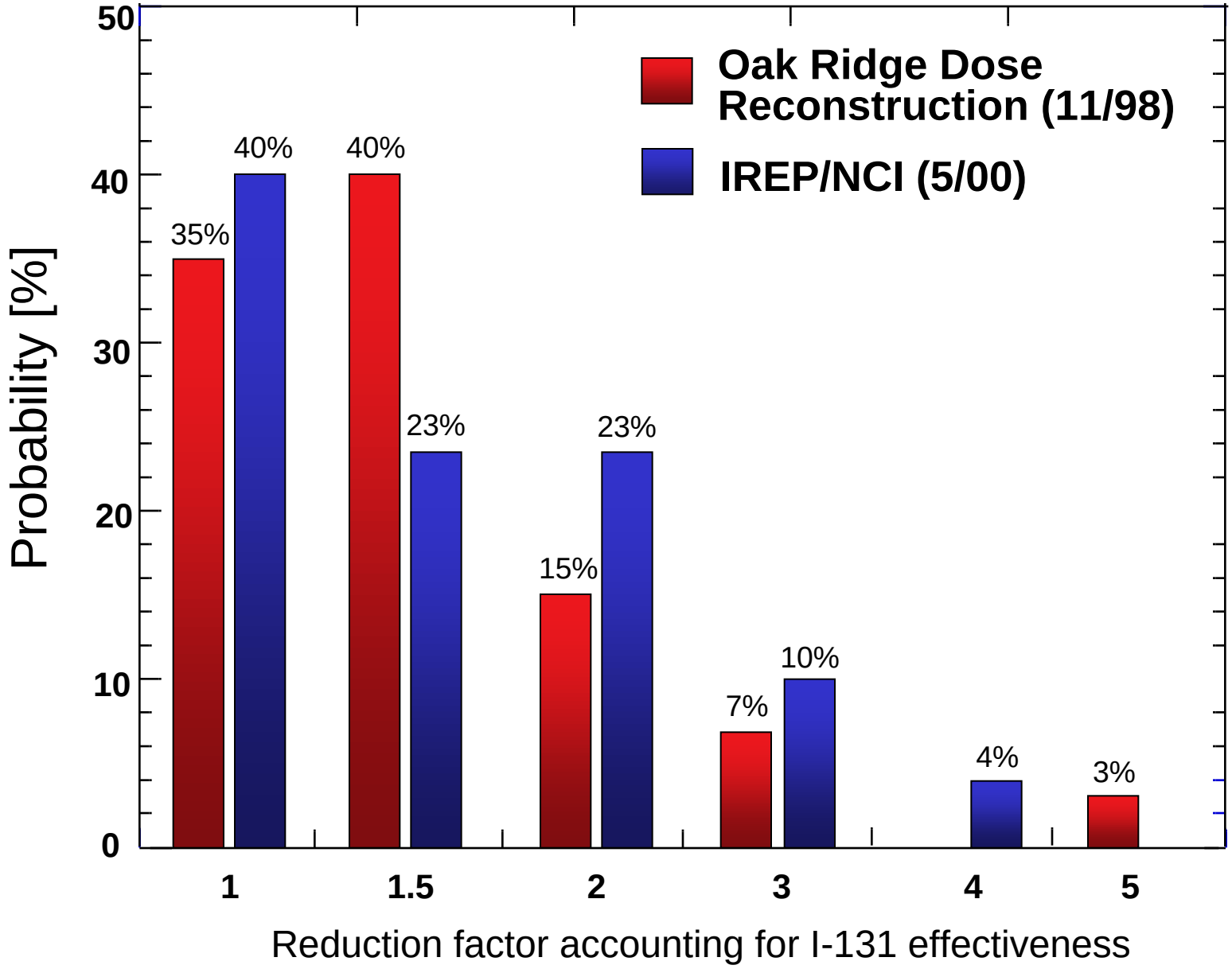
# The Evidence for Radiation Exposure and Thyroid Cancer

- **The link between exposure to ionizing radiation and cancer production is well established**
  - **Radiation is the only thyroid carcinogen identified by EPA**
- **For thyroid cancer, most evidence is from children exposed to external radiation**
  - **Therapeutic and diagnostic use of x-rays**
  - **Atomic bombings of Hiroshima and Nagasaki**
  - **Children are more at risk than adults, females more than males**
  - **The 20 to 30 year survival rate is greater than 90%**
  - **Limits of epidemiological detection at 10 to 30 cGy**
    - **But, there is no dose below which the risk is zero**

