Biokinetic Models and Dose Coefficients for Internal Exposure

ICRP Symposium on Radiological Protection Dosimetry

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Topics

- Publications providing internal dose coefficients
- Biokinetic models and developments
- New Publications and data
- Inhaled radon as a special case
- Scientific application of ICRP biokinetic models

ICRP Recommendations

Publication 26	ICRP 1977
Publication 60	ICRP 1991
Publication 103	ICRP 2007

ICRP dose coefficients, Sv/Bq

Committed equivalent and effective dose

- Inhalation or ingestion
- Workers and public
- Adults, children, fetus, breast-fed infant

Occupational exposures

Publication 30 **(ICRP, 1979, 1980, 1981, 1988)**

Dose coefficients relating to the 1977 Recommendations (Publication 26)

Publication 68 **(ICRP, 1994)**

Revised dose coefficients following 1990 Recommendations (Publication 60) with some revised models

Publications 54 and 78 **(ICRP, 1988, 1997)**

Bioassay data for interpretation of measurements

Public exposures

Publications 56, 67, 69, 71 and 72 **(ICRP, 1989, 1993, 1995)** Dose coefficients relating to the 1990 Recommendations (ICRP, 1991) for infants, 1,5, 10 and 15 year-old children and adults

Publication 88 and 95 **(ICRP, 2001, 2004)**
Dose coefficients for the embryo and fetus, and breast-fed infant following intakes by the mother

Recent Publications

Publication 119 Compendium of Dose Coefficients based on ICRP Publication 60. Ann ICRP 41 (Supp1) 2012

Publication 128 Radiation Dose to Patients from Radiopharmaceuticals: A Compendium of Current Information Related to Frequently Used Substances. Ann ICRP 44 (2S) 2015

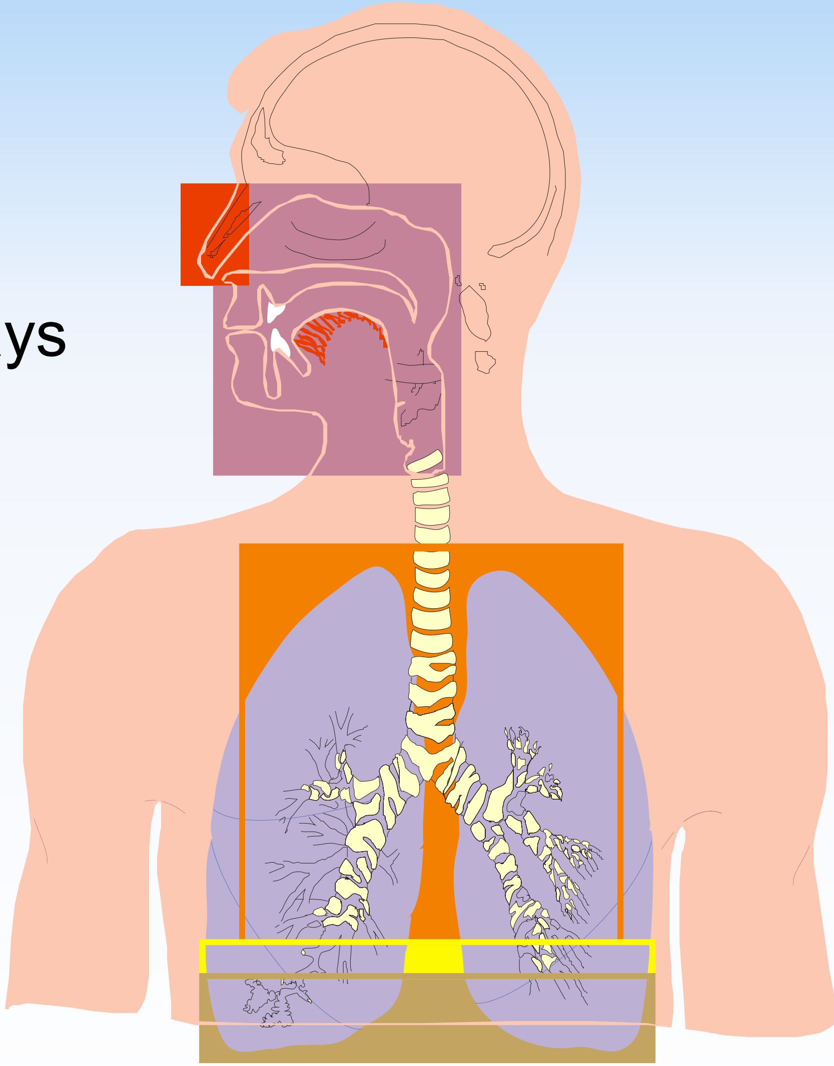
Biokinetic models

- **Respiratory tract**
- **Alimentary tract**
- **Systemic models** for each element / group

