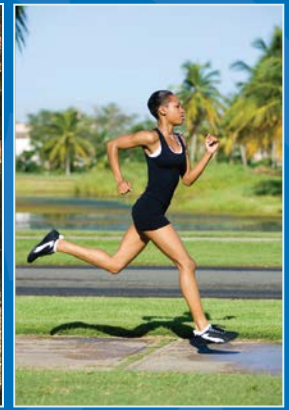
United States Environmental Protection Agency

Assessing Uncertainty and Variability in the Context of Exposure Assessment


RISK ASSESSMENT TRAINING AND EXPERIENCE

Exposure Assessment Course Series – EXA 407

Office of Research and Development
National Center for Environmental Assessment

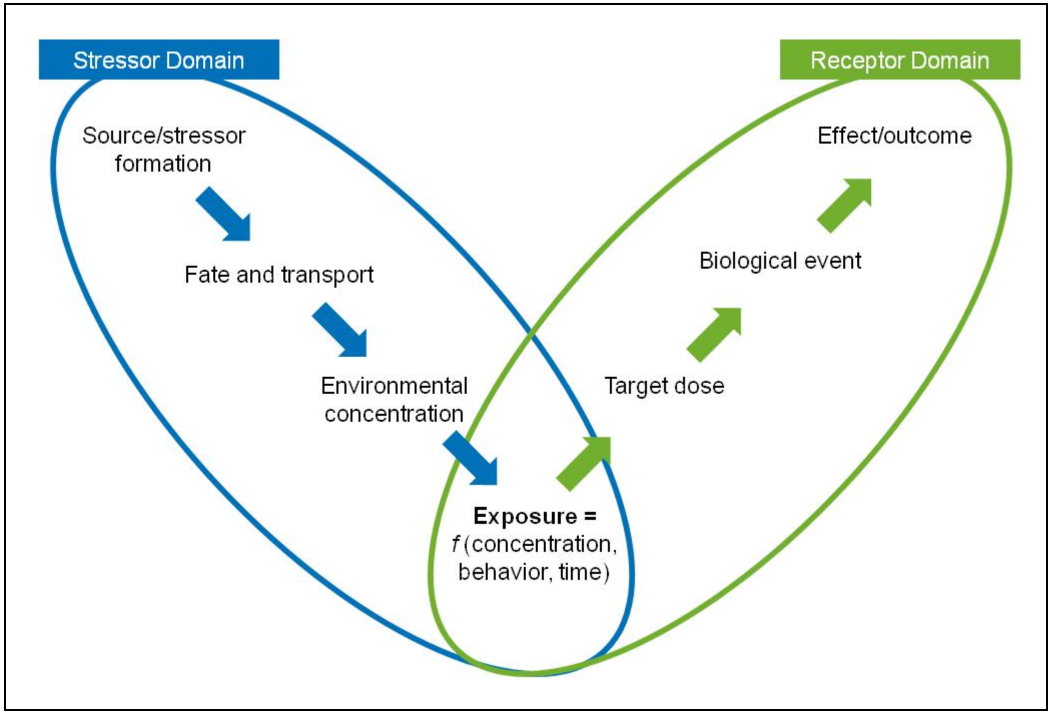
What You Can Expect to Learn From This Course

- Definitions of variability and uncertainty
- Factors that contribute to uncertainty and variability
- Types of variability and uncertainty

VARIABILITY AND UNCERTAINTY IN EXPOSURE ASSESSMENT

From Source to Receptor to Effect

- Variability and uncertainty are important to all components of the source-to-effect continuum
- Focus is on exposure in this course, but just as important to fate and transport



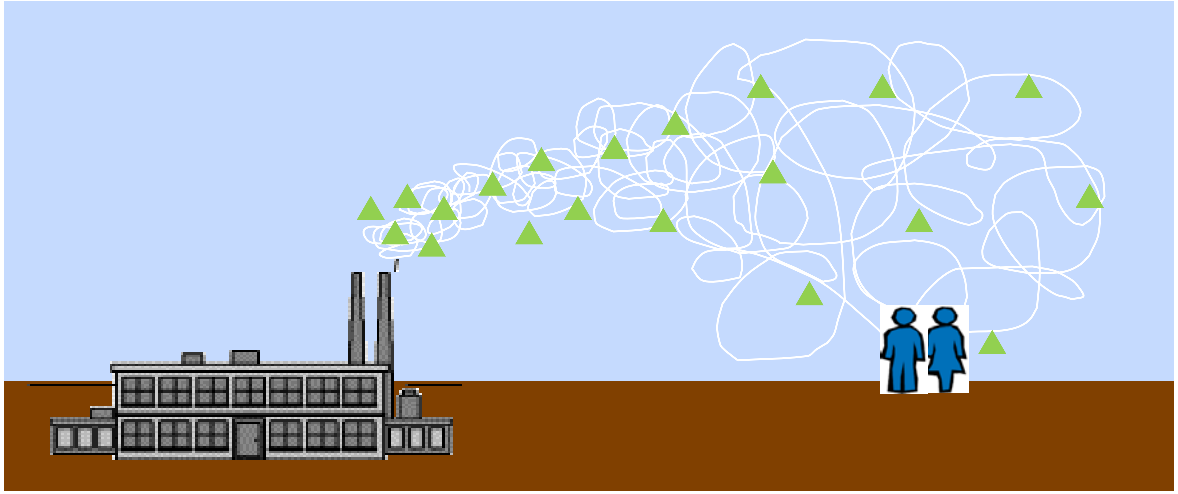
United States Environmental Protection Agency

What is Variability?

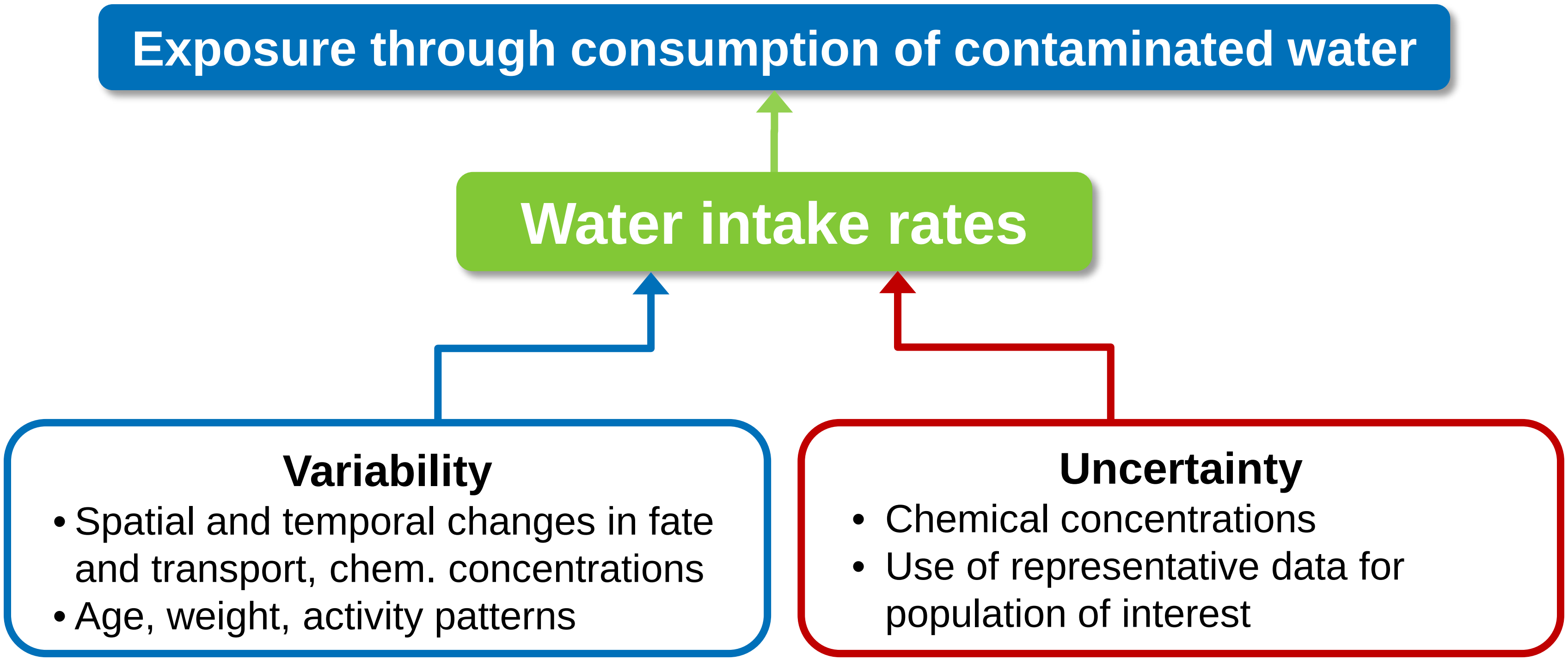
- **Variability** refers to true heterogeneity or diversity
  - Inherent property of a population
  - Cannot be reduced or eliminated
  - Can be better characterized with more data