# The Evidence for Iodine-131

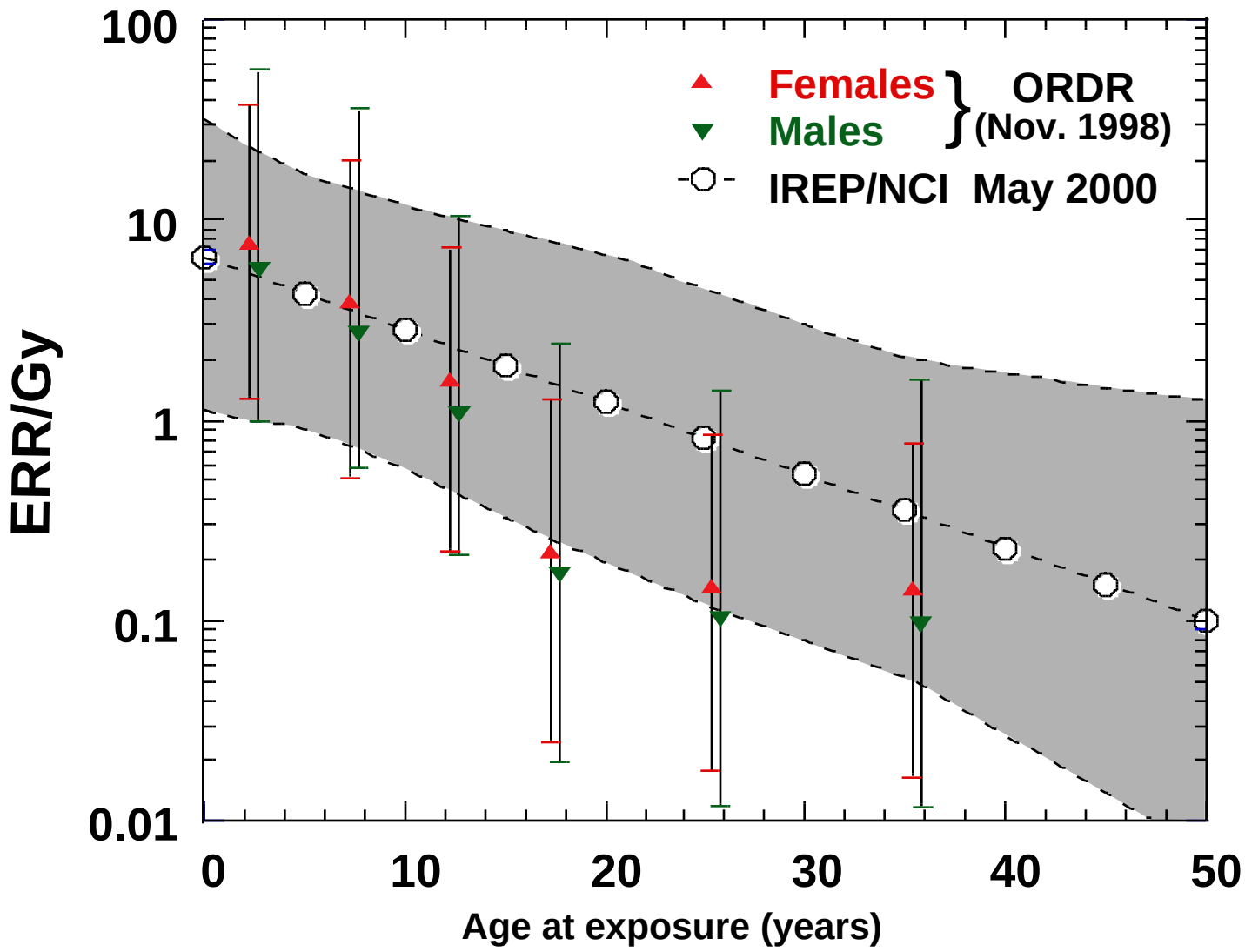
- **Mostly from research published in the last 8 years**
  - **Children exposed to I-131 from Chernobyl**
  - **Children exposed to NTS fallout (suggestive)**
  - **No substantial difference between external radiation exposure and exposure to I-131**
    - **Confirmed by animal experiments using I-131 and x-rays**
  - **Differences between external radiation and I-131, once thought to be real, now explained by**
    - **Older ages at time of exposure (medical diagnostics)**
    - **Low statistical power due to high uncertainty in reconstructed thyroid doses that occurred decades in the past (HTDS)**

# Reduction factor accounting for $^{131}I$ effectiveness



# An update of the excess relative risk for exposure to I-131

(thyroid cancer and other neoplasms)



# A Comparison of Risk Estimates (ERR/Gy) for $^{131}$I Induction of Excess Thyroid Cancers or Other Neoplasms

| | 95% confidence interval | | | | |
|---|---|---|---|---|---|
| | Lower limit | Central value | Upper limit | Notes | References |
| **Estimates using mathematical models** | | | | | |
| **ORDR** | **1.3** | **7.7** | **38** | **Females; age group 0-4** | **Apostoaei et al, 1998** |
| **IREP/NCI** | **1.1** | **6.4** | **32** | **Both genders** | **Land et al., 2000** |
| **Epidemological Studies of $^{131}$I from NTS fallout** | | | | | |
| **Utah Study** | **0.7** | **7.0** | **33** | **All neoplasms** | **Stevens et al., 1992** |
| **Entire US** | **2.8** | **12** | **31** | **1950-1959 birth cohort; cancer mortality** | **Gilbert et al., 1998** |
| **Epidemological Studies of $^{131}$I from Chernobyl accident** | | | | | |
| **Russia** | **2.4** | **7.3** | **12** | **Children and adolescents** | **Ivanov et al., 1999** |
| **Belarus/ Ukraine** | **22** | **46** | **90** | **Children & adolescents** | **Jacob et al., 1997** |

# Other health outcomes

- **Non-cancerous growths on the thyroid** (Benign nodules)
  - Manual exams detect 8 times more non-cancerous thyroid nodules than thyroid cancers
    - The use of ultrasound increases the frequency of nodule detection 7 times above manual exams
- **Diseases of thyroid function**
  - Includes autoimmune thyroiditis
    - Hashimoto's hypothyroidism (underactive thyroid)
    - Graves disease (overactive thyroid)

# The Radiation Risk of Autoimmune Thyroiditis

- **Extends to doses below 100 cGy,**
  - **but is unlikely below 10 to 20 cGy.**

    **Reference:**

    - **Institute of Medicine (IOM 1999)**

# Sources of Iodine-131 Exposure

- **Medicine**
- **Nuclear facilities**
- **Nuclear Weapons Testing**

# Amounts released from Oak Ridge

- **Routine operation of RaLa**
  - **6,300 to 36,000 Ci***
- **April 29, 1954 RaLa accident**
  - **105 to 500 Ci**
- **Total amount of I-131 released**
  - **8,800 to 42,000 Ci***

*May change pending re-evaluation of the efficiency of the caustic scrubber and additional sources of I-131 released from X-10

# Releases of Iodine-131 from other locations

- **Hanford plutonium production**
  - **~ 900,000 curies (1944 to 1956)**
- **Savannah River reprocessing**
  - **~ 60,000 curies from (1955 to 1962)**
- **Windscale, UK (accident)**
  - **~ 20,000 curies (October 1957)**
- **Chernobyl (accident)**
  - **~ 50,000,000 curies (April-May, 1986)**

# Iodine-131 released from atmospheric testing of nuclear weapons

- **Nevada Test Site**
  - 150 ***million*** curies, (1952 through 1957*),
- **Marshall Is. Thermonuclear tests**
  - 8 ***billion*** curies (1952 to 1958),
- **Former USSR Thermonuclear tests**
  - 12 ***billion*** curies (1958 to 1962)

