INTRODUCTION TO DOSIMETRY OF IODINE-131 (^{131}I)

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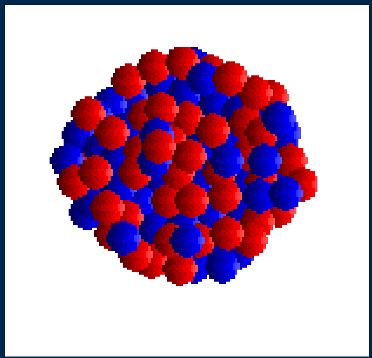
^{131}I is but one isotope of about 37 known isotopes of iodine. The isotopes of iodine have atomic masses from 108 to 144.

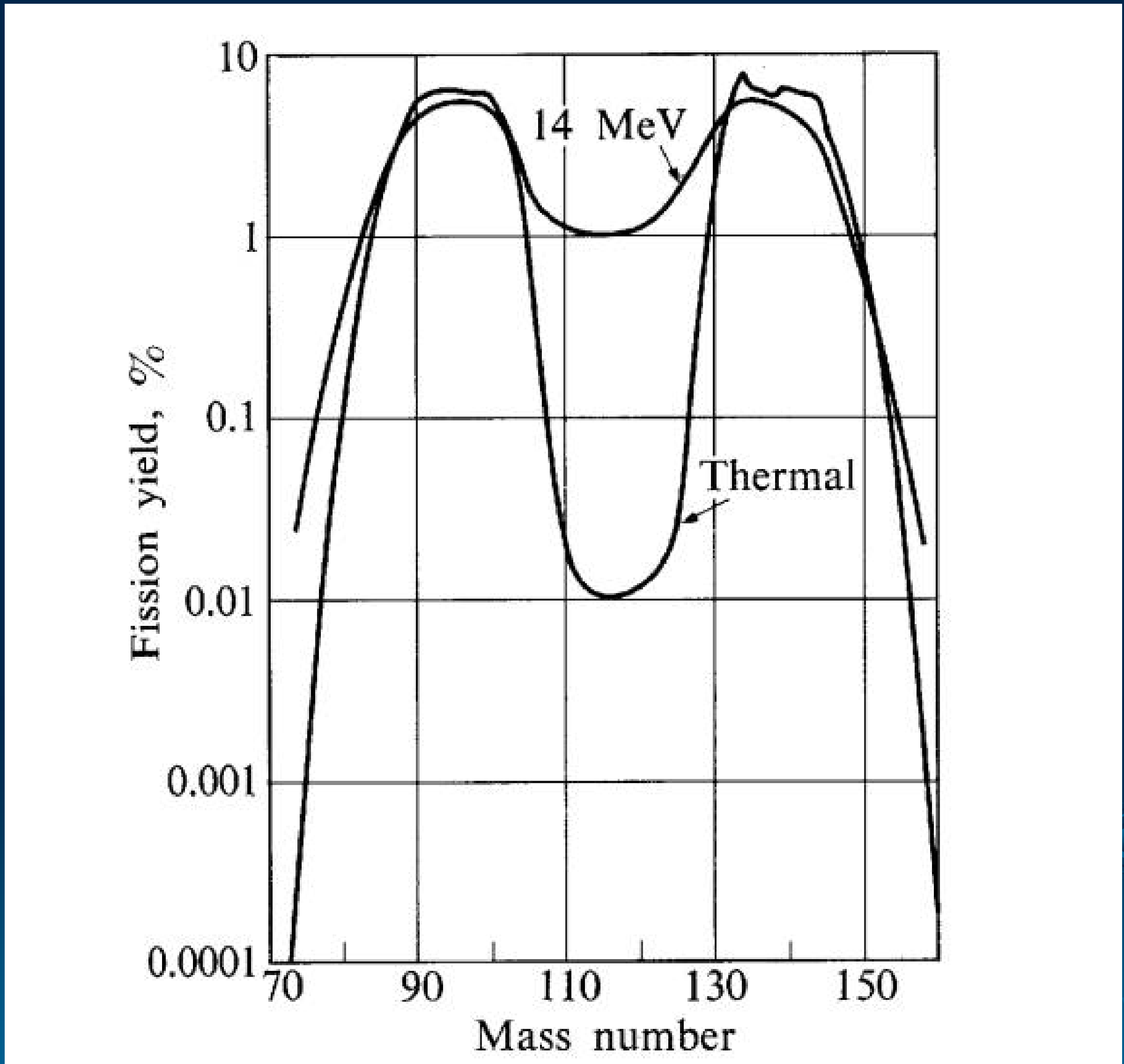
All are unstable against radioactive decay except ^{127}I.

<u>Examples of Iodine Isotopes</u>: $^{123}_{53}I$, $^{124}_{53}I$, $^{125}_{53}I$, $^{126}_{53}I$, $^{127}_{53}I$, $^{128}_{53}I$, $^{129}_{53}I$, $^{130}_{53}I$, $^{131}_{53}I$, $^{132}_{53}I$

Why are radioiodine isotopes associated with nuclear weapons fallout and nuclear reactor accidents?

