Uncertainties on internal dose assessment

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4th International MELODI Workshop, Helsinki, Finland
12th -14th September 2012

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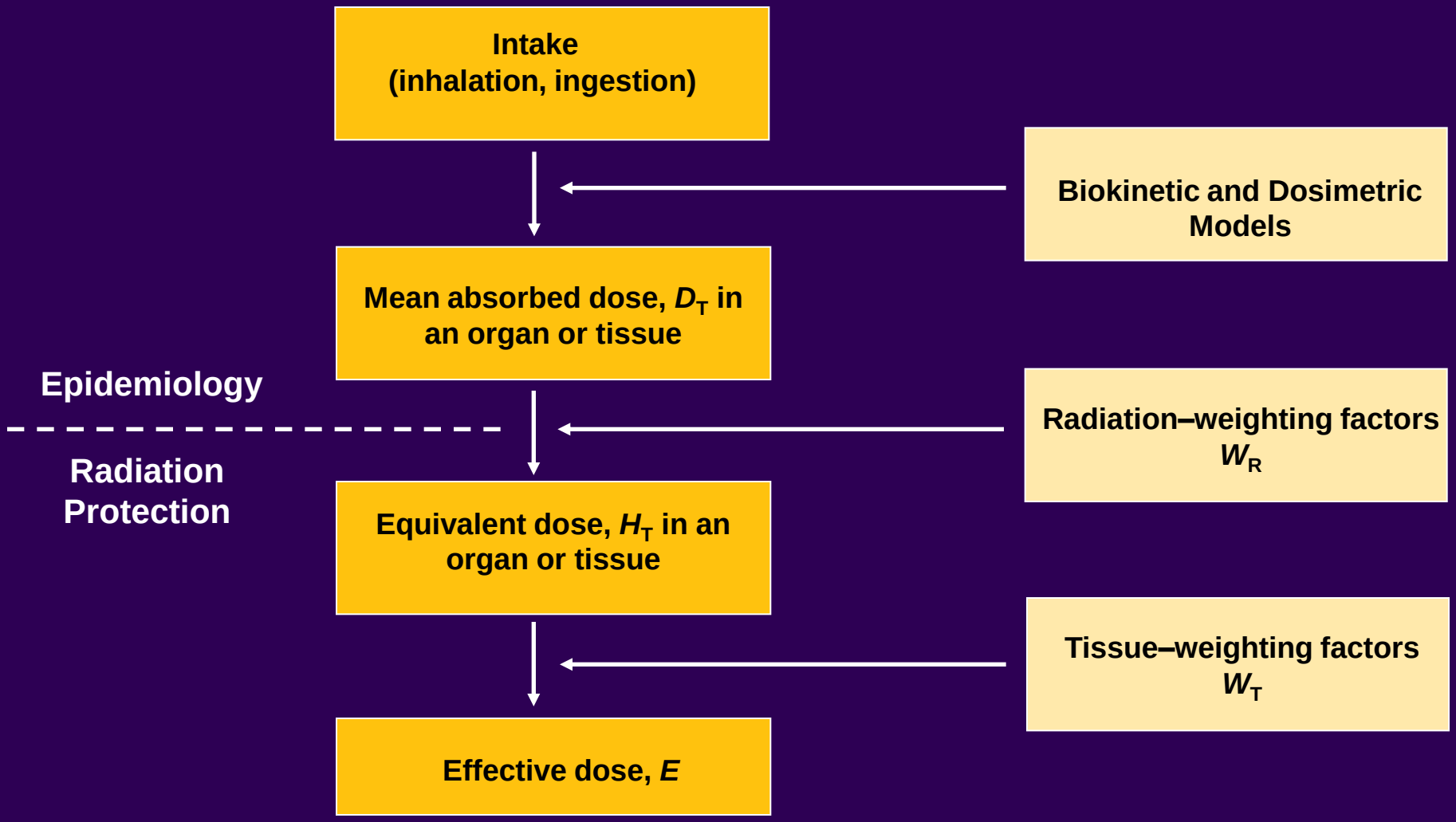
1. Introduction

Internal Doses - how are they calculated?