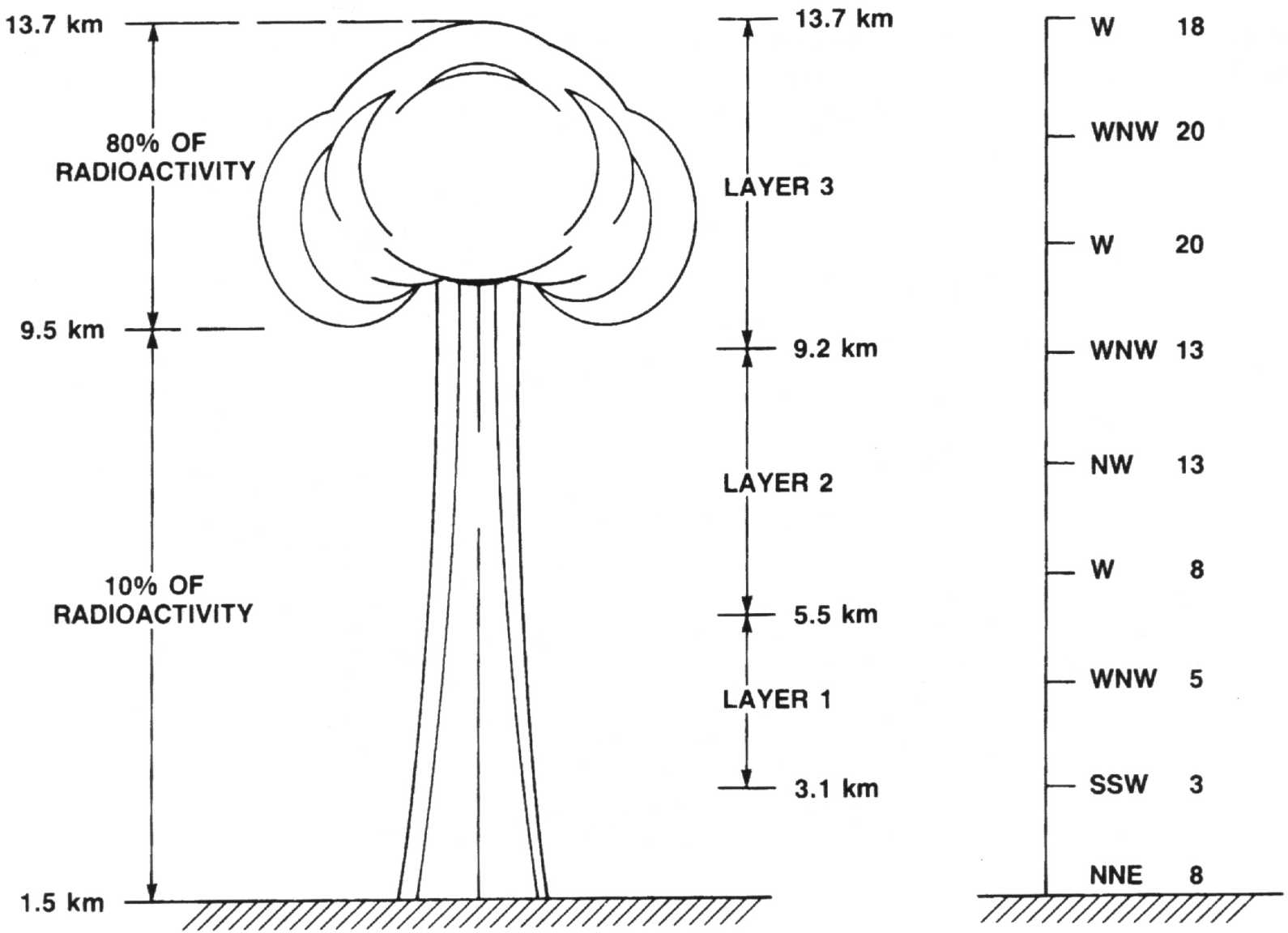
# Nationwide Exposure of the American People to Iodine-131 released during Atmospheric Weapons Testing in Nevada