Nuclear fission of uranium (or plutonium) creates intermediate size mass products, primarily with masses of 90-100 and 130-140



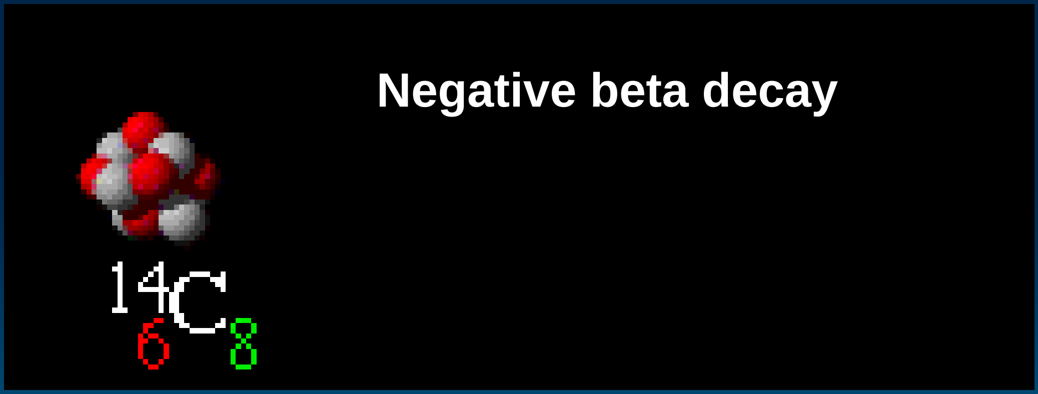


10
1
0.1
0.01
0.001
0.0001
70
90
110
130
150
Mass number
Fission yield, %
14 MeV
Thermal

Most all of the iodine isotopes (except for a few meta-stable states) decay by positive or negative beta decay.

We will only review negative beta decay here because that is what is relevant to ^{131}I.

Negative beta decay: the decay of a neutron into a proton, which remains in the nucleus, and an electron, which is emitted as a beta particle

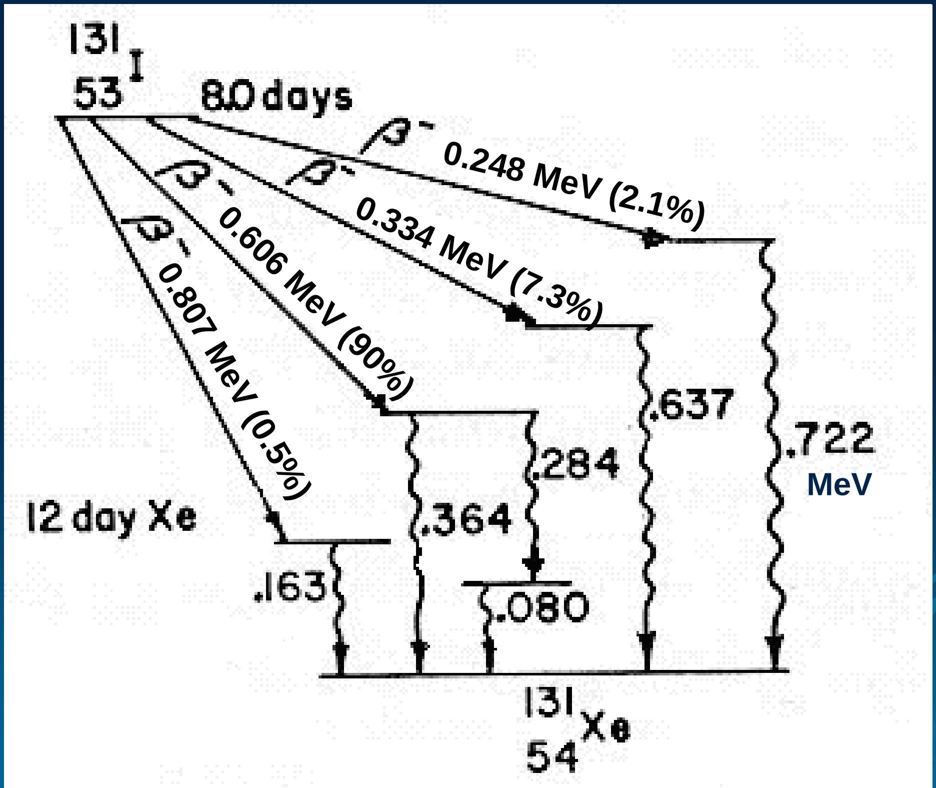


The Q value, or energy released from β^- decay is primarily the difference in the rest masses of iodine and its decay product, xenon.

Q_β = 970.8 keV (average energy of beta particles is about ~183 keV)

Half-life of ^{131}I about 8.02 days.

There are several beta-decay possibilities, each with their own probability of decay. The most important parts of the decay scheme are shown below.



Beta Decays of ^{131}I (8.02 d)

E_β endpoint (keV)	I_β (%)	Decay mode
247.89	2.10	β^-
303.86	0.651	β^-
333.81	7.27	β^-
606.31	89.9	β^-
629.66	0.050	β^-
806.87	0.48	β^-

