Human Health Risk Assessment Process and Exposure Modeling

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GOALS FOR TODAY

- **To give participants … <u>practicing industrial hygienists</u> … an overview and appreciation for the current health risk assessment paradigm currently used by government and the private sector. Plus provide some specific information about inhalation exposure models**

OUTLINE...

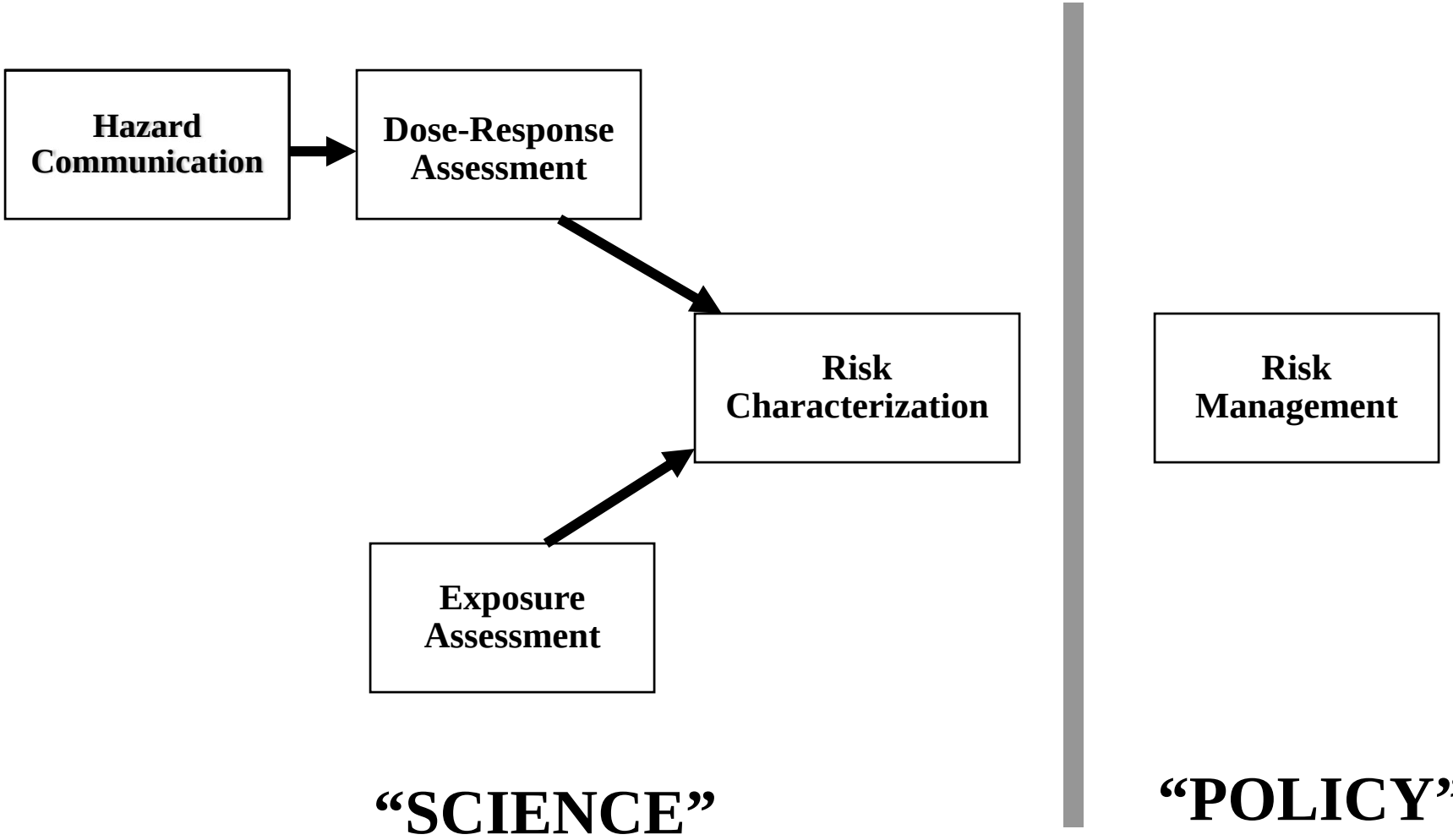
1. General Introduction to Risk Assessment
2. Putative vs. Actuarial Risk
3. Toxicology –
   a) Dose-Response
   b) Exposure Limits
4. Exposure Assessment
   a) Near-field versus Far-field
   b) Inhalation Models General
5. Inhalation Modeling Specifics
6. Software Demo
7. Modeling Case Study
8. References

INTRODUCTION

MAJOR CURRENT FRAMEWORK...

- National Academy of Science (NAS) Paradigm …. also known as the "NAS Red Book"
- Whether in government or industry, this paradigm has emerged as the major one (conceptually)

NAS RISK ASSESSMENT PARADIGM (1993)



Risk Assessment:
Risk of What?

- Being Poor?
- Being Ugly?
- Being Unhappy?
- Having “Bad Hair”?
- Being Sick?
- Being Killed?

Risk of Adverse Human Health Effects Coming From “Agents”

RISK ASSESSMENT

$$RISK = f\,\frac{\left(Bad\ Effects\right)}{Exposure}\left(Exposure\right)$$

Today we are going to look at:

- **Probability Statistics for Some Rare Events or Exposures (*Putative* vs *Actuarial* Risk)**
- **Overview of Risk Assessment and Risk Management for Human Health**
  - **Basic Concepts of the Paradigm**
  - **Technical Models**
- **Scientific Uncertainty as a Process Driver**
- **Our Opportunities in all this as Professionals and Citizens.**

Actuarial Risk and Putative Risk

Actuarial Risk

- **ac·tu·ar·y (k ch - r)**
  - ***n. pl.* ac·tu·ar·ies**
- **A statistician who computes insurance risks and premiums**

- **ac tu·ar i·al (-âr - l) *adj.***
  - **ac tu·ar i·al·ly *adv.***
- ***of or relating to the work of an actuary***

Putative Risk

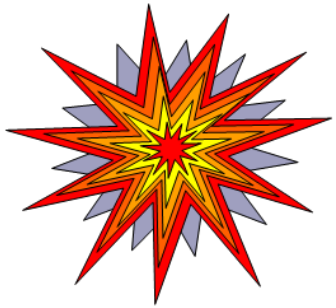
- ***pu·ta·tive***
  - **–adj. [*pyoo-tuh-tiv*]**
- **purported; commonly put forth or accepted as true on <u>inconclusive grounds</u> (emphasis added)**

Risk of Death Due to Injury, United States, for a person born in 2003

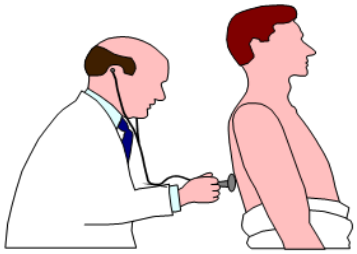
Type of Accident	Deaths	1-yr Risk	Lifetime Risk
All causes	166,857	1 in 1743 6×10^{-4}	1 in 22
Accidental Injury	109,277	1 in 2662	1 in 34
Transport Accident	48,071	1 in 6050 $(165/10^{6})$	1 in 78

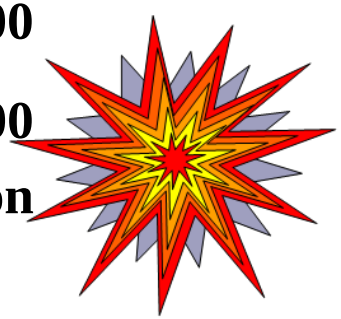
Re: http://www.nsc.org/lrs/statinfo/odds.htm

RISK COMPARISONS FOR INVOLUNTARY RISKS



Risk	Risk of Death / Person / Year
Influenza	1 in 5000
Leukemia	1 in 12,500
Struck by Automobile	1 in 20,000
Floods	1 in 455,000
Tornadoes (Midwest)	1 in 455,000
Earthquakes (California)	1 in 588,000
Nuclear Power Plant	1 in 10 million
Meteorite	?????





Source: Dinman, B.D., "The Reality and Acceptance of Risk," *Journal of the American Medical Association, Vol.* 244 (11): 1126-1128, 1980.

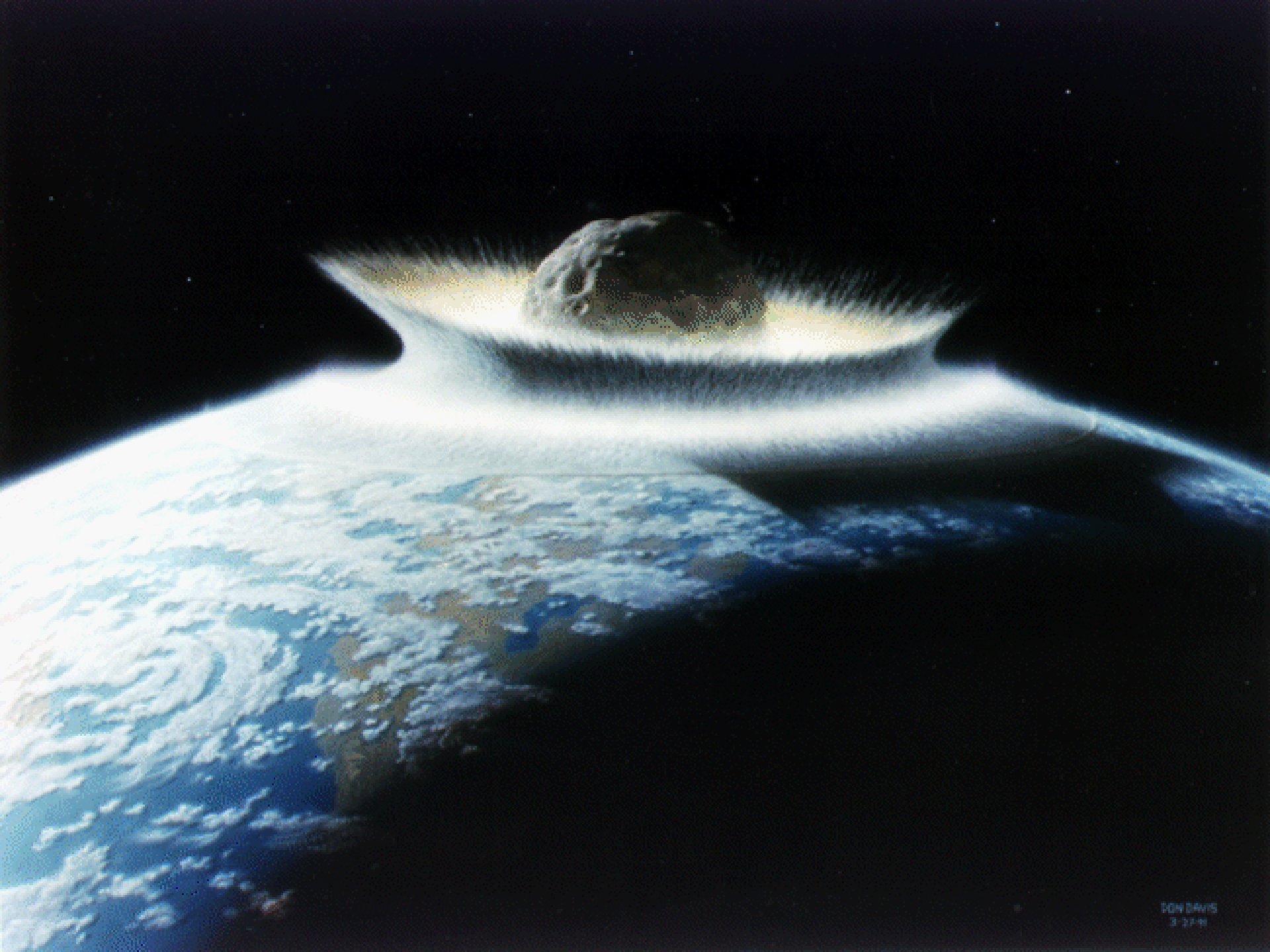
“The Sky is Falling! The Sky is Falling!”

