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General Concepts of Exposure Assessment



RISK ASSESSMENT TRAINING AND EXPERIENCE
Exposure Assessment Course Series – EXA 401

Office of Research and Development
National Center for Environmental Assessment

What You Can Expect to Learn from this Course

- How exposure assessment relates to human health risk assessment
- Important elements of exposure assessment
- Introduce the concepts of uncertainty and variability in exposure assessment
- What EPA resources are available for exposure assessors

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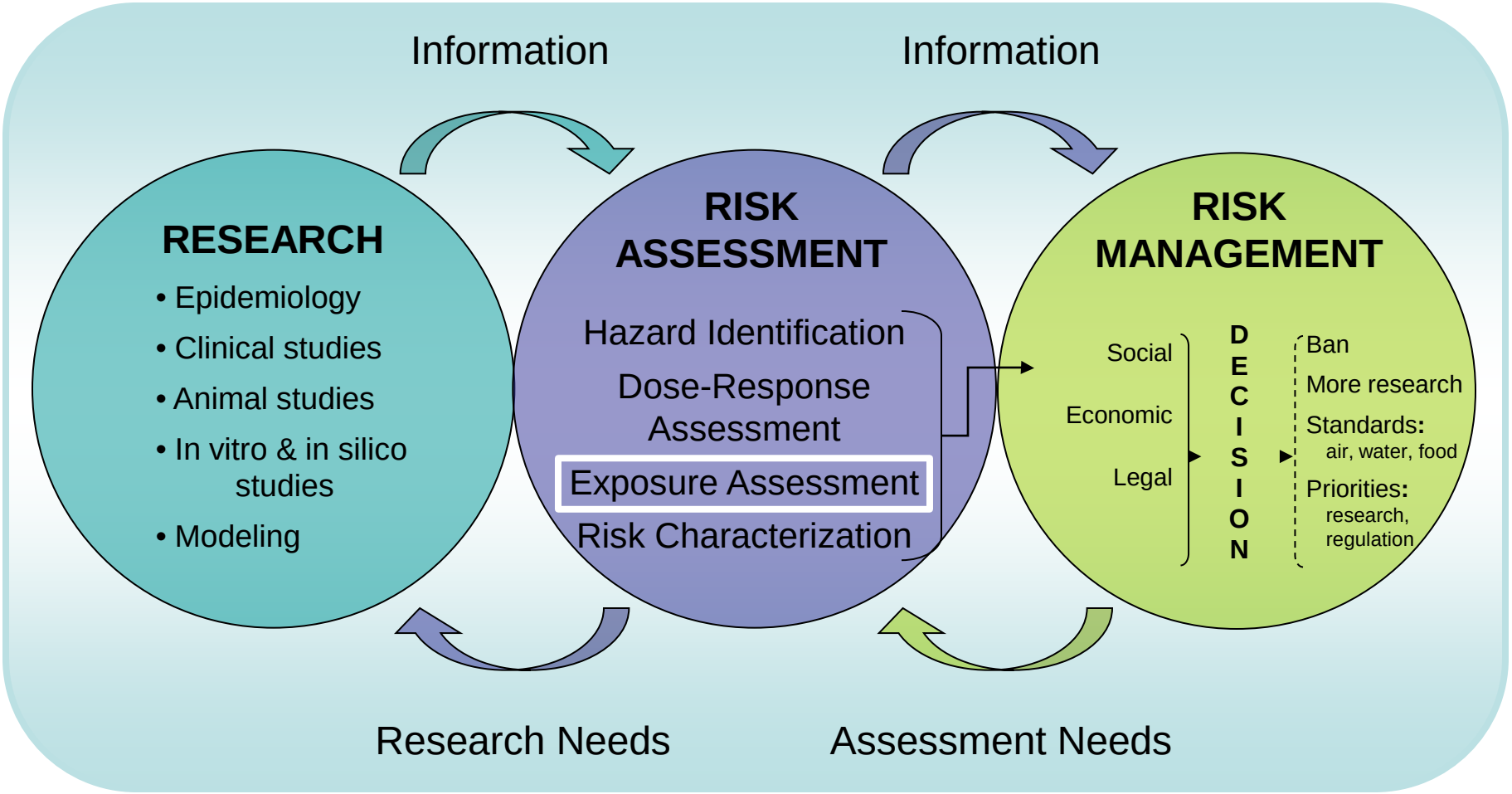
INTRODUCTION AND BACKGROUND CONCEPTS

