Internal dosimetry of workers

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ICRP Committee2

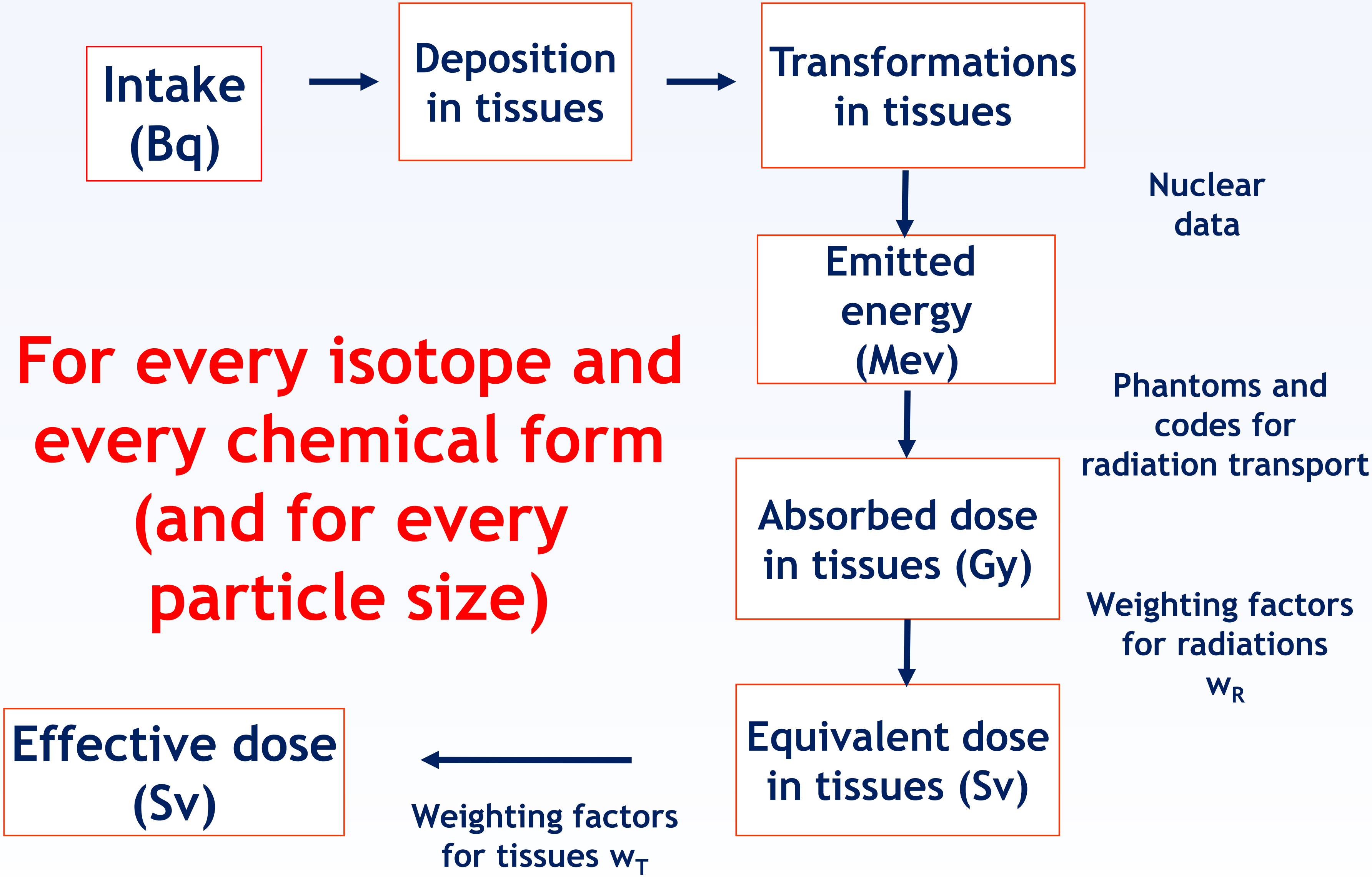
Seminar of the Federal Commission on Radiation Protection
25 March 2022

Internal exposures to radiations are managed by the use of the committed effective dose

$$e(\tau) = \sum_T w_T \left[\frac{h_T^M(\tau) + h_T^F(\tau)}{2} \right]$$

Cannot be measured !!

Calculating committed effective dose after internal contamination is a complex procedure



For every isotope and every chemical form (and for every particle size)