Chicken Little

(Early Risk Assessor)

Chicken Little was Right
The Sky IS FALLING:

METEORS
are Indeed <u>Significant</u>
AGENTS of RISK for
You and I


DON DAVIS

DEATH BY METEOR
What is the risk?

Morrison (NASA):**We don't know when the next NEO impact will take place, but we can calculate the odds. Statistically, the greatest danger is from an NEO with about 1 million megatons energy (roughly 2 km in diameter). On average, one of these collides with the Earth once or twice per million years, producing a global catastrophe that would kill a substantial (but unknown) fraction of the Earth's human population.**

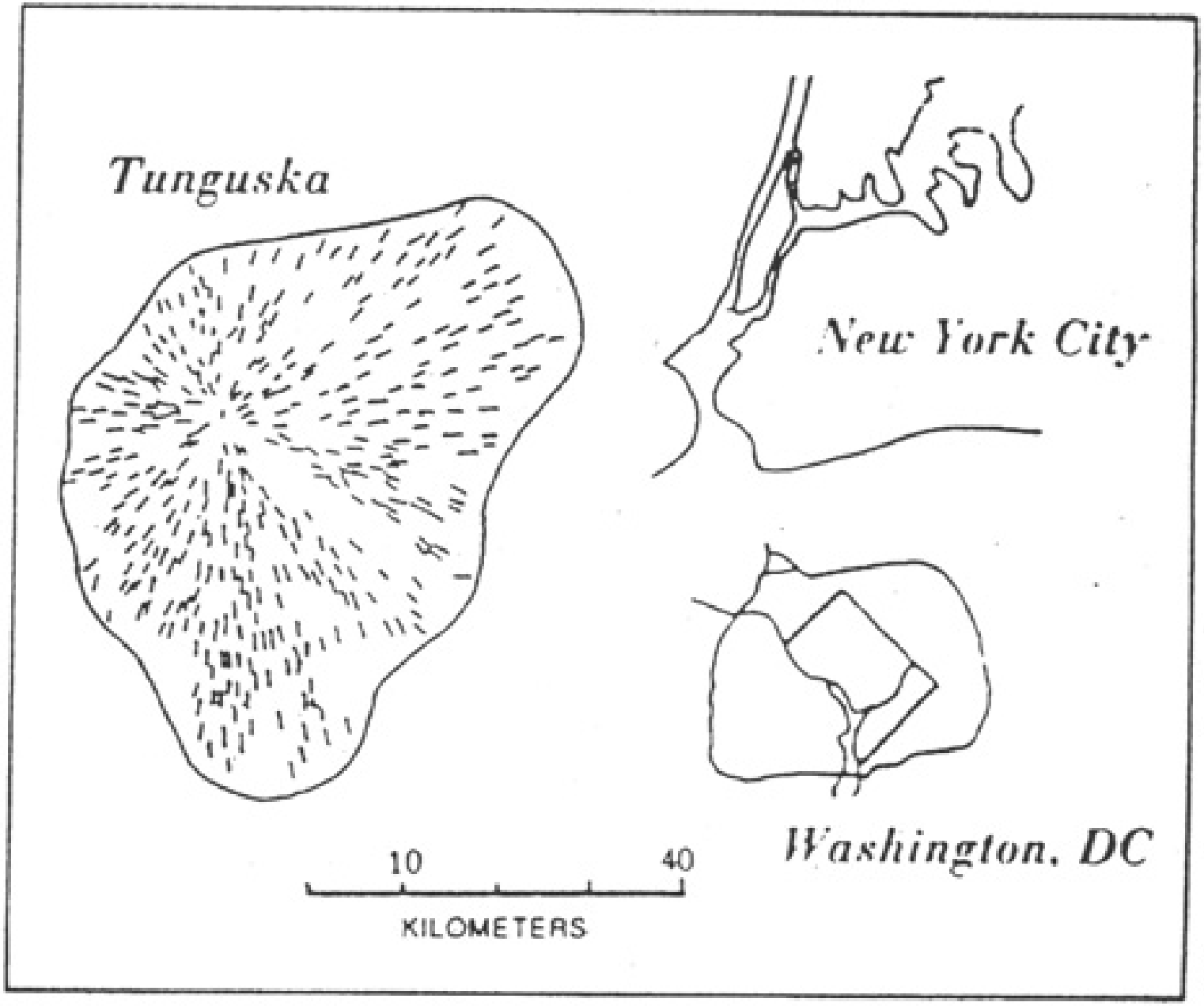
There are 140 major craters on the face of the Earth**, the vast majority of which are from 1-10 kilometer asteroids traveling at 11-74 km/s. Deadly, no?** We expect three of these every million years**, but there is, of course, no promise that a major NEO impact won't happen in our lifetime. Furthermore, a minor asteroid (50-100 meters wide) could cause large tsunamis** about every century**. Lastly, a 500 meter could devastate an area the size of Ontario and Quebec.**

Illinois Mathematics and Science Academy

http://www.imsa.edu/team/spi/SADVI/sadvi97/studentwork/ss/t3/RISK.html

Tunguska (Siberia) Meteor Explosion
June 30, 1908 **at 7:17am**

- **60 meter (200ft) diameter Asteroid 30 degrees to the Horizon**
- **10-15 Megaton TNT Equivalent (~500 Hiroshima bombs -no radiation)**
- **Detonated ~5 Miles Up**
- **Hundreds of Square Miles of Devastation.**
- **Herds of Incinerated Reindeer**
- **Unknown number of persons killed**



Art courtesy of John Pike

Tunguska in perspective

SPACE SCIENCE NEWS

Science@NASA

January 25, 2000 -- **Last week, one of the most dramatic meteors in 10 years streaked across the skies of the Yukon Territory in Canada. Witnesses reported two sonic booms, a foul odor, and sizzling sounds heard all the way from Alaska through northwestern Canada. Based on readings from defense satellites and seismic monitoring stations, scientists estimate that the meteor detonated with the energy of** two to three kilotons of TNT.

So What Are The Risks?

The chances of an Earth-impacting asteroid killing you have dropped dramatically, for example, from about 1-in-20,000 in 1994 to something like 1-in-200,000 or 1-in-500,000 today.

-Clark Chapman, Southwest Research Institute and David Morrison, NASA's Ames Research Center

Rule #1:

It is almost impossible to Effectively Manage Any Risk which has not been Reasonably Assessed.

CONCEPT OF DE MINIMIS RISK

- *De minimis* risks are those risks judged to be too small to be of social concern, or too small to justify the use of risk management resources for control.

- The *De minimis* risk level frequently used by government agencies (EPA, FDA) is 1 in 1,000,000 or "1 in a million" increased risk of an adverse effect occurring over a 70 year lifetime in a large population.

“There is no point in getting into a panic about the risks of life until you have compared the risks which worry you with those that don’t, but perhaps should.”
(Lord Rothschild, *The Wall Street Journal*, 1979).

The 1 in a million risk level used to regulate some chemicals and other hazards is many times below risks which people face every day.

Your Lifetime Risk of Dying from being Hit by an Airplane while you're on the Ground is <u>4.2 in a Million</u>!!

- **Source: The Risk of Groundling Fatalities from Unintentional Airplane Crashes Kimberly M. Thompson , R. Frank Rabouw & Roger M. Cooke, 2002**

Actuarial Risk of the Space Shuttle

- 1981 – predicted to be 1 in 78
- 1986 – Challenger lost on the 25th flight
  actual risk at that point = 1 in 25
- 1986+ NASA set goal 1 in 1000
- Later 40% budget cuts caused the predicted/goal risk to slip to 1 in 250
- 2003 – Columbia lost on 113th flight:
  actual risk at that point = 1 in 56.5
- Actual risk today?

Ref: Discovery, v25, n1, p.30

Your Lifetime Risk of Dying in an Automobile Accident is <u>1 in 65</u> !!!

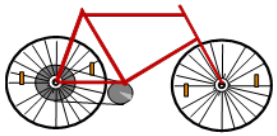
U.S. Occupational Fatality Risk for a Working Lifetime
(per 1000)

- **All private industry -- 2.1**
- **Manufacturing -- 1.6**
- **Mining -- 10.8**
- **Construction -- 5.9**
- **Finance -- 0.6**
- **Commercial Fishing -- 61**
  (Deadliest Catch)