What is Uncertainty?

- **Uncertainty** refers to a lack of knowledge due to incomplete data or an incomplete understanding of the process
  - Can be reduced or eliminated by collecting more or better data



What is the Difference Between Variability and Uncertainty?



- Variability cannot be reduced, only better characterized
- Uncertainty can be reduced and in some cases even eliminated

UNDERSTANDING VARIABILITY

United States
Environmental Protection
Agency

Factors Contributing to Exposure Variability

Age

Gender

Behavioral patterns

Location

Socioeconomic factors

Types of Variability

- Spatial variability
- Temporal variability
- Inter-individual variability
- Intra-individual variability

Spatial Variability

Spatial variability refers to variability across locations

Regional
Macroscale

Local
Microscale

United States Environmental Protection Agency

TYPES OF VARIABILITY:

Temporal Variability

Temporal variability refers to variation over time

Long-term variability:

- Seasonal fluctuations in weather
- Amount of time a person spends outdoors

Short-term variability:

- An individual’s activities at different times of day
- Industrial operations during weekdays versus weekends

Inter-individual Variability

Inter-individual variability refers to variability between individuals

- Characteristics:
  - Gender
  - Age and lifestage
  - Body weight
  - Genetic predisposition
- Behaviors:
  - Activity patterns
  - Ingestion and inhalation rates
  - May be related to spatial and temporal factors

TYPES OF VARIABILITY:

Intra-individual Variability

Intra-individual variability refers to variability within an individual

Function of fluctuations in an individual's physiologic or behavioral characteristics

United States Environmental Protection Agency

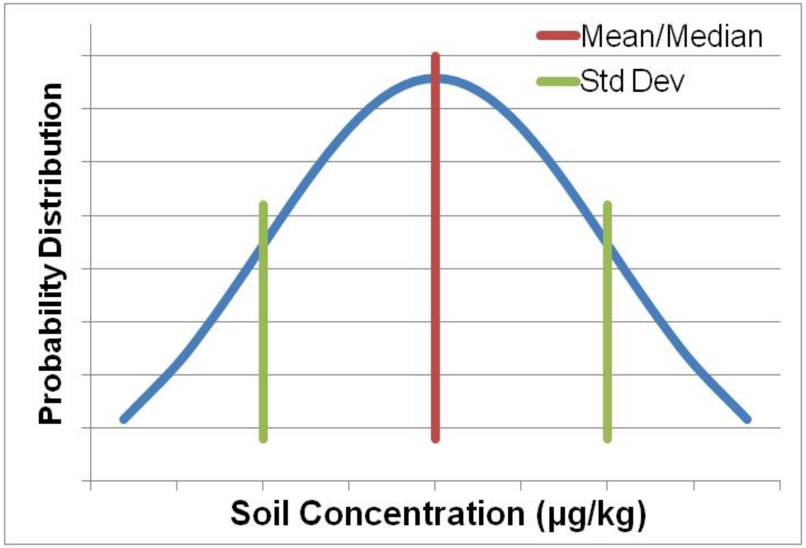
ADDRESSING VARIABILITY IN AN EXPOSURE ASSESSMENT

Presenting Variability

- Tables with percentiles or ranges of values
- Probability distributions with specified parameters
- Qualitative discussion

Recommended Values for Intake of Grains, Edible Portion, Uncooked, Per Capita
(Source: EPA Exposure Factors Handbook, 2011)

Age Group	Mean (g/kg-d)	95th Percentile (g/kg-day)
Birth to 1	3.1	9.5
1 to <2	6.4	12.4
2 to <3	6.4	12.4
3 to <6	6.2	11.1
6 to <11	4.4	8.2
11 to <16	2.4	5
16 to <21	2.4	5
21 to <50	2.2	4.6
≥50	1.7	3.5

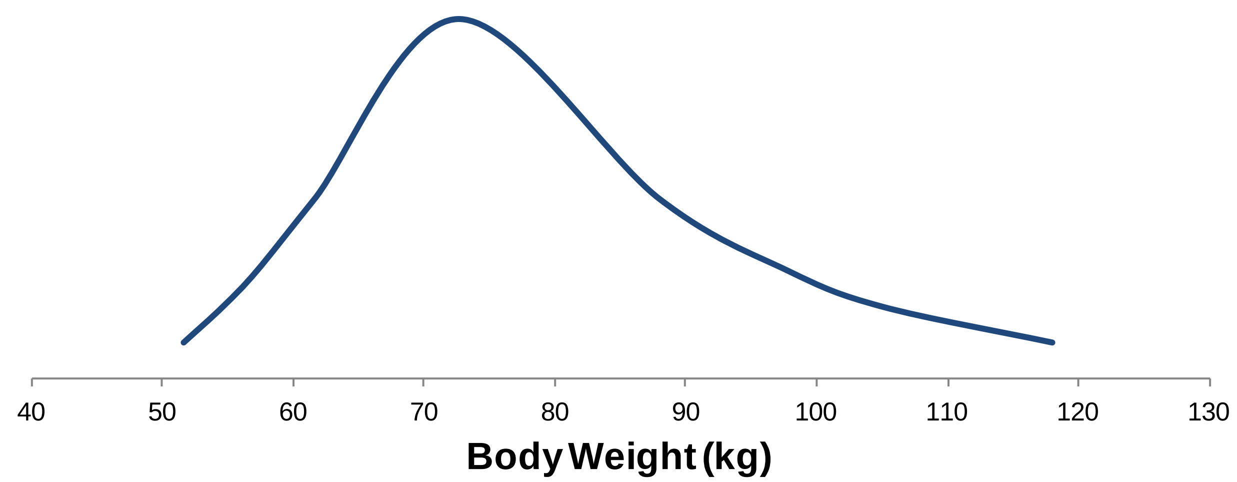


- Other ways to address variability:
  - Ignore
  - Disaggregate
  - Use an average, min, or max value
  - Probabilistic or bootstrap techniques