Complex procedure, limited to experts

ICRP proposes tools, to allow non-specialists to perform dose assessment

1. Biokinetic models
2. Dose coefficients
3. Bioassays functions

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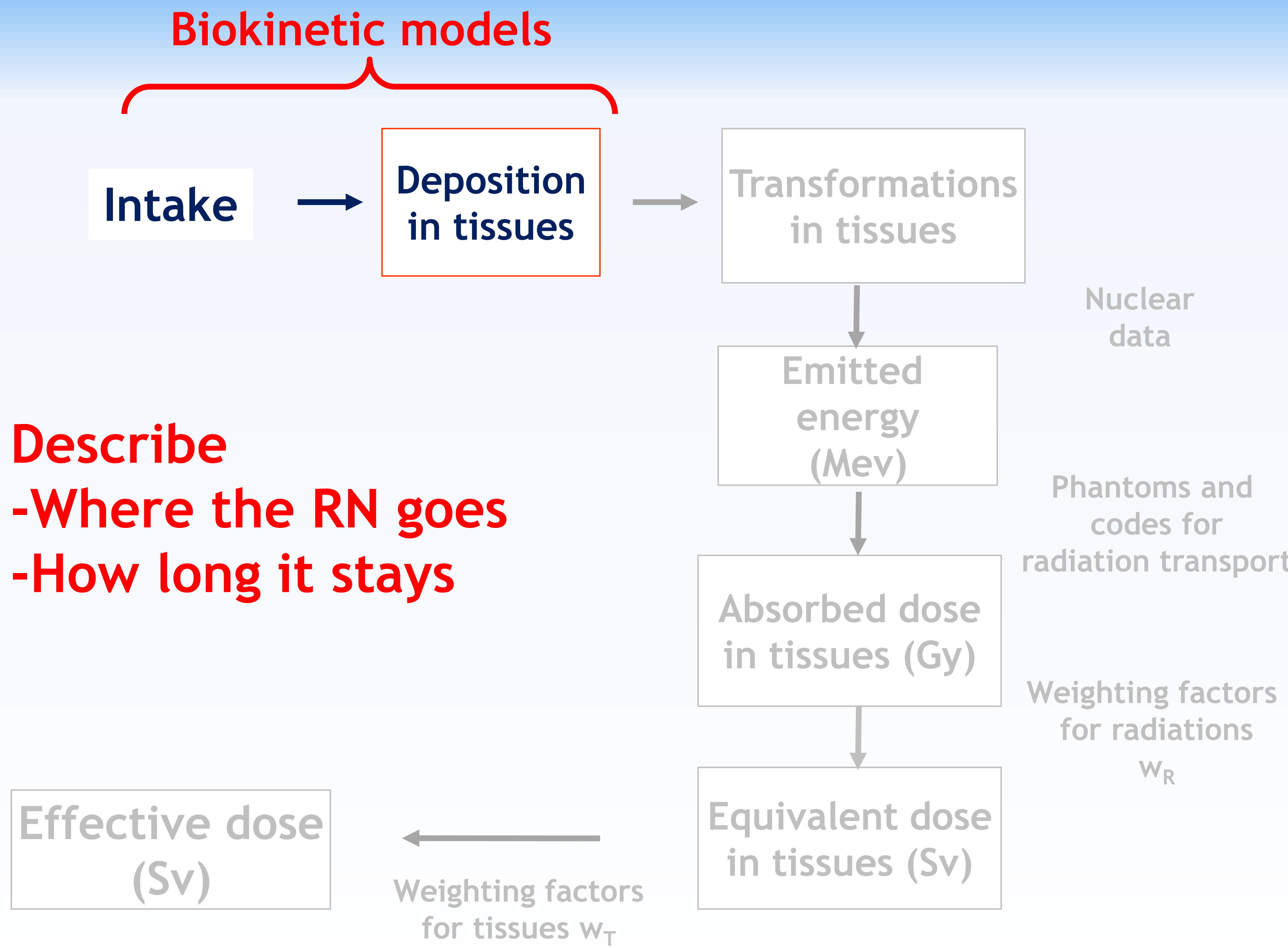
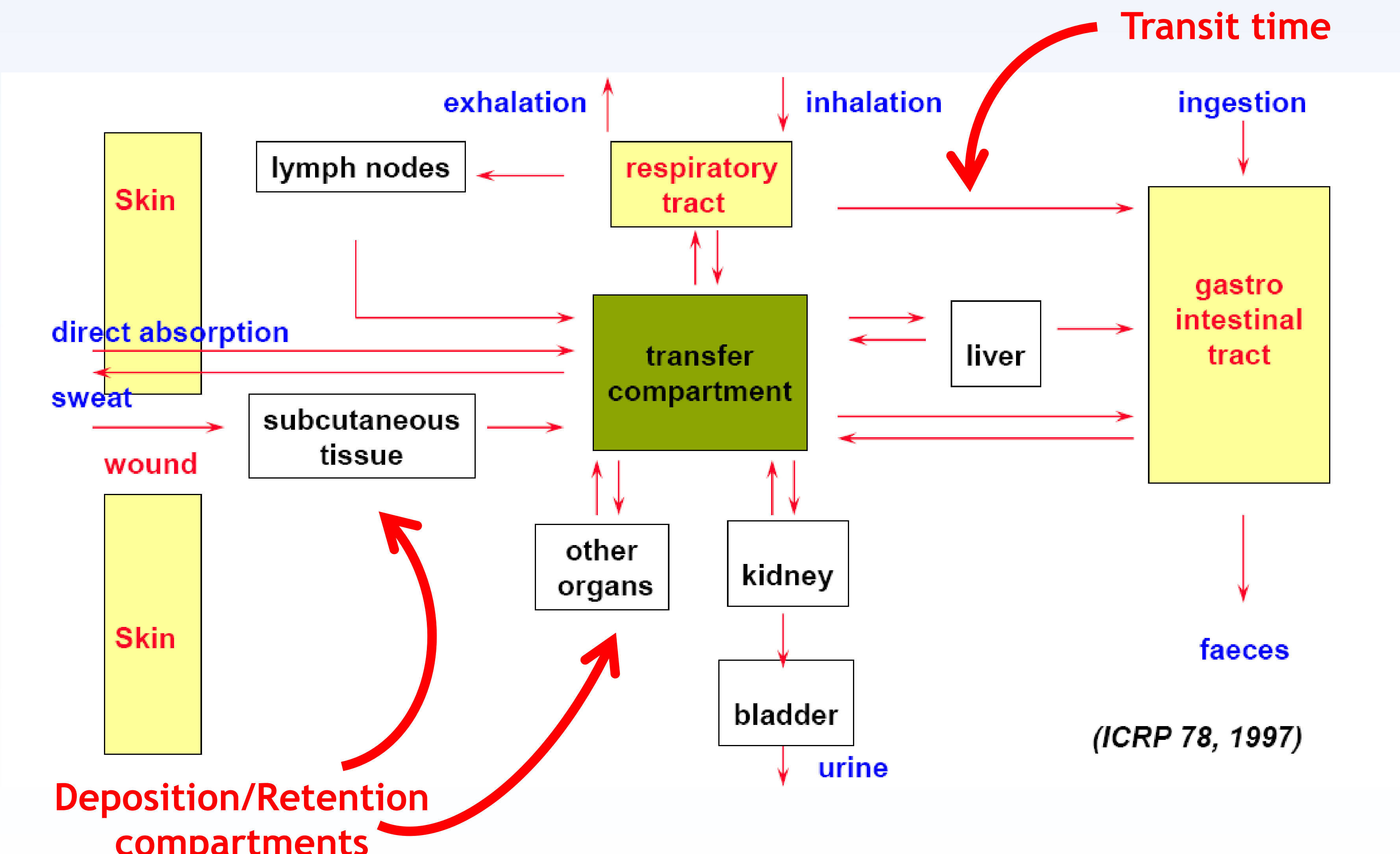
ICRP proposes tools, to allow non-specialist to perform dose assessment

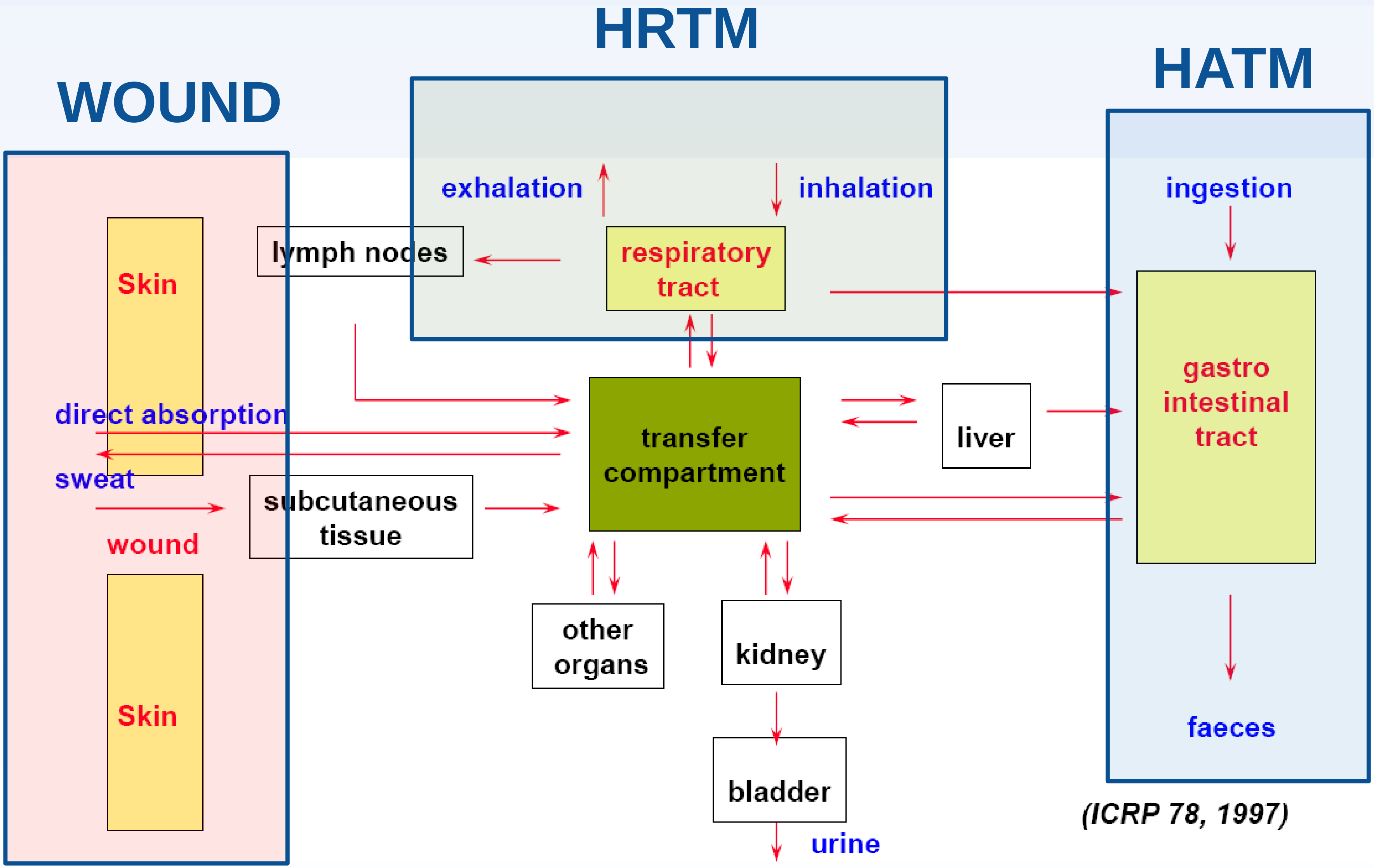
1. **Biokinetic models**
2. Dose coefficients
3. Bioassays functions