1. Introduction

Sources of uncertainty

- **Biokinetic model**
  - **Model structure**
  - **Model parameter values**
- **Dosimetry model**
  - **Target tissues**
  - **Tissue geometries and masses**
- **Relative Biological Effectiveness (RBE)**
- **Risk estimates to target tissues**

1. Introduction

Uncertainties – why important?

- **Radiation Protection** – adequacy of protection
- **Epidemiology** – reliability of risk estimates

2. Uncertainties for radiation protection

The system of protection

Effective dose: a protection device

- Allows summation of doses from different radionuclides and external dose
- Use within the system of protection for comparison with limits, constraints, reference levels
- ICRP effective dose coefficients are reference values for control purposes

2. Uncertainties for radiation protection

Uncertainties?

- Uncertainties not considered in the application of dose coefficients

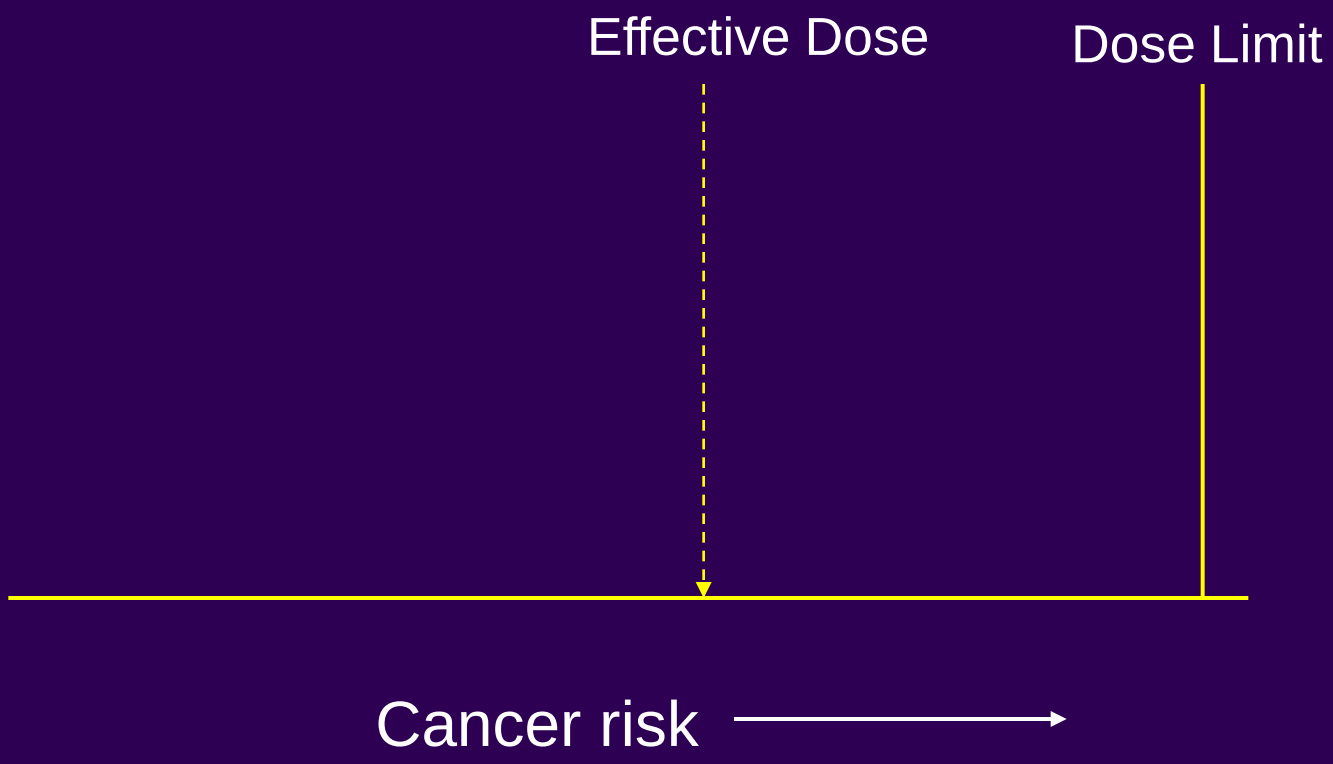
- However - uncertainties are clearly present at all stages of the derivation of dose coefficients