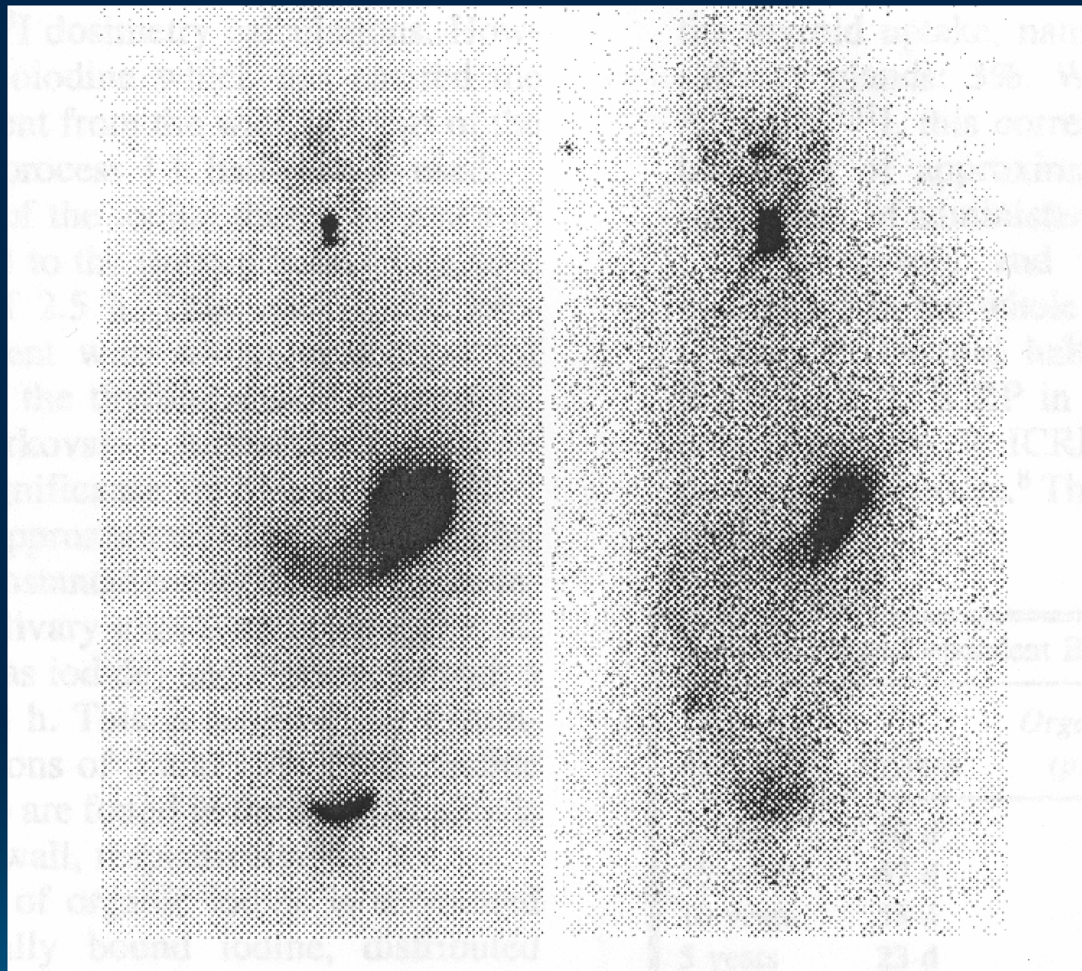
X-rays from ^{131}I (8.02 d)

E (keV)	I (%)	Assignment
4.11	0.215	Xe $L_{\alpha1}$
4.41	0.133	Xe $L_{\beta1}$
29.46	1.40	Xe $K_{\alpha2}$
29.78	2.59	Xe $K_{\alpha1}$
33.56	0.24	Xe $K_{\beta3}$
33.62	0.46	Xe $K_{\beta1}$
34.42	0.14	Xe $K_{\beta2}$

Gammas from ^{131}I (8.02)

$E\gamma$ (keV)	$I\gamma$ (%)	Decay mode
80.185	2.62	β^-
85.9	0.00009	β^-
163.93		β^-
177.21	0.270	β^-
232.18	0.0032	β^-
272.50	0.0578	β^-
284.31	6.14	β^-
295.8 *2*	0.0018	β^-
302.4 *2*	0.0047	β^-
318.09	0.0776	β^-
324.65	0.0212	β^-
325.79	0.274	β^-
358.4 *2*	0.016	β^-
364.49	81.7	β^-
404.81	0.0547	β^-
503.00	0.360	β^-
636.99	7.17	β^-
642.72	0.217	β^-
722.91	1.773	β^-

Whole-body nuclear medicine scan showing iodine gamma emissions



^{123}I ($t_{1/2}$=13.2 h) at 4 and 24 fhr after injection (158 keV γ)

The general equation to determine the dose following an accidental intake or following an oral medical administration of ^{131}I is:

$$D = \int_0^\infty \frac{A\ f_1\ f_2\ R(t)}{M_T(a)} [\sum_{i=1}^{n} Y_i\ E_i\ AF_i(T \leftarrow S, a)]dt$$

where,

A is the activity intake (or the administered activity of ^{131}I (Bq),

f_1 is the fraction of the iodine intake that is transferred to blood (generally assumed to be close to 100%)

f_2 is the fraction of the iodine intake that is absorbed by the thyroid (the rest is excreted primarily through urine),

R(t) is the fraction of the amount that enters the thyroid that is retained at any time, t,

Y_i is the fractional yield of radiation type i, per nuclear transformation,

E_i is the energy released per decay (~0.19 MeV β and ~0.38 MeV γ per nuclear transformation).

