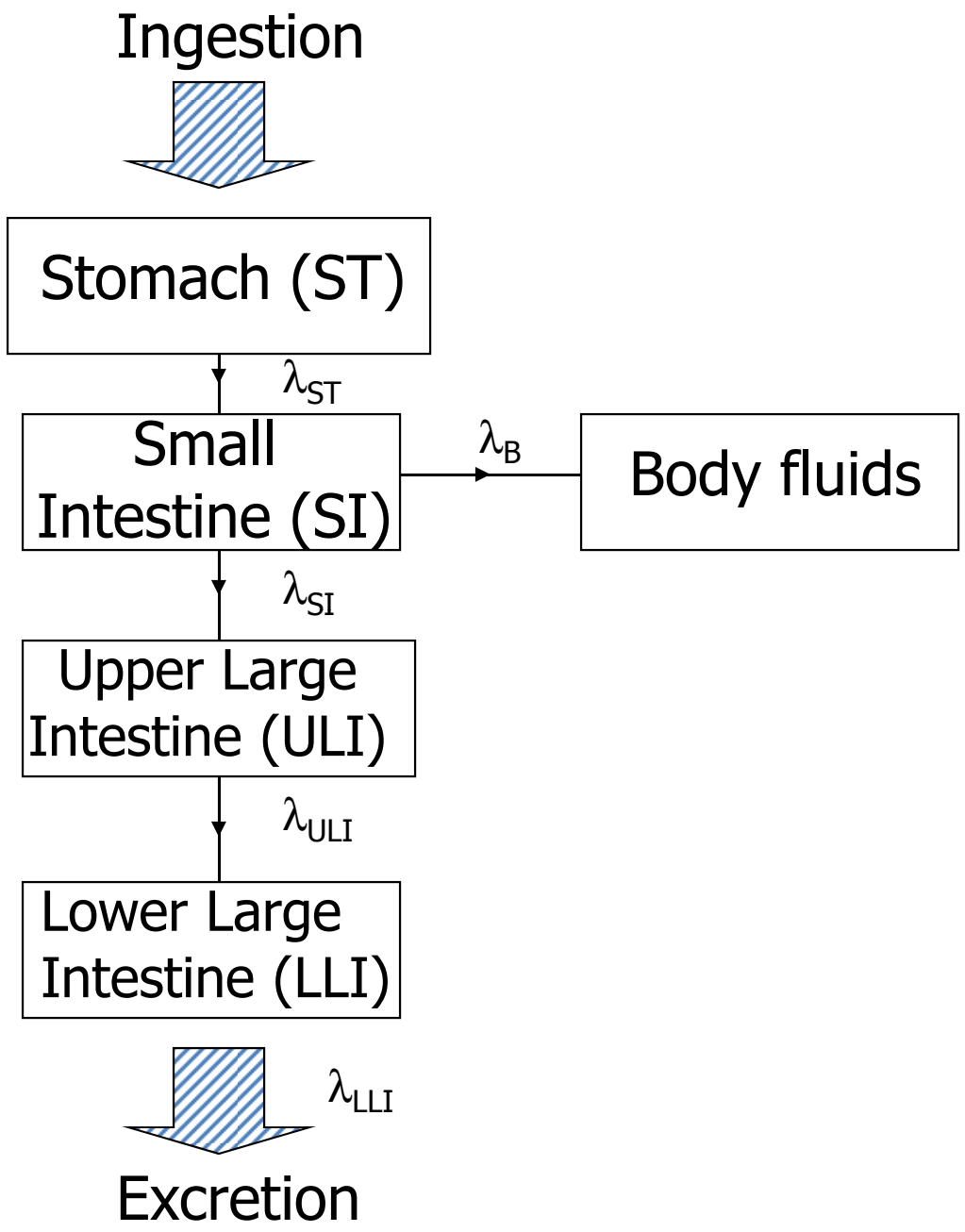
Intake Models for Ingestion

Learning Objectives

- Describe the structure and use of ingestion models
- Identify the differences between the ICRP-30 and ICRP-100 models

ICRP 30 Gastro-Intestinal Tract Model (1979)

- Similar to the lung model (i.e., boxes and arrows), but simpler
- Four compartments:
  - Stomach (ST)
  - Small Intestine (SI)
  - Upper Large Intestine (ULI)
  - Lower Large Intestine (LLI)
- Absorption to body fluids assumed only from SI


Ingestion
Stomach (ST)
λ_{ST}
Small Intestine (SI)
λ_B
Body fluids
λ_{SI}
Upper Large Intestine (ULI)
λ_{ULI}
Lower Large Intestine (LLI)
λ_{LLI}
Excretion

Mean Residence Times (in days)

ST:	$\tau = 1/24$	$\lambda_{ST} = 24\ day^{-1}$
SI:	$\tau = 4/24$	$\lambda_{SI} = 6\ day^{-1}$
ULI:	$\tau = 13/24$	$\lambda_{ULI} = 1.8\ day^{-1}$
LLI:	$\tau = 24/24$	$\lambda_{LLI} = 1\ day^{-1}$

- The most important parameter to remember is f_1, the fraction of ingested radioactivity that is absorbed from the SI and enters the transfer compartment.