  - simple eg. tritium, caesium-137

  - complex eg. strontium-90, plutonium-239

Human Respiratory Tract Model



Extrathoracic airways — ET$_1$, ET$_2$

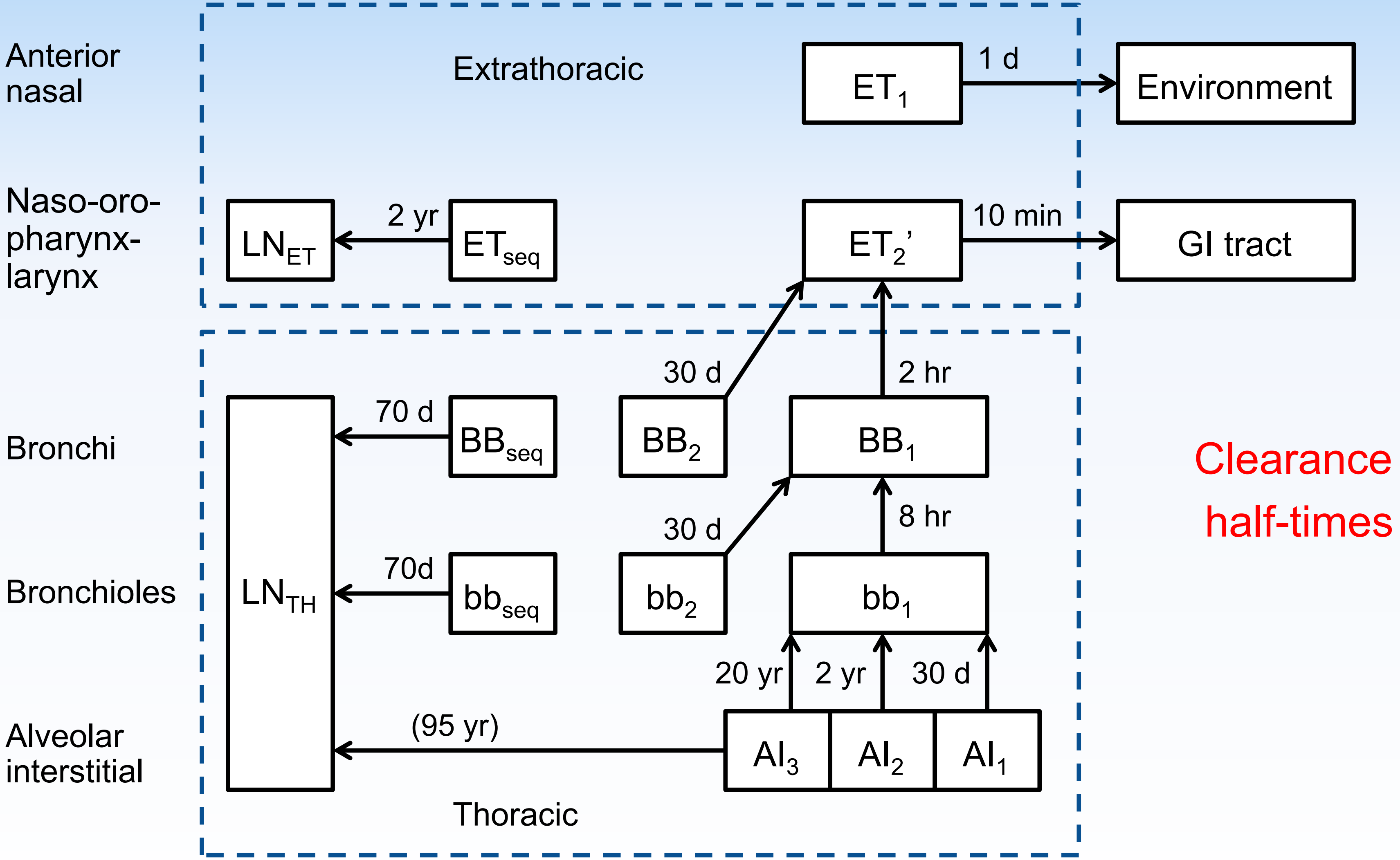
Bronchial — BB

Bronchiolar — bb

Alveolar interstitial — AI

Publication 66 (ICRP 1994)

Particle transport model



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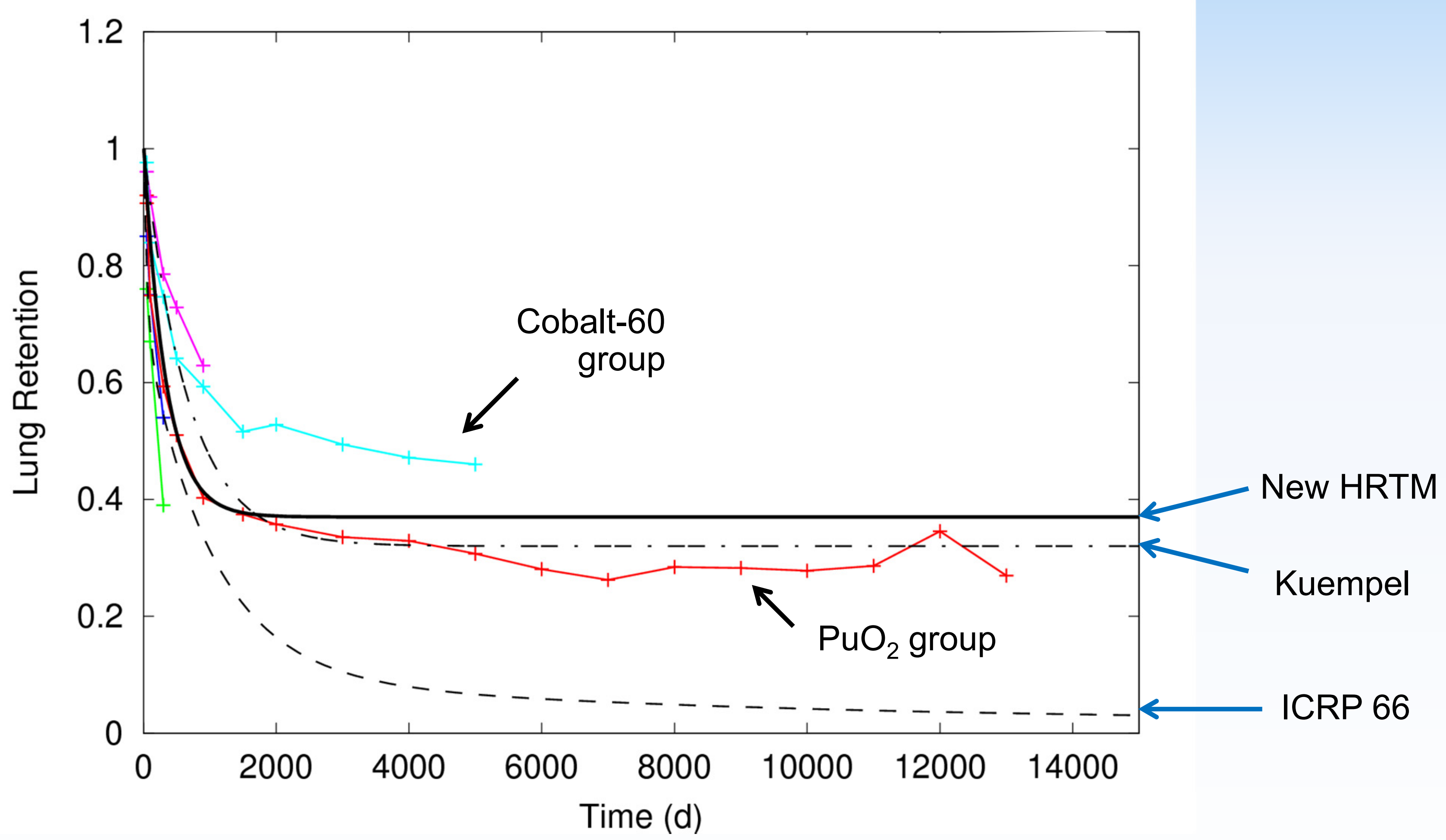
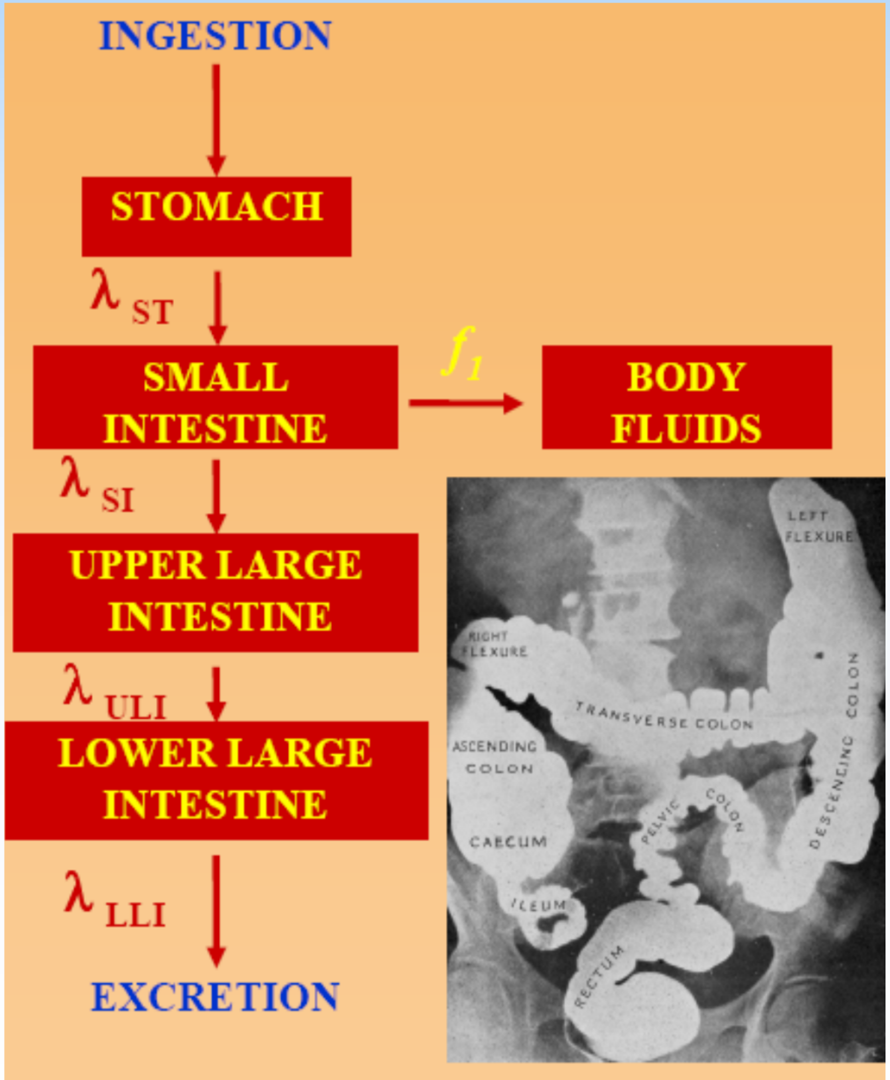
Al Retention: new data