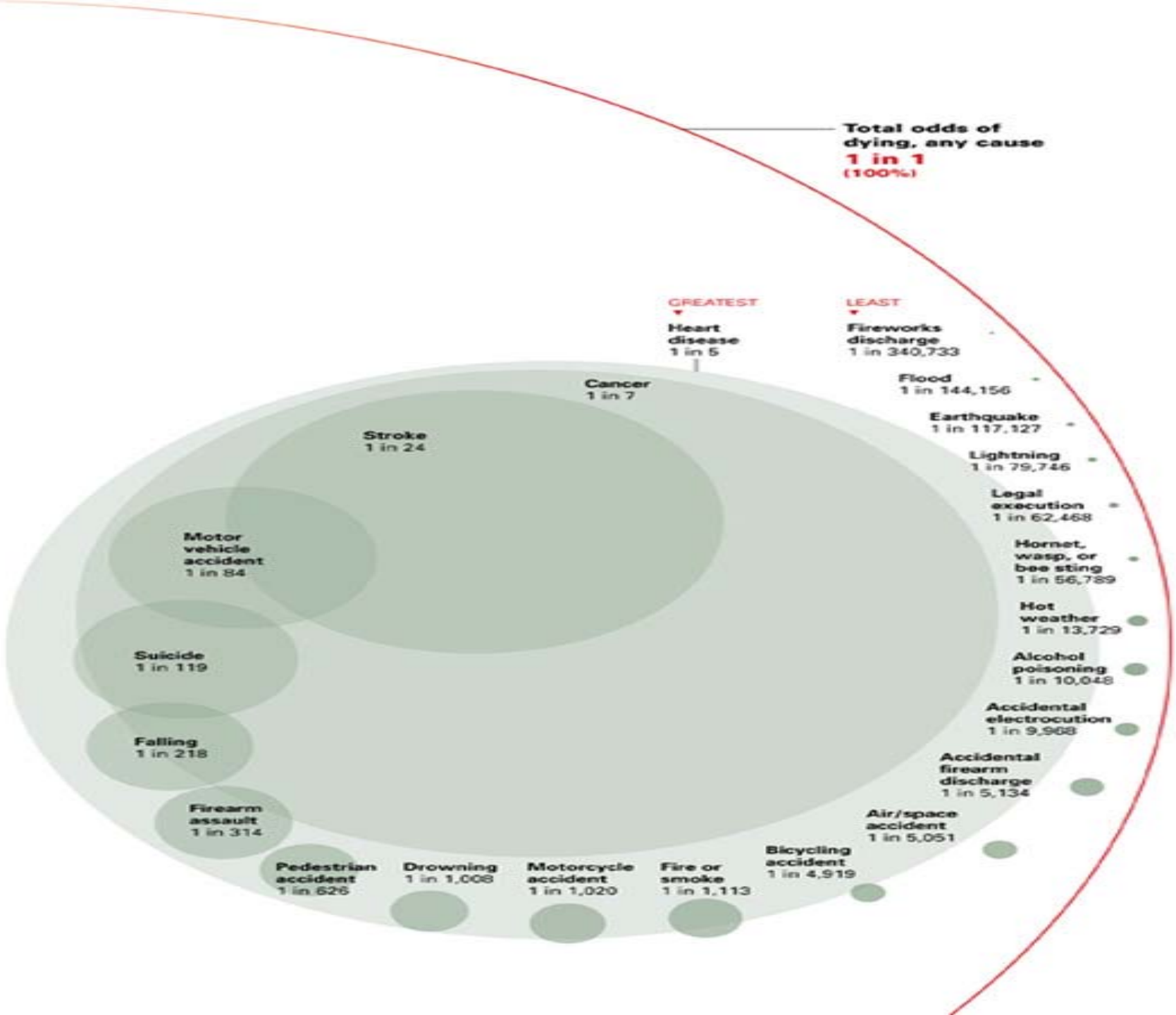
Ref: BLS

RISKS THAT INCREASE PROBABILITY OF DEATH BY ONE IN A MILLION

Activity	Cause of Death
Smoking 1.4 Cigarettes	Cancer, Heart Disease
Traveling 10 miles by Bicycle	Accident
Traveling 300 miles by Car	Accident
Flying 1000 miles by Jet	Accident
One Chest X-Ray	Cancer from Radiation



Source: Wilson, R., "Analyzing the Risks of Daily Life," *Technology Review*, 81, (1979).


Total odds of dying, any cause
1 in 1
(100%)
GREATEST
LEAST
Heart disease
1 in 5
Cancer
1 in 7
Stroke
1 in 24
Motor vehicle accident
1 in 84
Suicide
1 in 119
Falling
1 in 218
Firearm assault
1 in 314
Pedestrian accident
1 in 626
Drowning
1 in 1,008
Motorcycle accident
1 in 1,020
Fire or smoke
1 in 1,113
Bicycling accident
1 in 4,919
Air/space accident
1 in 5,051
Accidental firearm discharge
1 in 5,134
Accidental electrocution
1 in 9,968
Alcohol poisoning
1 in 10,048
Hot weather
1 in 13,729
Hornet, wasp, or bee sting
1 in 56,789
Legal execution
1 in 62,468
Lightning
1 in 79,746
Earthquake
1 in 117,127
Flood
1 in 144,156
Fireworks discharge
1 in 340,733

Overview of Risk Assessment and Risk Management

Principal Elements of Risk Assessment

- Anticipation
- Recognition
- Evaluation

  Effect/Dose = Dose-Response

  Dose = Exposure

<u>Control is NOT an element</u>

Anticipation, Recognition and Evaluation are <u>Risk Assessment</u>

Control is <u>Risk Management</u>

Rule #1 (again):

It is highly problematic to rationally MANAGE any risk which has not been reasonably assessed.

or

"Doing Risk Management without Risk Assessment (i.e., DATA) is Tough"

Risk is an EQUAL Function of Toxicity and Exposure

Paracelsus Understood Risk Assessment

- **Risk = Toxicity X Dose**
- **Exposure ≡ Dose**
- **Risk ≡ Toxicity X Dose**

$$\text{Risk} = \left(\left(\text{Effect/Dose}\right)\left(\text{Dose}\right)\right)$$

$$\text{Risk} = \left(\frac{1}{\text{Exposure Limit}}\right)\left(\text{Exposure}\right)$$

Operationally: Dose = Exposure

Toxicity and Exposure are Equal Partners in Risk Assessment

Rule #2:

<u>The Precautionary Principle</u>

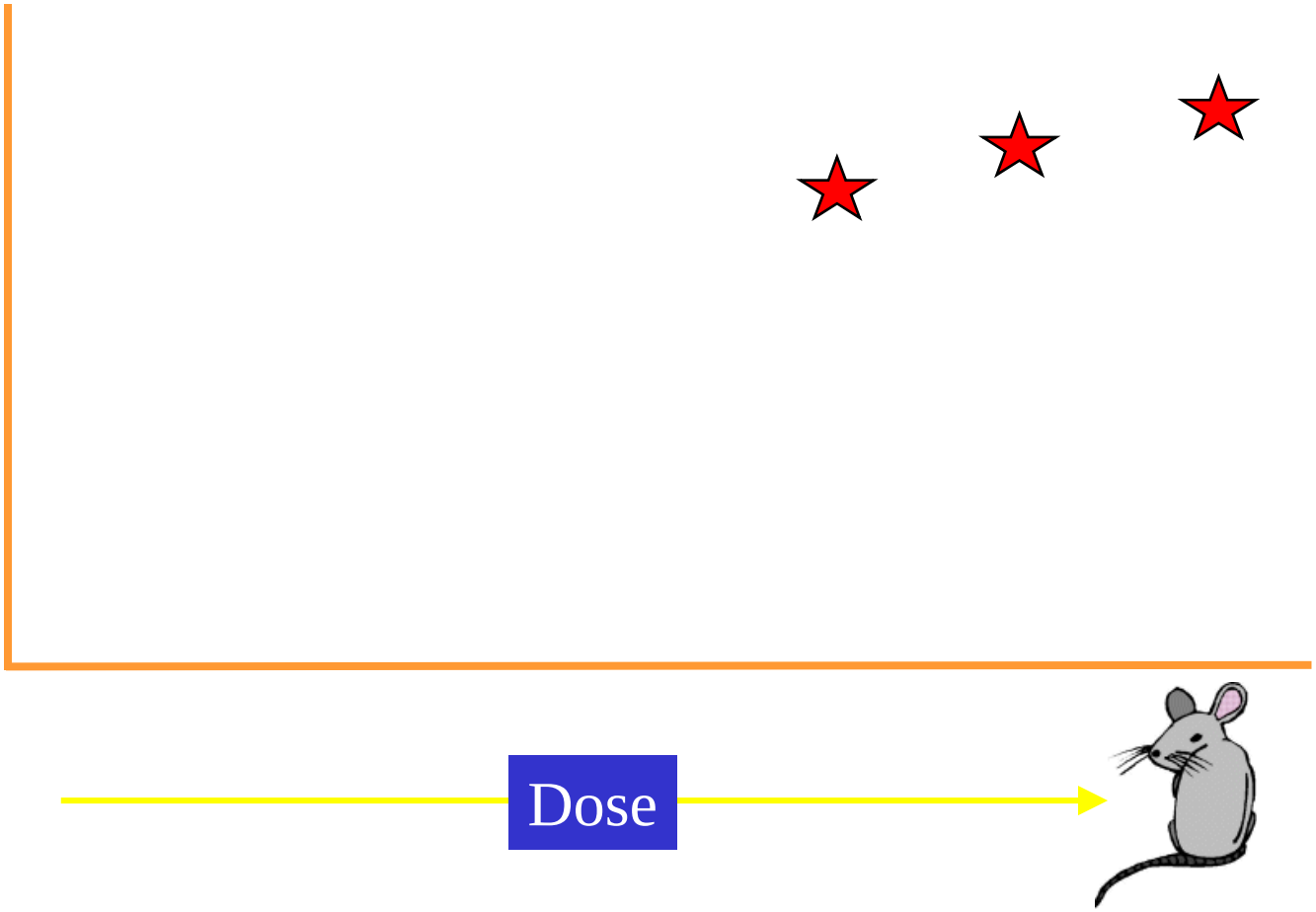
- **Axiom of Conservatism**
  - **Err on the Side of Safety**
  - **Trade Conservatism for DATA**

TOXICOLOGY: THE FIRST HALF OF HUMAN HEALTH RISK ASSESSMENT

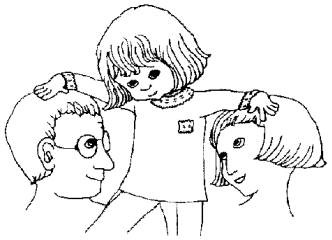
Putative versus Actuarial Risk

- **The Estimated Quantitative Risk at the Low Dose of an OEL are essentially PUTATIVE (*i.e.*, ascribed based on testable but untested assumptions).**
- **High Consequence - Low Probability (*e.g.*, lotteries, accidents) events occur with historically validated consistency - ACTUARIAL.**

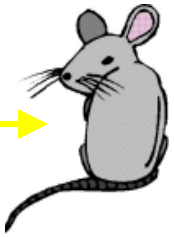
Typical rodent data



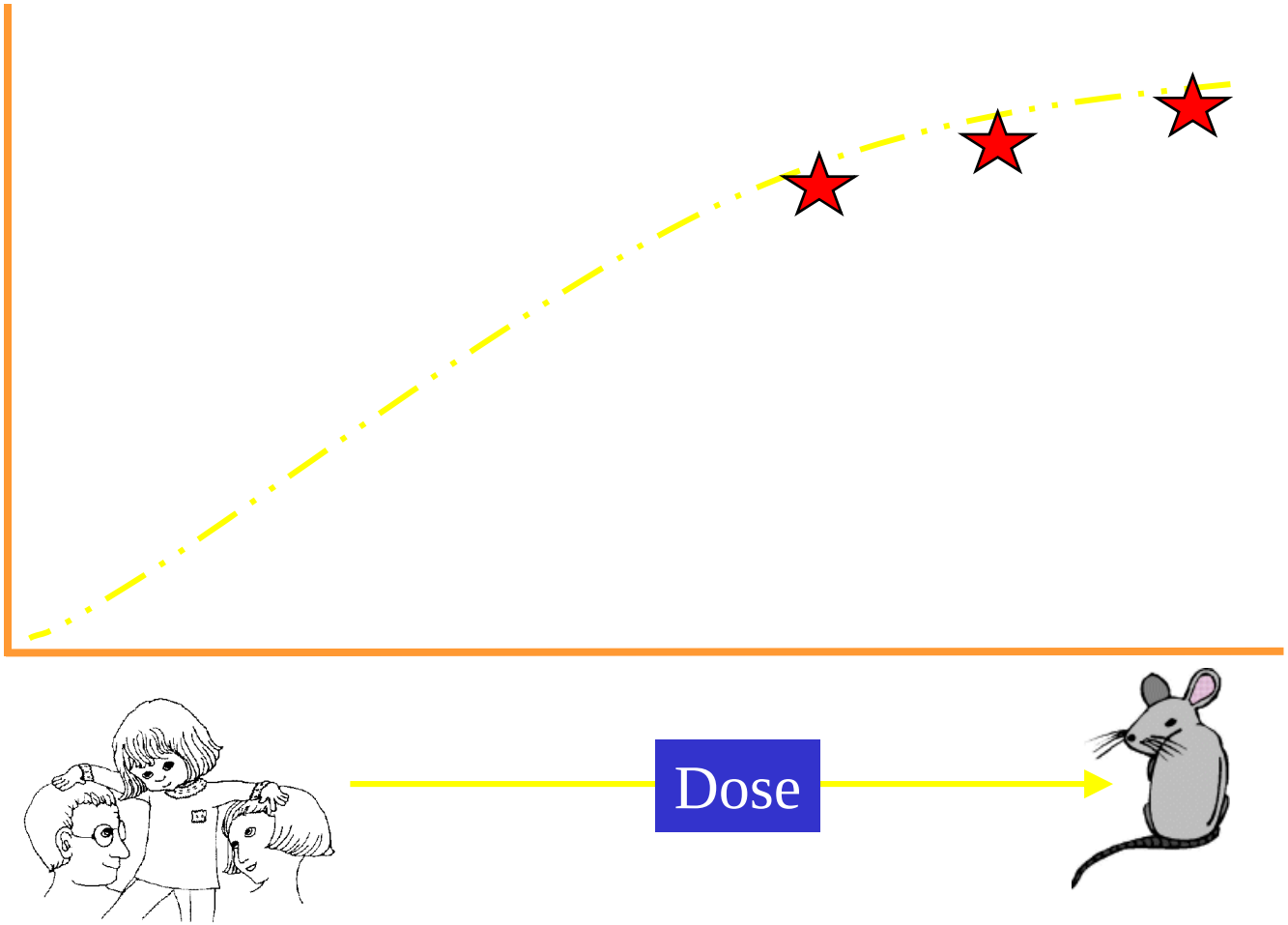
How do you get there from here?