Biokinetic models
Intake
Deposition in tissues
Transformations in tissues
Nuclear data
Emitted energy (Mev)
Phantoms and codes for radiation transport
Absorbed dose in tissues (Gy)
Weighting factors for radiations w_R
Equivalent dose in tissues (Sv)
Weighting factors for tissues w_T
Effective dose (Sv)
Describe
-Where the RN goes
-How long it stays

Generic biokinetic model

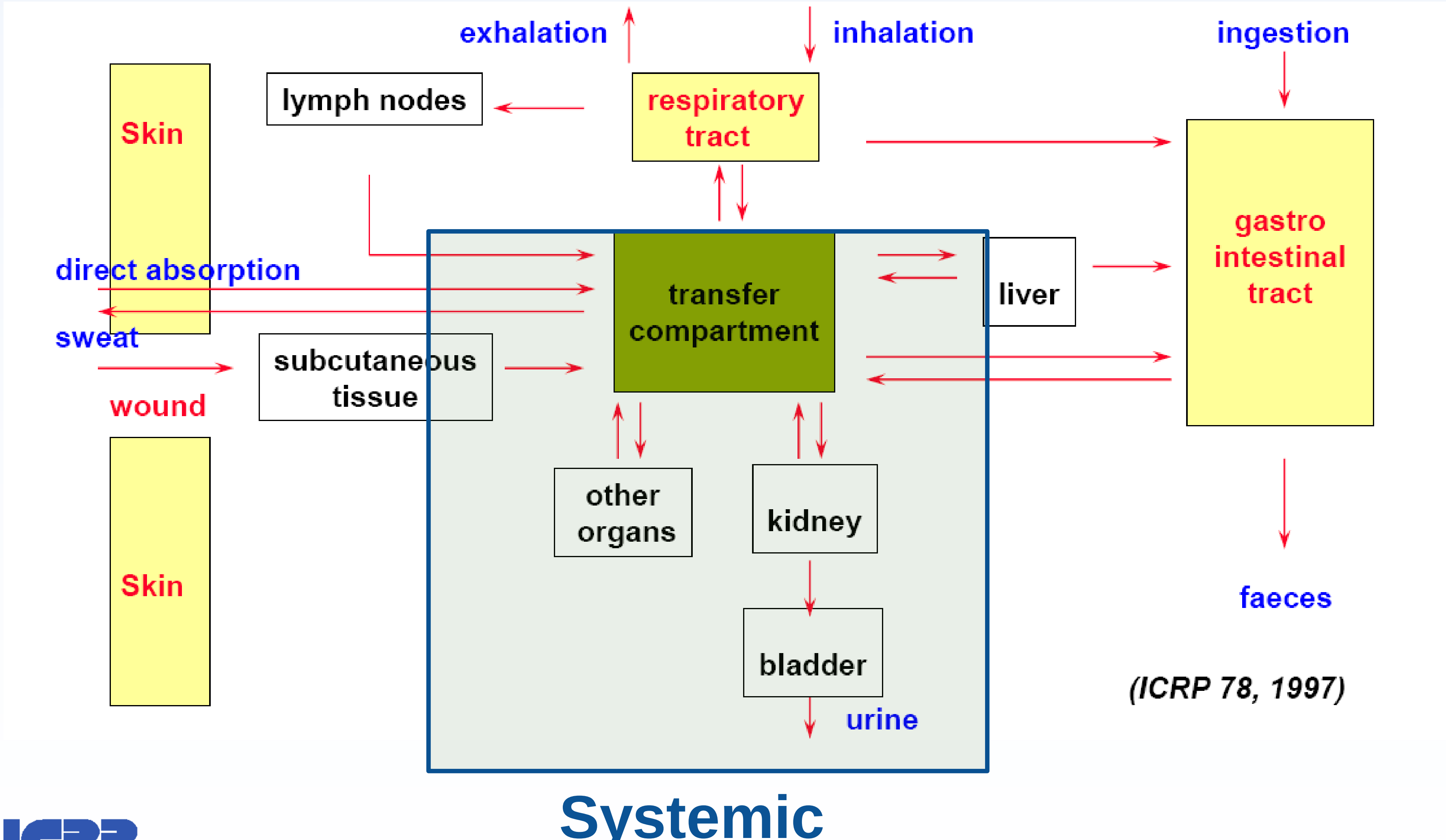


Parameters depend mainly on chemical forms



(ICRP 78, 1997)