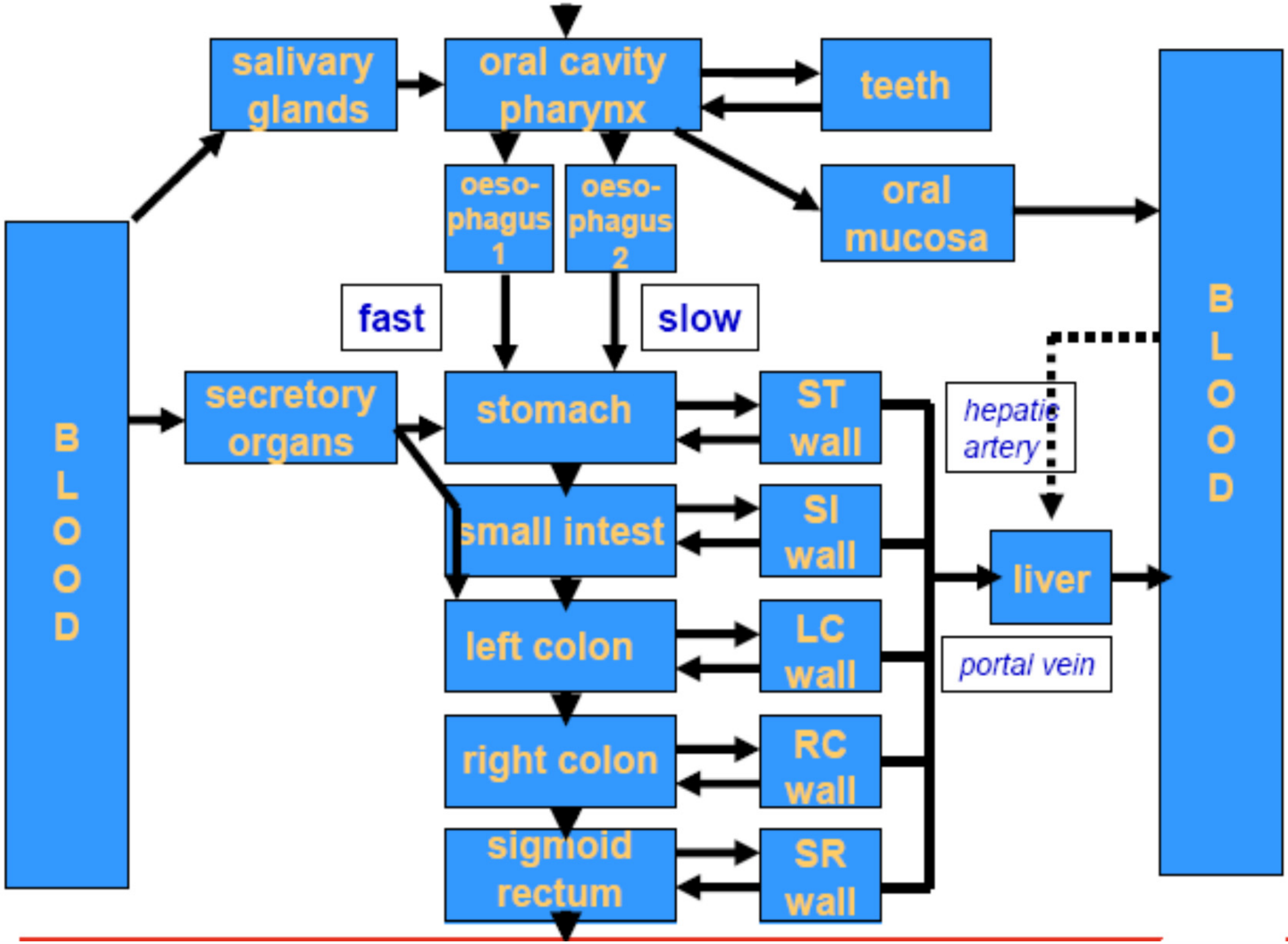


Human Alimentary Tract Model



Publication 30 (ICRP 1979)

Human Alimentary Tract Model



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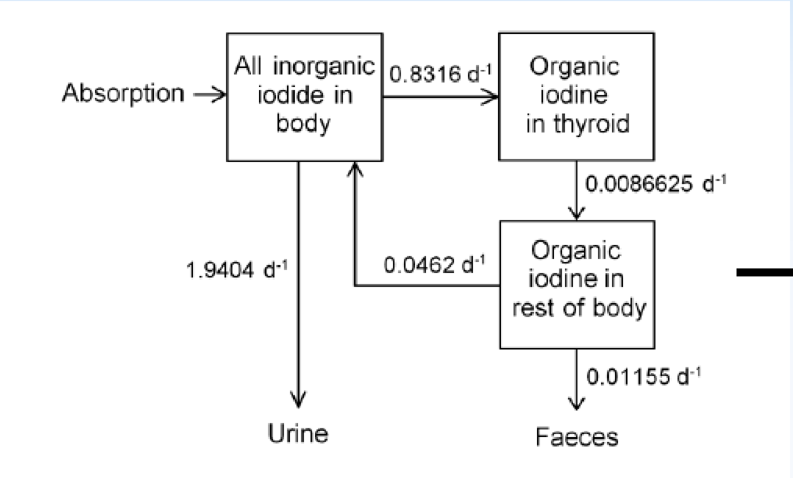
Publication 100 (ICRP 2001)