Dose



How do you get there from here?



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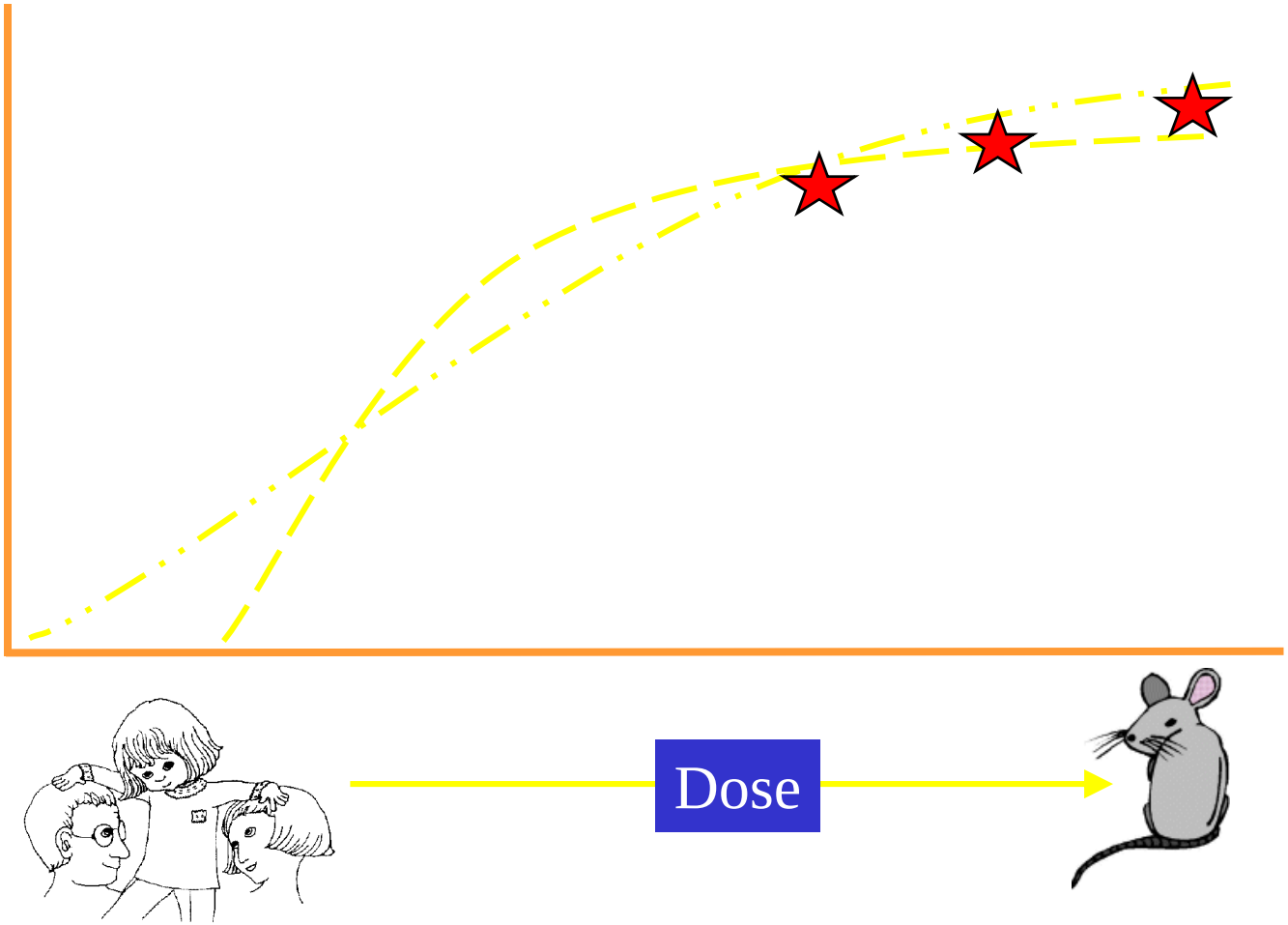

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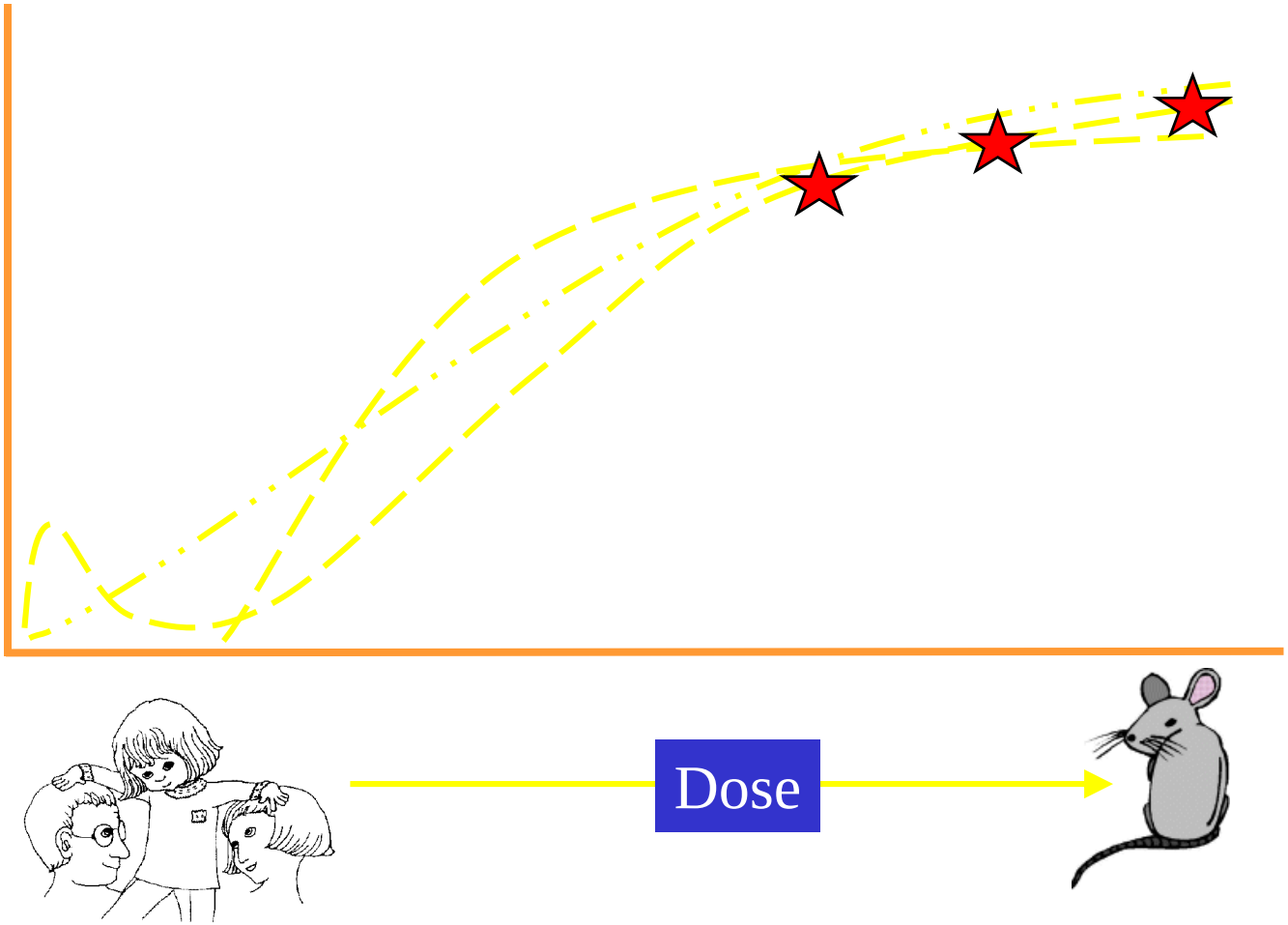