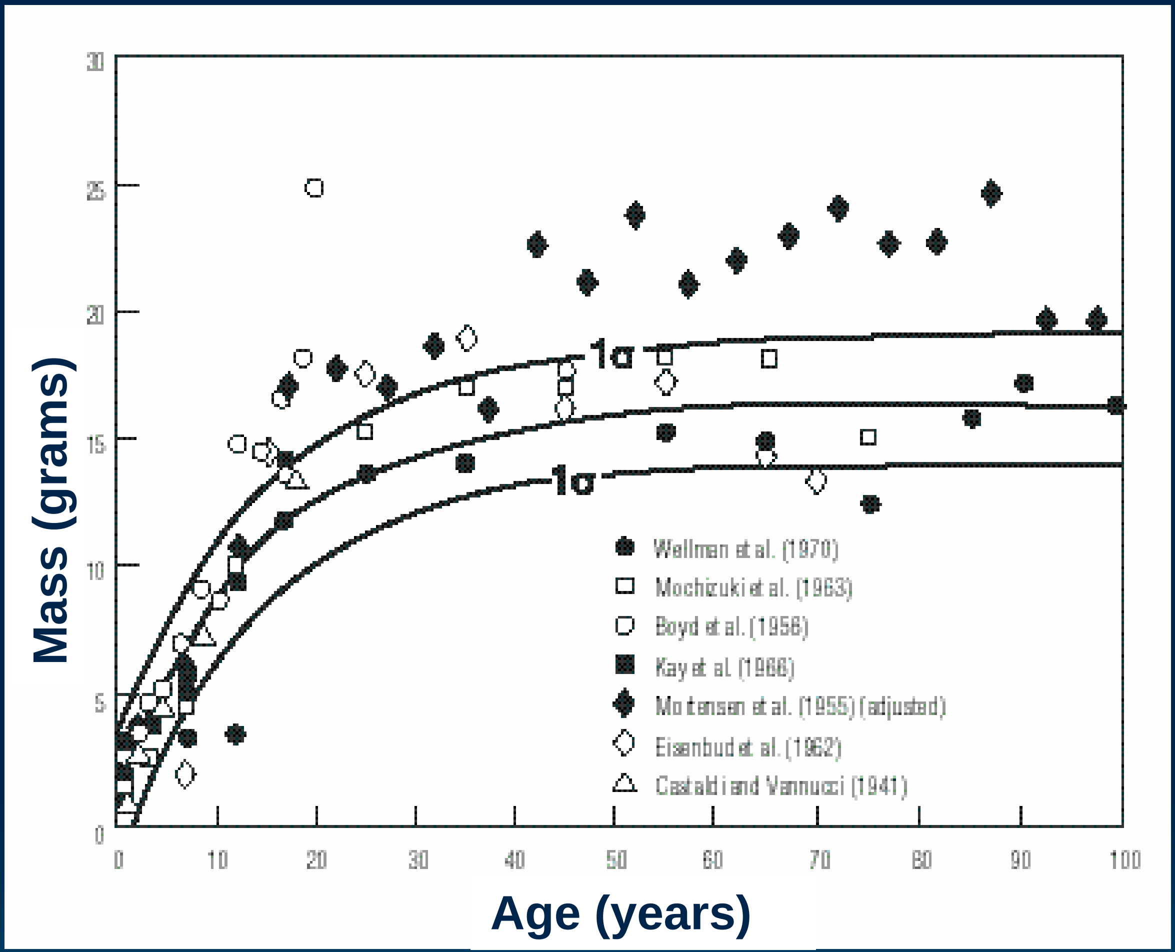
$AF_i(T \leftarrow S,a)$ is the fraction of the energy emitted in the source organ S that is absorbed, in the target organ T, and is a function of age, a,

$M_{th}(a)$ is the mass of the thyroid in this case) and is a function of age, a

Some typical assumptions that affect the estimated dose:

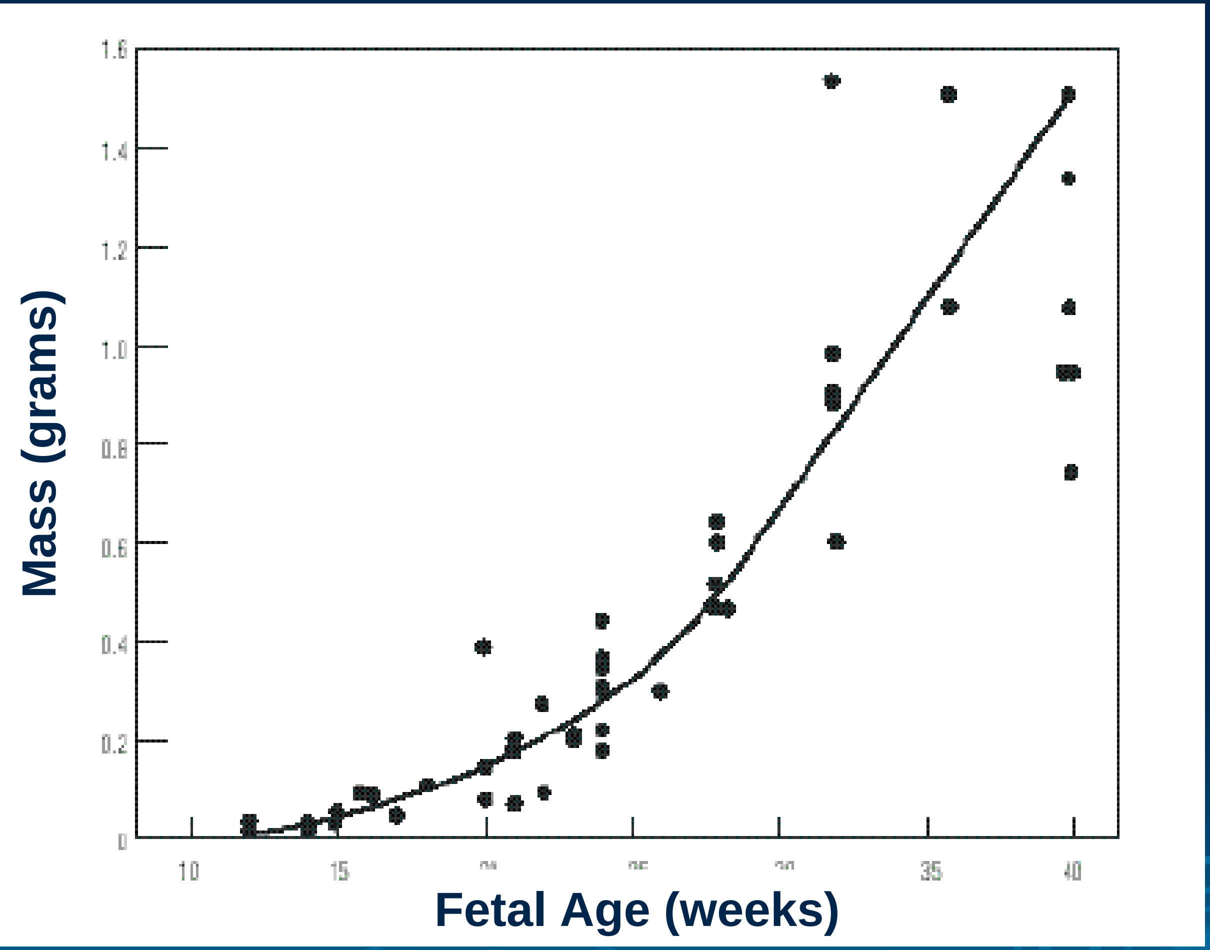
1) The kinetic energy of beta particles and photons <10 keV are fully absorbed in the target organ.
2) The fractional uptake by the gland is 25-30%, from age 3 mos. and afterwards.
3) Everyone has a normal inventory of stable iodine (^{127}I) in their thyroid which is about 10 mg for the adult.
4) In countries where stable iodine intake is low, a physiologically-based increase in thyroid mass usually occurs (sometimes resulting in goiters).
5) If stable iodine inventory is low, additional uptake of radioiodine may take place but is generally compensated by the increase in mass.
5) The retention of iodine in the thyroid gland follows a 2-component exponential loss. The "apparent" retention half-time in adults is assumed to be 80 days, and 15, 20, 30, 70 days for 3 months, 1 yr, 5 yr, 10yr old children, respectively.
6) Thyroid mass is predictable (though uncertain on an individual level) based on age alone.
7) Absorbed dose within the thyroid gland is moderately uniform.
8) Doses received by other organs from radioiodine are small compared to the thyroid.