Systemic model for Iodine



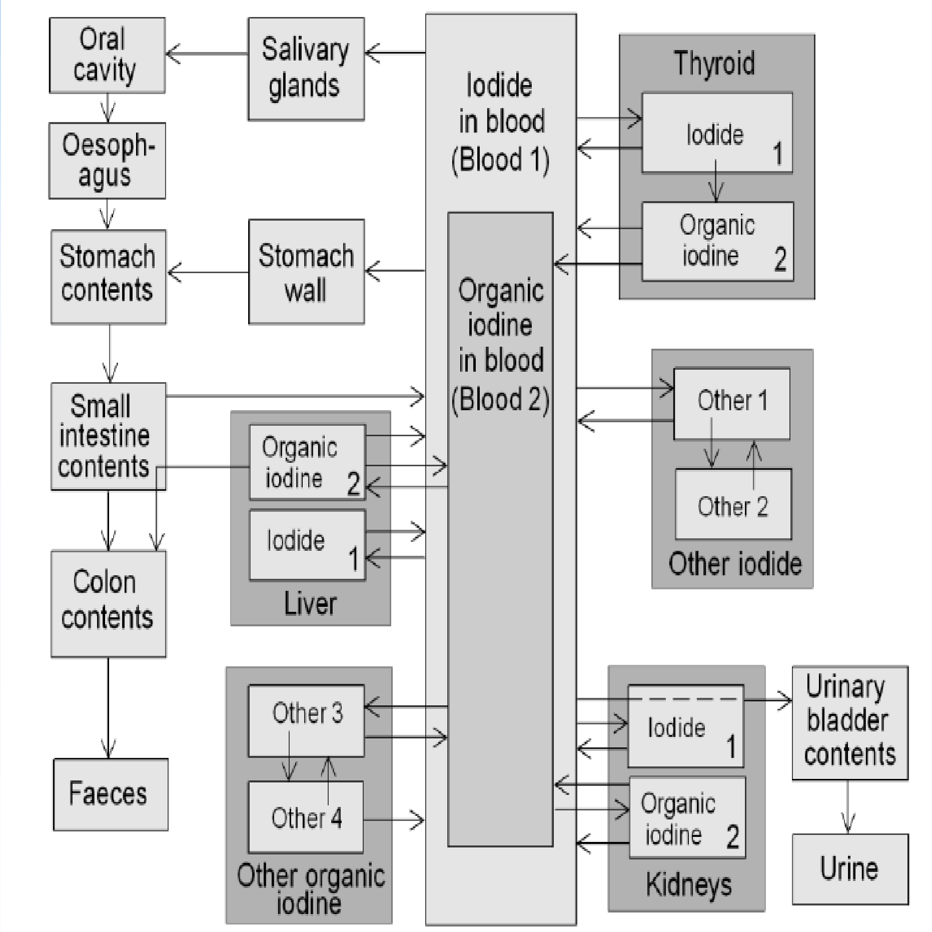
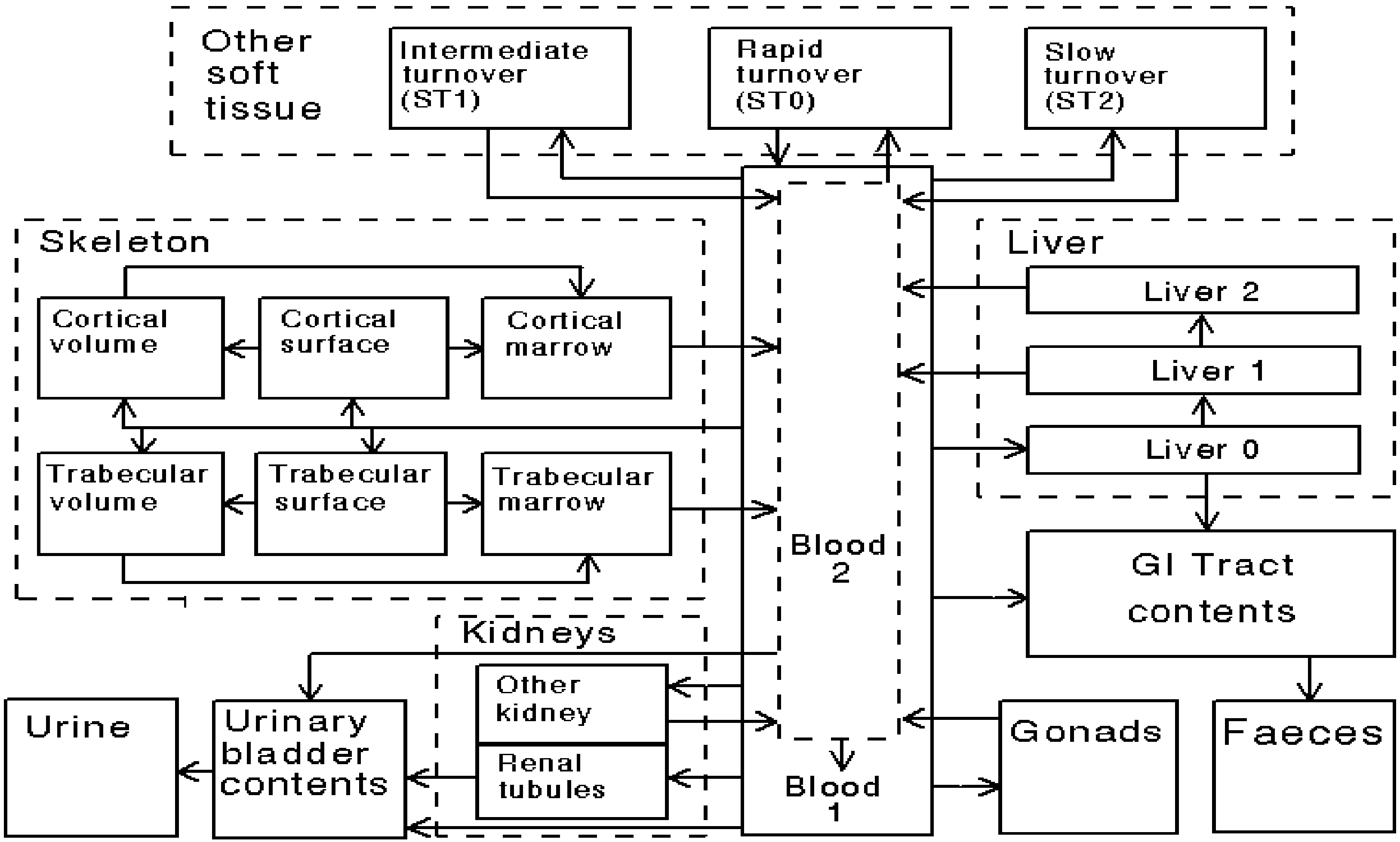
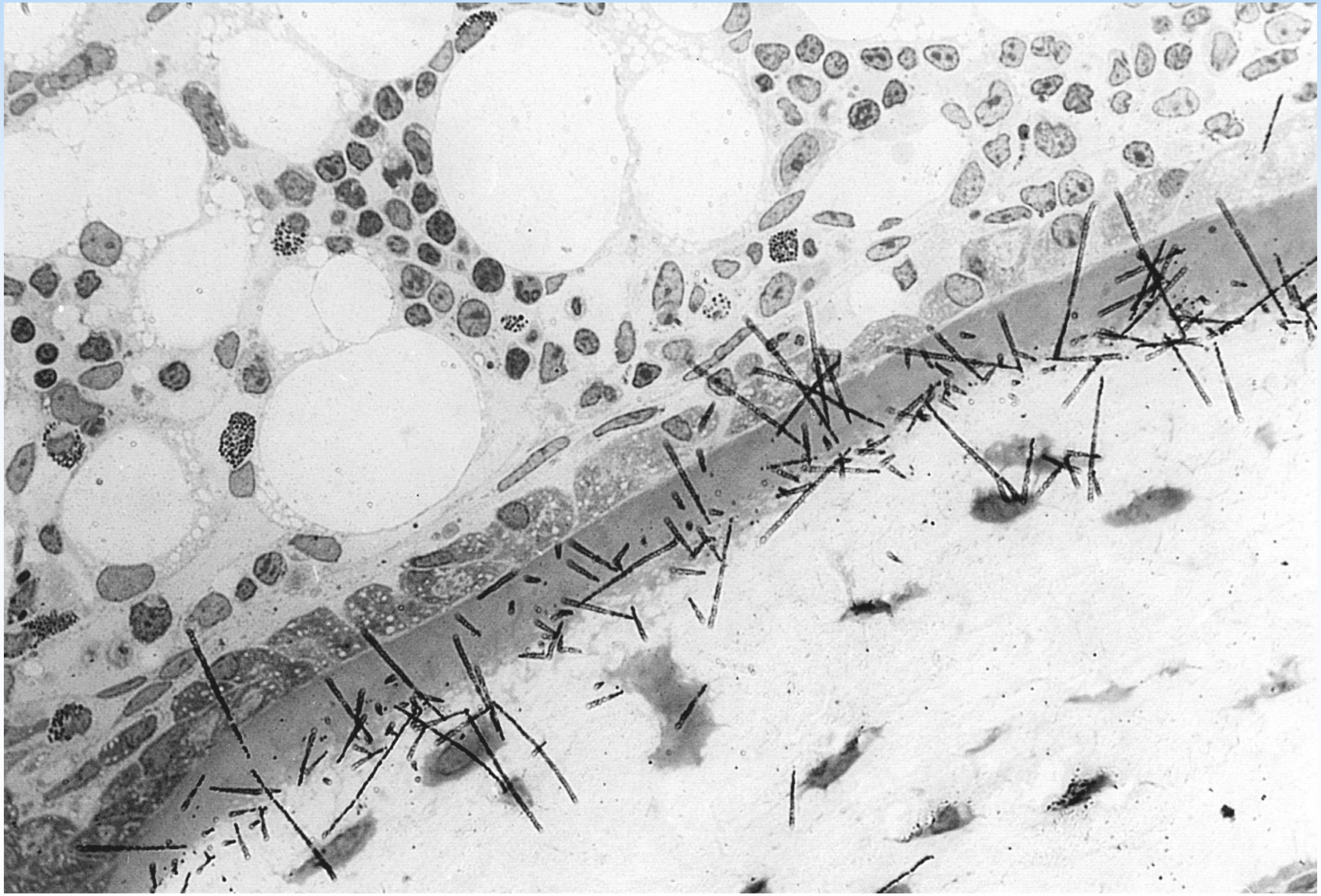