- A knowledge of the uncertainties on doses are required to assess the reliability of protection – how?

2. Uncertainties for radiation protection

What is “reliability”?

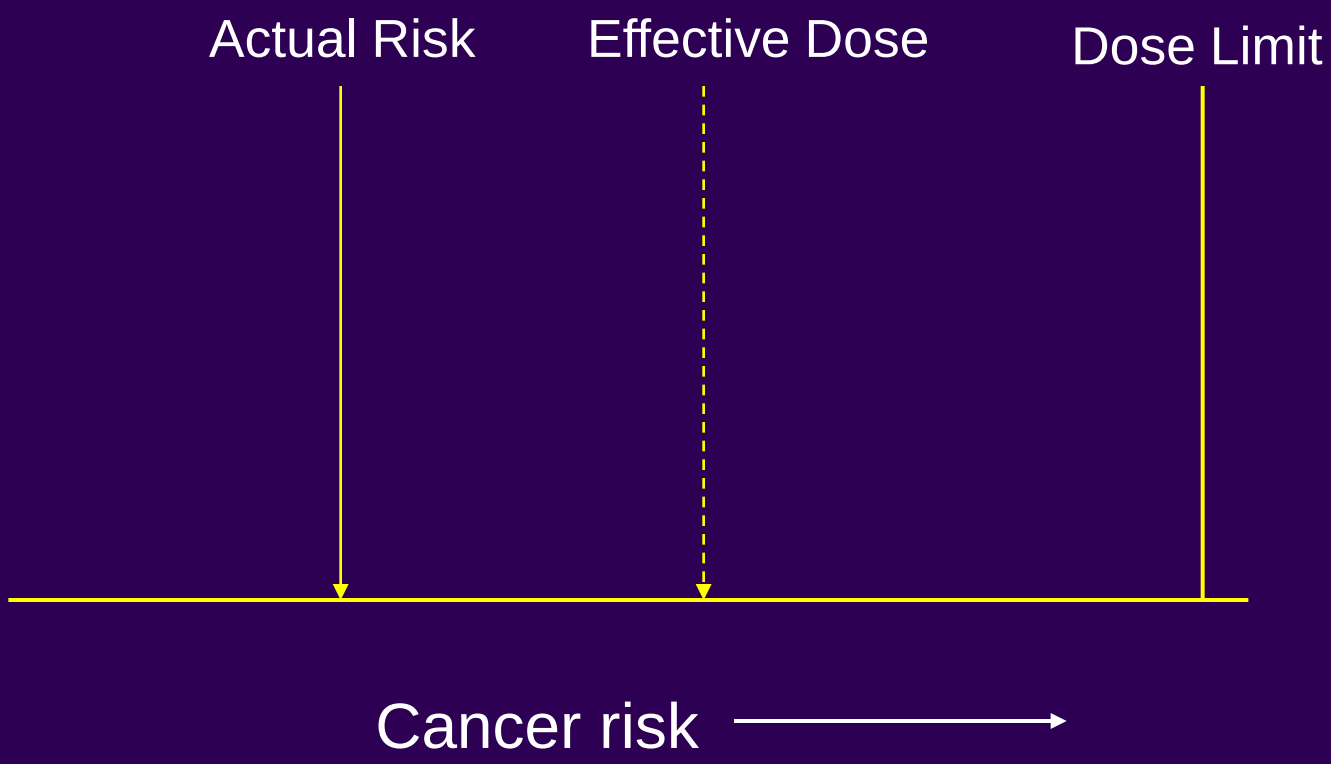
A dose coefficient is “reliable” if it ensures that the radiation risk associated with the exposure is less than the “acceptable” risk (the dose limit) for the exposed population.