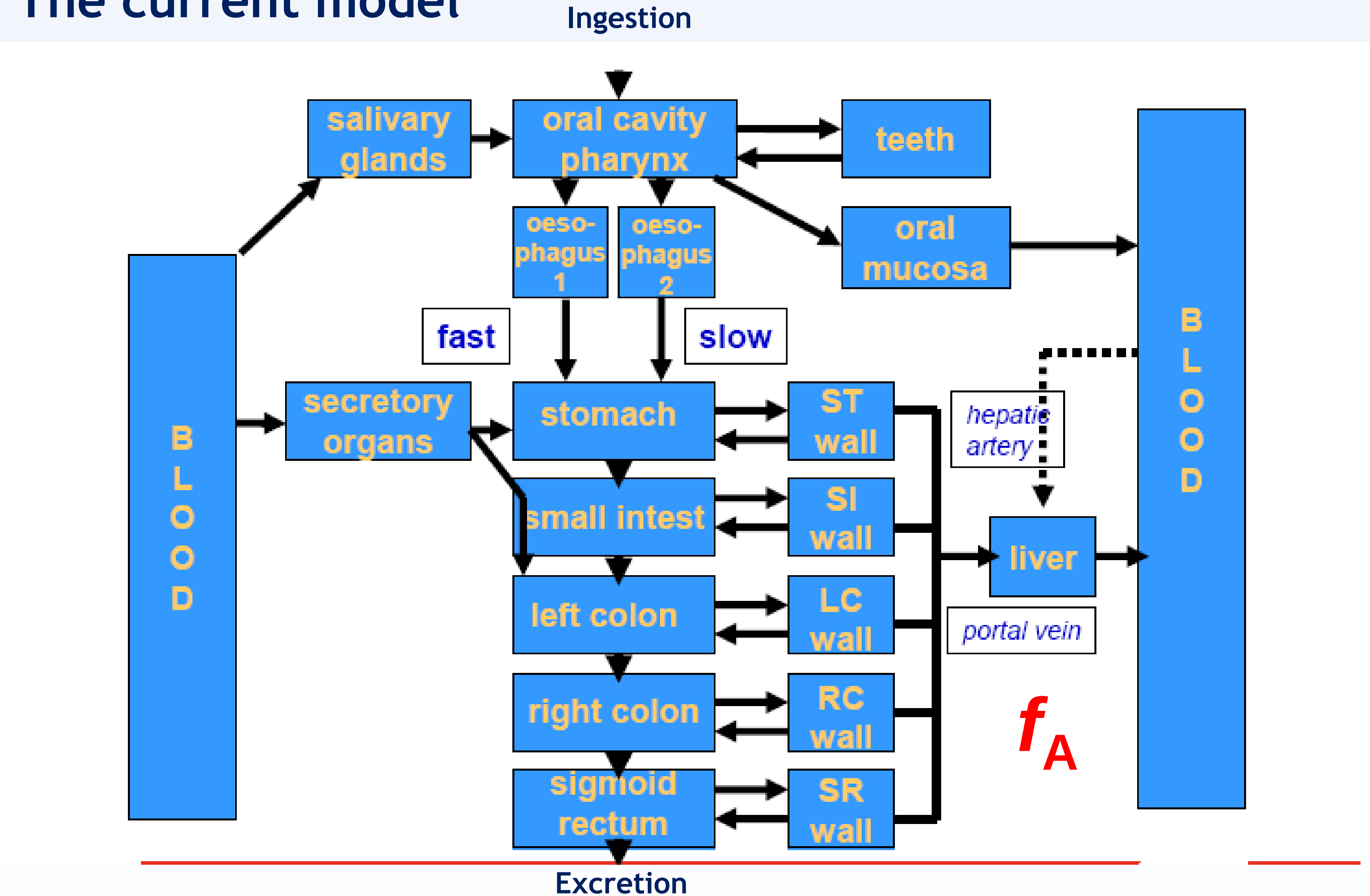
Parameters are element-specific



(ICRP 78, 1997)

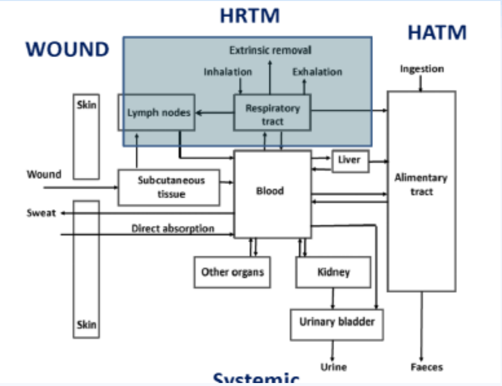
The Human alimentary tract model

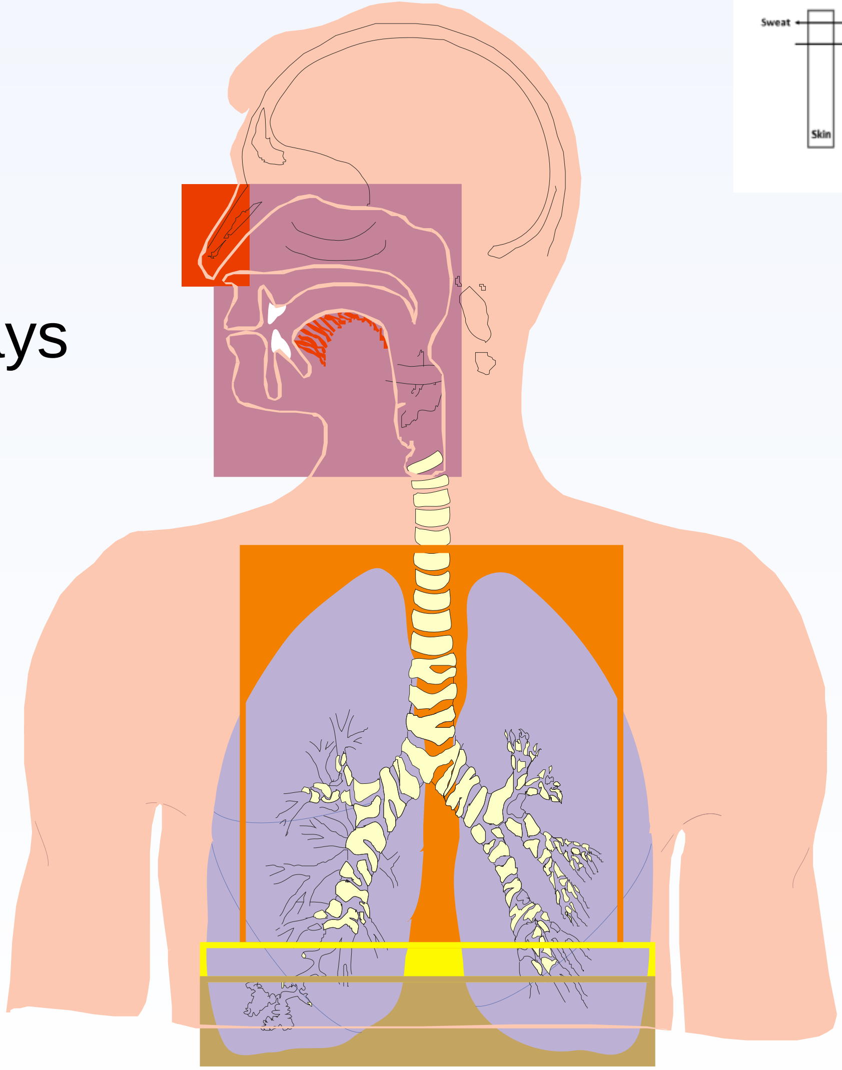
The current model



ICRP Publication 100 (2006)