Figure 5-2. Structure of the biokinetic model for systemic iodine used in this report.

Systemic model for Plutonium



Plutonium-239 on bone surface



Biokinetic and Dosimetric models

Biokinetic models : Transformations in ***source*** organs / tissues

Dosimetric models : Energy deposition in and committed dose to *target* organs / tissues per transformation in source organs / tissues

Planned publications

Phantoms and radiations transport calculations
- Radiation Transport for Adult Phantoms (Adult SAFs)
- Pediatric Reference Computational Phantoms + SAFs
- Pregnant Female and Fetus Reference Computational Phantoms + SAFs

Internal dose coefficients
- Occupational Intakes of Radionuclides, Parts 1 - 5
- Internal Dose Coefficients for Members of the Public, Pts 1 & 2
- *In utero* Dose Coefficients for Maternal Intakes
- Breast-feeding Infant Dose Coefficients for Maternal Intakes

External dose conversion coefficients
- External Dose Coefficients for Members of the Public

Radiopharmaceutical dose coefficients

Use of Effective Dose

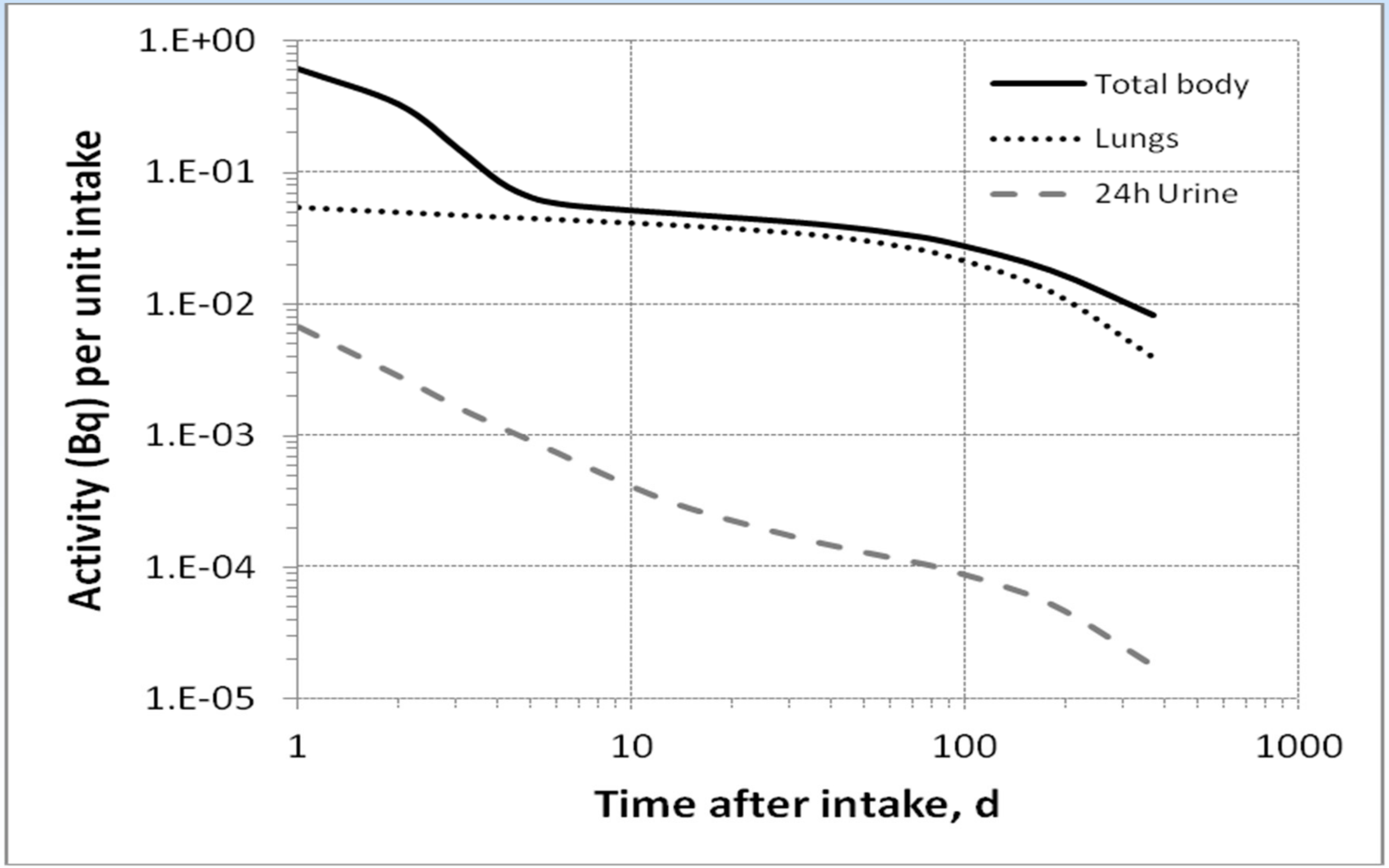
Occupational Intakes of Radionuclides (OIR)