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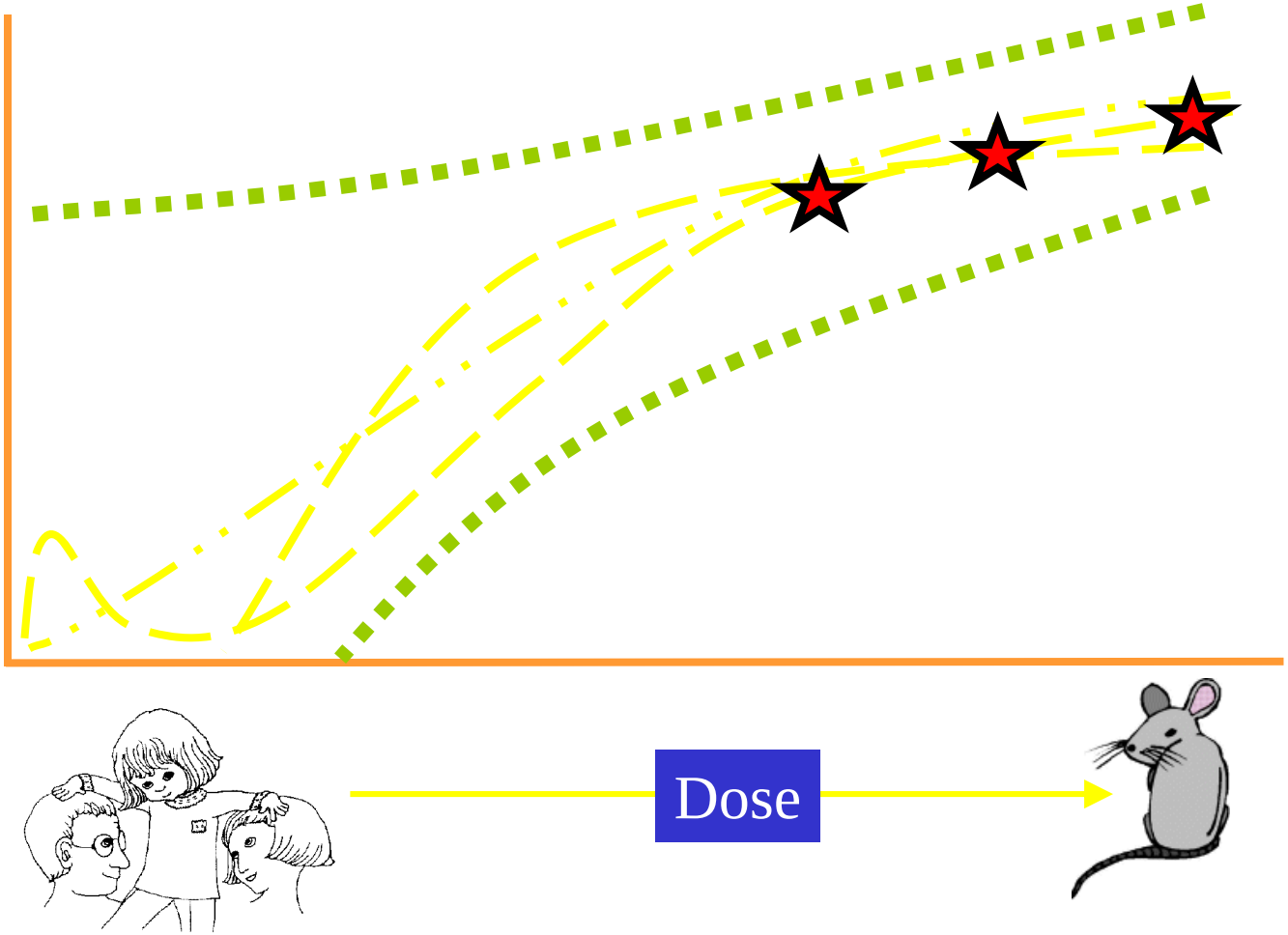
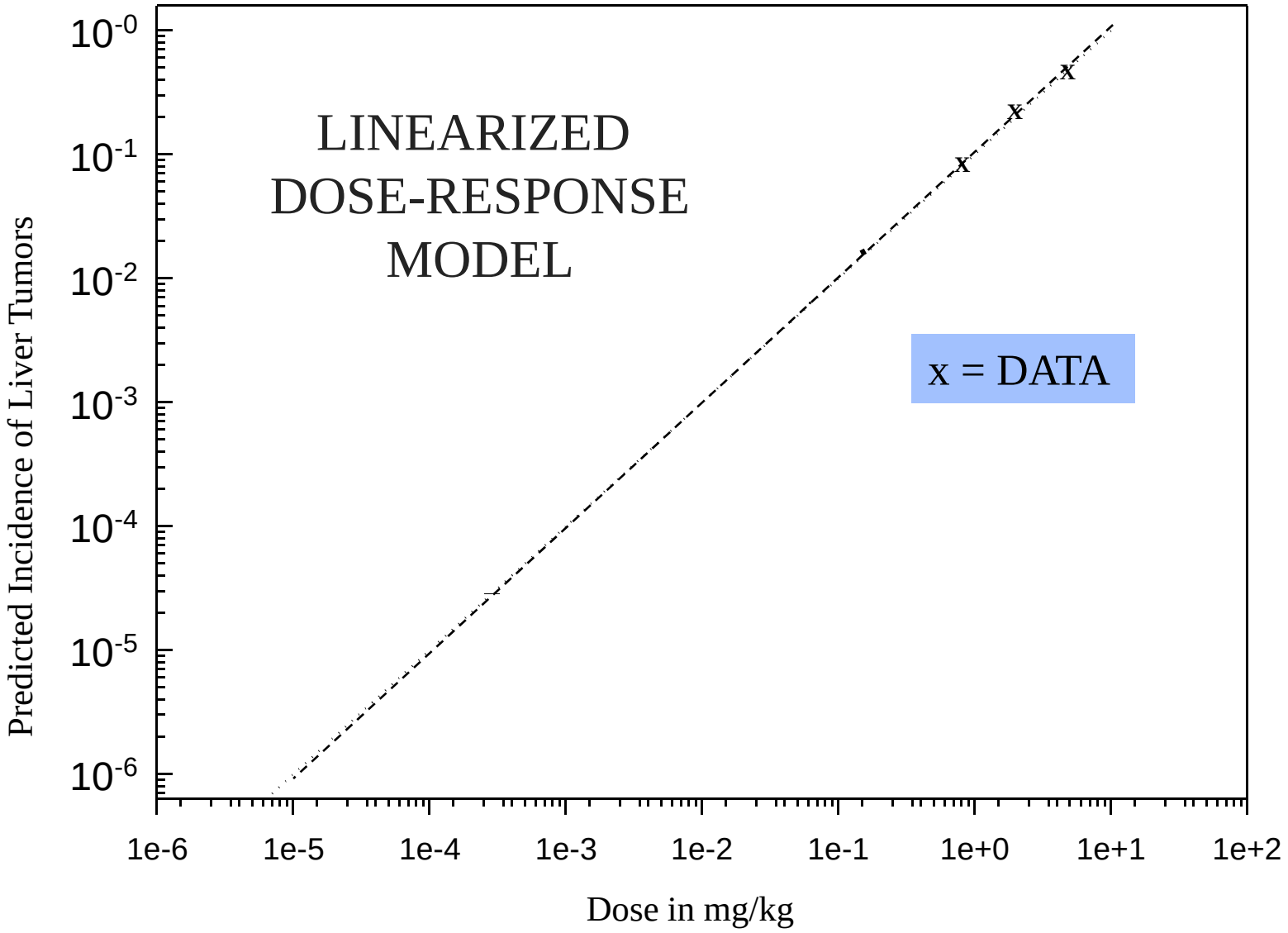


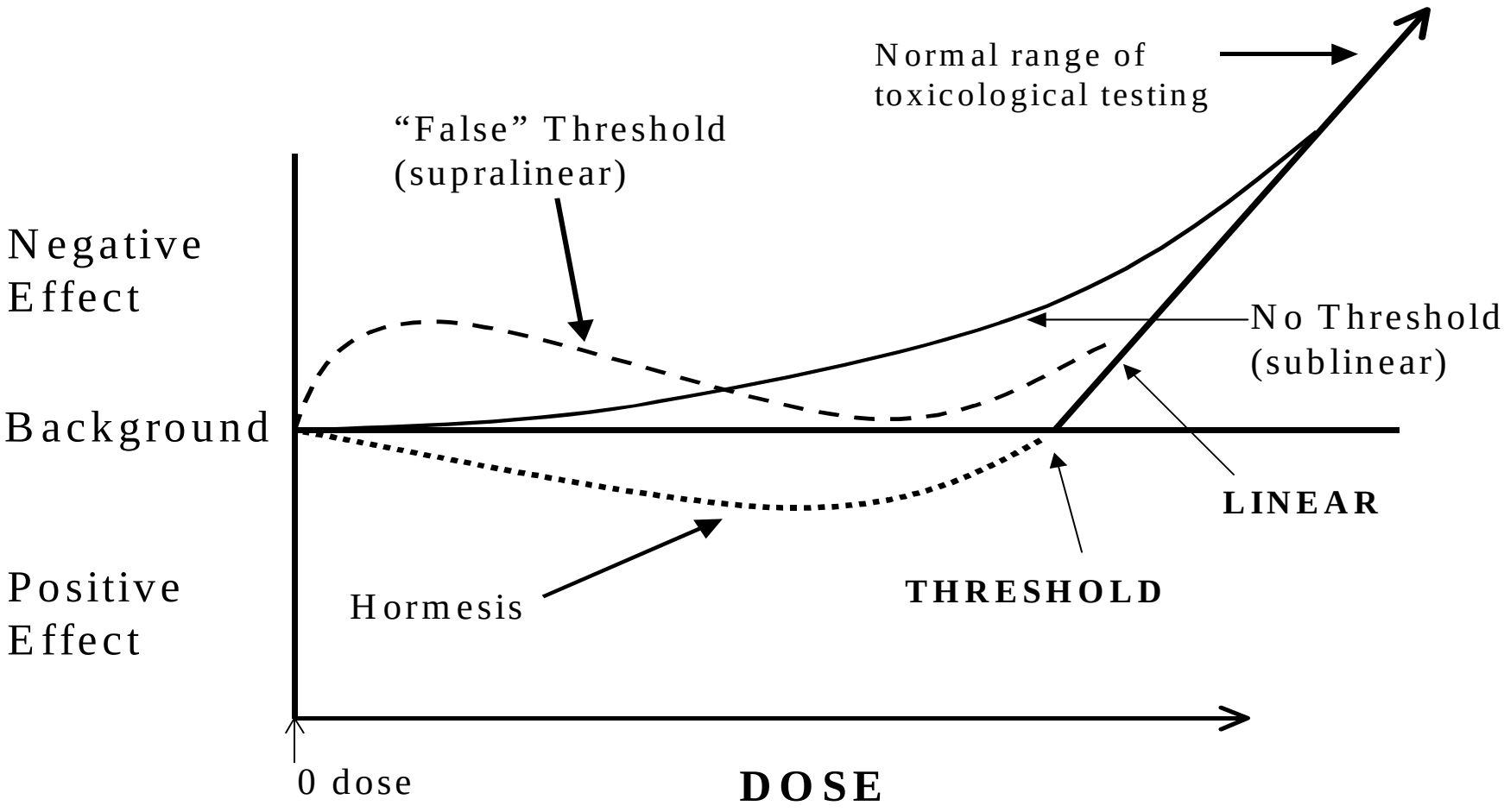
The only time a quantitative level of risk is estimated at an exposure limit is in the case of cancer risk. (10^{-5} or 10^{-6} for non-workers, ca. 10^{-3} for workers).

It is <u>assumed</u> that there is an acceptably "low" but essentially indeterminate level of adverse risk for other health effects at the exposure limits.

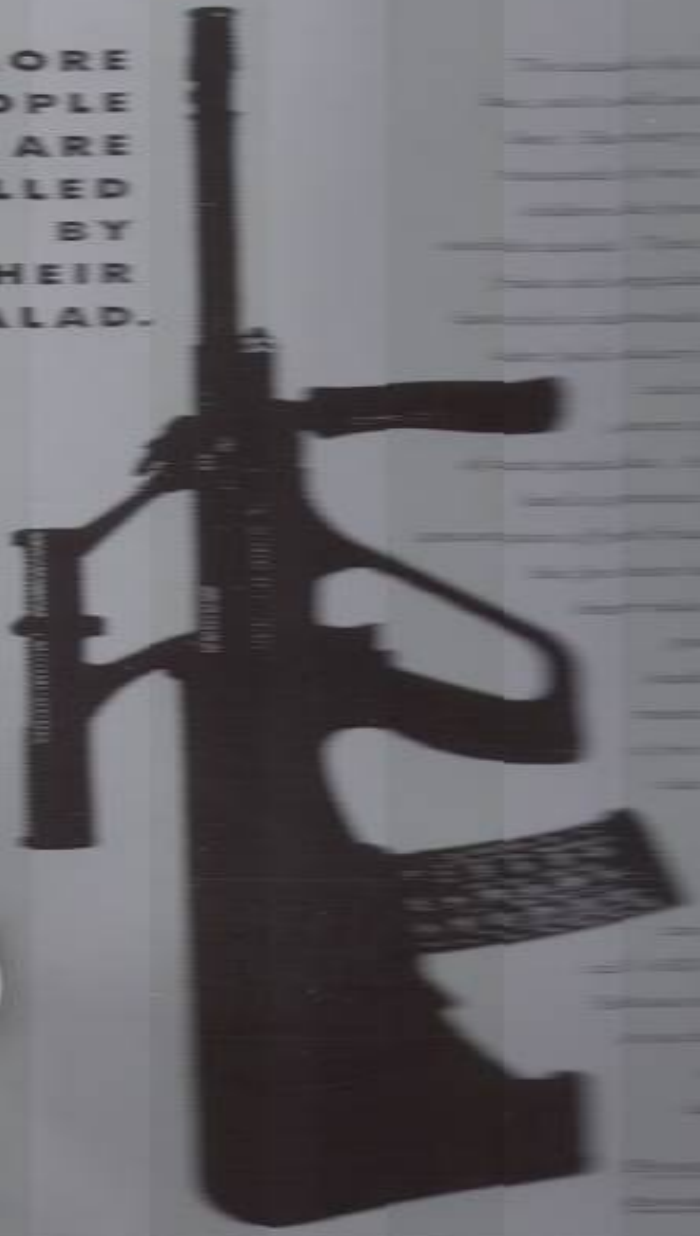
Cancer Risk


LINEARIZED
DOSE-RESPONSE
MODEL
x = DATA
Predicted Incidence of Liver Tumors
10-0
10-1
10-2
10-3
10-4
10-5
10-6
1e-6
1e-5
1e-4
1e-3
1e-2
1e-1
1e+0
1e+1
1e+2
Dose in mg/kg

DRAW and Discuss Various DR Possibilities HERE


Normal range of
toxicological testing
"False" Threshold
(supralinear)
Negative
Effect
No Threshold
(sublinear)
Background
LINEAR
Positive
Effect
Hormesis
THRESHOLD
0 dose
DOSE

MORE PEOPLE ARE KILLED BY THEIR SALAD.