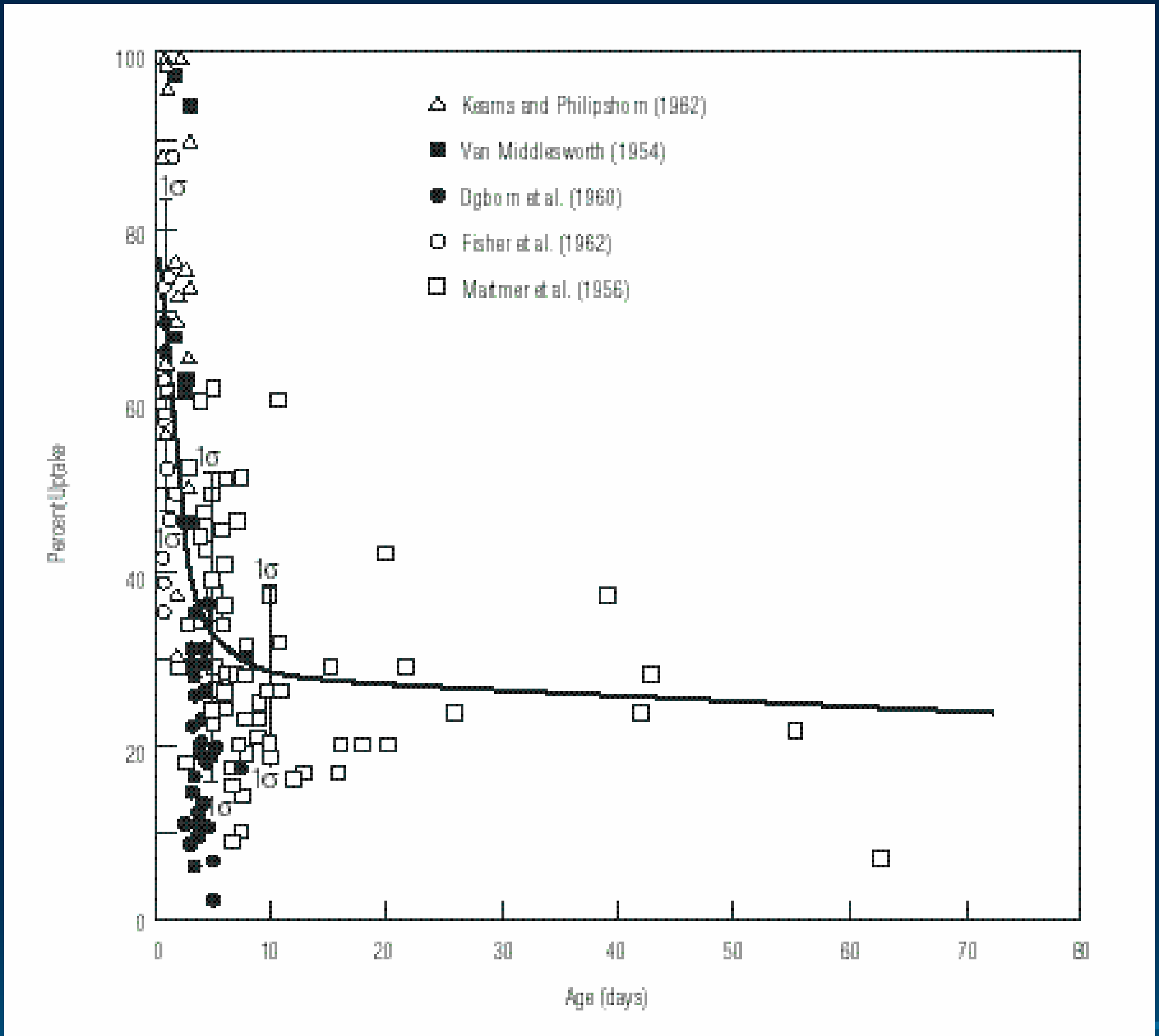
Some of the data



Thyroid gland mass as a function of age. Adapted from Wellman et al. (197) by NCI (1997).

When in utero exposure takes place, parameters for the fetus must be used. Here the fetal thyroid gland mass as a function of gestation age is shown NCI (1997).





Thyroid uptake as a function of age shortly after birth (NCI 1997 from many sources).