Ignoring Variability

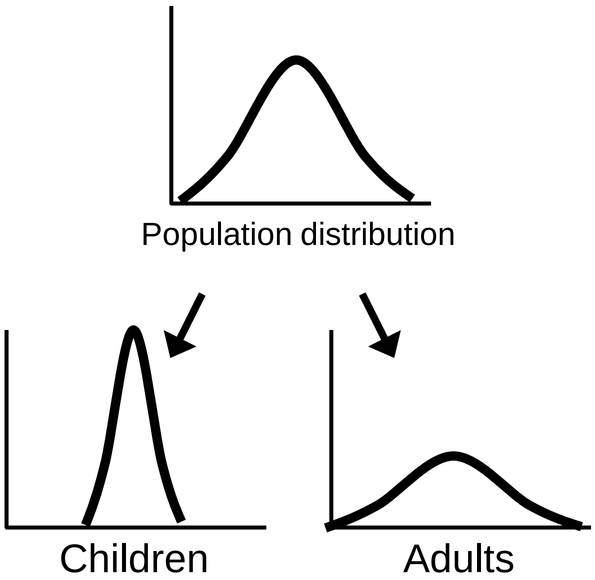
- Used in combination with other strategies
- Should only be used when variability is small or there is a reasonable expectation that impact would be small

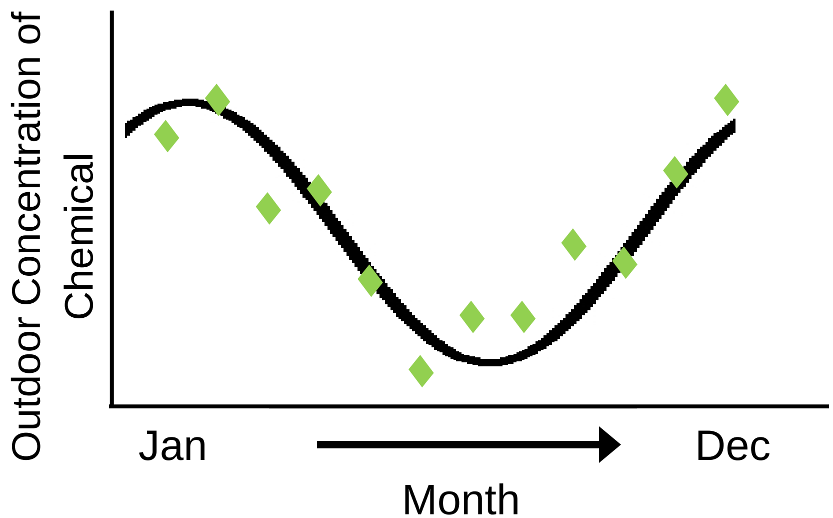
Mean Body Weight Distribution of Females age 40-50 Years Derived from NHANES 1999-2006



Disaggregating Variability

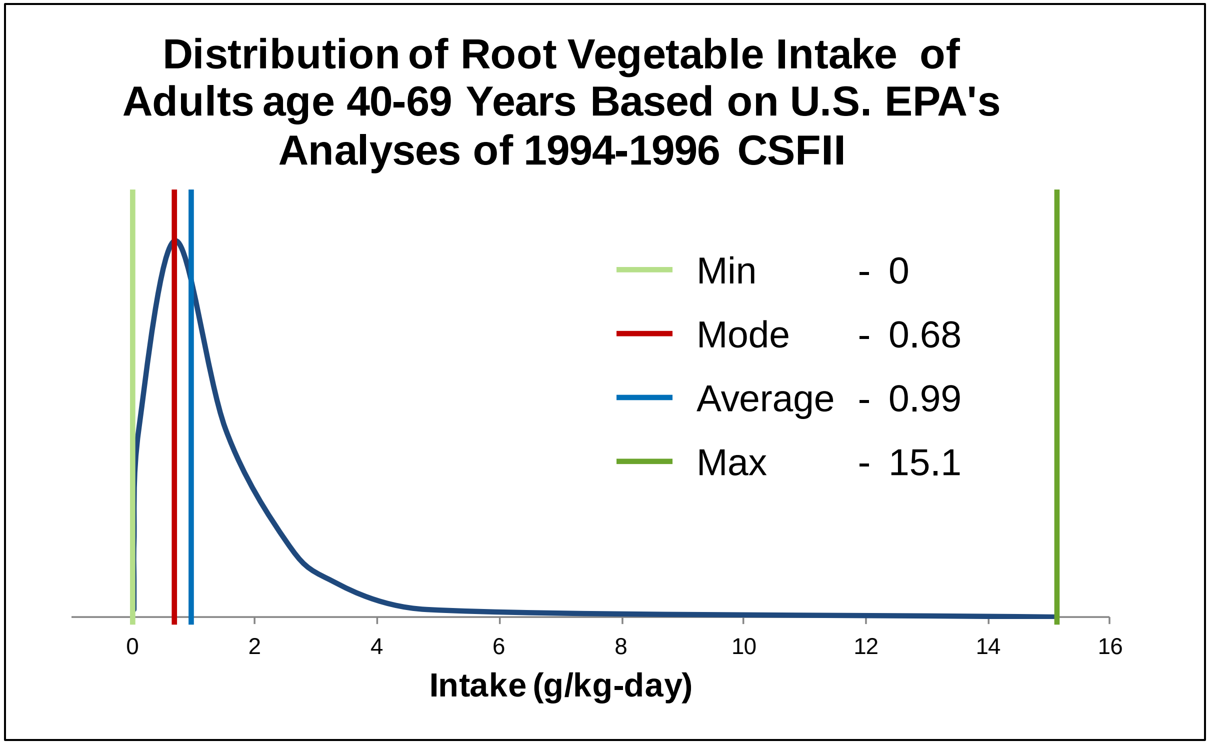
- Can be a tool to better understand or reduce variability
- Consideration of population cohorts and lifestages, time scales, subregions, and/or microenvironments
- Application of mathematical models





Average or Minimum/Maximum

- Requires confidence in value and small variability
- Minimum and maximum values to characterize range
  - Most common method
  - Might results in over- or underestimation of exposure



Probabilistic or Bootstrapping Techniques

- Characterize variability by repeated sampling of probability distributions of equation variables
- Result: Distribution of outcomes with associated probability
- Bootstrap techniques estimate confidence intervals for parameters by simulated re-sampling of empirical distributions