The Risk Analysis Paradigm and the Role of Exposure Assessment



The Dose Makes the Poison

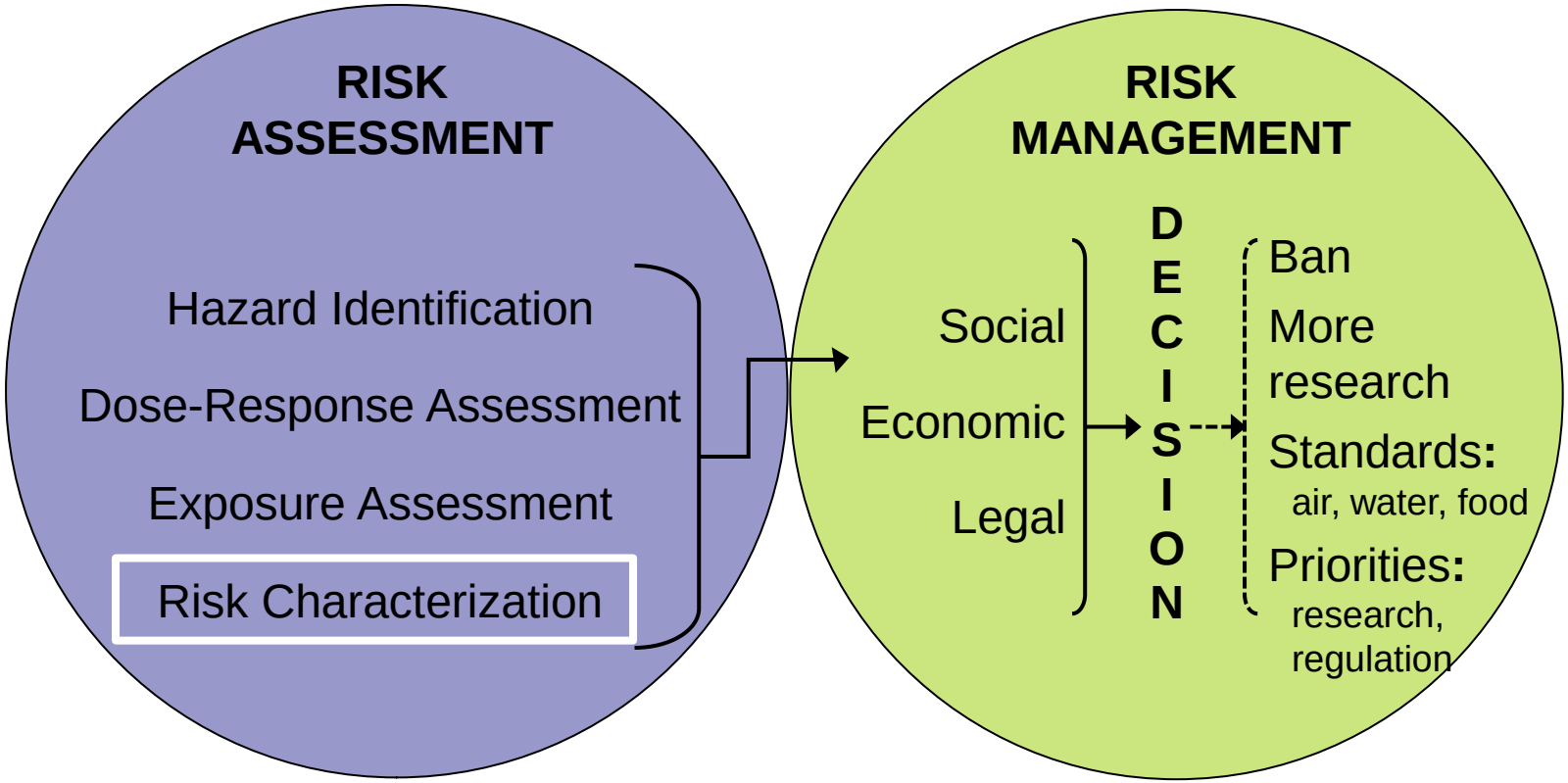
– Attributed to Paracelsus, 16th c. Swiss physician & chemist