OIR Part 1	***Publication 130* (2015)** Introduction
OIR Part 2	H, C, P, S, Ca, Fe, Co, Zn, Sr, Y, Zr, Nb, Mo, Tc
OIR Part 3	Ru, Sb, Te, I, Cs, Ba, Ir, Pb, Bi, Po, Rn, Ra, Th, U
OIR Part 4	Lanthanides and Actinides
OIR Part 5	F, Na, Mg, K, Mg, Ni, Se, Mo, Tc, Ag

OIR dose coefficients for cobalt

	Effective dose coefficients (Sv Bq^{-1})		
Inhaled particulate materials (5 µm AMAD aerosols)	^{57}Co	^{58}Co	^{60}Co
Type F, cobalt nitrate, chloride	3.3E-10	1.4E-09	1.1E-08
Type M, all unspecified forms	1.0E-09	4.3E-09	2.7E-08
Type S, cobalt oxide, FAP, PSL	2.4E-09	6.6E-09	1.7E-07
Ingested materials			
f_A = 0.1, all chemical forms	2.4E-10	1.2E-09	7.6E-09
f_A = 0.05, insoluble oxides	1.7E-10	9.8E-10	4.8E-09

Bioassay data for ^{60}Co : inhalation of 1 Bq Type M



Dose conversion convention for inhaled radon-222 + progeny

ICRP *Publication 65* (1993)

Compare lung cancer risk in miners (LEAR)

2.83 x 10^{-4} per Working Level Month (WLM)

with total detriment from cancer and hereditary effects from Pub 60 (1991):

Workers	5.6 x 10^{-2} per Sv	**5 mSv per WLM**
Public	7.3 x 10^{-2} per Sv	**4 mSv per WLM**

Revised radon risk coefficient and Statement on Radon

ICRP *Publication 115* (2010)

Revised nominal risk coefficient of 5 10^{-4} WLM^{-1} to replace the Pub 65 value of 2.83 10^{-4} WLM^{-1}

Intention to publish dose coefficients for radon isotopes calculated using biokinetic and dosimetric models

Lowered Upper value of Reference Level for homes from 600 Bq m^{-3} to 300 Bq m^{-3}

Epidemiological approach

USING 5 x 10^{-4} per WLM lung cancer risk

Workers	4.2 x 10^{-2} Sv^{-1}	**12 mSv WLM^{-1}**
Public	5.7 x 10^{-2} Sv^{-1}	**9 mSv WLM^{-1}**

Publication 65 values

Workers	5 mSv WLM^{-1}
Public	4 mSv WLM^{-1}

ICRP Dose coefficients – preliminary values

	Equilibrium factor	Unattached fraction, %	Effective dose mSv per WLM
Home	0.4	10	**14**
Indoor workplace	0.4	10	**21**
		lower breathing rate	**14**
Mine	0.2	1	**12**

OIR 3 dose coefficients for radon

Inhalation or ingestion :

Radon-222 (Radon)	Effective dose
Radon-220 (Thoron)	Organ equivalent doses
Radon-219 (Actinon)	

- BUT for inhaled Rn-222 – use **12 mSv per WLM** in most circumstances
- Information provided so that account can be taken of specific information on exposure conditions
  - – aerosol characteristics, equilibrium factor

Protection against radon exposures

ICRP *Publication 126* (2014)

Upper Reference Level of 300 Bq m^{-3} applying to all exposures in homes and workplaces

Exposure	Effective dose mSv / y
Home (≈7000h)	15.8
Work (≈ 2000h)	4.5
Total (8760h)	19.8