Input Distributions **Sampling and Calculation** **Risk Estimates**

United States Environmental Protection Agency

Exposure Modeling with APEX

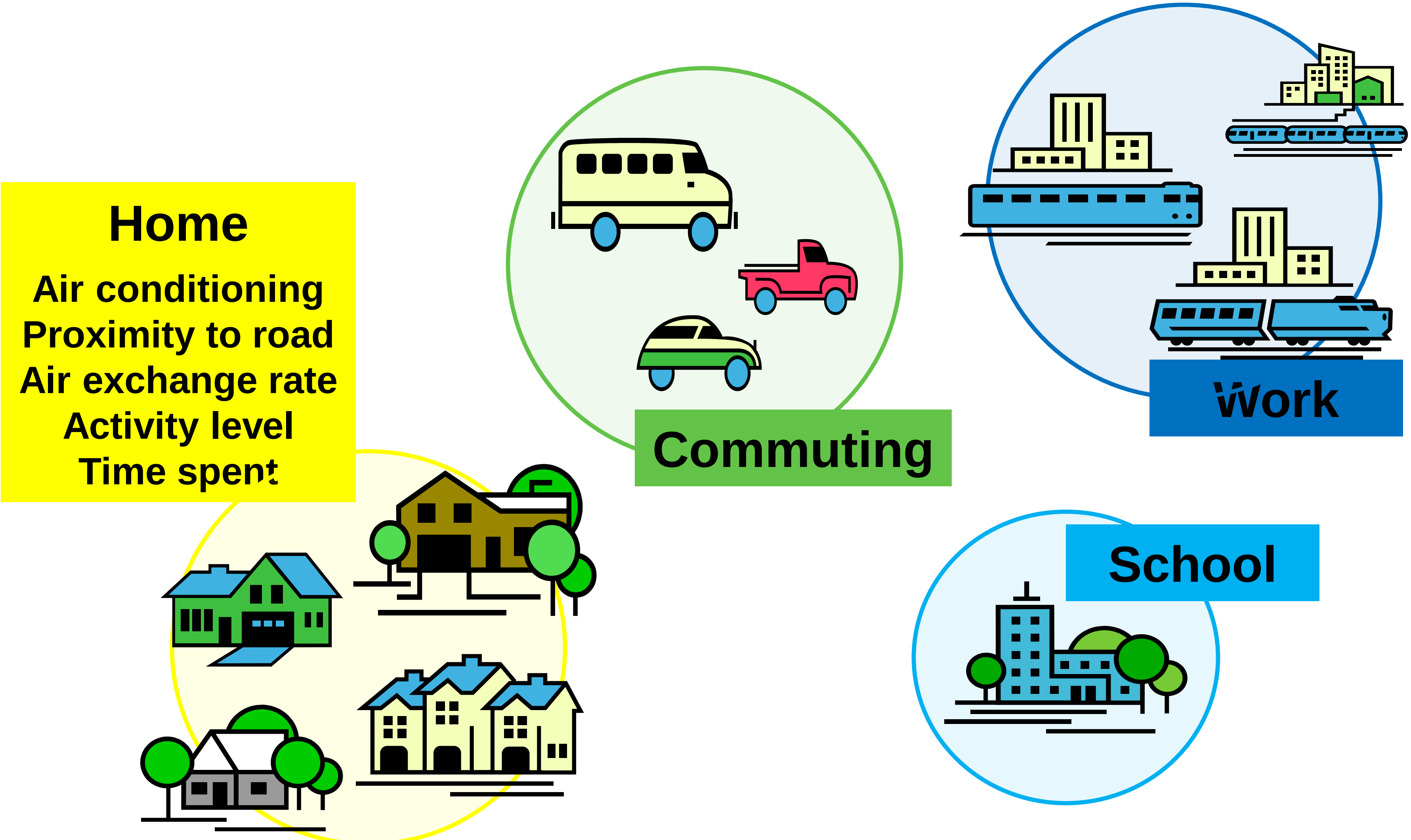
Characterize Study Area
- Air quality data
- Meteorological data

Characterize Population
- Ages
- Genders
- Races

Create Simulated Individuals
- Age, gender, race
- Physiological characteristics
- Home & work locations
- Home characteristics

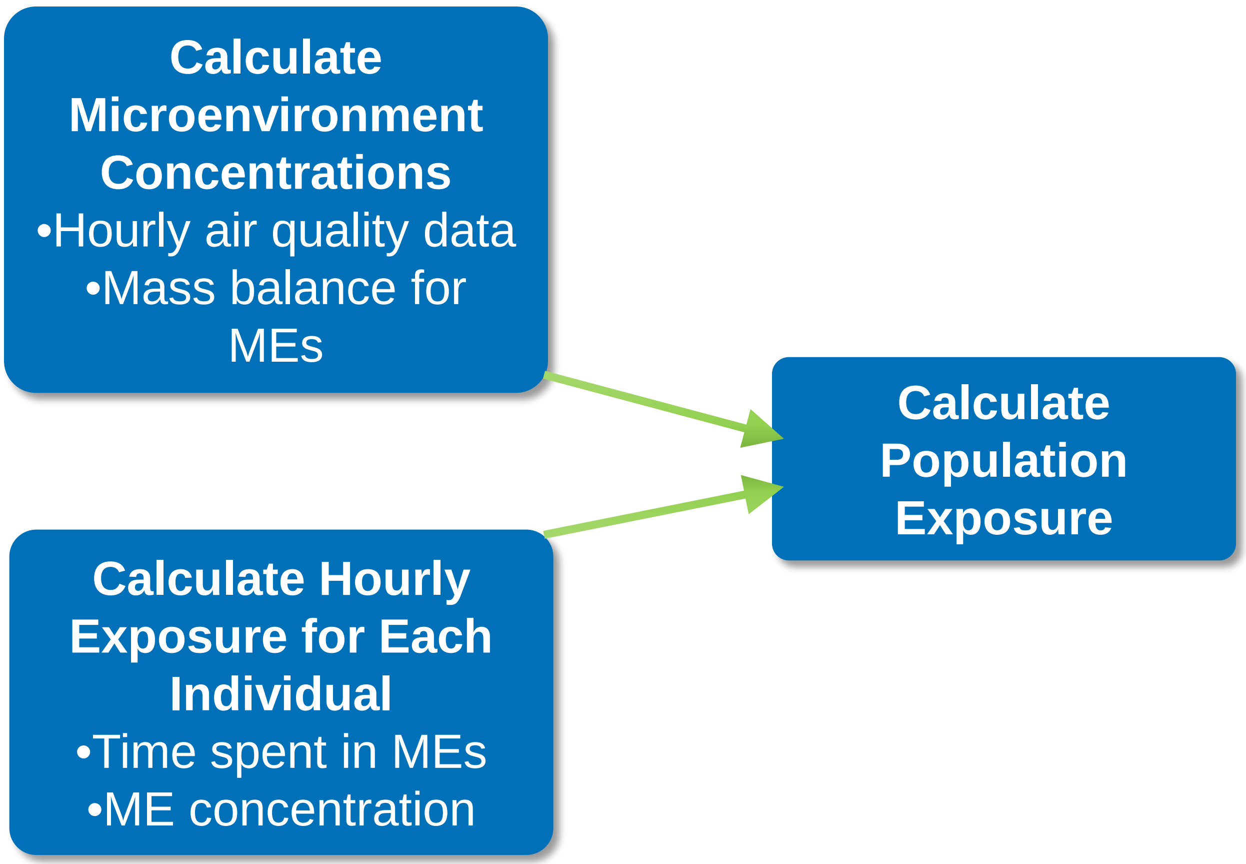
Construct Activity Sequence
- Use CHAD diaries
- Locations
- Activities