- Exposure is a critical element of risk

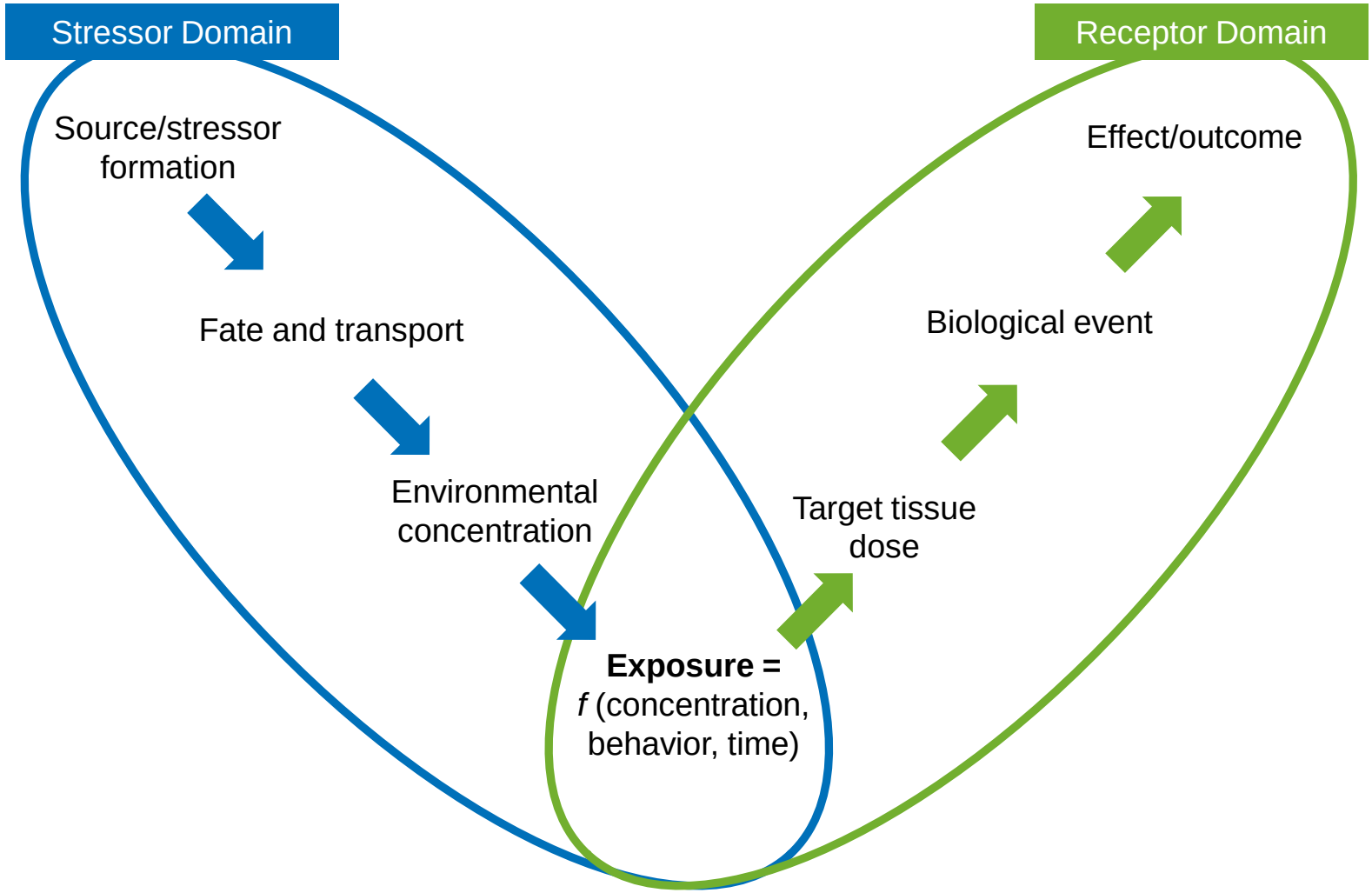
Hazard × Exposure = Risk

- A hazardous chemical release does not *necessarily* mean a high-risk situation
- Exposure assessment used to evaluate risk for future and past decision-making
  - **Future:** More uncertainty, but can prevent health impacts
  - **Past:** Less uncertainty, accurately quantify population health impacts and mitigation

The Utility of Risk Assessment in Environmental Decision-Making



Source-to-Effect Continuum



What is Exposure?

Exposure is contact made between a chemical, physical, or biological agent and the outer boundary of an organism.

Exposure Assessment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.

The Exposure Equation

Exposure = *f* (Concentration, Time, Behavior)

EPA Guidelines for Exposure Assessment (1992)

What is Dose?

- **Dose:** The amount of substance available for interactions with metabolic processes or biologically significant receptors after crossing the outer boundary of an organism
  - **Potential dose** is the amount of substance ingested, inhaled, or applied to skin, not all of which will be absorbed.
  - **Applied dose** is the amount of substance at an absorption barrier (skin, respiratory tract, gut) that can be absorbed by the body.
  - **Internal dose** is the amount of substance absorbed and available for interaction with biological receptors.