The Human Respiratory Tract model





ET_1

Extrathoracic airways — ET_2

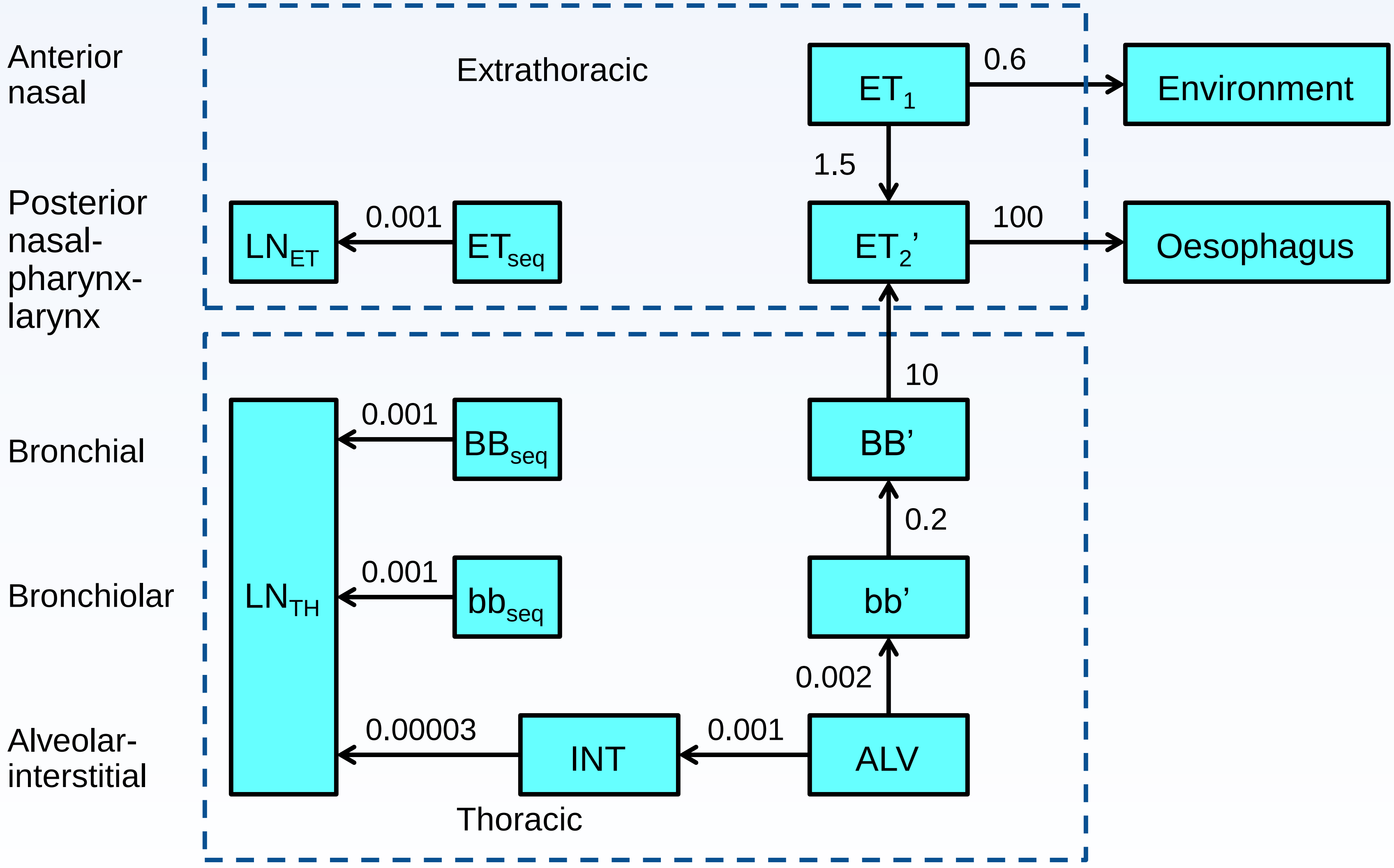
Bronchial — BB

Bronchiolar — bb

Alveolar interstitial — AI

ICRP Publication 66 (1994)

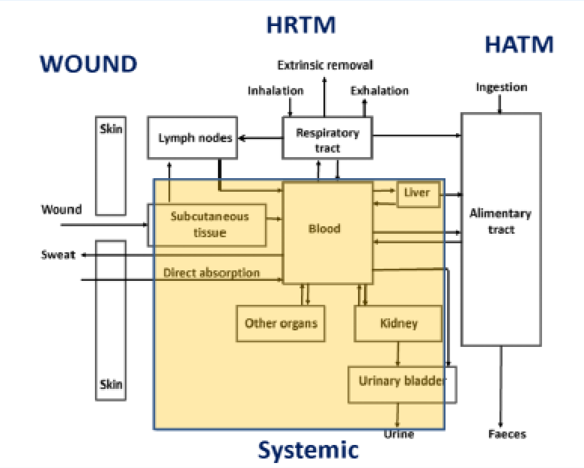
New particle transport model



Example of Uranium absorption

Compound	Absorption parameter values			Type
	f_r	s_r (d^{-1})	s_s (d^{-1})	
Default Type F (UF6, U-TBP)	***1.0***	***10***		
Uranyl nitrate, $UO_2(NO_3)_2$	0.8	1	0.01	(F/M)
Uranium peroxide hydrate	0.8	1	0.01	(F/M)
Ammonium diuranate, ADU	0.8	1	0.01	(F/M)
Default Type M (UF4)	***0.2***	***3***	***0.005***	
Uranium Octoxide U_3O_8; Uranium dioxide	0.03	1	0.0005	(M/S)
Default Type S	***0.01***	***3***	***0.0001***	

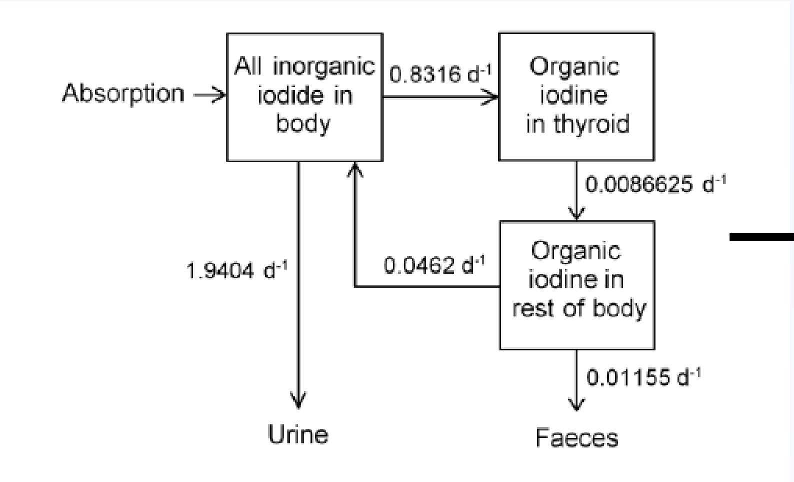
The systemic models

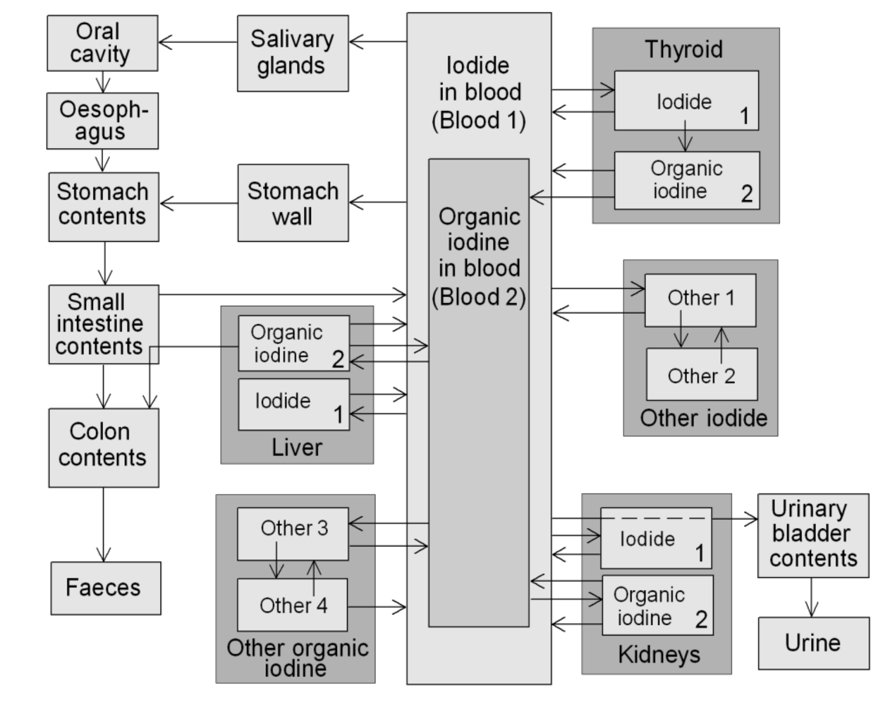


Describe the time-dependent distribution and retention of a radionuclide in the body after absorption to blood,
and its excretion from the body.