APEX Activity Modeling



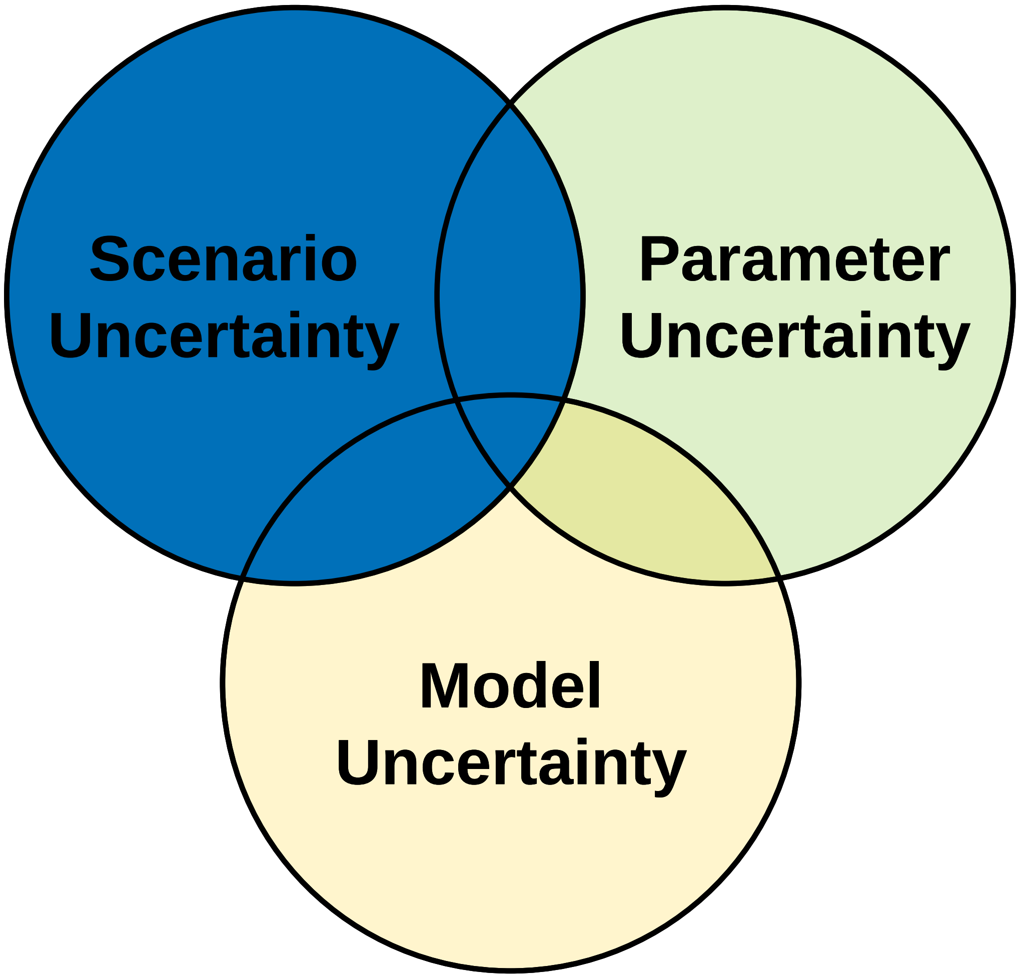
Concentrations and Exposure in APEX

For simulated individuals



UNDERSTANDING UNCERTAINTY

Types of Uncertainty



Scenario Uncertainty

- **Scenario uncertainty:** uncertainty regarding missing or incomplete information on the scenario
  - Can be attributed to incomplete descriptions of key information
- Sources of scenario uncertainty:
  - Descriptive errors
  - Aggregation errors
  - Errors in professional judgment
  - Incomplete analysis

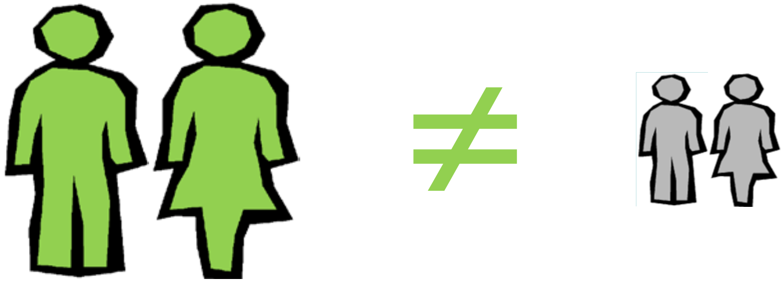
Descriptive Errors

- Errors in basic information about exposure pathways, scenarios, and populations of concern
- For example:
  - Misidentifying chemical producers, uses, or properties of a chemical
  - Neglecting to include population cohort

Aggregation Errors

- Result from too much "lumping" of information

Assumption that population is homogeneous



Spatial and temporal approximations

Sources of Scenario Uncertainty:

Errors in Professional Judgment

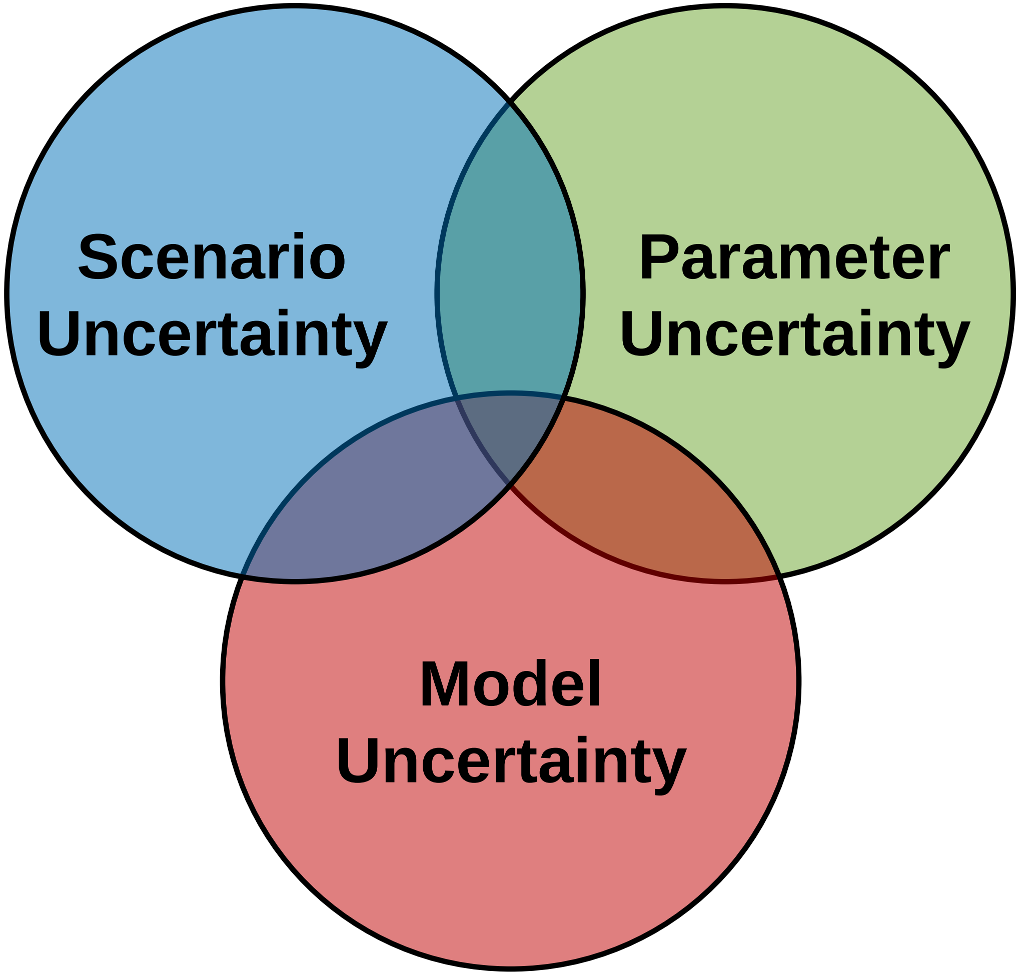
- Affect how the exposure scenario is defined
  - Population of concern
  - Exposure routes and pathways
  - Chemical of concern
- Related to selection of appropriate models