  $f_1 = \lambda_B/[\lambda_{SI} + \lambda_B]$

  f_1 values are tabulated by radionuclide and chemical form (solubility class)

Table 3. Gastrointestinal Absorption Fractions (f_1) and Lung Clearance Classes for Chemical Compounds

Element	Inhalation			Ingestion	
	Compound	f_1/Class		Compound	f_1
Actinium (Ac)	Oxides & hydroxides	$1\ 10^{-3}$	Y	All forms	$1\ 10^{-3}$
	Halides & nitrates	$1\ 10^{-3}$	W		
	All others	$1\ 10^{-3}$	D		
Aluminum (Al)	Oxides, hydroxides, carbides, halides, nitrates & elemental	0.01	W	All forms	0.01
	All others	0.01	D		
Americium (Am)	All forms	$1\ 10^{-3}$	W	All forms	$1\ 10^{-3}$
Antimony (Sb)	Oxides, hydroxides, halides, sulfides, sulfates & nitrates	0.1	W	Tartar emetic	0.1
				All others	0.01
	All others	0.01	D		
Arsenic (As)	All forms	0.5	W	All forms	0.5
Astatine (At)	See halide assignment	1	D	All forms	1
	of associated element	1	W		
Barium (Ba)	All forms	0.1	D	All forms	0.1
Berkelium	All forms	$1\ 10^{-3}$	W	All forms	$1\ 10^{-3}$

GI Tract Absorption

f_1 values for radioelements

H-3	1.0
Co	0.05 - 0.3
Sr	0.3
Zr	0.002
Te	0.2
I	1.0
Cs	1.0
Ra	0.2
Th	2.0E-04
U	0.05 - 0.002
Pu	1.0E-4 - 1.0E-5

Region	Number of transformations per Bq intake
Stomach	$\frac{1}{\lambda_{ST} + \lambda_R}$
Small Intestine	$\frac{\lambda_{ST}}{(\lambda_{ST} + \lambda_R)(\lambda_{SI} + \lambda_B + \lambda_R)}$
Upper Large Intestine	$\frac{\lambda_{ST}\lambda_{SI}}{(\lambda_{ST} + \lambda_R)(\lambda_{SI} + \lambda_B + \lambda_R)(\lambda_{ULI} + \lambda_R)}$
Lower Large Intestine	$\frac{\lambda_{ST}\lambda_{SI}\lambda_{ULI}}{(\lambda_{ST} + \lambda_R)(\lambda_{SI} + \lambda_B + \lambda_R)(\lambda_{ULI} + \lambda_R)(\lambda_{LLI} + \lambda_R)}$

Further, the activity translocated from the gastrointestinal tract to the transfer compartment per unit activity ingested is

$$\frac{\lambda_{ST}\lambda_B}{(\lambda_{ST} + \lambda_R)(\lambda_{SI} + \lambda_B + \lambda_R)}$$

and, since all residence times in the gastrointestinal tract are short compared with 50 years, this transfer may, for the purpose of radiological protection, be regarded as occurring instantaneously.

Sample Calculation

One MBq of a radionuclide having a radiological half life of 0.69 hr enters the stomach where it mixes instantaneously and uniformly and is transferred to the small intestine where it again mixes instantaneously and uniformly. The mean residence time of the stomach contents is 1 hour, and the mean residence time of the small intestine contents is 4 hours. How many atoms disintegrate in the small intestine, if there is no absorption to blood?