Dose Equation

$$\textbf{Potential Dose} = \frac{C \times IR \times CF \times ED \times EF}{AT \times BW}$$

Absorbed Dose = Potential Dose x AF

Absorbed Dose = Internal Dose

Where:

C = Contaminant Concentration

IR = Intake Rate

CF = Contact Fraction

ED = Exposure Duration

EF = Exposure Frequency

AT = Averaging Time

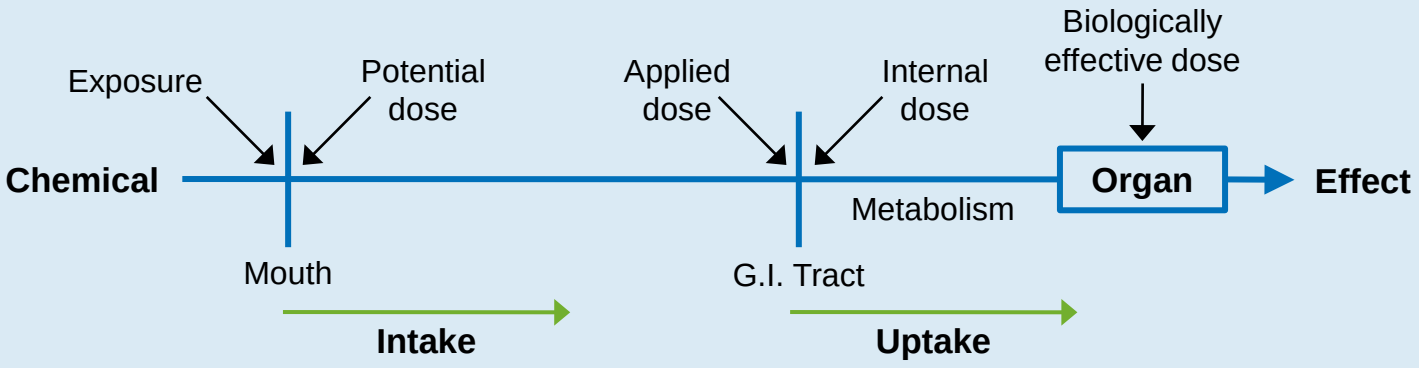
BW = Body Weight

AF = Fraction of Potential Dose Absorbed

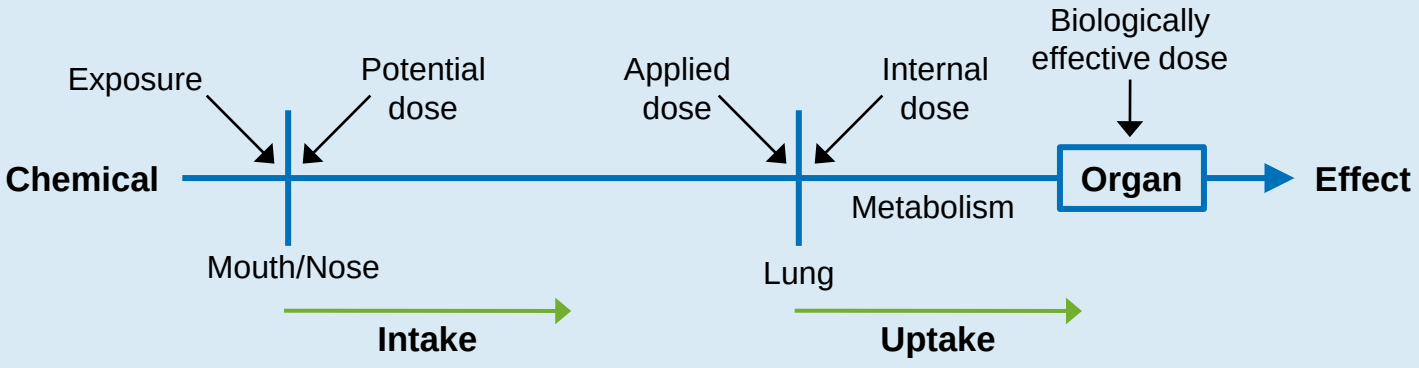
$$\textbf{General units for dose:} \quad \frac{\text{Mass contaminant}}{\text{time x mass}}$$