Sources of Scenario Uncertainty:

Incomplete Analysis

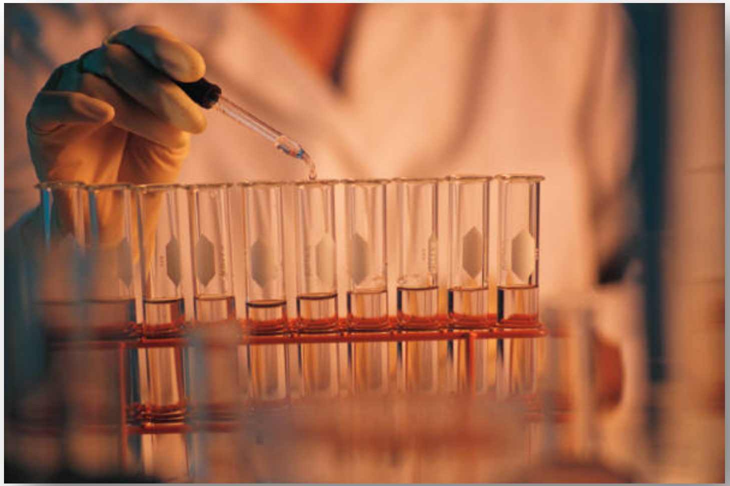
- Result from overlooking exposure scenarios or populations due to lack of data
- Difficult to quantify
- Recommended approach:
  - Include rationale for excluding potential exposure scenarios
  - Explain whether decision was based on data, analogs, or professional judgment
- Example: Is dermal exposure relevant?

Types of Uncertainty



Parameter Uncertainty

- **Parameter uncertainty** refers to uncertainty regarding a specific exposure parameter
- Numerical values for exposure parameters typically derived from EPA's *Exposure Factors Handbook* and other sources
- Sources include:
  - Measurement errors
  - Sampling errors
  - Variability
  - Data type

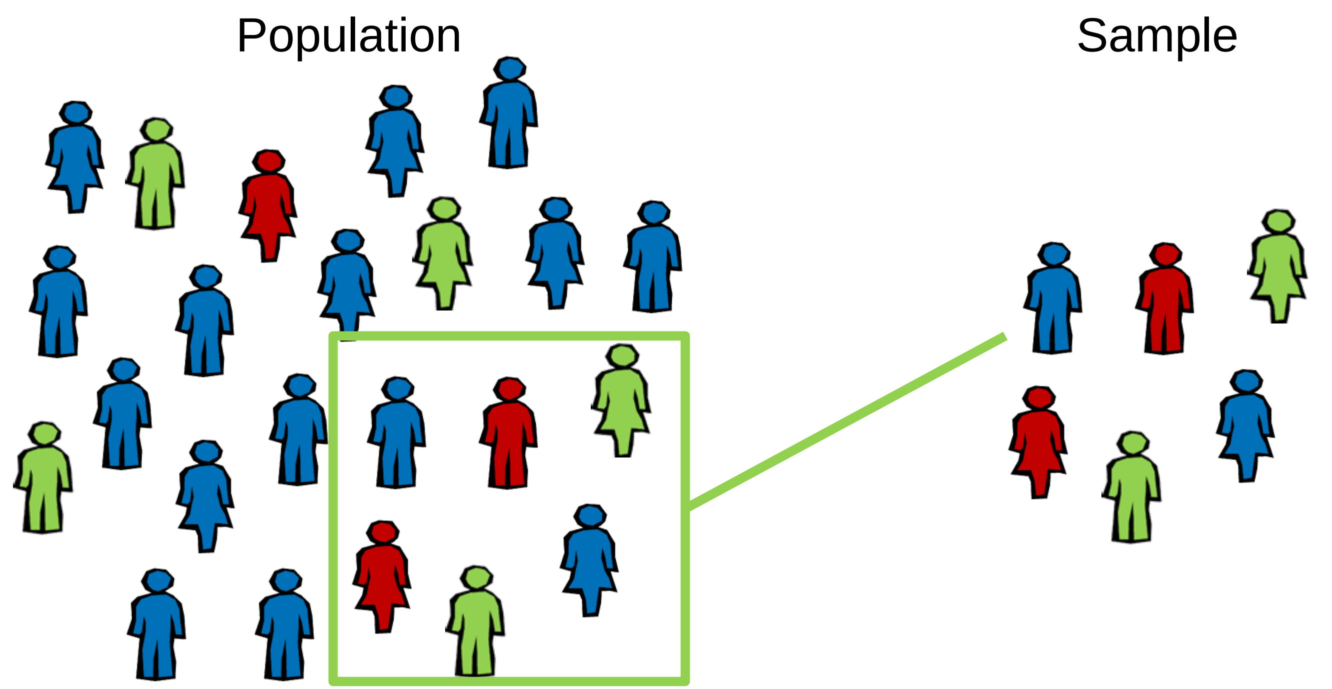


Measurement Errors

- Errors associated with anything measured
  - **Random error:** results from imprecision in the measurement process
  - **Systematic error:** bias or tendency away from true value

Sources of Parameter Uncertainty:
Sampling Errors

- Sample representativeness is important
  - There are implications of extrapolating from small data sets