**Information from the**

**National Cancer Institute**

**(October, 1997)**

# Schematic depiction of the mushroom cloud and stem from the test Simon (4/25/53)

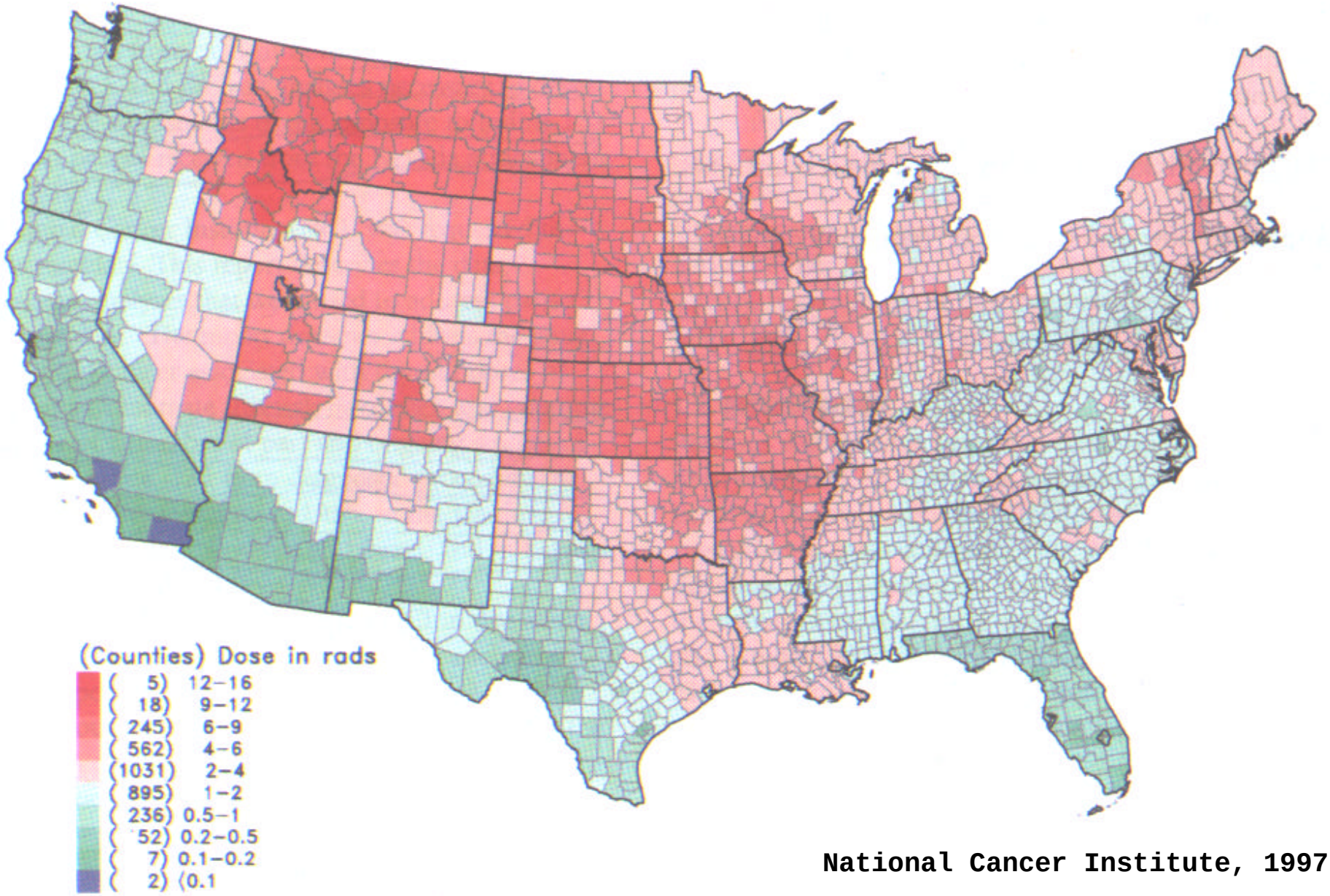


# Graphical coverage of the gummed-film network

# NCI estimate of average doses per county in the US

**Results are given in the old units of rad instead of cGy, but remember…1 rad = 1 cGy**

**Per capita thyroid doses resulting from all exposure routed from all tests**

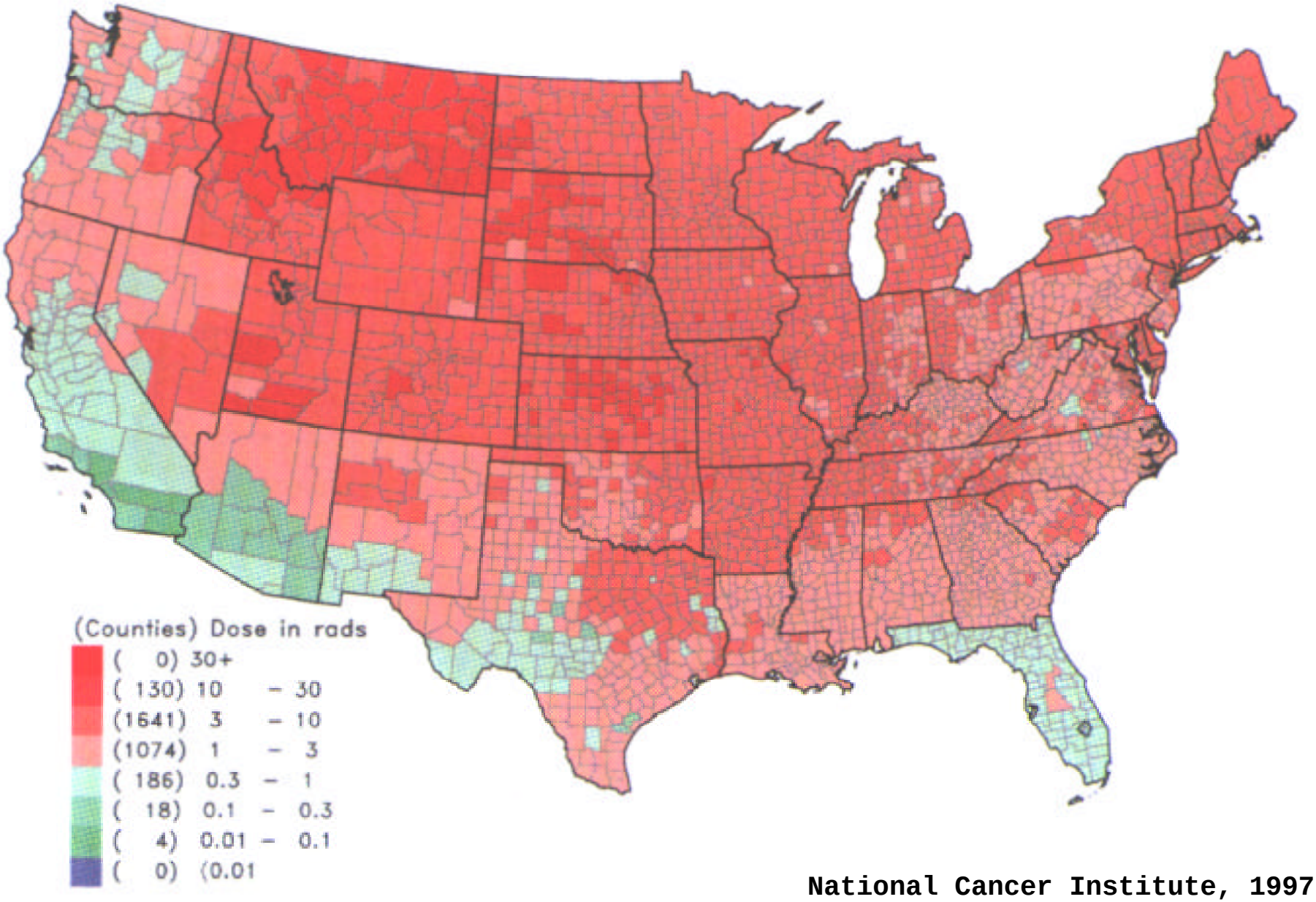



**National Cancer Institute, 1997**

# Average doses for all ages, and diet, may be misleading

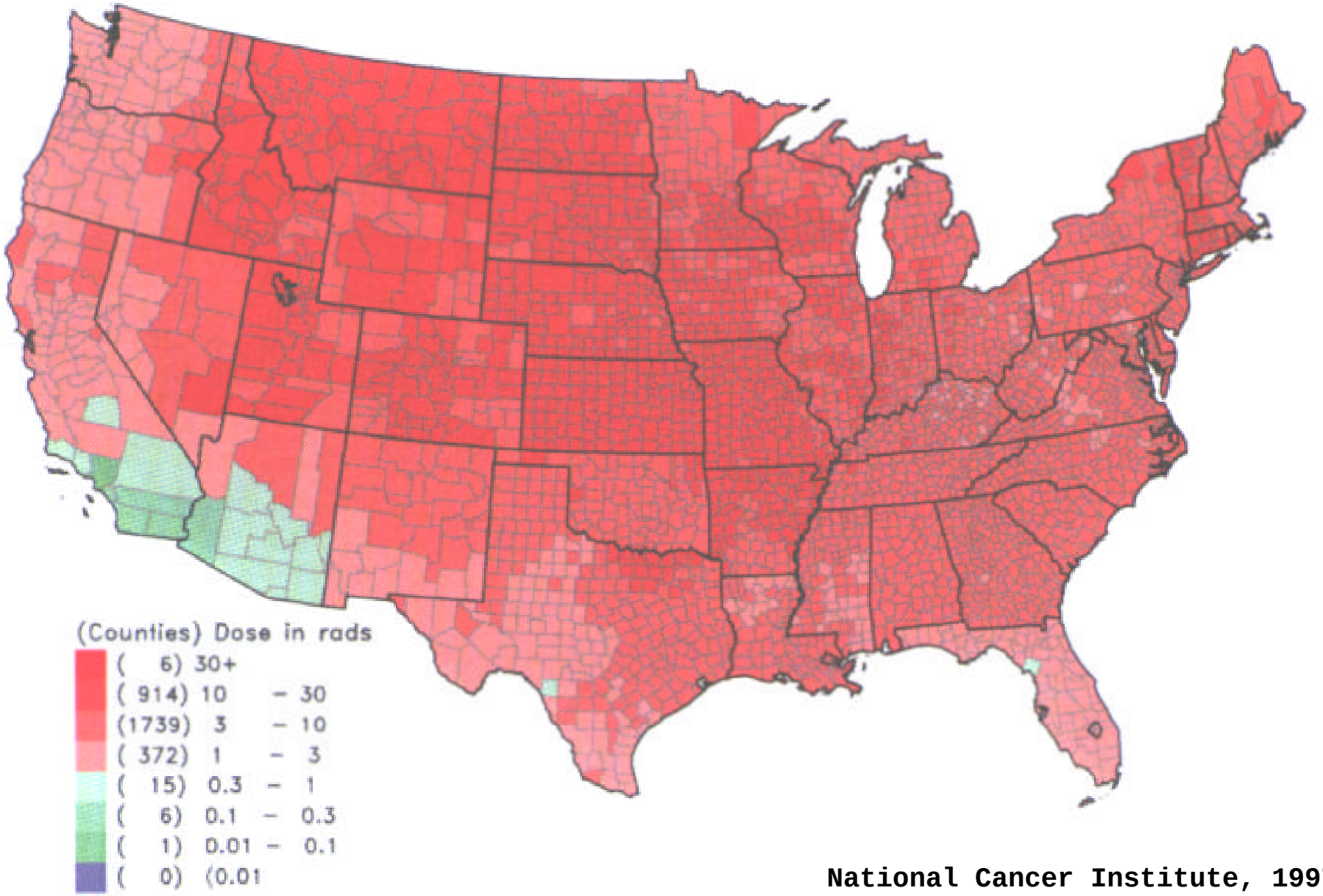
**Let’s look at thyroid doses for those in childhood at time of testing who drank milk**