Dose Illustrated

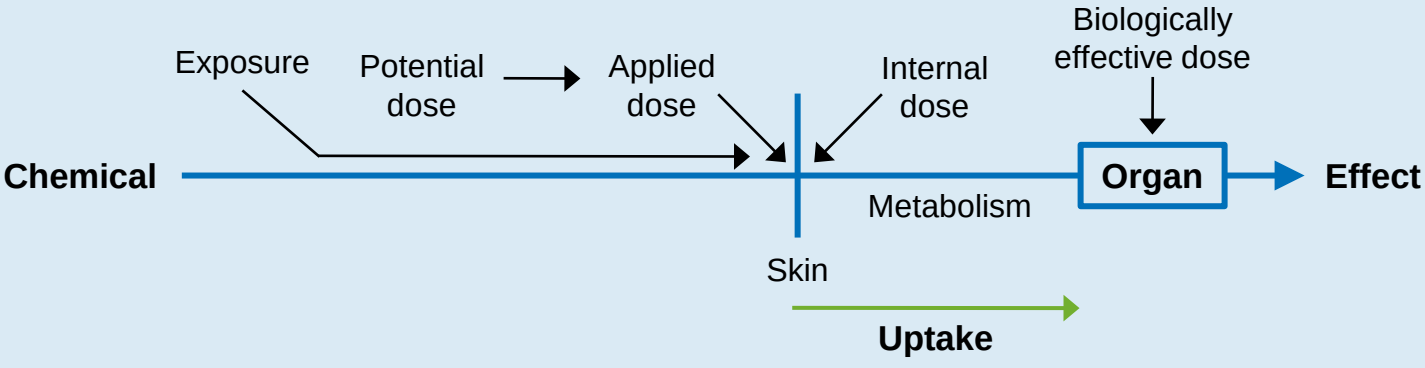
Oral Route



Respiratory Route



Dermal Route



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EXPOSURE ASSESSMENT: EXAMPLES OF EXPOSURE

Four Exposure Examples

- Meet Jim
- Four hazards in and around Jim's home
  - Benzene in drinking water
  - Nickel and lead in garden soil
  - Smoke in the kitchen
  - Pesticide residue on garden vegetables
- Four different routes of exposure
  - Consumption of drinking water, skin absorption, inhalation, eating

Exposure Example 1: Benzene in Drinking Water

- Jim has a well and drinks 2L of water/day
- Old, leaking underground storage tank in adjoining lot

Exposure: Occurs when a chemical or agent contacts the visible exterior of the person, making contact with the skin or openings into the body such as the mouth or the nose

- Benzene in Jim's water: >5 ppb

Intake: The substance enters Jim's body without passing through a barrier – for ingestion and inhalation

- Intake versus uptake, discussed more later in the course

Exposure Example 1: Benzene in Drinking Water

Chronic Exposure: Repeated exposures by either ingestion, inhalation, or skin exposure for more than about 10 percent of a person's lifespan

- How much benzene was Jim exposed to, on average?
  - Average Daily Dose (ADD)
- Estimate average daily dose based on assumptions

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Exposure Example 1: Average Daily Dose

$$ADD = \frac{C \times IR \times ED \times EF}{BW \times AT}$$

$$\text{Jim's ADD} = \frac{\left[\begin{array}{c}\text{levels of}\\ \text{benzene in}\\ \text{Jim's water}\end{array}\right] \times \left[\begin{array}{c}\text{how much}\\ \text{water}\\ \text{Jim drinks}\end{array}\right] \times \left[\begin{array}{c}\text{how long Jim}\\ \text{has been drinking}\\ \text{the water}\end{array}\right] \times \left[\begin{array}{c}\text{how often}\\ \text{Jim drinks}\\ \text{water}\end{array}\right]}{\left[\begin{array}{c}\text{Jim's weight}\\ \text{in kg}\end{array}\right] \times \left[\begin{array}{c}\text{number of}\\ \text{years to}\\ \text{average over}\end{array}\right]}$$

Exposure Example 1: Lifetime Average Daily Dose

- Lifetime Average Daily Dose (LADD)