Sample does not accurately represent population color

United States Environmental Protection Agency

Characterization of Variability

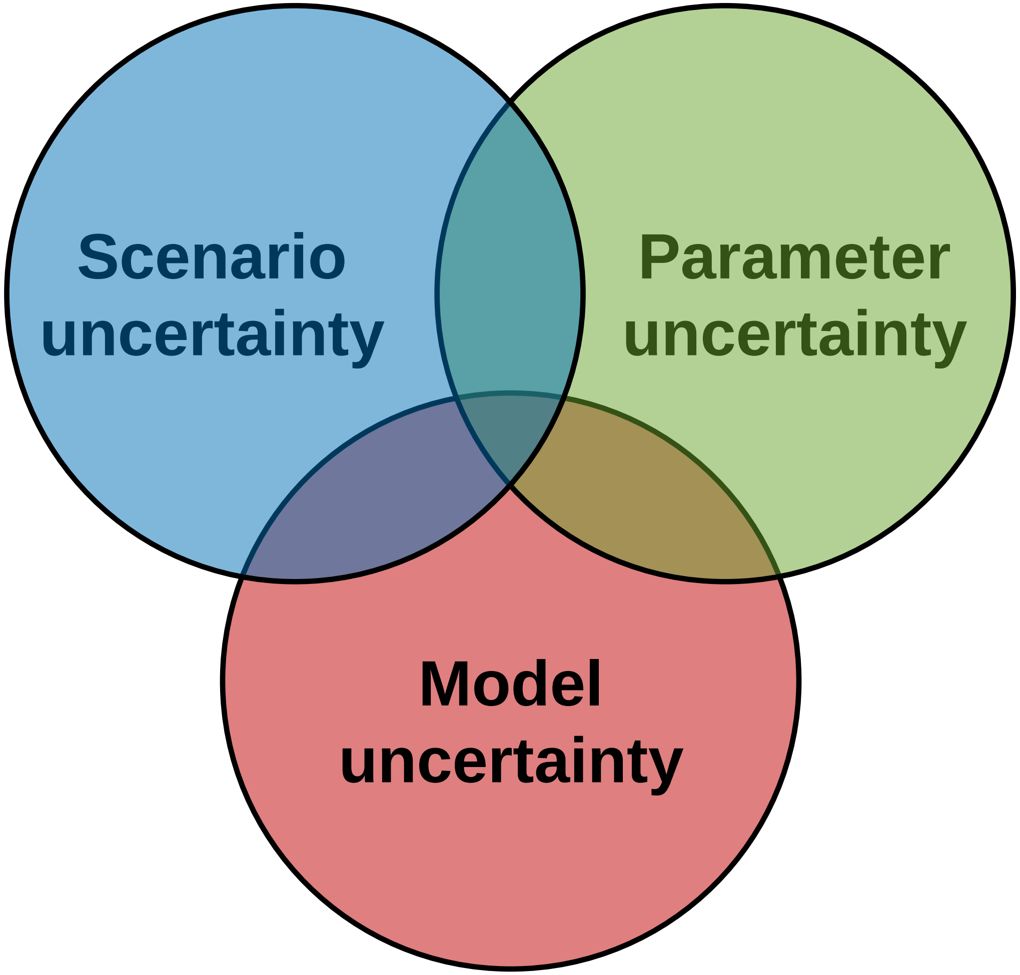
- Inability to characterize variability contributes to uncertainty

Data Type Uncertainty

- Surrogate or generic data
- Expert judgment or elicitation
- Default data (especially for screening-level assessments)

≈

Types of Uncertainty



Model Uncertainty

- **Model uncertainty** results from gaps in scientific knowledge required to make predictions
- Models represent exposure process and fate and transport processes
  - Quantitatively describe relationship between input parameters and responses to changes in inputs
- Sources of uncertainty include:
  - Relationship errors
  - Modeling errors
  - Selection of the incorrect model
  - Parameter uncertainty

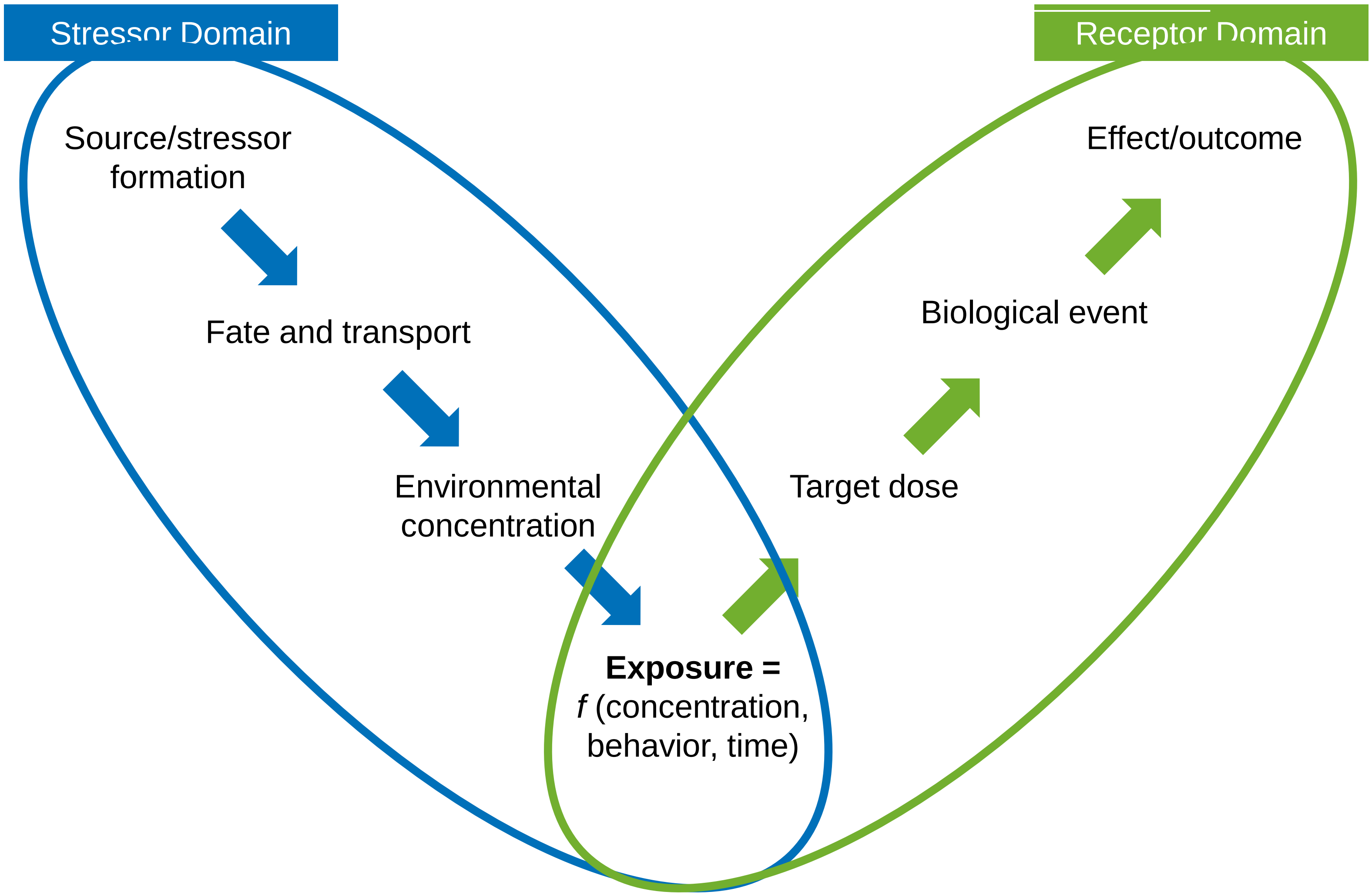
Relationship Errors, Modeling Errors, and Model Selection

- **Relationship errors** result from drawing incorrect conclusions from correlations
- **Modeling errors** result from failure to consider exposure parameters
- **Model selection** and implementation considerations:
  - Boundary conditions
  - Dependencies
  - Assumptions
  - Level of detail
  - Extrapolation
  - Implementation and technical aspects

CLASS ACTIVITY

Class Activity:

Source to Effect Continuum



CLASS ACTIVITY:

London Smog of 1952

United States Environmental Protection Agency

ADDRESSING UNCERTAINTY IN AN EXPOSURE ASSESSMENT

United States Environmental Protection Agency

Why Address Uncertainty in Exposure Assessments?