2. Uncertainties for radiation protection

Assessing reliability

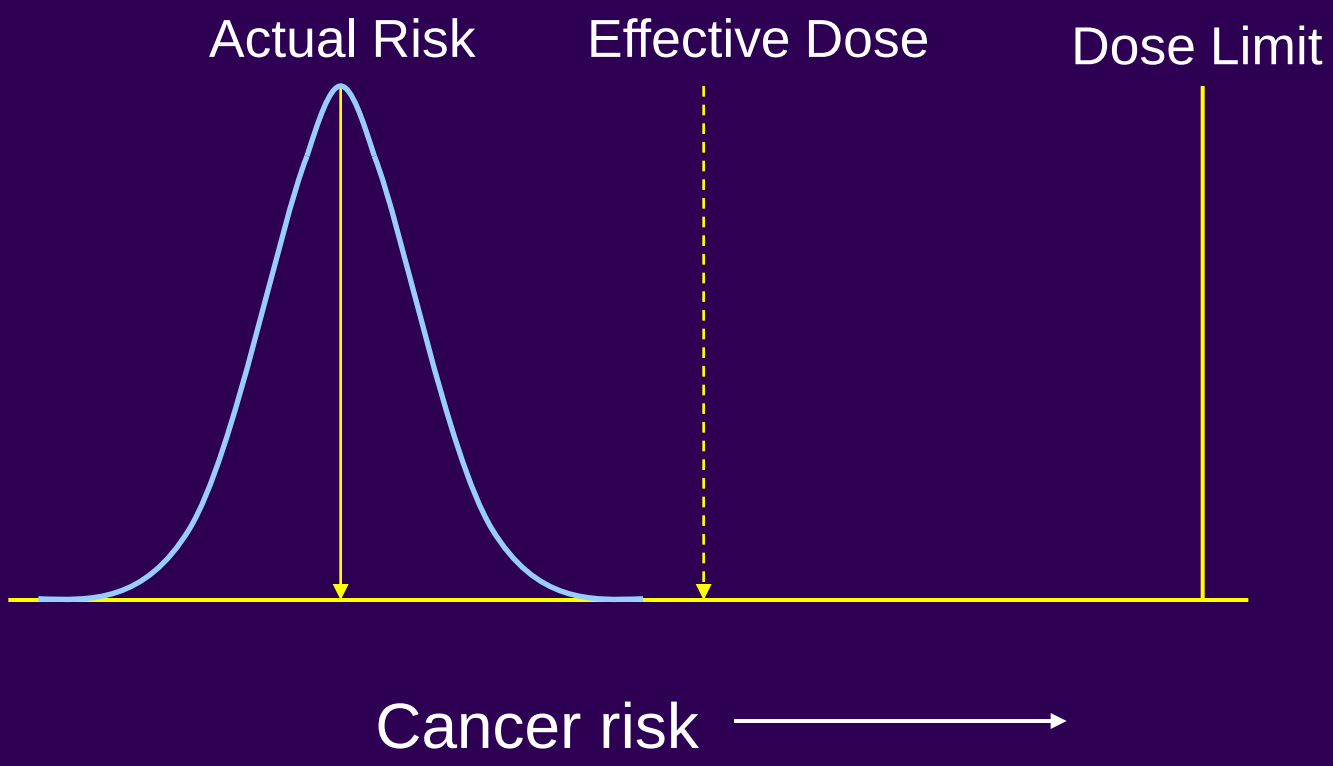
To assess reliability we need to know the actual risk for the exposure pathway in which the dose coefficient is applied