Reprint of advertisement [illegible]
information about Food & Water [illegible]
(802) 563-3300, write to us at [illegible]
message at 800-EAT-SAFE.

Practical Risk Evaluation versus Pure Risk Assessment

- Practical Risk Evaluation as Practiced Today – is Not Elegant Science
- Uses Best Estimates and Subjective Judgment
- Relatively Inexpensive but (if done correctly) a Somewhat Crude OVERESTIMATION of Risk
- Fraught with Uncertainty and Controversy

The Essence of Practical Risk Evaluation

Comparing <u>Exposure</u> to <u>Exposure</u> <u>Limit(s)</u>

$$\text{Risk} \propto \frac{1}{(\text{Exposure})}(\text{Ex}$$

Example of a Practical Risk Evaluation

$$\text{Risk} = \left(\frac{1}{\text{Exposure Limit}} \right) (\text{Exposure})$$

$$\text{Exposure} = \left(\frac{1 \text{ mg}}{\text{Kg. Day}} \right)$$

Practical Risk Evaluation is simply the comparison of the Estimated Exposure (EXP) with an exposure that represents a Level of Concern relative to untoward health effects (EL). Thus the “Game” is straightforward:

Margin of Exposure = MOE

MOE = 1/Risk = EL/EXP

Risk or MOE = EL/EXP

- When the **MOE** is >>1 then ☺
- When the **MOE** is <<1 then ☹
- When the **MOE** is ≈1 then 😐 ??

Hazard or Effects Assessment

EXPOSURE LIMITS come from:

- Anecdotal Reports of Human Irritation
- NOEL/SF
- Applied Dose-Response
- PB-PK Modeling
- (Mechanistic Modeling)

(On the Compound of Interest or a Reasonably Potent Structural Analog of the Compound)

The Limited Power of Quantal Toxicological Assays

Let p = Proportion of the Population <u>truly positive</u> (i.e., have a Toxic Response)

q = Proportion of the Population truly negative

r = Number Responding in Any Study with n Number of Subjects

Prob = Chance of Getting r Responses in a Test of n Subject

$$Prob = ((n!/(r!)(n-r)!))p^r q^{n-r}$$

The Limited Power of Quantal Toxicological Assays

(Continued)

- **When**

  r = 0 (i.e., No Responders)

  Prob = Chance of getting no response in a test of n subjects

  $= q^n$

  q = Proportion truly negative

The Power of a Quantal Test with 100 Animals

- $q^n = 0.99^{100} = 36.6\%$

- i.e. > 1 in 3 chance of seeing <u>no</u> responders in a population with 1% truly positive

The Power of a Quantal Test with 300 Animals

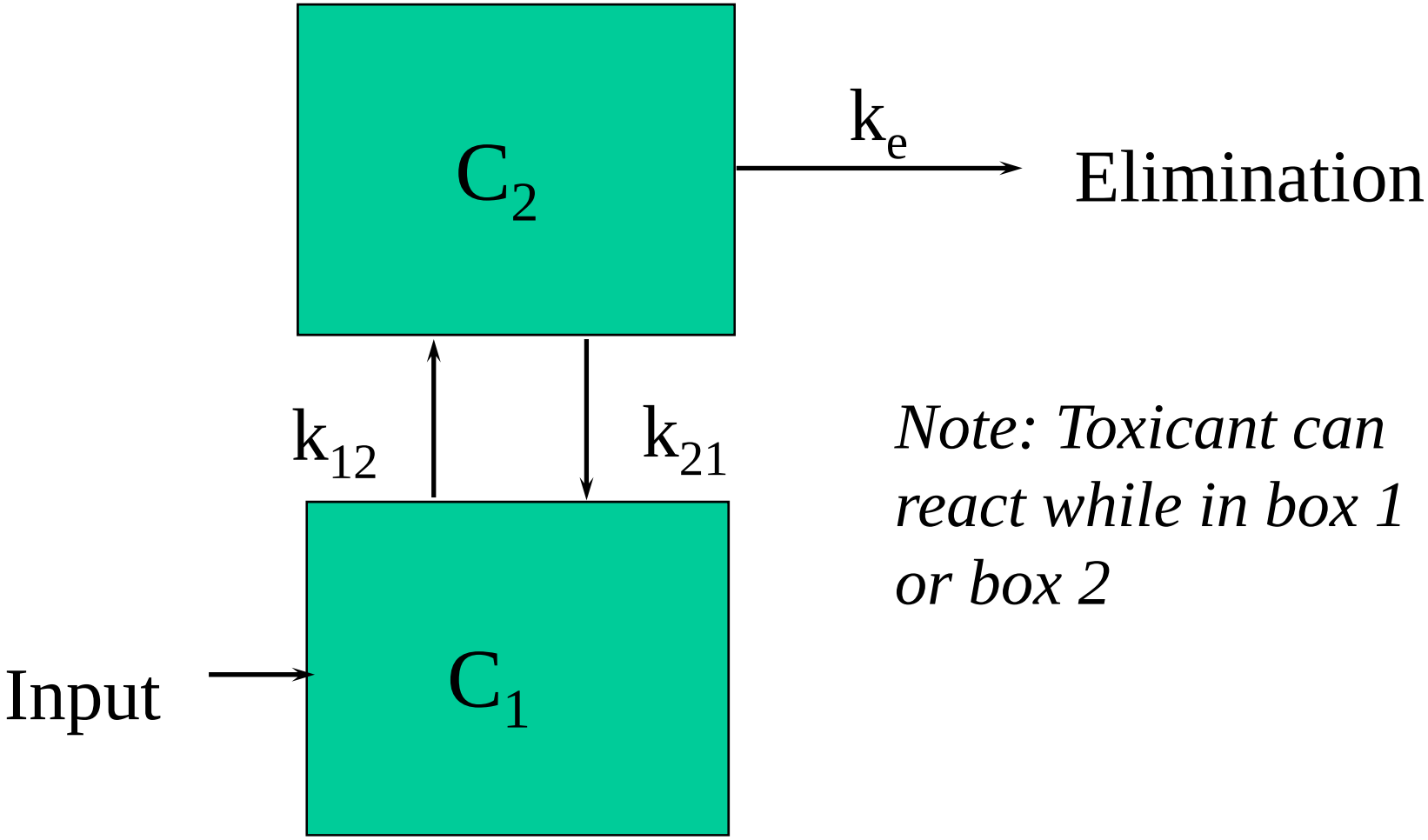
- $q^n = 0.99^{300} = 4.9\%$

- *i.e.*, a 5% chance of not seeing a response in a population with 1% truly positive

Physiologically Based-Pharmacokinetic Modeling (PB-PK Modeling)

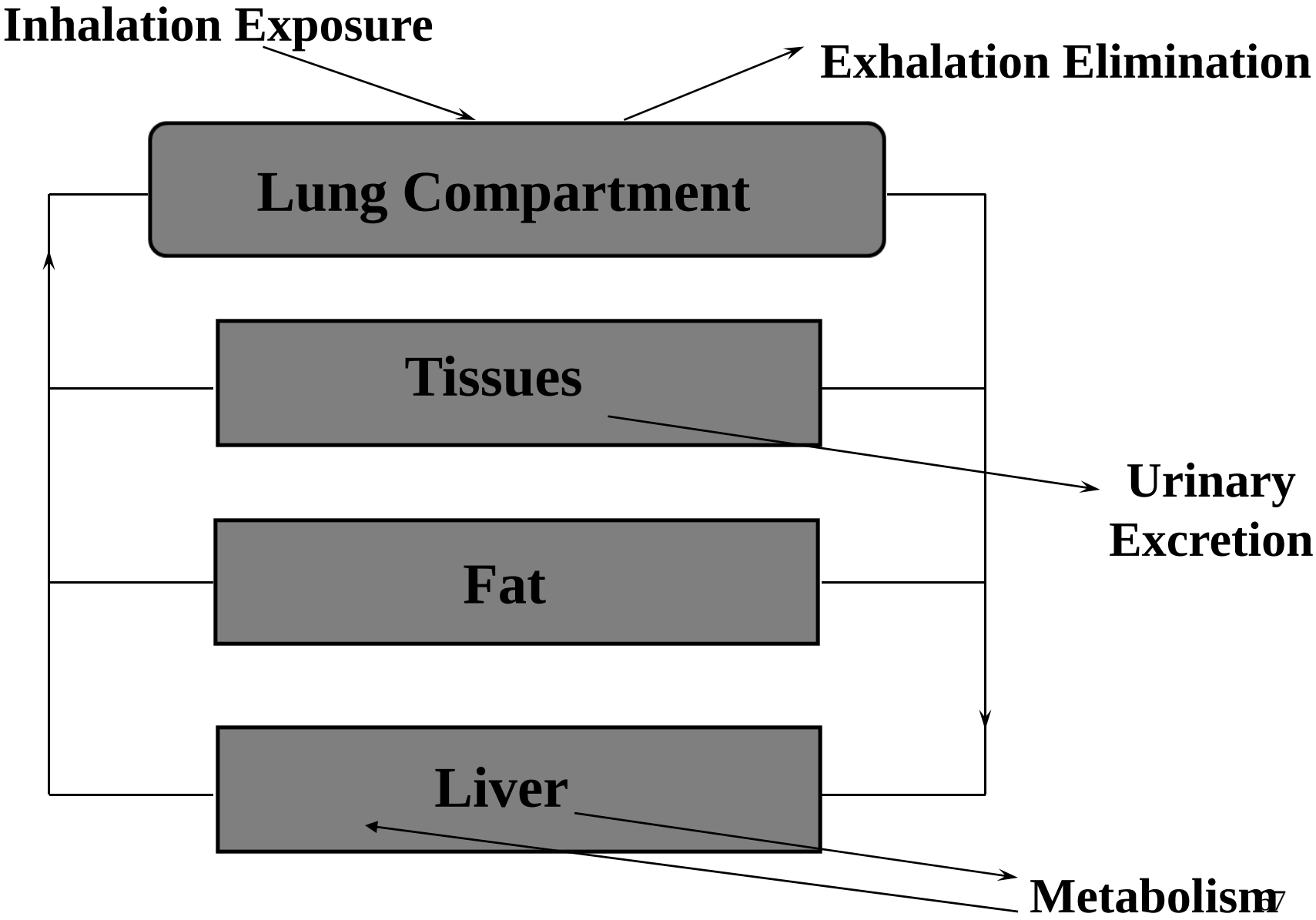
- Represents the State-of-the-Science in Toxicology
- An opportunity to look deeply into the “black box”
- Allows elucidation of the target tissue dose at low applied doses