**Estimates of I-131 thyroid doses for persons born on January 1, 1945**
**(Average diet; average milk consumption)**



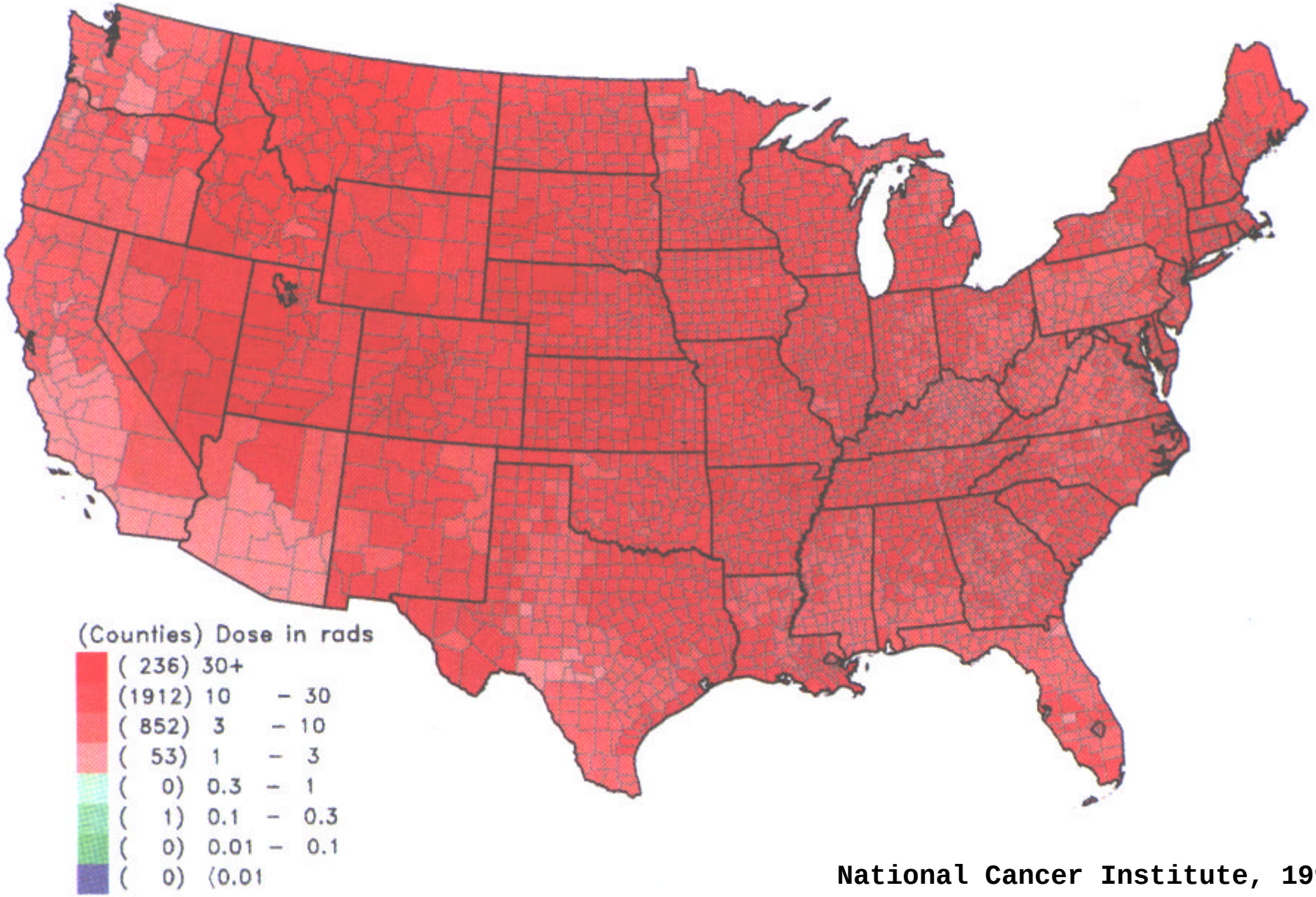

**National Cancer Institute, 1997**

**Estimates of I-131 thyroid doses for persons born on January 1, 1952**
**(Average diet; average milk consumption)**



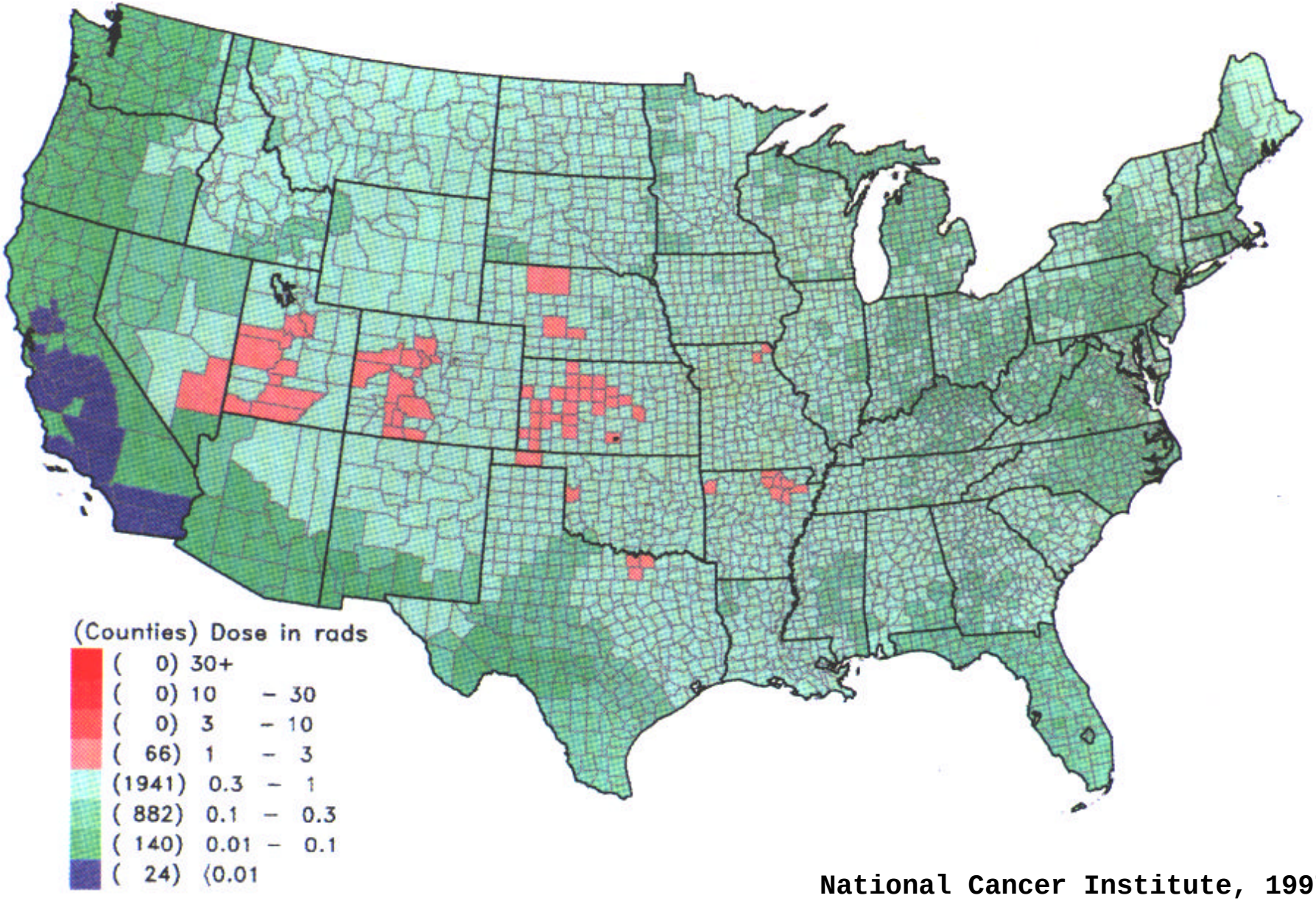

**National Cancer Institute, 1997**

**Estimates of I-131 thyroid doses for persons born on January 