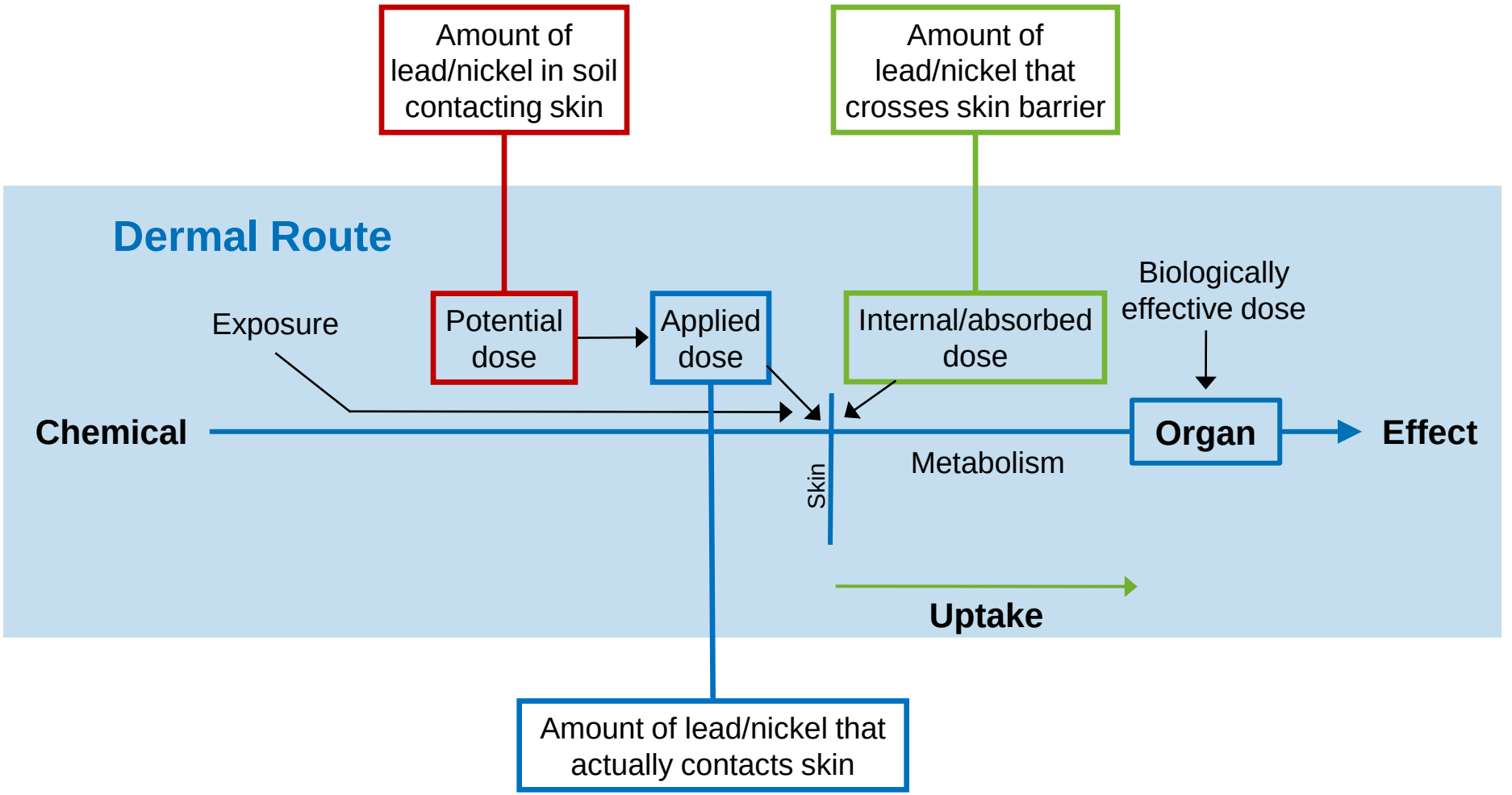
$$LADD = \frac{[C \times IR \times ED \times EF]}{[BW \times LT]}$$

- LADD is a projection based on current data
- Key element of risk assessment

Exposure Example 2: Skin Exposure to Soil Metals

- Jim's vegetable garden
- Raised beds for tomatoes and other vegetables
- Garden soil contaminated with nickel and lead
- Jim doesn't use gloves

Exposure Example 2: Skin Exposure to Soil Metals



Exposure Example 3: Kitchen Smoke Inhalation

- Jim likes to cook burgers on his kitchen range
- Hamburgers + Hot Pan + Too Much Time = Smoke!
- Smoke inhalation from the fire

Exposure Example 3: Kitchen Smoke Inhalation

- Jim's smoke exposure was brief, but he still didn't feel well

Acute Exposure: Short-term exposure that lasts no longer than a day

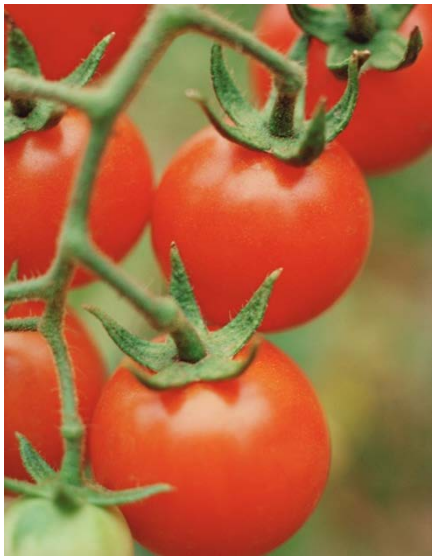
Contaminants in smoke are varied and complex