2. Uncertainties for radiation protection

Assessing reliability: the role of uncertainty analysis

Need to estimate the actual risk and its uncertainty to make a judgment on reliability



2. Uncertainties for radiation protection

Uncertainty analysis studies

- Existing studies mostly calculate uncertainties on effective dose or equivalent dose per unit intake

  Mostly biokinetic uncertainties

  Identify parameters that affect uncertainty on dose

- Few studies have estimated uncertainties in the actual risk per unit intake (USEPA)

- The described strategy could be applied to a representative selection of dose coefficients/exposure scenarios for a general evaluation of the reliability of dose coefficients

3. Uncertainties for epidemiology

Nuclear worker studies

Why study nuclear workers?

The study of nuclear workers important to support the extrapolation of risk from external to internal exposure

….this assumption underpins the system of internal radiation protection

3. Uncertainties for epidemiology

Nuclear worker studies

Internal dose reconstruction:

- Worker exposure histories reconstructed from occupational data

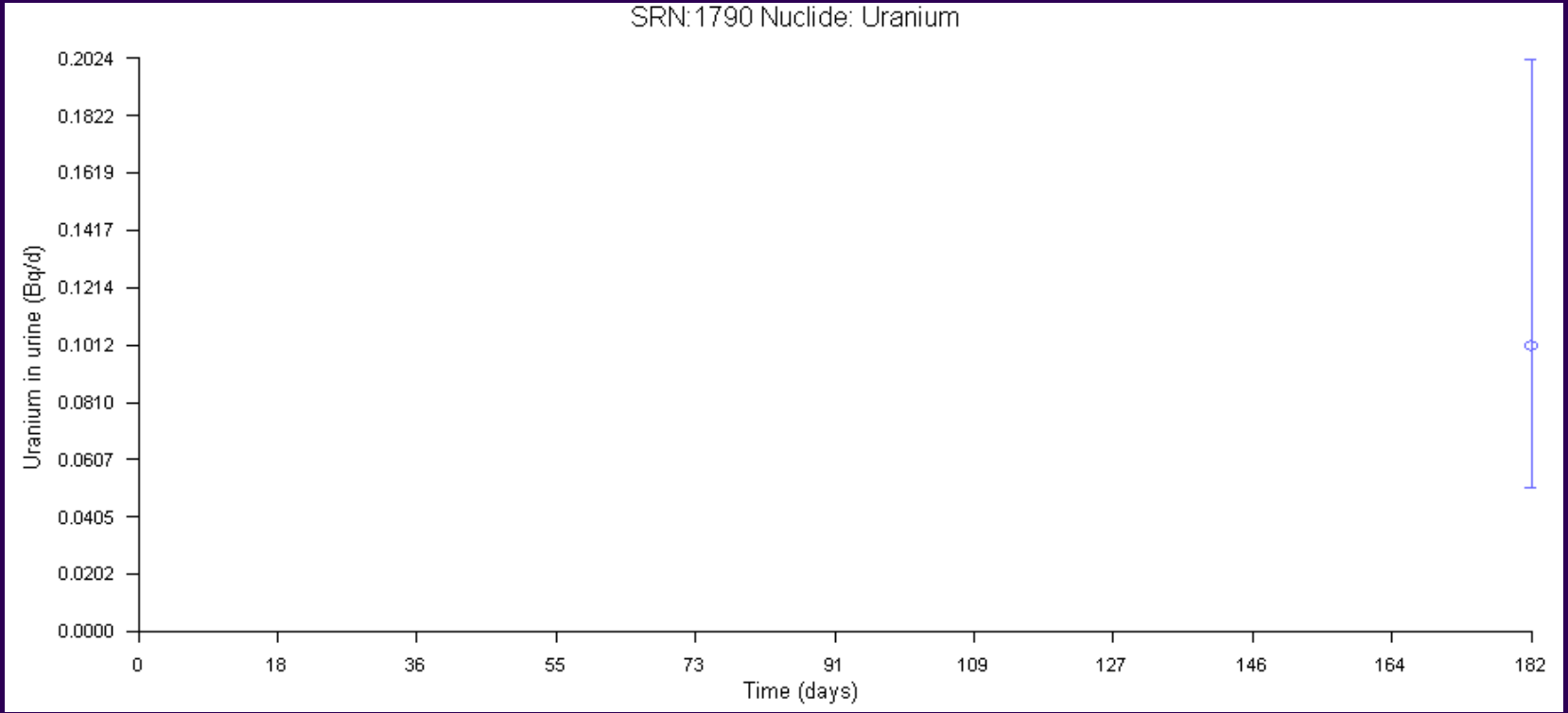
- Point estimates of lung doses from bioassay monitoring data (no uncertainty)