New models are physiologically realistic, with recycling of elements

Systemic model for Iodine





The former model (ICRP 1994, 1997)

The new model
ICRP Publication 137 (2017)

Three subsystems:

- **circulating inorganic iodide;**
- **thyroidal organic iodine**
- **extrathyroidal organic iodine.**

Systemic model for Strontium

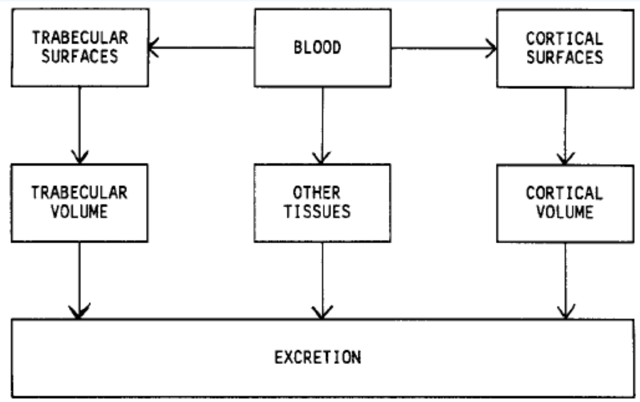
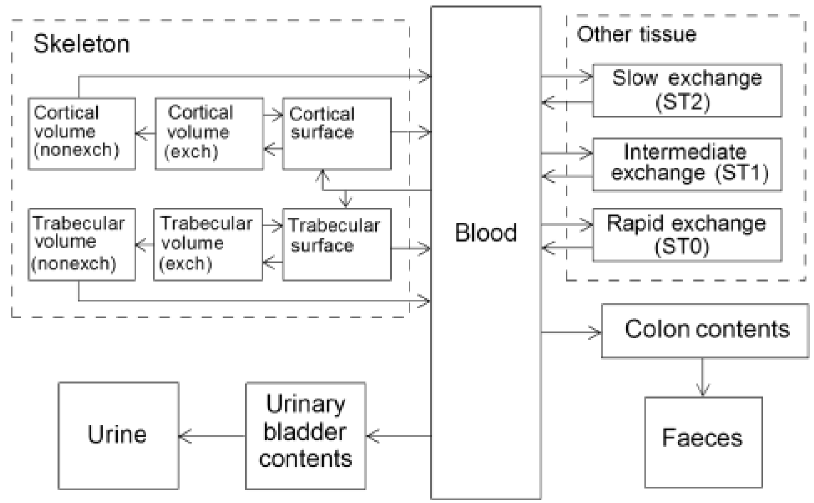


Fig. 2. Diagram of the biokinetic model for strontium.



Structure of the biokinetic model for systemic strontium. ST, soft tissue; exch, exchangeable; nonexch, non-exchangeable.

The former model (ICRP 1989)

The new model
ICRP Publication 134, 2016

Biokinetic models

Intake → Deposition in tissues → Transformations in tissues

↓ (Nuclear data)

Emitted energy (Mev)

↓ (Phantoms and codes for radiation transport)

Absorbed dose in tissues (Gy)

↓ (Weighting factors for radiations w_R)

Equivalent dose in tissues (Sv)

← (Weighting factors for tissues w_T)

Effective dose (Sv)

Biokinetic models make it possible to initiate the chain of dosimetric calculations

Complex procedure, limited to experts

ICRP proposes tools, to allow non-specialist to perform dose assessment

1. Biokinetic models

2. Dose coefficients

3. Bioassays functions

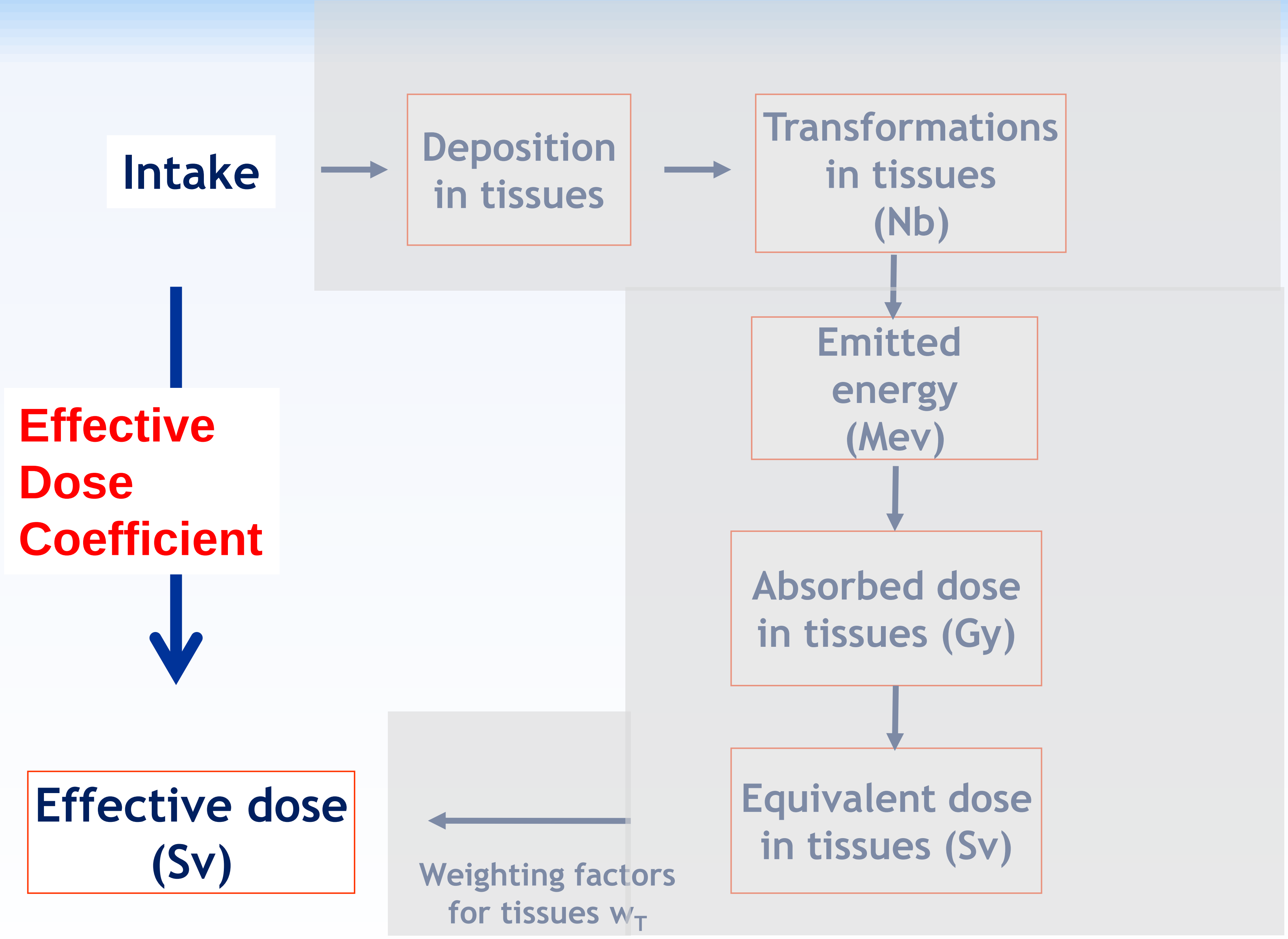

Intake
Deposition in tissues
Transformations in tissues (Nb)
Emitted energy (Mev)
Absorbed dose in tissues (Gy)
Equivalent dose in tissues (Sv)
Weighting factors for tissues w_T
Effective Dose Coefficient
Effective dose (Sv)

Table 22.16. Committed effective dose coefficients (Sv Bq^{-1}) for the inhalation or ingestion of ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Pu compounds.