PB-PK Made Simple

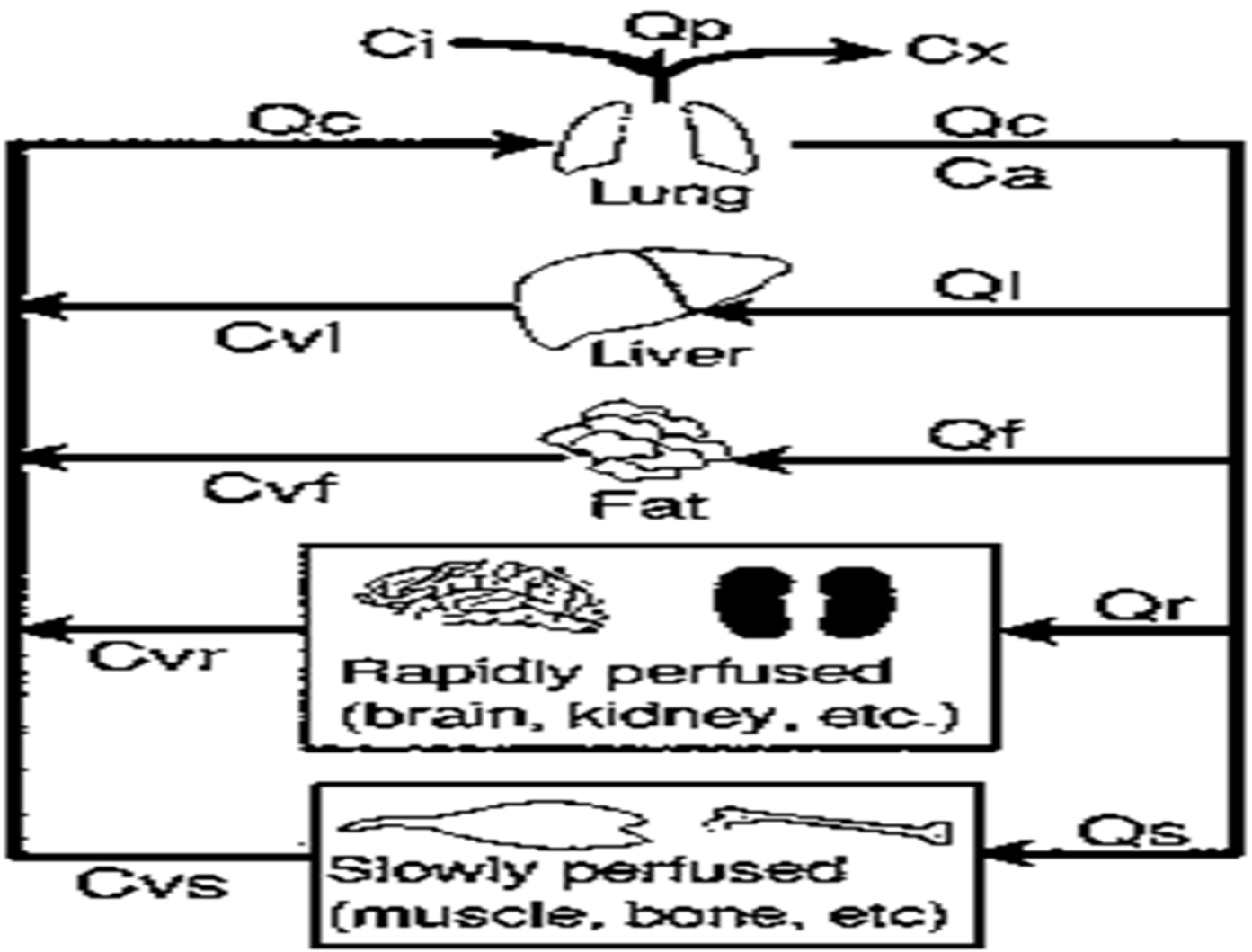


Note: Toxicant can react while in box 1 or box 2

PB-PK Model Structure



Building and Running - Physiological Models



Rory B. Conolly, Sc.D.,CIIT PBPK Course, March 12, 1991

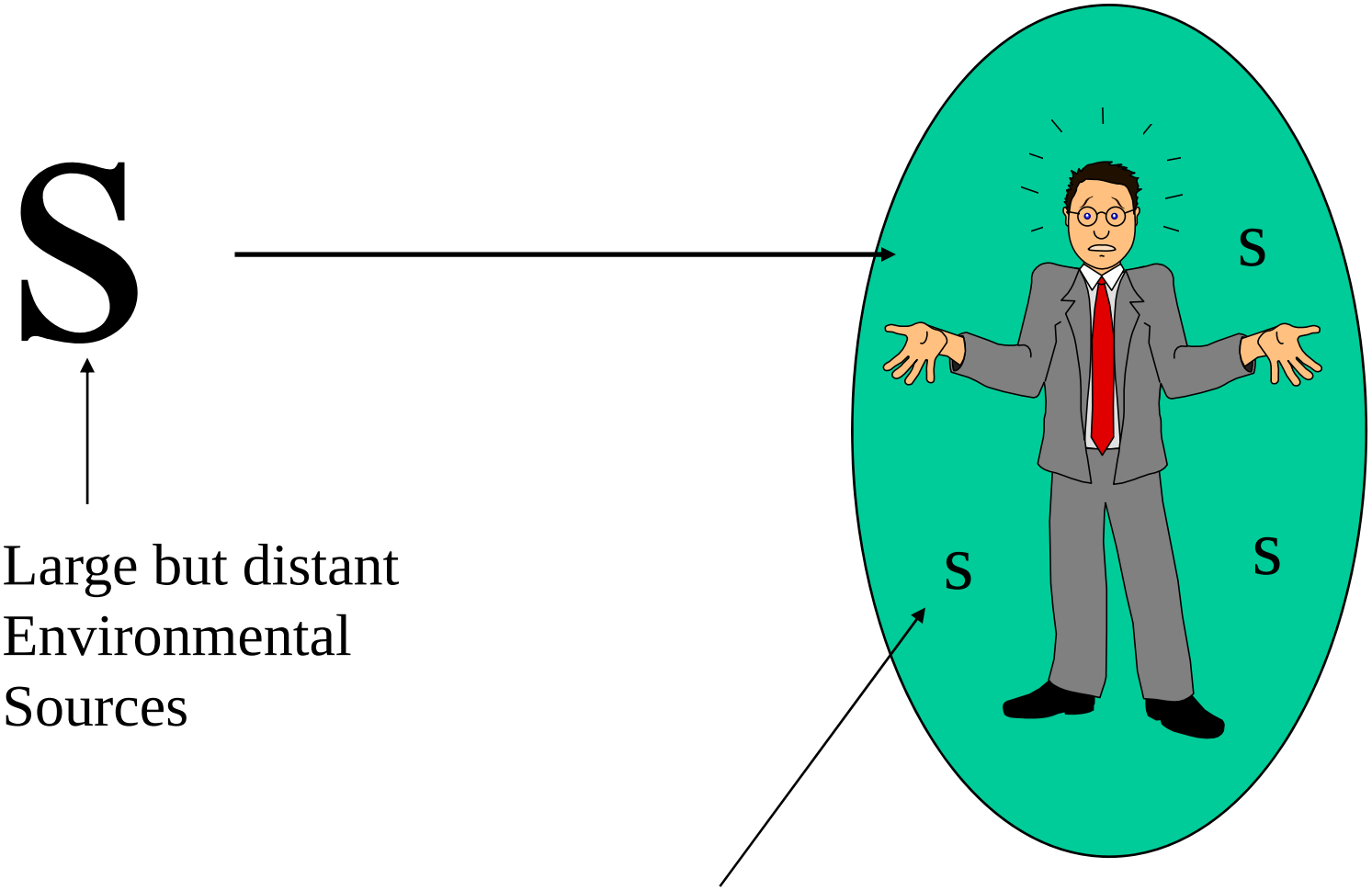
The “omics” in Risk Assessment

- **Genomics**
- **Proteinomics**
- **Transcriptomics**
- **Toxicogenomics**

All address the issue of gene expression as a result of stress or exposure. Understanding the up- and down-regulations of genes could finally provide the key to low dose-response effects.

EXPOSURE ASSESSMENT

- **The Other Half of Risk Assessment**


S
S
S
S
Large but distant
Environmental
Sources
Small Sources within
the Microenvironment

Exposure Estimation Progression

Low

High Cost

- **Models**
  - **Worst Case - Easy/Cheap Overestimating**
  - **Typical Case - Difficult/Expensive Better-Estimating**
- **Inhalation Monitoring**
  - **Sample Statistics**
  - **Representative (?)**
  - **Log-normal Distribution**

Inhalation Models

1. Model (i.e., estimate) Airborne Concentration in a Volume of Air

2. “Time” the Person in This Volume to Estimate Exposure

$$\left(\frac{mg}{m^3}\right)\left(\frac{m^3\ inhal}{8\ hours}\right)\left(\frac{hours}{8\ hours}\right) = Ex$$

DETERMINISTIC EXPOSURE MODELS

- **Fundamentals and Background**
- **Modeling as a Tiered Approach**
  - **ZeroVentilation Model**
  - **Well-Mixed Box Model**
  - **2-Box and Gradient Models**
- **The "problem" with dust/aerosol modeling**
- **Empirical Models – EASE**

Tiered Model Types

- **Tier 1 - Zero Ventilation (Saturation)**
  - **Assumes no ventilation**
- **Tier 1^+ to 2 includes the Well Mixed Box (WMB)**
  - **Assumes perfect and instant mixing of any source within a volume around the person**
- **Tier 3 - Gradient Models (describe airborne concentration(s) near the source and at some distance from the source)**
  - **Eddy Diffusivity**
  - **2 Zone Model**