- The approach used for Mayak and Sellafield workers

3. Uncertainties for epidemiology

Point estimates – disadvantages?

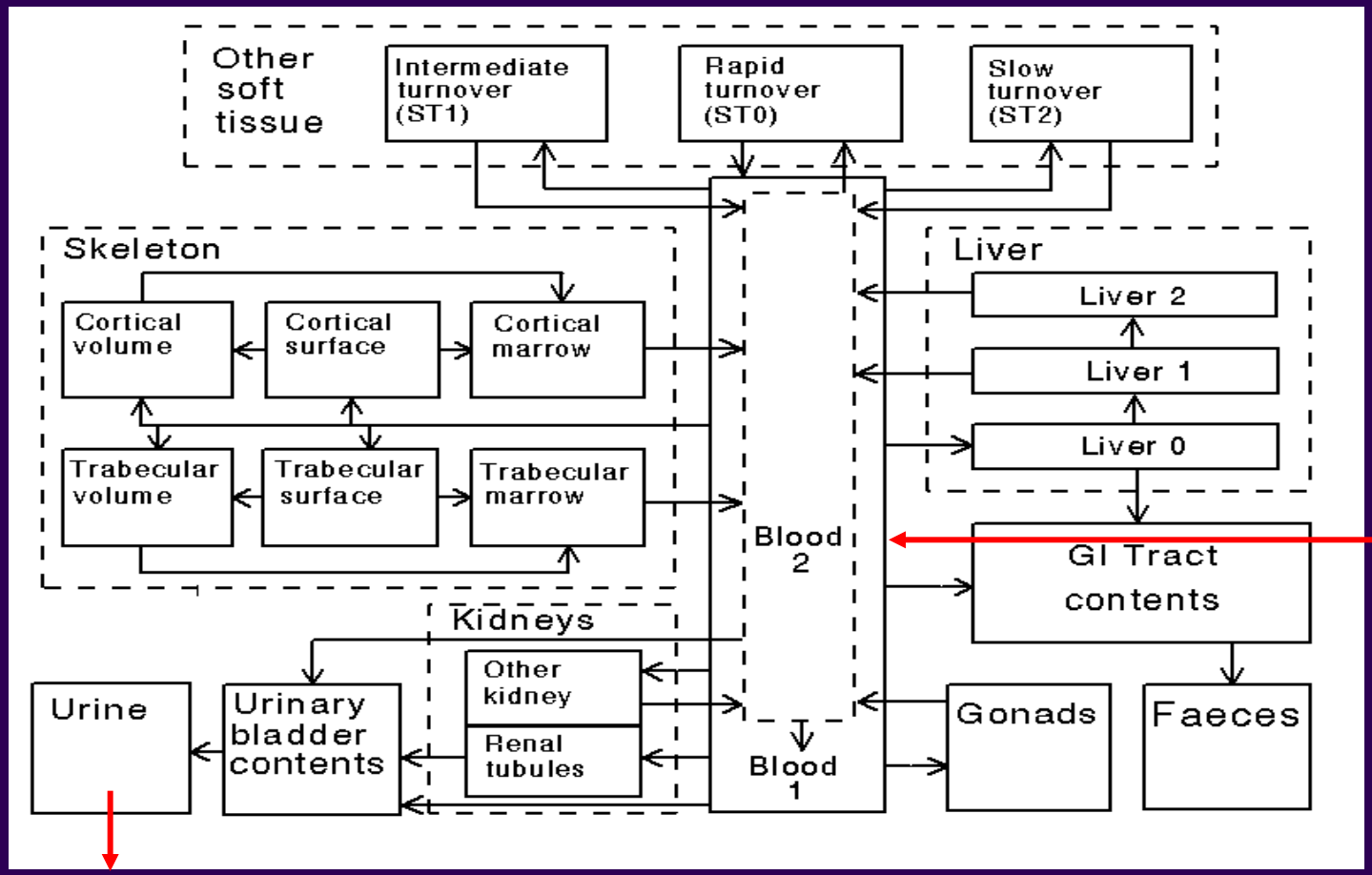
Worker bioassay data are generally weak …