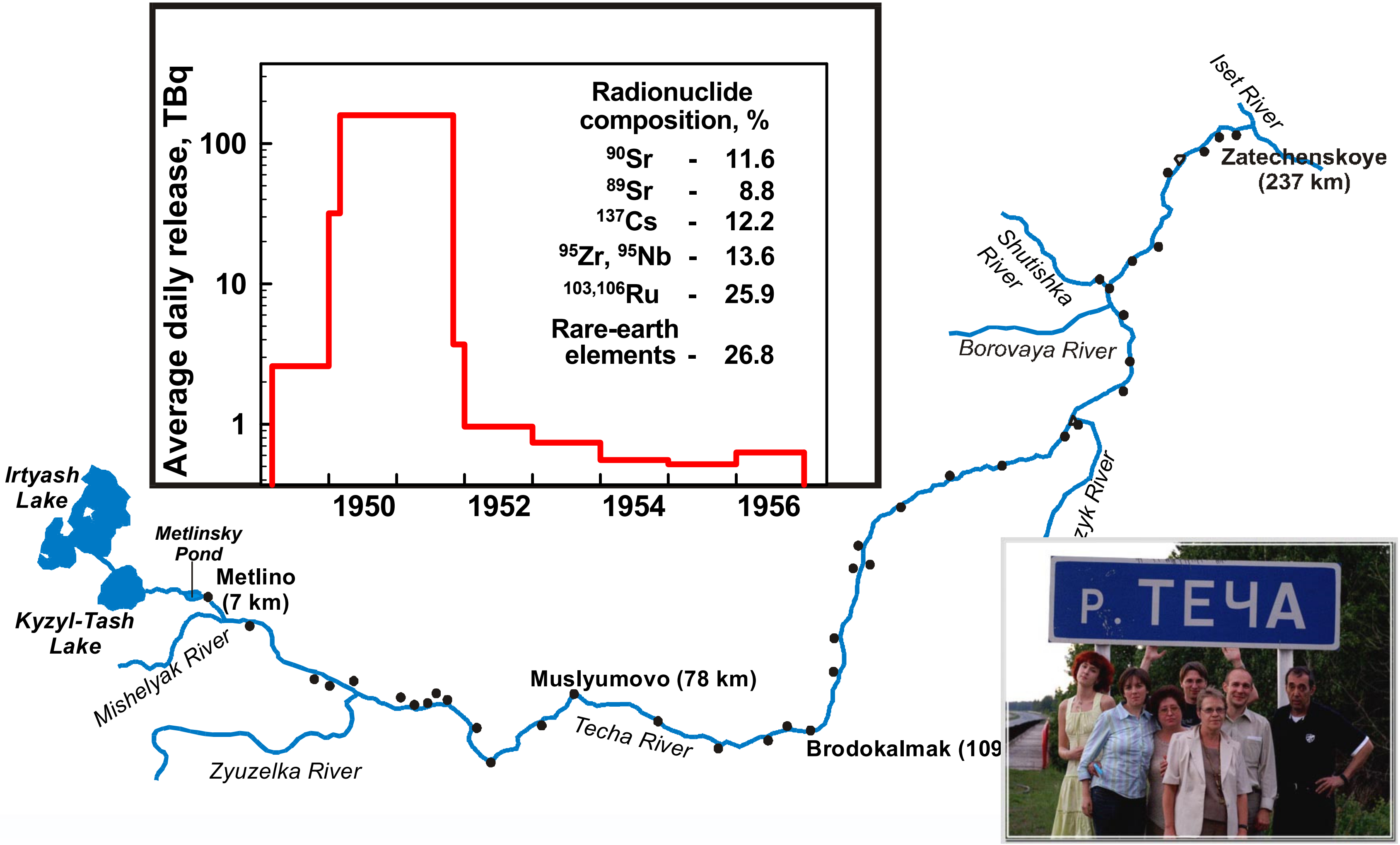
Plutonium production plants

Sellafield, Cumbria, UK

Mayak Nuclear Complex, Southern Urals, Russia

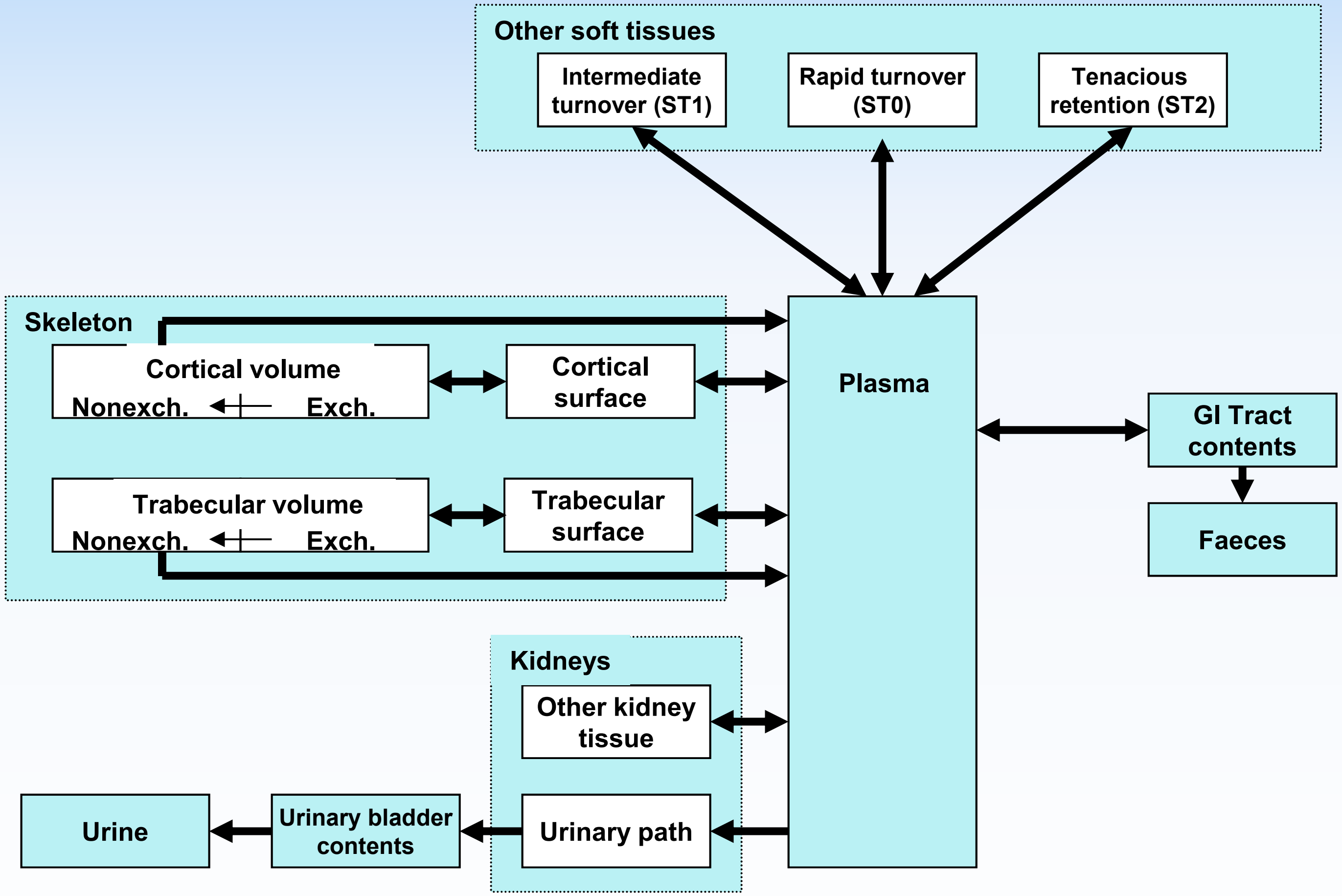
Mayak Pu production – early years

Techa River

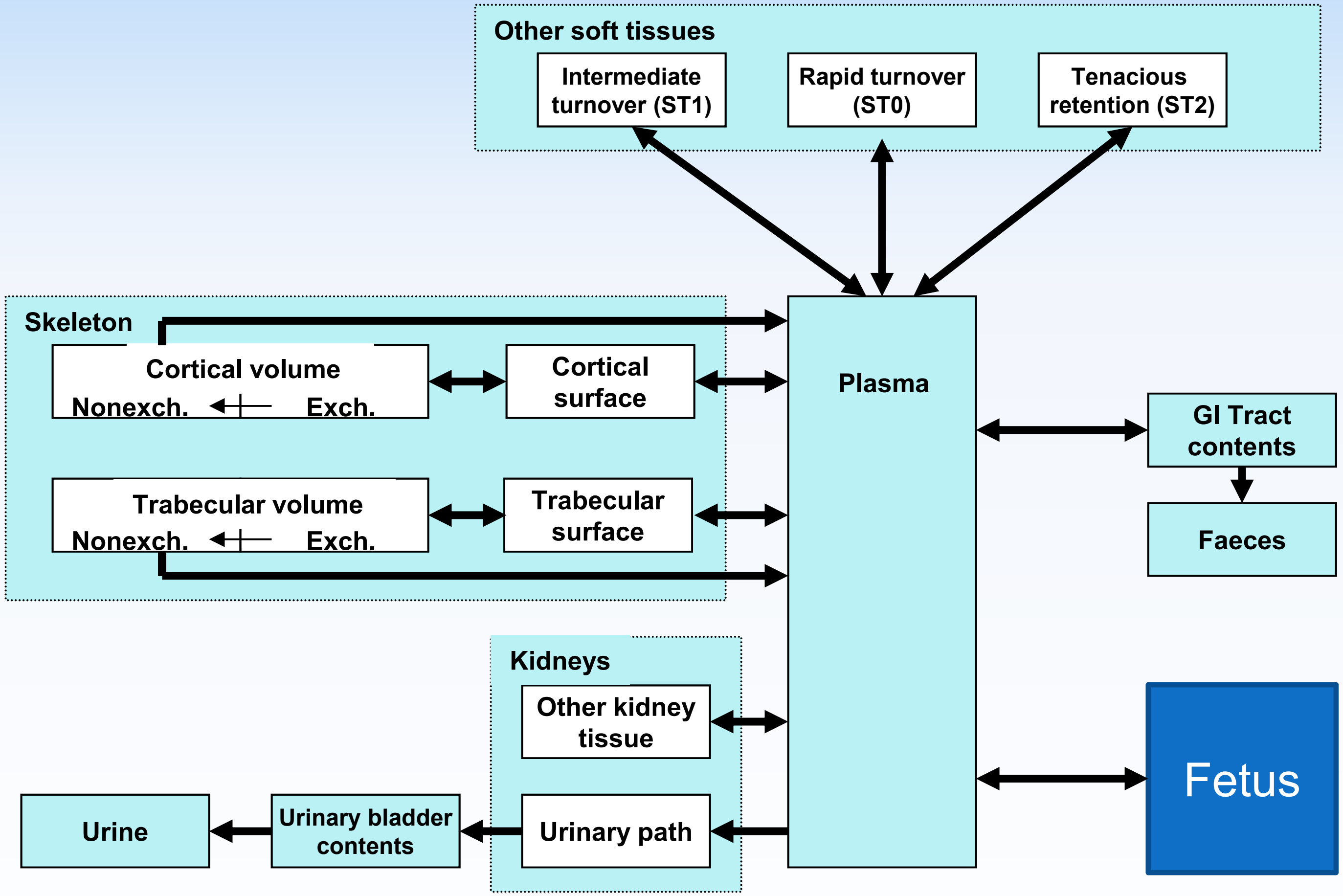


Average daily release, TBq
100
10
1
1950
1952
1954
1956
Radionuclide composition, %
^{90}Sr - 11.6
^{89}Sr - 8.8
^{137}Cs - 12.2
^{95}Zr, ^{95}Nb - 13.6
$^{103,106}Ru$ - 25.9
Rare-earth elements - 26.8
Iset River
Zatechenskoye (237 km)
Shutishka River
Borovaya River
Irtyash Lake
Metlinsky Pond