In the dose equation, only R(t) has any time-dependence within the short half-life of 8 days. The age dependence arises from the $AF_i(T \leftarrow S,a)$ and $M_T(a)$.

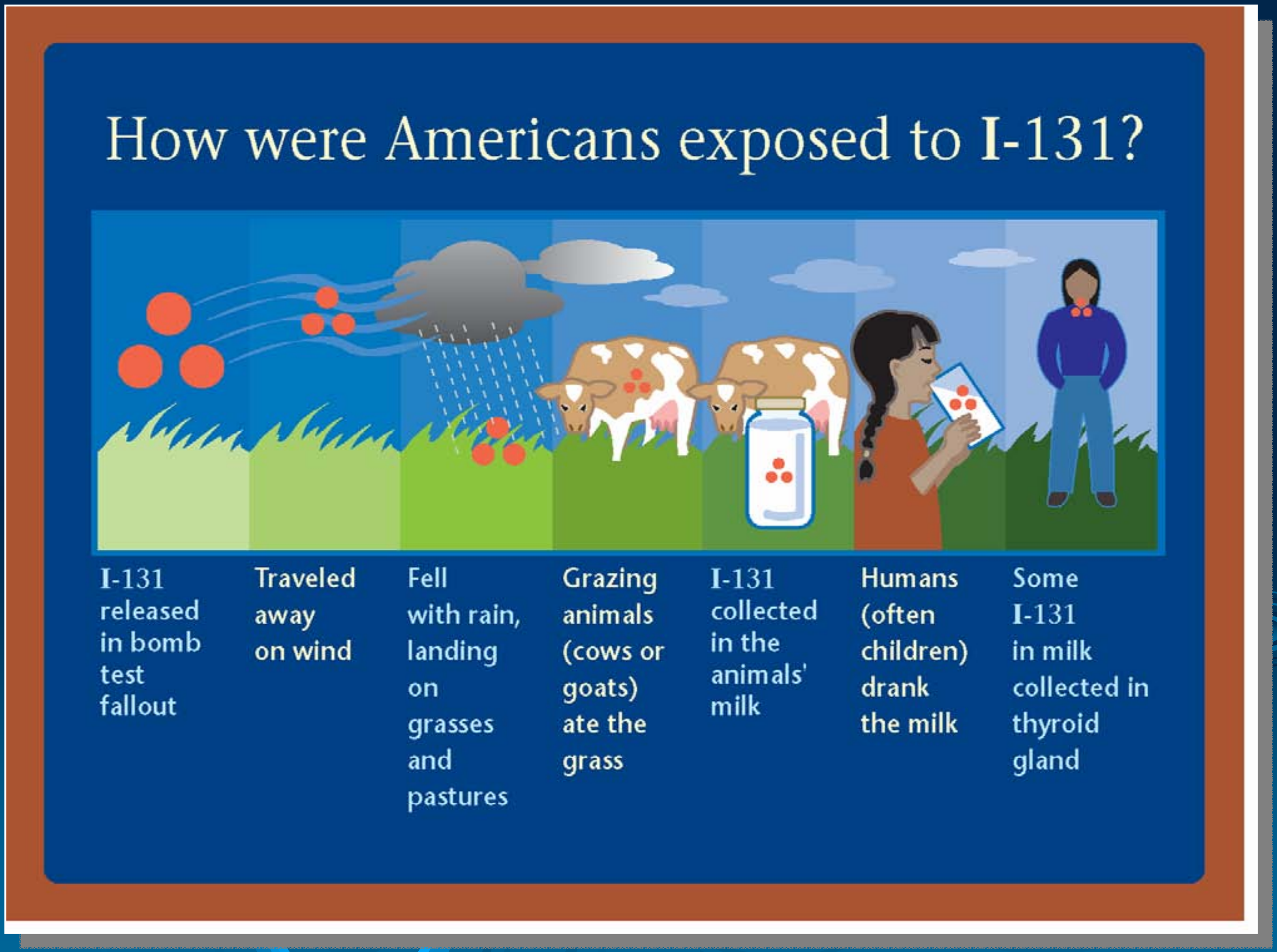
Calculated values of absorbed dose per unit activity intake are available

Absorbed Dose (Gy) Received per Bq of ^{131}I Ingested for Selected Organs (ICRP 1989)