- Difficult exposure to characterize, compared to others

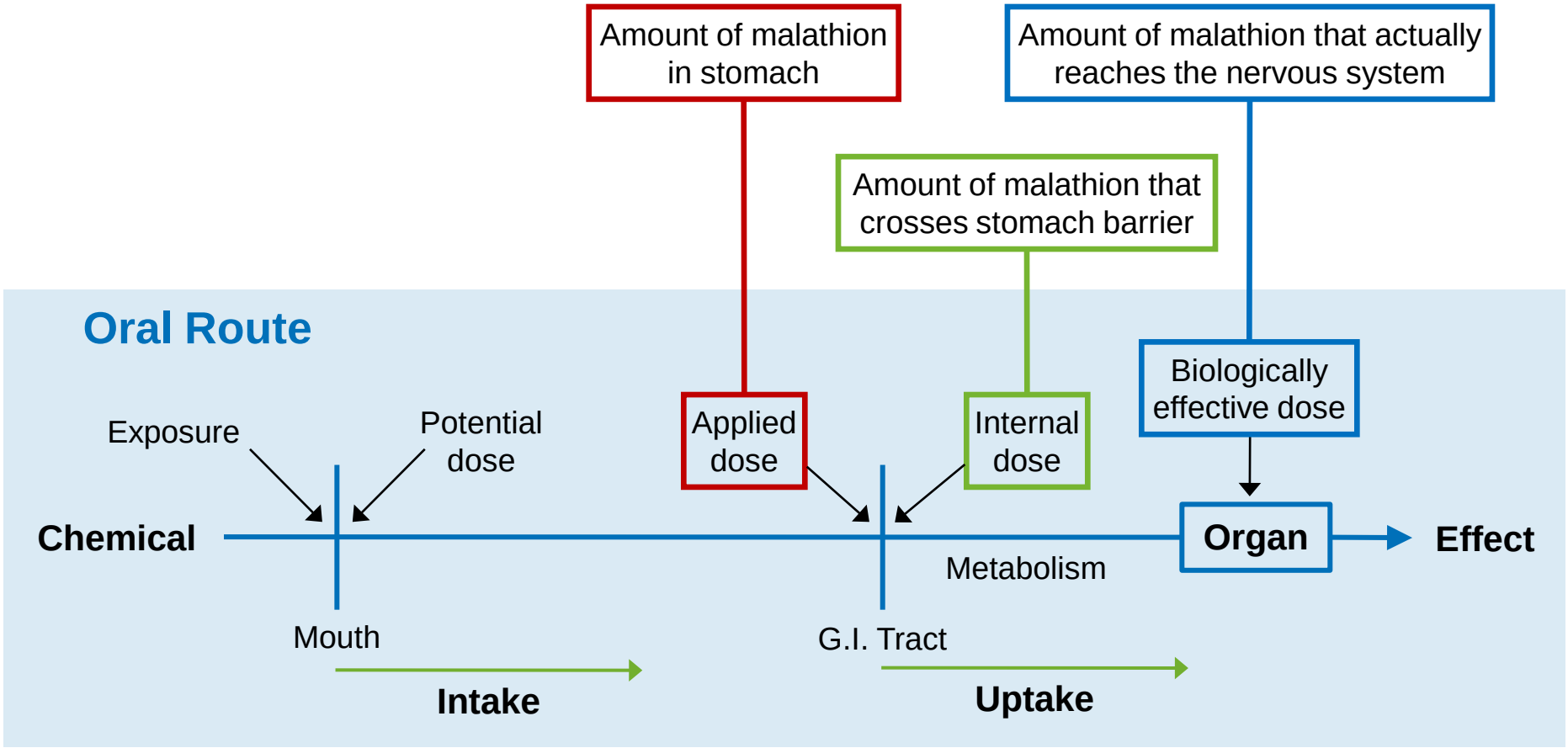
Exposure Example 4: Ingestion of Pesticide Residues

- Jim grows tomatoes and peppers in the garden
- He uses malathion to control insect problems

- He eats produce in the garden or in the home without washing
- Exposure during application
  - Dermal
  - Inhalation



Exposure Example 4: Ingestion of Pesticide Residues



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Exposure Examples: Concepts Introduced

Benzene in Drinking Water
- Intake versus Uptake
- Chronic Exposure
- Average Daily Dose

Skin Exposure to Soil Metals
- Dose (Potential and Internal)
- Absorbed Dose
- Uptake versus Intake

Kitchen Smoke Inhalation
- Acute Exposure
- Complex Mixtures
- Exposure Characterization

Pesticide Residues on Produce
- Applied Dose
- Internal Dose
- Biologically Effective Dose