	Effective dose coefficients (Sv Bq^{-1})			
Inhaled particulate materials (5 µm AMAD aerosols)	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu
Plutonium nitrate, $Pu(NO_3)_4$	1.2E-05	1.3E-05	1.3E-05	1.1E-07
^{239}Pu dioxide, $^{239}PuO_2$; plutonium in mixed oxide [$(UO_2 + PuO_2)$ or $(U,Pu)O_2$]	2.3E-05	2.5E-05	2.5E-05	4.4E-07
^{238}Pu dioxide, $^{238}PuO_2$ ceramic	1.1E-05	–	–	–
^{238}Pu dioxide, $^{238}PuO_2$ non-ceramic	1.1E-05	–	–	–
Plutonium dioxide 1-nm nanoparticles, 1-nm PuO_2	1.6E-05	1.7E-05	1.7E-05	1.9E-07
Type F	1.8E-05	1.9E-05	1.9E-05	2.2E-07
Type M, plutonium citrate; plutonium tri-butyl-phosphate (Pu-TBP); plutonium chloride ($PuCl_3$)	1.2E-05	1.4E-05	1.4E-05	1.3E-07
Type S	1.7E-05	1.7E-05	1.8E-05	2.2E-07

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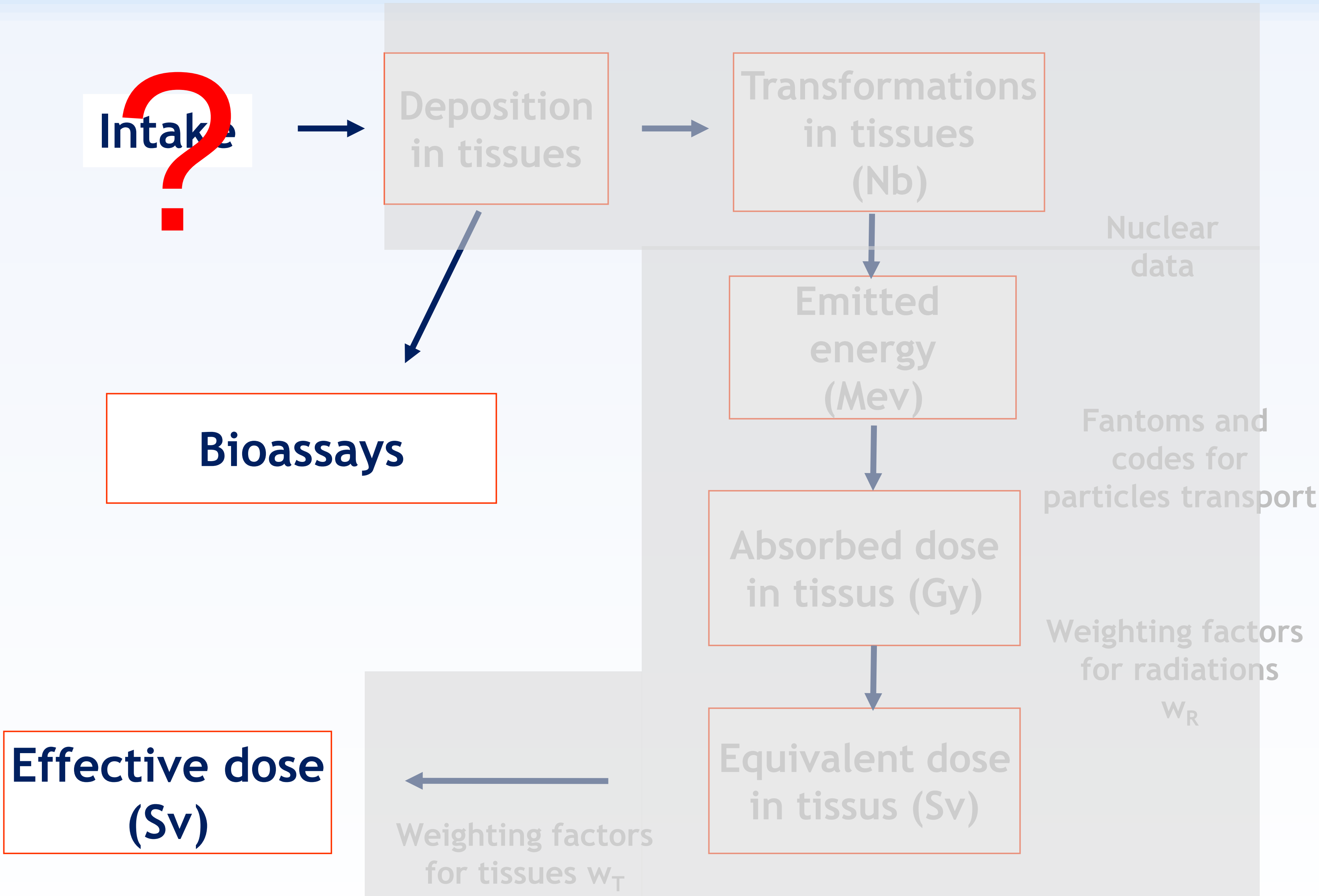
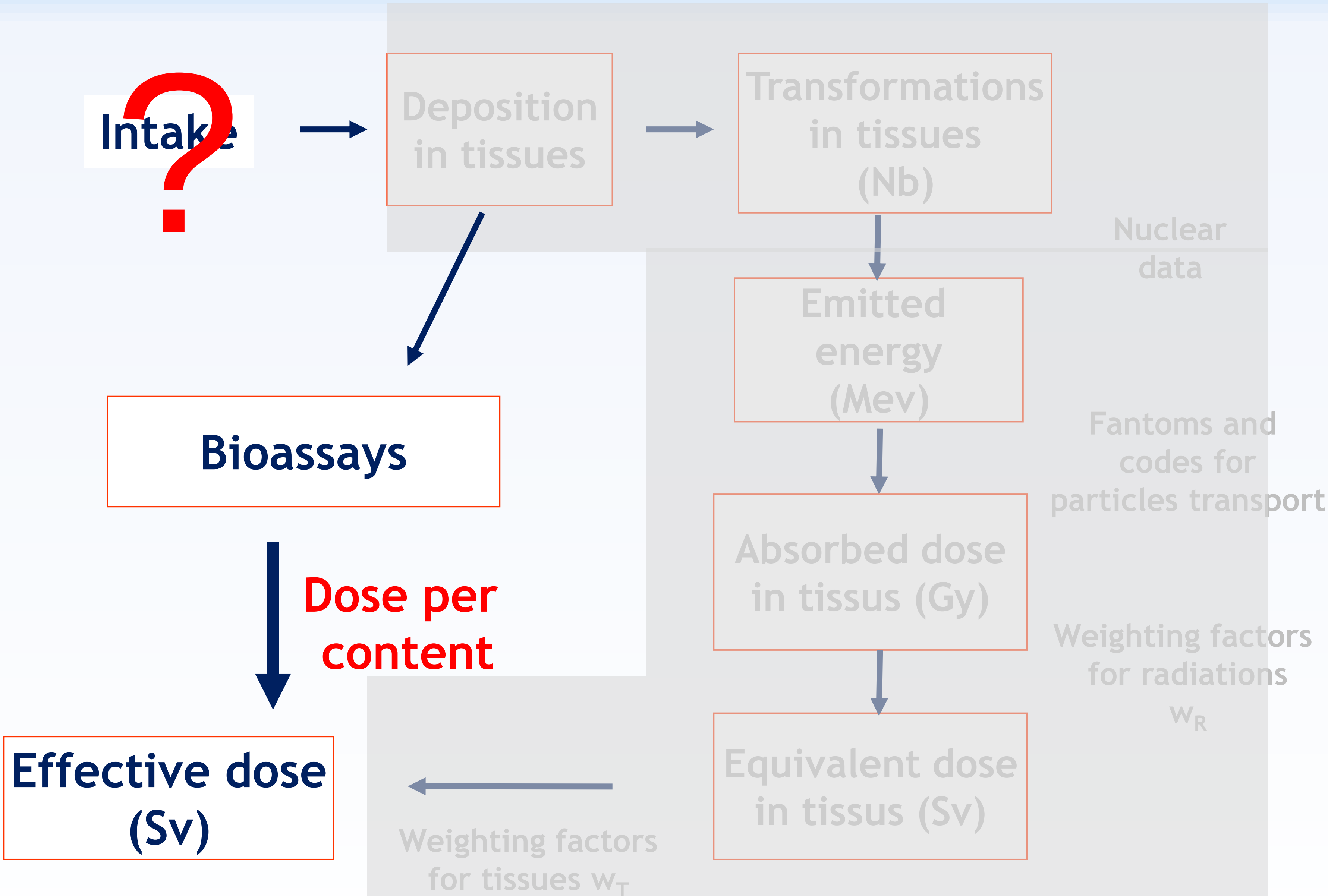
Dose = Intake x EDC