1, 1952**
**(Average diet; high milk consumption)**




**National Cancer Institute, 1997**

**Estimates of I-131 thyroid doses for persons born on January 1, 1952**
**(Average diet; no milk consumption)**




**National Cancer Institute, 1997**

# The risk of radiation induced autoimmune thyroiditis

- **For exposures to NTS fallout I-131 alone,**

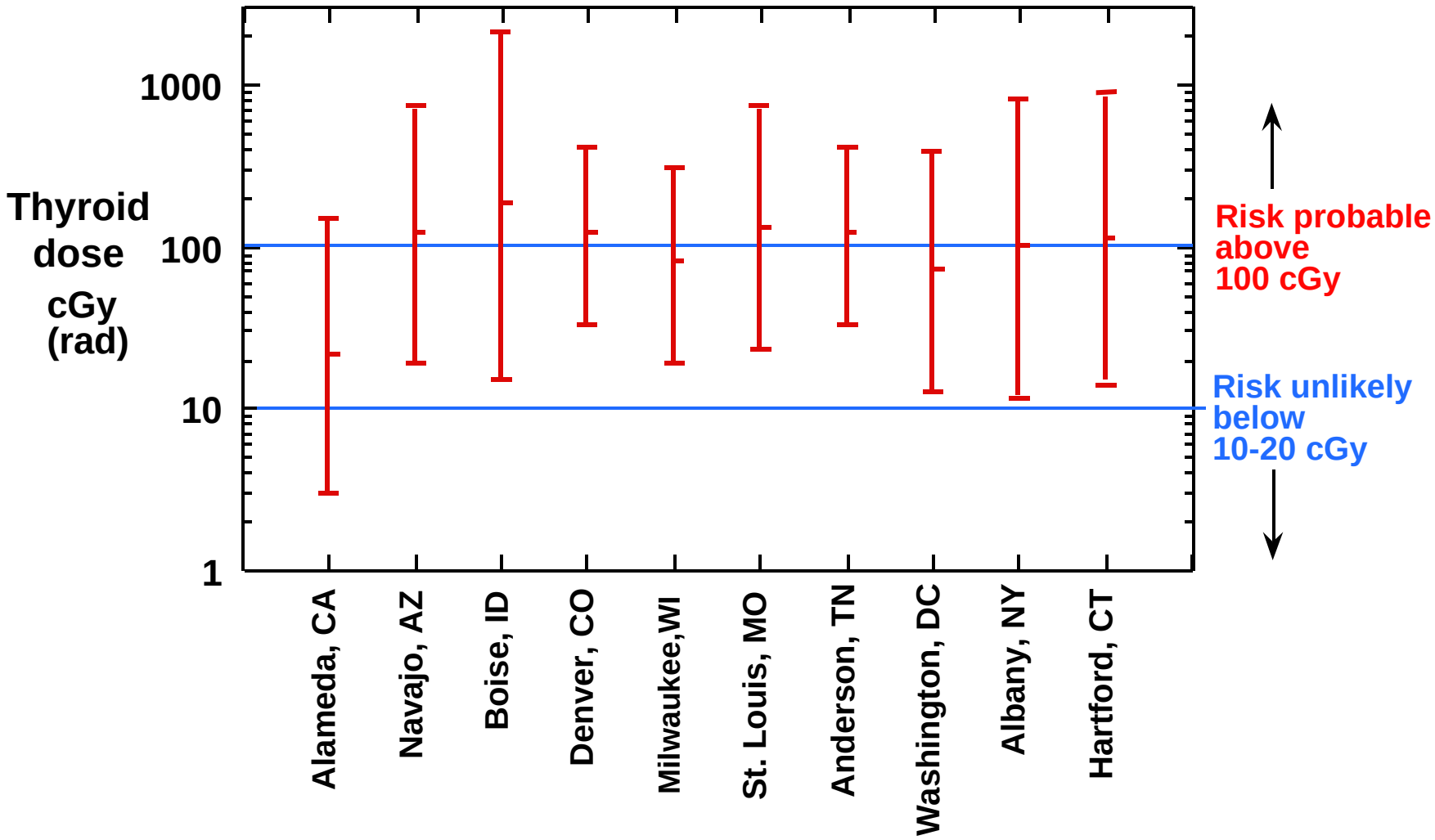
  **thyroid doses approaching or exceeding 100 cGy were likely**