Metlino (7 km)
Kyzyl-Tash Lake
Mishelyak River
Zyuzelka River
Muslyumovo (78 km)
Techa River
Brodokalmak (109
Р. ТЕЧА

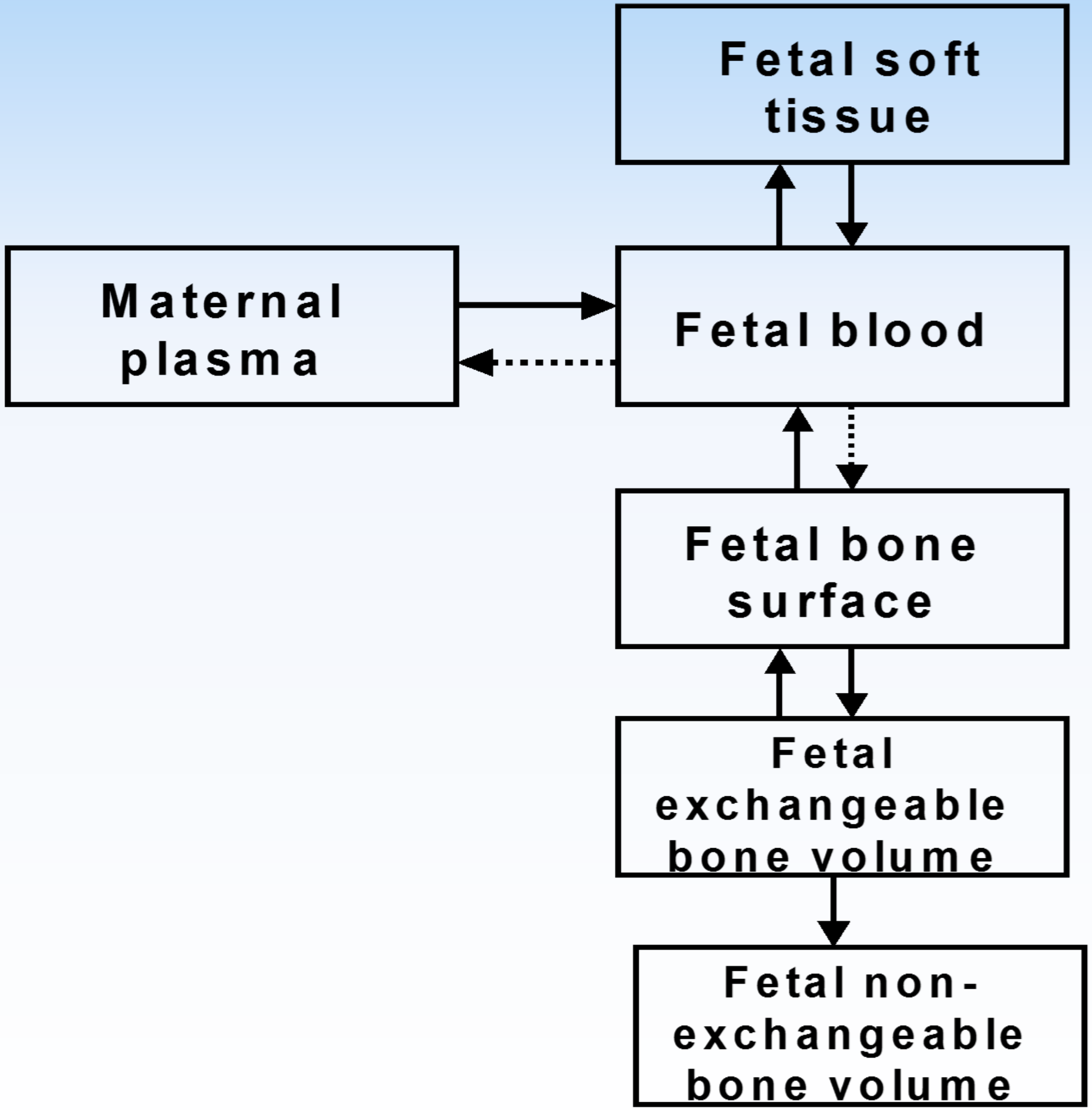
Calcium / strontium model for adults



Calcium / strontium model for adults



Calcium/Strontium transfer to the fetus



Summary points

- ICRP biokinetic models being updated to make best use of current knowledge
- Primary purpose is calculation of reference dose coefficients in support of the system of protection
- Also used for scientific applications

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