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EXPOSURE CONSIDERATIONS

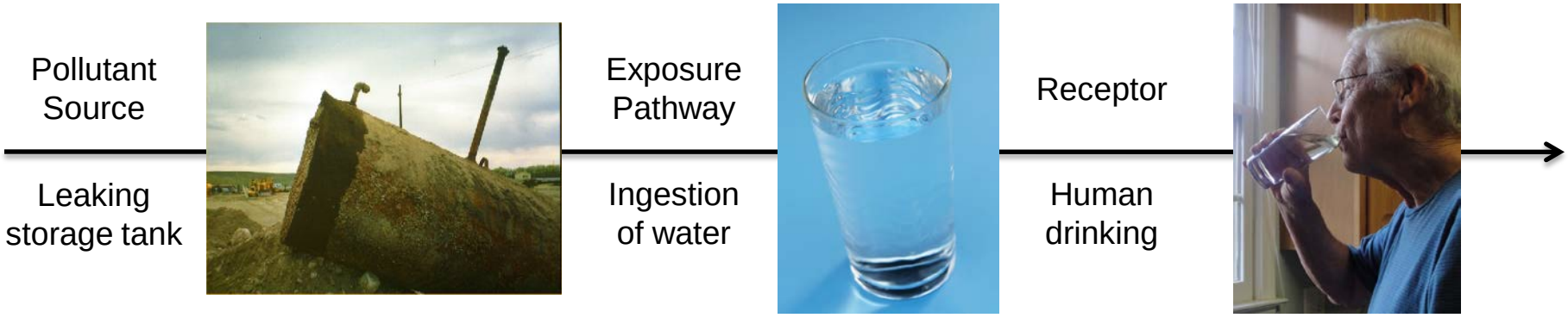
Individual- versus Population-Level Assessments

- Exposure assessment usually conducted for populations or groups
- **Exposure factors**, or characteristics of the population, important to estimate exposure and risk:
  - Food and water intake
  - Population behaviors
  - Inhalation rates
  - Other factors relevant to scenario

- **Variability** and **uncertainty** in exposure factors

Elements of Exposure

- **Pollutant source:** Where are the pollutants coming from, at what rate, and where are they going?
- **Exposure pathways:** Connection between pollutant source and exposure including exposure media and route of exposure. Useful in identifying exposures of concern
- **Contaminants of concern:** Specific contaminants that are of concern for human health for the exposure pathway
- **Receptor:** The individual or population that is exposed



Exposure Factors

- **Exposure Factors**: Account for variability in populations, and allow for assessment of the risks to those populations
- Include:
  - Ingestion and inhalation rates
  - Skin exposure factors
  - Body weight
  - Life expectancy
  - Others

Uncertainty and Variability

- **Uncertainty** refers to a lack of knowledge arising from:
  - Incomplete data
  - Incomplete understanding of processes
- Reduce by collecting more data or better data
- Compensate for by approximations and assumptions

- **Variability** refers to heterogeneity or diversity
  - Inherent property of a population
- Characterize with more data
- Cannot reduce or eliminate, only describe

Variability versus Uncertainty in Water Intake

Variability

- Known
  - Water intake within age groups or population groups
  - Differences in intake based on activities or climate
  - Variability in contaminant concentrations

Uncertainty

- Unknown
  - Missing water intake data
  - Media concentration data
  - Information about the geographic extent of population exposed
  - Other exposure information for the population

EPA's Guidelines for Exposure Assessment

- Published in 1992
  - Revised version currently under development
  - Topics and chapters

    Introduction

    Chapter 1: General Concepts in Exposure Assessment

    Chapter 2: Planning an Exposure Assessment

    Chapter 3: Gathering and Developing Data for Exposure Assessments

    Chapter 4: Using Data to Determine or Estimate Exposure and Dose

    Chapter 5: Assessing Uncertainty

    Chapter 6: Presenting the Results of the Exposure Assessment

Other Key EPA Resources

- EPA-Expo-Box
  http://www.epa.gov/risk/expobox/
- Exposure Factors Handbook and Child-Specific Exposure Factors Handbook
- Example Exposure Scenarios
- Risk Assessment Guidance for Superfund (RAGS)
- Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants
- Dermal Exposure Assessment: Principles and Applications
- Additional resources available

EXA Course Series

402 – Approaches for Quantifying Exposure

403 – Developing Exposure Scenarios and Calculating Dose

404 – Fate and Transport

405 – Monitoring and Modeling Strategies

406 – Obtaining and Using Exposure Factor Data

407 – Assessing Uncertainty and Variability

408 – Interpreting Biomonitoring Data

409 – Lead Case Study

410 – Dioxin Case Study