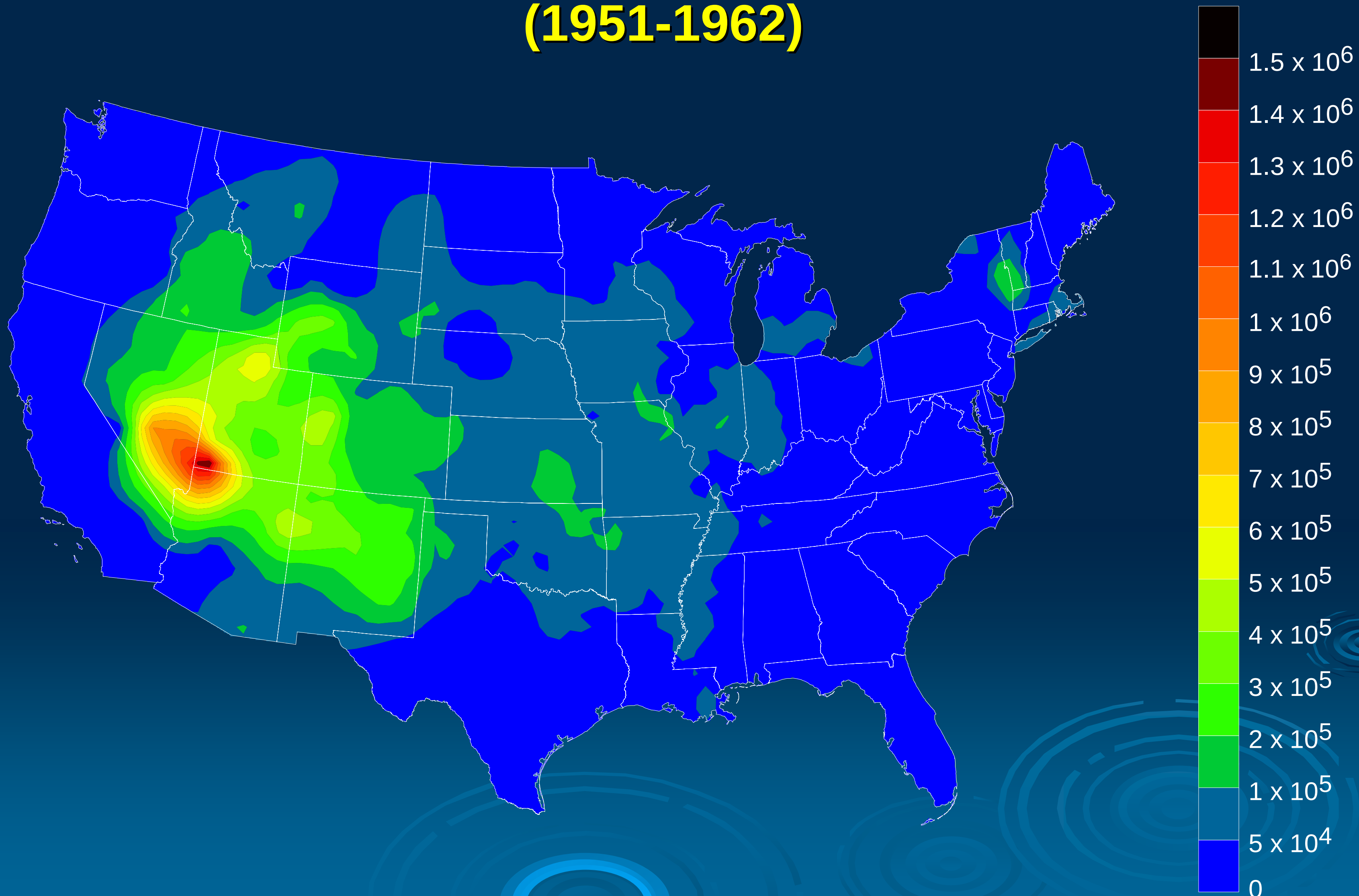
ORGAN	3 mos	1 Year	5 Year	10 Year	15 Year	Adult
Bladder wall	3.70E-10	2.40E-10	1.30E-10	7.30E-11	4.50E-11	3.80E-11
Breast	5.60E-10	4.10E-10	2.30E-10	1.50E-10	7.30E-11	5.80E-11
Stomach wall	3.40E-09	2.00E-09	9.80E-10	5.6E-10	3.80E-10	3.00E-10
Liver	4.60E-10	3.20E-10	1.70E-10	9.8E-11	5.90E-11	4.70E-11
Ovaries	3.90E-10	2.70E-10	1.40E-10	7.80E-11	4.70E-11	4.00E-11
Testes	3.40E-10	2.30E-10	1.10E-10	6.60E-11	4.00E-11	3.40E-11
Thymus	2.30E-09	1.70E-09	8.50E-10	4.70E-10	2.30E-10	1.50E-10
Thyroid	3.70E-06	3.60E-06	2.10E-06	1.10E-06	6.90E-07	4.40E-07

In addition to studies of medical administrations of ^{131}I, NCI has been heavily involved in assessing the exposure of the American people to ^{131}I from fallout originating from nuclear weapons tests conducted in Nevada during the 1950s and early 1960s.

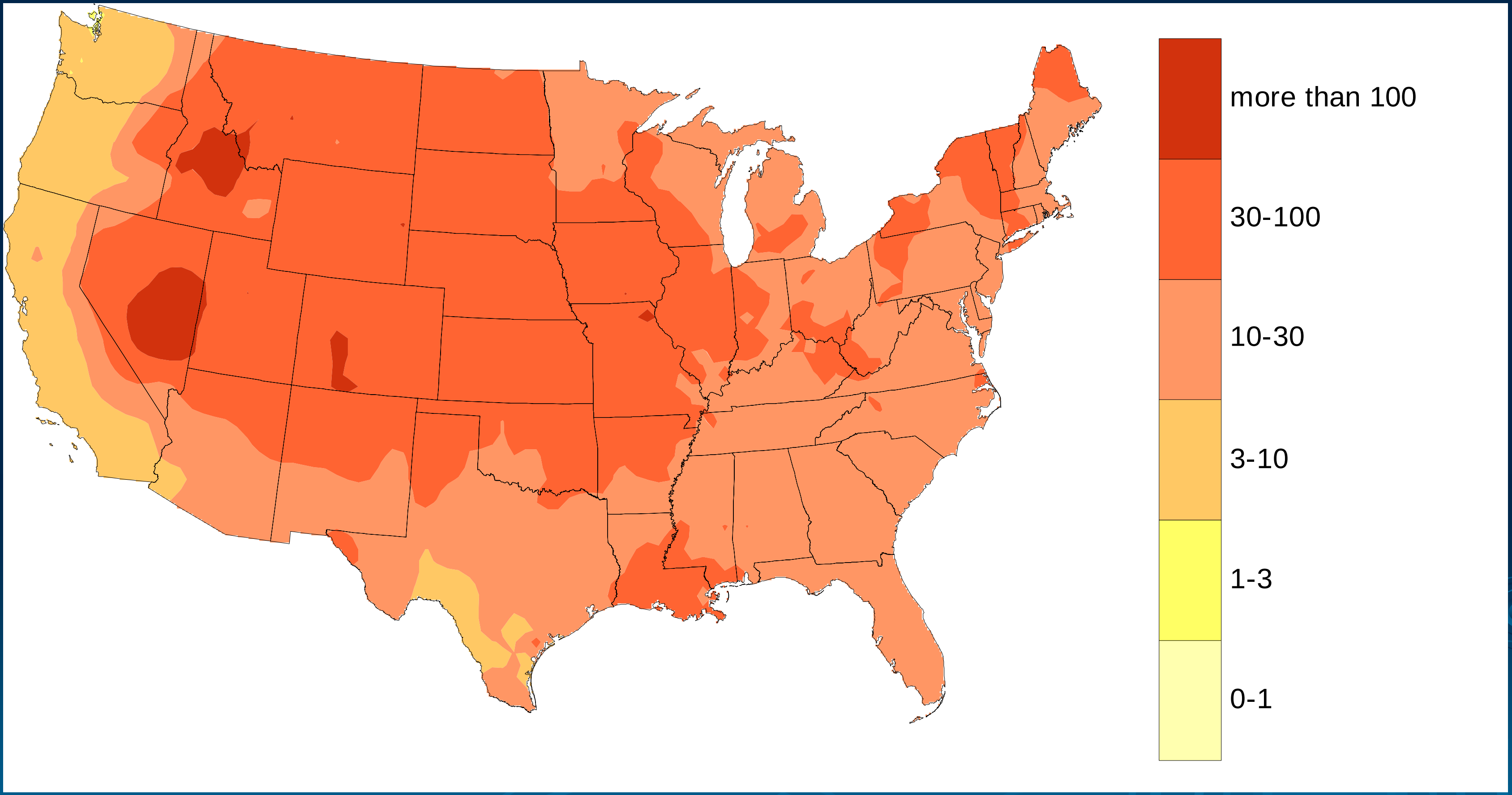
Example of some of the materials produced to communicate with the public. →