Solution

given: T1/2 (R) = 0.693 h, so $\lambda(R) = 1\ h^{-1}$ and $\tau\ (R) = 1$ h

$\tau\ (ST) = 1$ h, $\lambda(ST) = 1\ h^{-1}$

$\tau\ (SI) = 4$ h, $\lambda(SI) = 0.25\ h^{-1}$

$\lambda(B) = 0$

$$\text{No. dis./Bq} = \frac{\lambda_{ST}}{(\lambda_{ST} + \lambda_R)(\lambda_{SI} + \lambda_B + \lambda_R)}$$

$= 1/\{(1+1)(0.25+0+1) = 1/2.5 = 0.4$

No. dis. $= 0.4 \times 1 \times 10^6$ Bq $= 4 \times 10^5$

The Human Alimentary Tract (HAT) Model (ICRP 100, 2006)

- The new model includes more identified organs, e.g., the oral cavity and esophagus
- Absorption to the transfer compartment occurs from almost all compartments, not just the small intestine
- The model separates intestinal contents from the intestinal walls (target organs)
- The model includes recycling through the hepatobiliary pathway

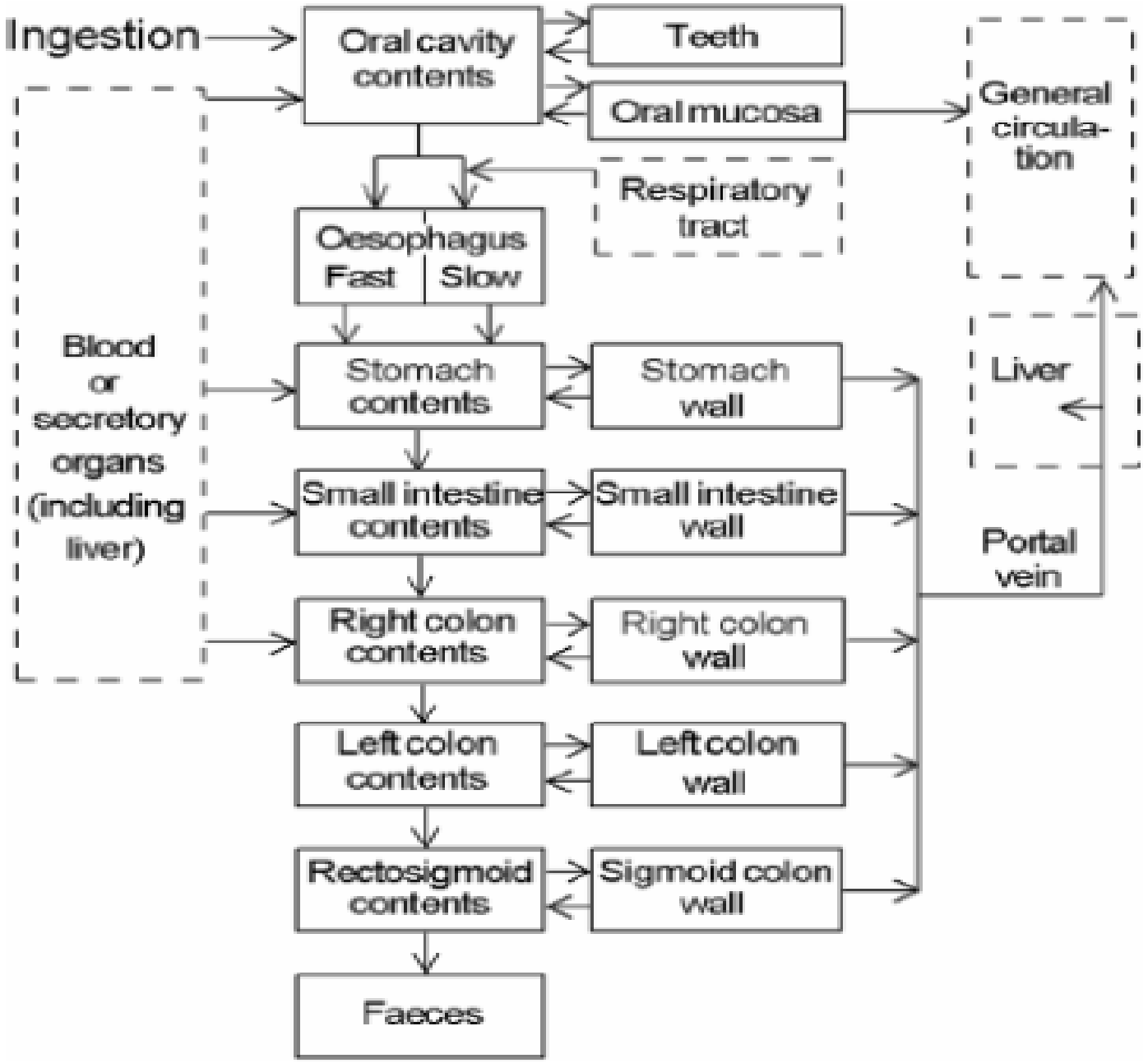


Fig. 5.1. Structure of the human alimentary tract model (HATM). The dashed boxes are included to show connections between the HATM and the human respiratory tract model or systemic biokinetic models.