3. Uncertainties for epidemiology

Point estimates – disadvantages?

Uncertainties in model parameter values are significant …



Pu systemic model

Pu from lungs

3. Uncertainties for epidemiology

A Bayesian problem

- Convolute model uncertainties with measurement data:

$$P(\text{Dose} \mid \text{Measurement data})$$

- This distribution is calculated using Bayesian Inference

$$P(D|M) \propto P(M|D).P(D)$$

- Model parameter uncertainties are the “Prior” - **P(D)**

3. Uncertainties for epidemiology

Testing the methodology

- Calculated uncertainties on lung doses for UK plutonium workers

  200 plutonium exposures

- Compared distributions of doses with point estimates

  How “uncertain” are the uncertainties?

  Which parameters dominate the uncertainties?

3. Uncertainties for epidemiology

Testing the methodology

Prior distributions?

- Intakes of plutonium

  Pattern and magnitude of intake

- Deposition parameters

  Aerosol and breathing parameters

- Clearance parameters

  Absorption and particle transport have the greatest impact on lung doses

3. Uncertainties for epidemiology

How large are the uncertainties?

Posterior Distribution: Point Estimate

P(D or I|M)	Soluble Pu		Insoluble Pu	
	Intake	**Lung dose**	Intake	**Lung dose**
Mean	1.1	**4.1**	0.5	**1.7**
Median	0.8	**2.8**	0.3	**0.7**
2.5%	0.2	**0.5**	0.1	**0.1**
97.5%	3.6	**15.0**	2.0	**9.0**

- Mean dose 2-4x greater than point estimates
- Uncertainties on doses cover a wide range
- Reliability of risk estimates that ignore dosimetric uncertainties?

3. Uncertainties for epidemiology

What dominates the uncertainties?

- A prior dominant problem

  urine bioassay data uninformative for lung parameter values

- Plutonium lung solubility is the dominant uncertainty

  a reducible uncertainty

  more and better data on solubility will reduce uncertainties on lung doses

3. Uncertainties for epidemiology

Mayak worker studies

- An important cohort – large number of exposed individuals (~18,0000) with a wide range of lung doses and temporal pattern of dose delivery

- Previous studies suggest risk of lung cancer from Pu exposure are consistent with A-bomb survivor studies

- Previous studies based on point estimates of dose

- New analyses funded under JCCRER (USDOE) and SOLO will use improved lung model and include Bayesian uncertainties on dose estimates

Uncertainties on internal dose assessment

Summary

- Uncertainties present at all stages of the calculation of dose
- Need to consider uncertainties to assess the reliability of protection and epidemiology studies
- A strategy for assessing reliability of dose coefficients using uncertainty analysis
- Bayesian methods for estimating uncertainties on doses for epidemiology studies
- Current applications of the methodology to Mayak workers