  – For most children on a diet of goat's milk

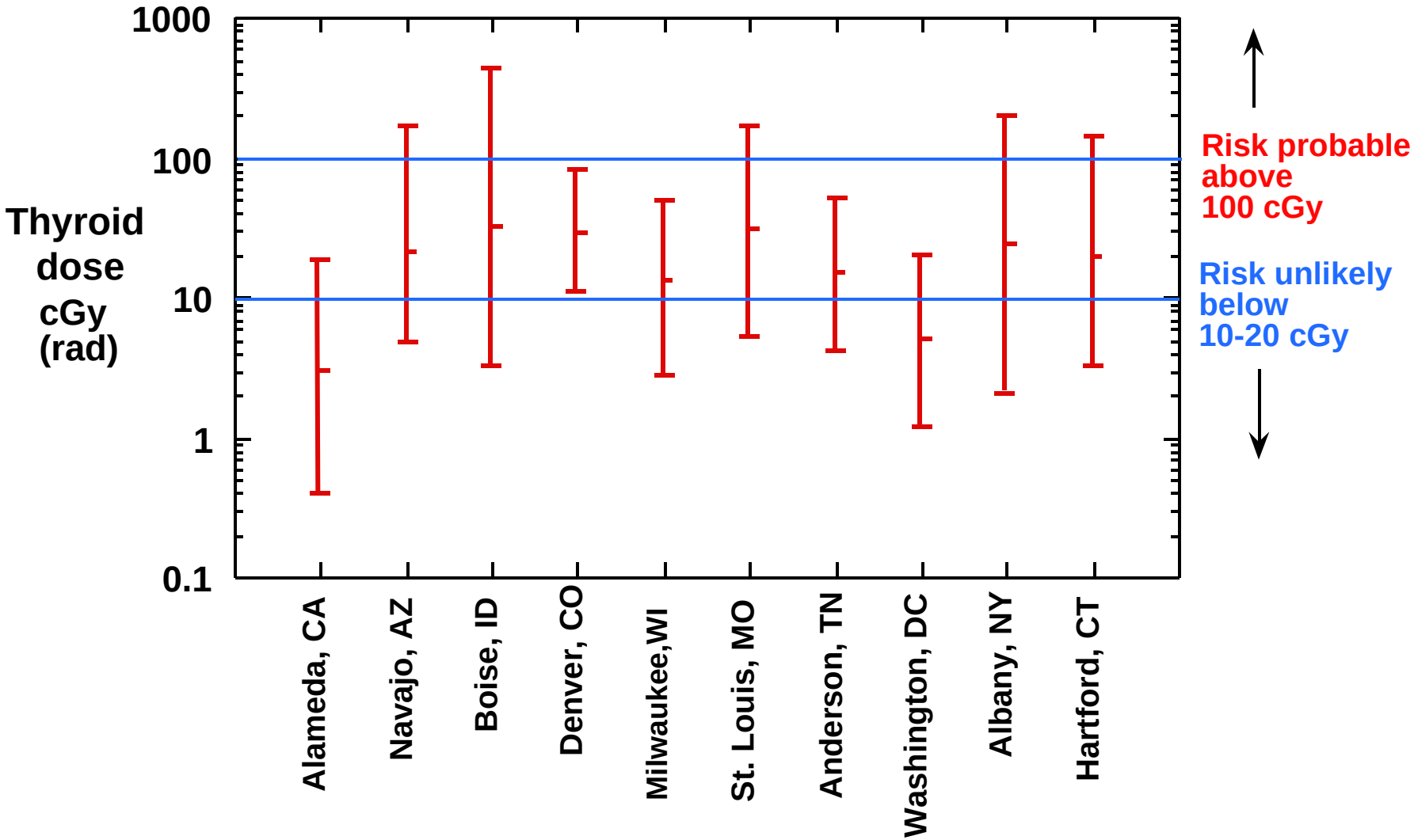
  – For some children on a diet of milk from a family cow

  – For many children who drank fresh whole milk contaminated with I-131 from multiple sources

# The risk of autoimmune thyroiditis: a child born in 1952 on a diet of goat's milk

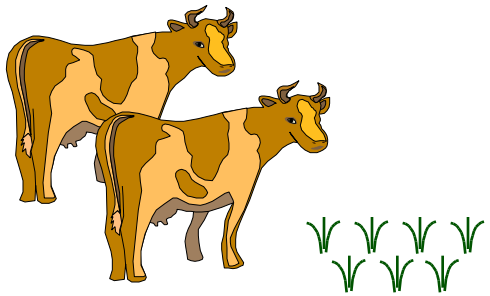


# The risk of autoimmune thyroiditis: a child born in 1952 who drank milk from a family cow



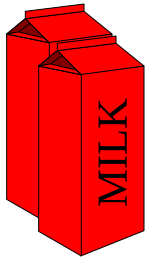
# Demonstration of Dose and Risk Calculations for Combined Exposures