NCI Estimated I-131 Deposition Density (Bq/m²)
From all NTS Atmospheric Tests
(1951-1962)



Geographic pattern of average internal dose (mGy) to the thyroid of a child born 1 January 1951 from ^{131}I from all NTS tests



NCI dosimetry model (see NCI 1997) accounts for:

- Geographic variation of deposition.
- Wet and dry deposition processes and historical meteorologic data.
- Reconstruction of pasture practices and milk distribution networks in the 1950s.
- Multiple pathways of exposure (dairy products, other food types, inhalation).
- Individual residence history and estimates of milk consumption rate including breast feeding.

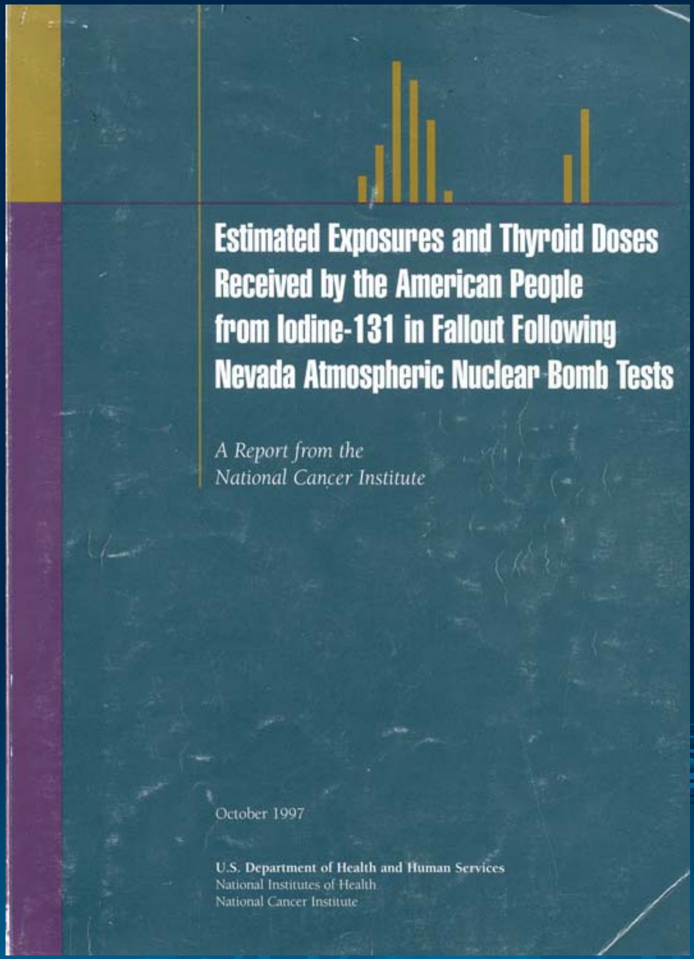


Illustration of Importance of Pathways

Estimated thyroid doses per unit deposition normalized to the dose from cow's milk for 1-year old child. Example is for cows on pasture, light rain, long distance (>1000 km) from NTS.

	Age (years)			Per capita
	1-4	5-9	10-14	
Ingestion				
Cows' milk	1.00	0.67	0.43	0.25
Goats' milk	0.002	0.002	0.001	0.001
Cottage cheese	0.006	0.003	0.003	0.003
Eggs	0.06	0.03	0.02	0.03
Leafy vegetables	0.01	0.01	0.01	0.02
Inhalation				
Air	0.003	0.002	0.002	0.002

You can find the
NCI ^{131}I Fallout Information on the web

and NCI Thyroid Cancer Screening Decision Aid Pamphlet at

http://cancer.gov/i131

or

Dose Calculator

http://ntsi131.nci.nih.gov/

Now (if time permits) for a demonstration of NCI web-based dose and risk calculator for ^{131}I in fallout.