From ICRP 141, 2019


Intake
?
Deposition in tissues
Transformations in tissues (Nb)
Nuclear data
Emitted energy (Mev)
Fantoms and codes for particles transport
Absorbed dose in tissus (Gy)
Weighting factors for radiations w_R
Equivalent dose in tissus (Sv)
Weighting factors for tissues w_T
Bioassays
Effective dose (Sv)



Intake
?
Deposition in tissues
Transformations in tissues (Nb)
Nuclear data
Emitted energy (Mev)
Fantoms and codes for particles transport
Bioassays
Dose per content
Absorbed dose in tissus (Gy)
Weighting factors for radiations w_R
Effective dose (Sv)
Equivalent dose in tissus (Sv)
Weighting factors for tissues w_T

Table 22.17. Dose per activity content of ^{238}Pu in the lungs and in daily excretion o aerosols inhaled by a reference worker at light work.

Time after intake	Plutonium nitrate			Plutonium dioxide etc.			Dioxide, ceramic			Dioxide, non ceramic			
(d)	Lung	Urine	Faeces	Lung	Urine	Faeces	Lung	Urine	Faeces	Lung	Urine	Faeces	Lung
1	2.0E 04	5.6E 01	1.4E 04	3.7E 04	5.6E+01	2.7E 04	1.8E 04	2.1E+04	1.3E 04	1.7E 04	3.4E+01	1.2E 04	3.2E
2	2.2E 04	3.0E 01	4.4E 05	3.8E 04	3.0E+01	8.6E 05	1.8E 04	6.9E+03	4.1E 05	1.7E 04	1.5E+01	3.9E 05	4.1E
3	2.3E 04	3.1E 01	6.8E 05	3.9E 04	3.1E+01	1.3E 04	1.9E 04	4.0E+03	6.3E 05	1.8E 04	1.2E+01	6.0E 05	5.0E
4	2.4E 04	3.6E 01	1.8E 04	4.0E 04	3.6E+01	3.4E 04	1.9E 04	2.7E+03	1.6E 04	1.8E 04	1.1E+01	1.6E 04	6.0E
5	2.5E 04	4.5E 01	6.0E 04	4.1E 04	4.5E+01	1.2E 03	1.9E 04	2.1E+03	5.5E 04	1.8E 04	1.0E+01	5.2E 04	6.8E
6	2.6E 04	5.6E 01	2.1E 03	4.1E 04	5.7E+01	4.1E 03	2.0E 04	1.6E+03	1.9E 03	1.9E 04	1.0E+01	1.8E 03	7.6E
7	2.7E 04	6.9E 01	6.6E 03	4.2E 04	7.1E+01	1.2E 02	2.0E 04	1.4E+03	5.7E 03	1.9E 04	9.6E+00	5.4E 03	8.2E
8	2.7E 04	8.3E 01	1.4E 02	4.2E 04	8.8E+01	2.3E 02	2.0E 04	1.2E+03	1.1E 02	1.9E 04	9.3E+00	1.1E 02	8.7E
9	2.7E 04	9.9E 01	2.0E 02	4.3E 04	1.1E+02	3.3E 02	2.0E 04	1.0E+03	1.6E 02	1.9E 04	9.0E+00	1.5E 02	9.1E
10	2.8E 04	1.1E+00	2.5E 02	4.3E 04	1.2E+02	4.1E 02	2.0E 04	8.9E+02	1.9E 02	2.0E 04	8.7E+00	1.8E 02	9.5E
15	2.9E 04	1.8E+00	5.4E 02	4.4E 04	2.1E+02	8.5E 02	2.1E 04	5.5E+02	4.1E 02	2.0E 04	7.7E+00	3.9E 02	1.0E
30	3.1E 04	2.7E+00	1.4E 01	4.6E 04	3.7E+02	2.2E 01	2.2E 04	2.5E+02	1.0E 01	2.2E 04	5.9E+00	1.0E 01	1.2E
45	3.3E 04	3.1E+00	1.6E 01	4.7E 04	4.6E+02	2.4E 01	2.3E 04	1.6E+02	1.2E 01	2.3E 04	4.9E+00	1.1E 01	1.3E
60	3.5E 04	3.3E+00	1.8E 01	4.9E 04	5.2E+02	2.6E 01	2.3E 04	1.2E+02	1.2E 01	2.4E 04	4.4E+00	1.2E 01	1.5E
90	3.9E 04	3.6E+00	2.1E 01	5.1E 04	5.9E+02	2.8E 01	2.5E 04	7.7E+01	1.3E 01	2.7E 04	3.7E+00	1.4E 01	1.8E
180	5.5E 04	4.3E+00	3.2E 01	6.0E 04	7.2E+02	3.7E 01	2.9E 04	4.2E+01	1.8E 01	4.1E 04	3.3E+00	2.4E 01	3.2E
365	1.0E 03	5.2E+00	7.8E 01	7.9E 04	7.8E+02	6.5E 01	4.0E 04	2.6E+01	3.3E 01	1.0E 03	4.0E+00	7.3E 01	9.9E

From ICRP 141, 2019

Many models, dose coefficients and bioassay functions have been issued since the 70s

For the workers

Publication 30 series (ICRP, 1979, 1980, 1981, 1988)
Publication 68 (ICRP, 1994)

For the members of the public

Publications 56, 67, 69, 71 and 72 (ICRP, 1989, 1993, 1995)
age-specific models

Publications 88 and 95 (2001,2004)
transfers to embryo/fetus and infants

Up to date models, dose coefficients and bioassay functions for workers

OIR Part 1 *ICRP Publication 130, 2015*

Models and methods for monitoring

OIR Part 2 *ICRP Publication 134, 2016*

Hydrogen (H), Carbon (C), Phosphorus (P), Sulphur (S), Calcium (Ca), Iron (Fe), Cobalt (Co), Zinc (Zn), Strontium (Sr), Yttrium (Y), Zirconium (Zr), Niobium (Nb), Molybdenum (Mo) and Technetium (Tc).

OIR Part 3 *ICRP Publication 137, 2017*

Ruthenium (Ru), Antimony (Sb), Tellurium (Te), Iodine (I), Caesium (Cs), Barium (Ba),
Iridium (Ir), Lead (Pb), Bismuth (Bi), Polonium (Po), Radon (Rn), Radium (Ra), Thorium (Th) and Uranium (U).

OIR Part 4, *ICRP Publication 141, 2019*

Lanthanides series, actinium (Ac), protactinium (Pa) and transuranic elements

OIR Part 5, *ICRP Publication 151 (In Press)*

Most of the remaining elements

The « Public » series; 5 volumes to come

Public Part 1, ***scheduled 2022***

Dose coefficients for 29 elements

Public Part 2, ***scheduled 2023***

Dose coefficients for actinides and lanthanides

Public Part 3, ***scheduled 2024***

Dose coefficients for every other elements

Public Part 4, > 2025

Breast-feeding Infant Internal Dose Coefficients from Maternal Intakes

Public Part 5, > 2025

In utero Internal Dose Coefficients from Maternal Intakes

The end

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