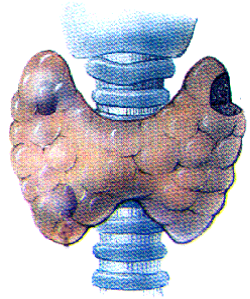
- I-131 released from X-10 (ORNL)
  - (1944-1956)*
- I-131 from the Nevada Test Site
  - (1952-1957)
- Still to be evaluated
  - I-131 from Marshall Islands
    - (1952-1958)
  - I-131 from former USSR
    - (1958-1962)



X-10

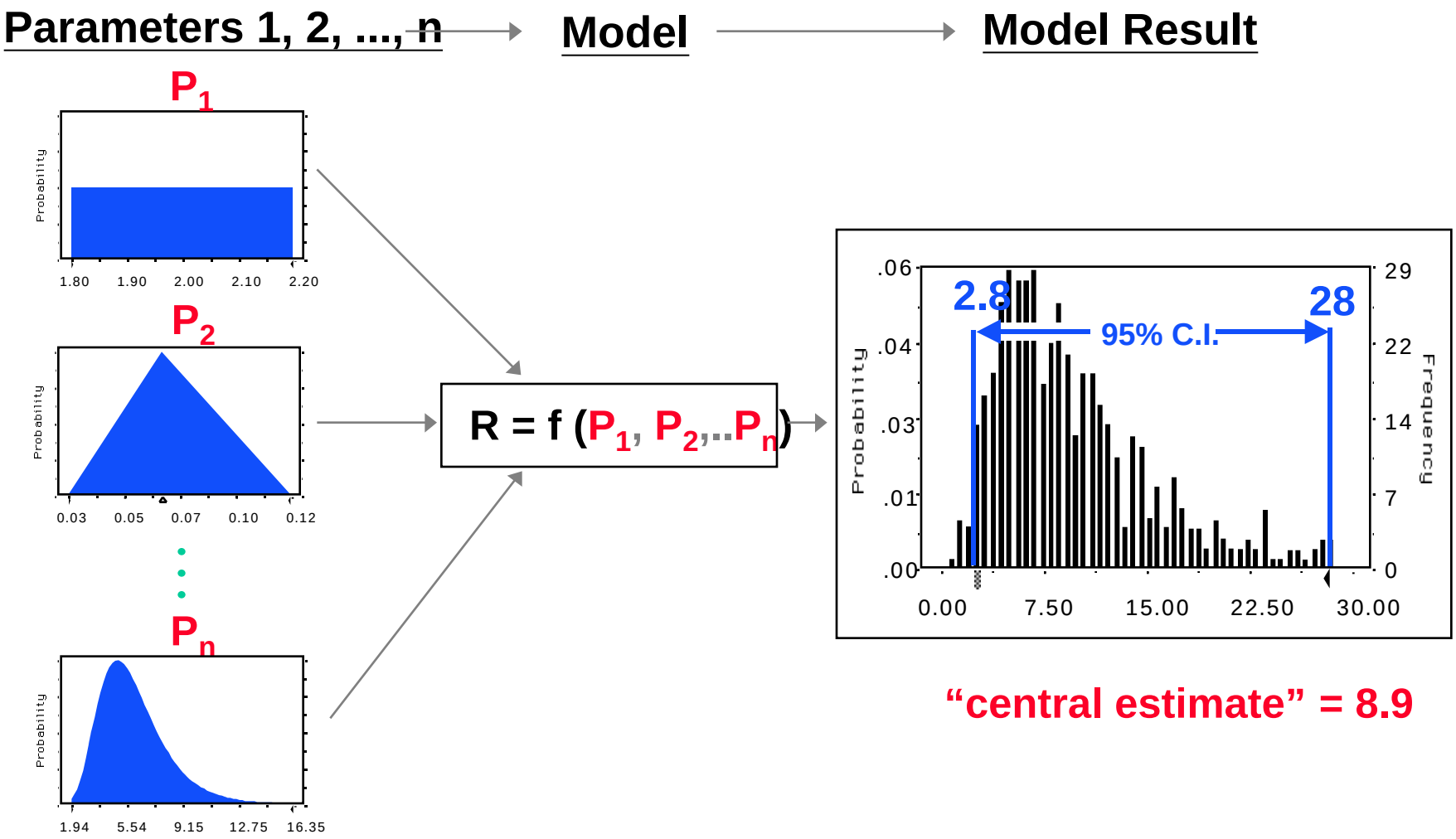
# Transport of $^{131}I$ to the human thyroid



Thyroid

# Monte Carlo simulation is the preferred method for propagating uncertainty




"central estimate" = 8.9

# The Interactive Risk and Dose Calculator (IRAD)

## A prototype developed for a presentation to the Scarboro Community

IRAD

# Conclusions

- For those presently without disease,
  - The chances are low that exposure will cause future disease
    - but, risks appear significant from the standpoint of Superfund assessment standards
  - Highest risks are to children who consumed goat's milk,
    - next highest for children consuming milk from a family owned cow
- Combined exposure to I-131 in local releases and in fallout
  - increases the risk of autoimmune thyroiditis
    - hypo- and hyperthyroidism

# Conclusions

- **For those with a diagnosed thyroid cancer or other neoplasm,**
  - **Exposure could be a substantial contributing factor to the presence of disease**
- **For children on a diet of goat's milk**
  - **Exposure could (more likely than not) have caused the disease**
- **Present estimates of the probability of causation**
  - **Exceed the eligibility criteria recommended for compensation and care of DOE workers and Atomic veterans**
  - **Upper 99th percentile of PC ≥ 50%**

# What remains to be done?

- **The present results are sufficient for consideration of a public health response**
  - **those with thyroid disease exposed to I-131 in childhood**

# What remains to be done?

- **Account for all significant sources of radioiodines released from X-10 (1944-1963)**
  - **Quantify releases from plutonium production, THOREX, and fuel ruptures at the Graphite Reactor**
  - **Re-evaluate the efficiency of the RaLa caustic scrubber**
  - **Match release periods with prevailing meteorological conditions**
  - **Use dispersion models appropriate for complex terrain, regional transport, and time-varying releases**
- **Consider the cumulative effect of exposure to fallout radioiodines**
  - **NTS, Marshall Is., former USSR**
    - **(1952 through 1962)**