Addressing uncertainty allows us to:

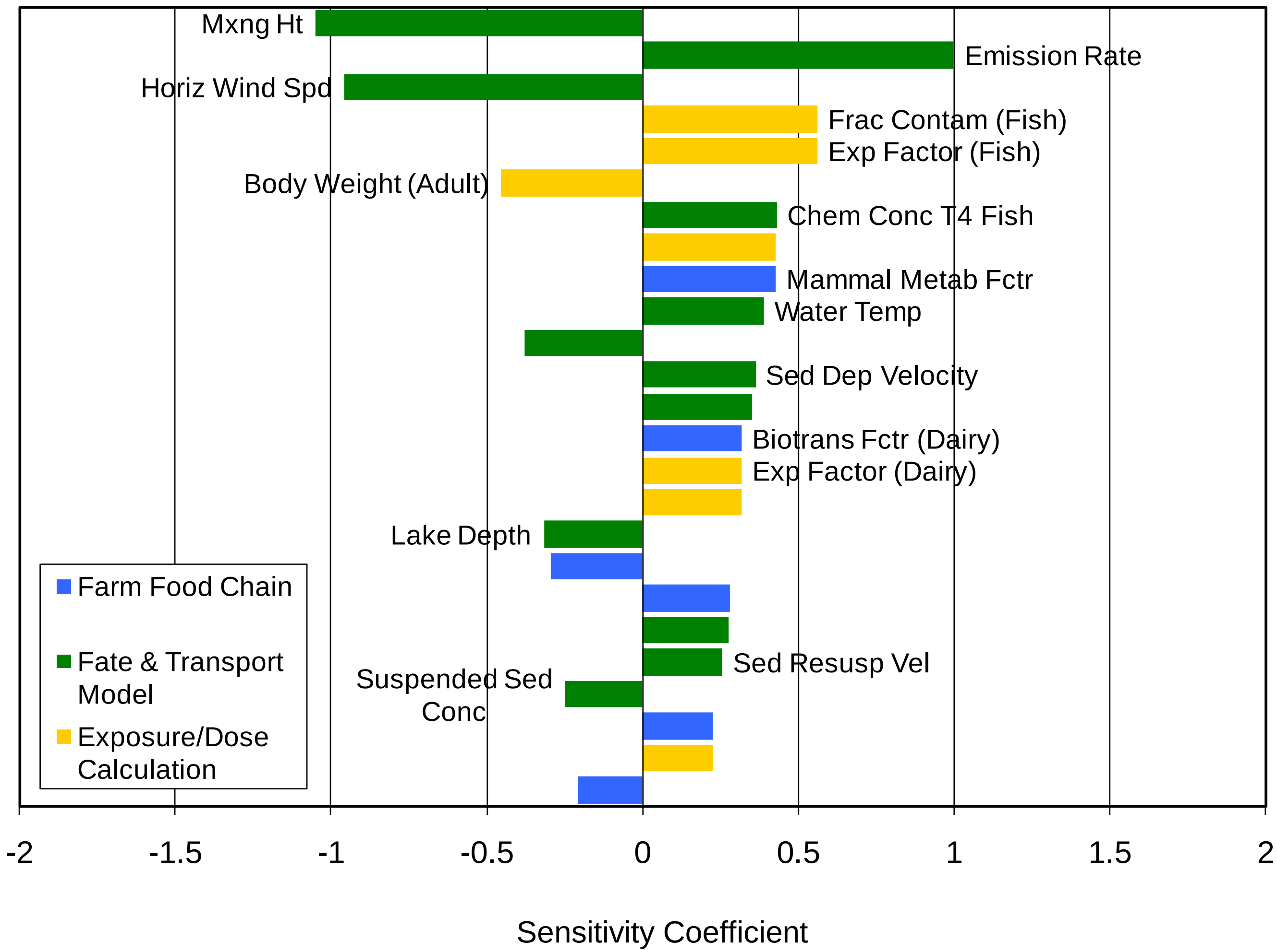
- **Demonstrate** our level of understanding and confidence in exposure estimate
- **Combine** uncertain information from different sources
- **Provide** context for evaluation
- **Improve** quality of best estimates
- **Inform** decisions about expending resources to acquire more data
- **Guide** refinement process
- **Increase** transparency

Qualitative and Quantitative Uncertainty Analysis

	Qualitative	Quantitative
What are Sources of Uncertainty?	• Scenario • Parameter • Model	• Parameter • Model
How is Uncertainty Approached?	Characterize: • Level of uncertainty in influential parameters • Data gaps • Impact of subjective decisions	• Probabilistic methods • Non-probabilistic methods

Sensitivity Analysis

Elasticity of TCDD Lifetime Risk (-5% Perturbation of Variable)

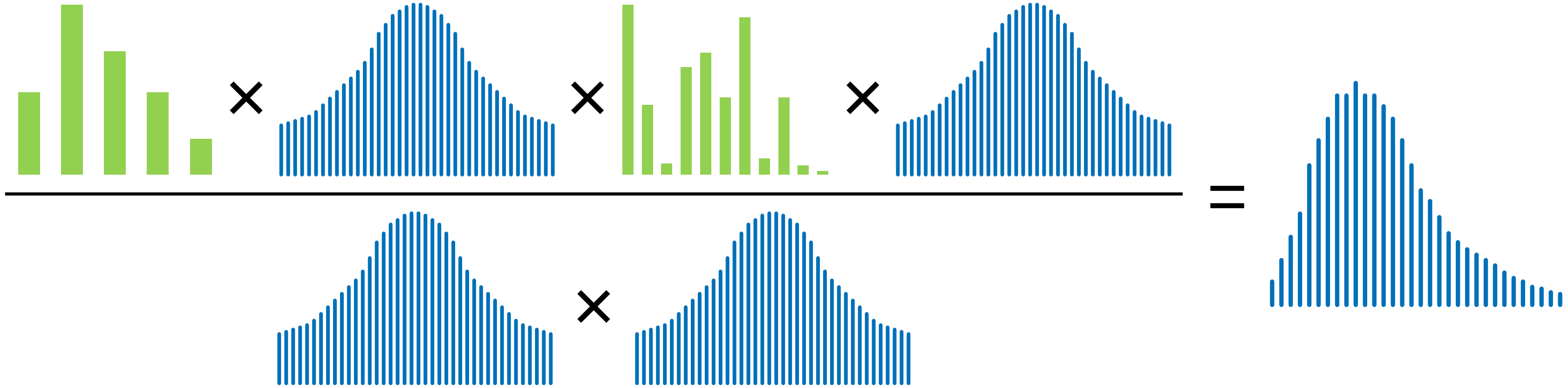


- Change one variable and leave others constant
- Useful to identify variables with greatest effect on outcome

Source: EPA's Risk and Technology Review (RTR) Risk Assessment Methodologies (2009)

Probabilistic Approaches to Uncertainty Analysis

- Monte Carlo
  - Probability density functions assigned to each parameter
  - Values from distribution selected randomly and inserted into exposure equation
  - Process repeated many times
  - Result is a distribution of values that reflects the overall uncertainty in the inputs



Monte Carlo Analysis

- Strength:
  - Applicable to many situations
- Complications:
  - Must have confidence in distributions
  - Must understand relationships between parameters (or assume independence)
  - One change $\rightarrow$ re-run simulation
  - Results do not tell assessor which variables are most important contributors to uncertainty
- Remember! Garbage in = Garbage out

CONCLUSION

Conclusion

- **Variability:** true heterogeneity or diversity
  - Can be characterized, not reduced
- **Uncertainty:** lack of knowledge due to incomplete data
  - Can be reduced

It is important to address both variability and uncertainty in exposure assessments.