RISK ASSESSMENT AND SCIENTIFIC UNCERTAINTY

UNCERTAINTY

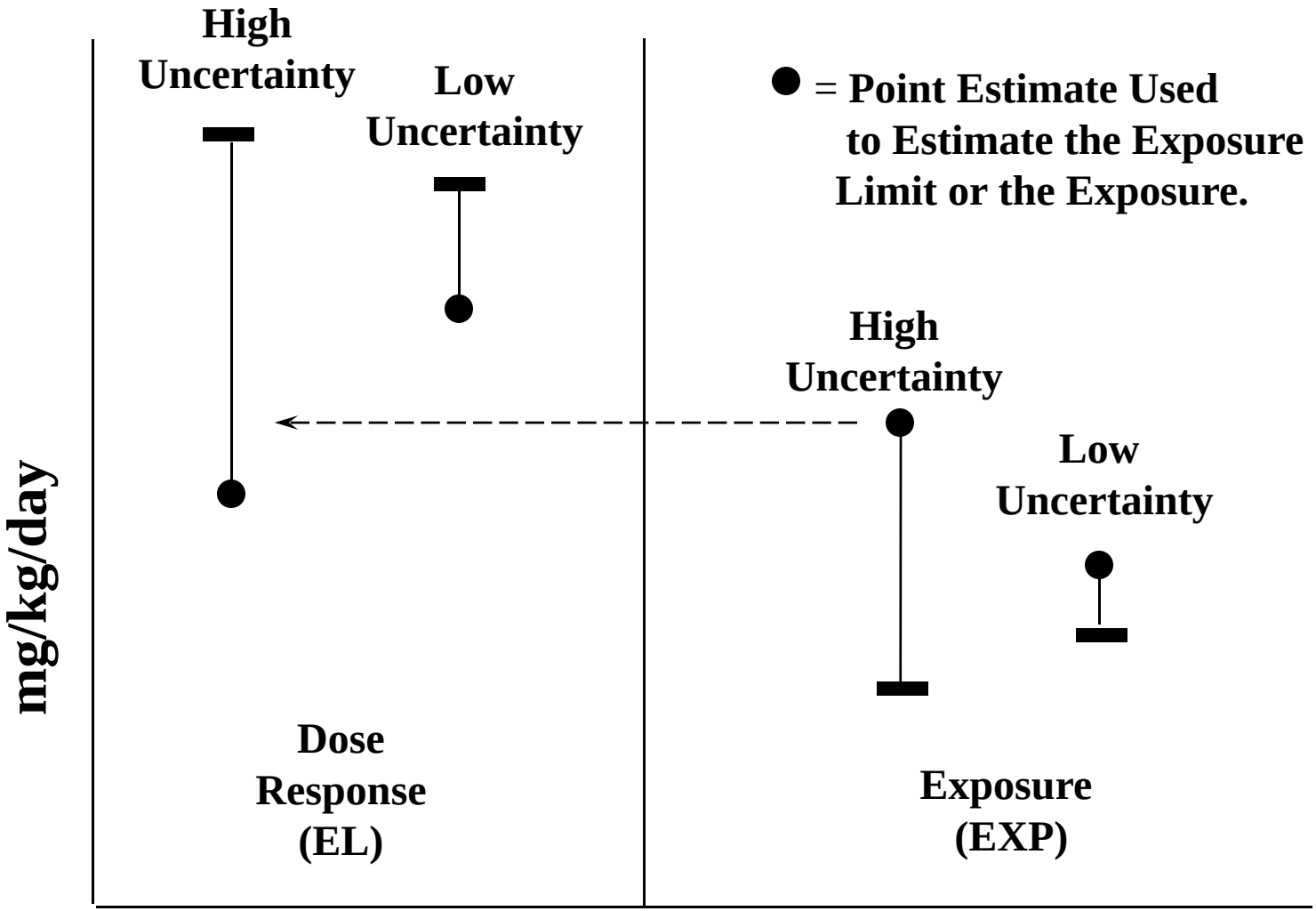
PROBABISTIC ANALYSIS AND MONTE CARLO SIMULATION

- Monitor/Modeling Uncertainty
- Normal Statistics
- Exposure Modeling Example
  - Deterministic versus Probabalistic (Stochastic)
  - Worst Case vs Monte Carlo
- My Dog Libby as an Object Example

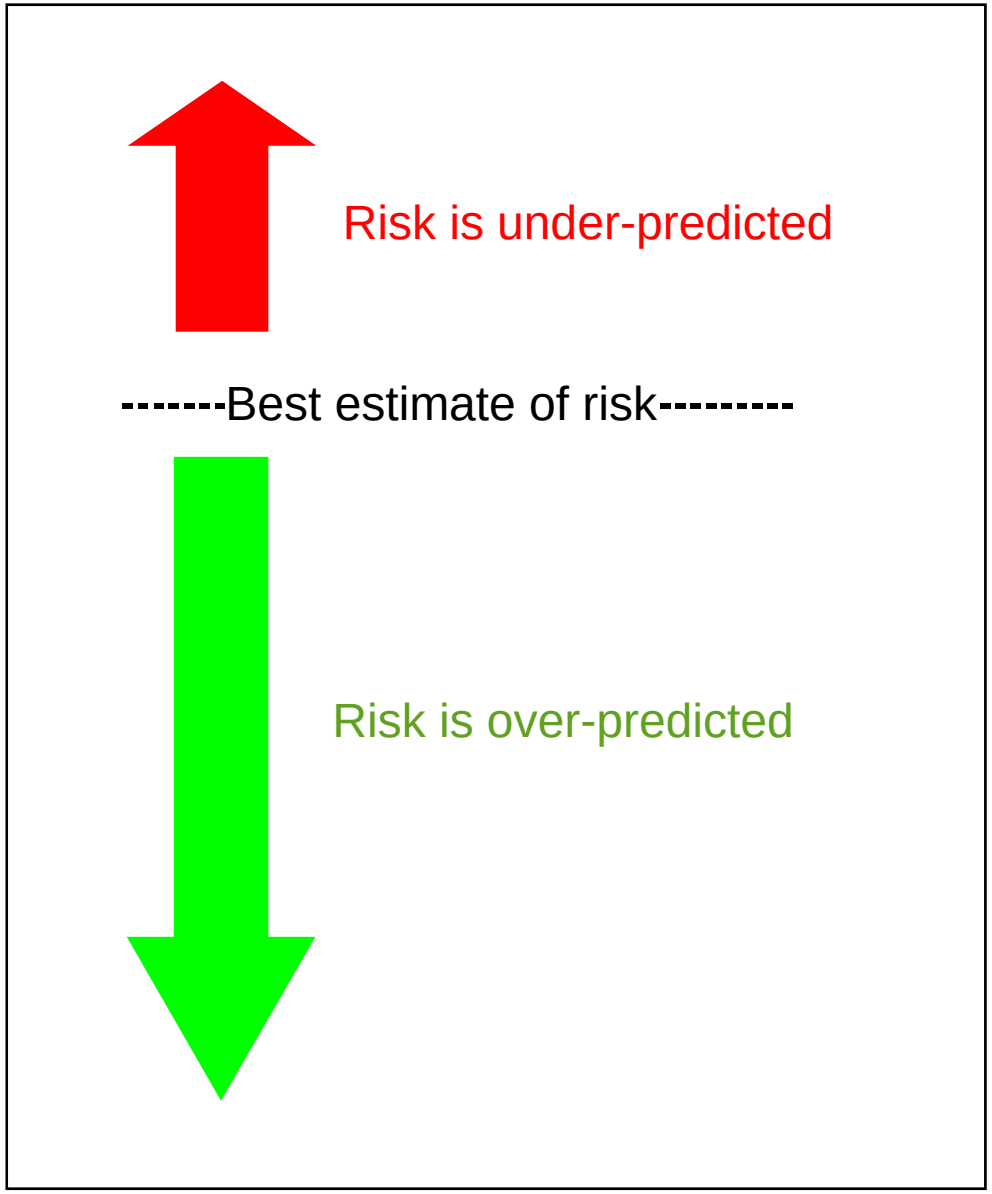
Risk Assessment is:

- **Driven and Limited by Scientific UNCERTAINTY**
- **An Iterative Process that Should Reasonably Trade Conservatism for Data**

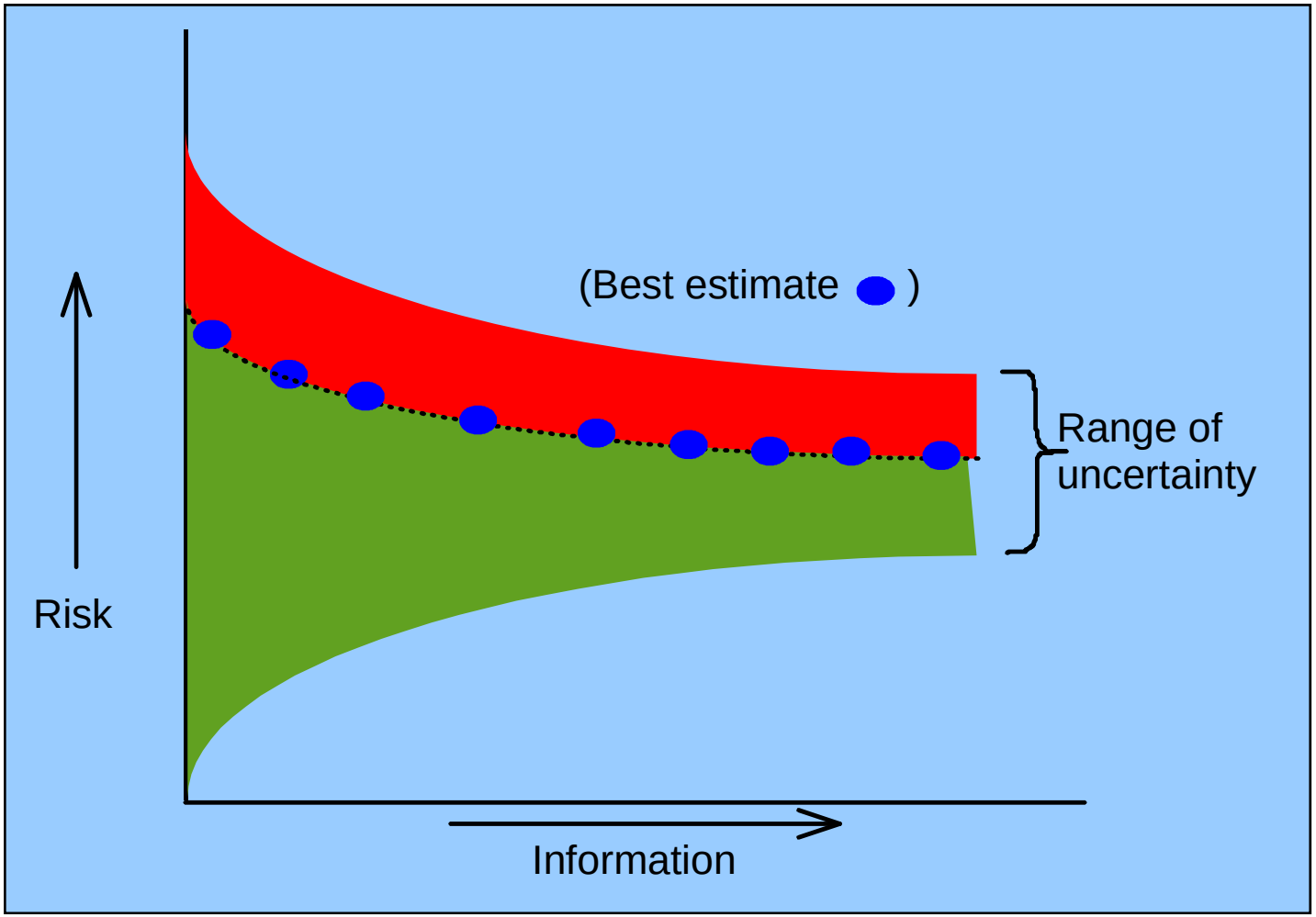
Levels of Confidence in Exposure and Dose-Response Assessments



Uncertainty



Greater use of data on toxicological mechanisms reduces risk assessment uncertainty



Uncertainty Has Two Components

Variability

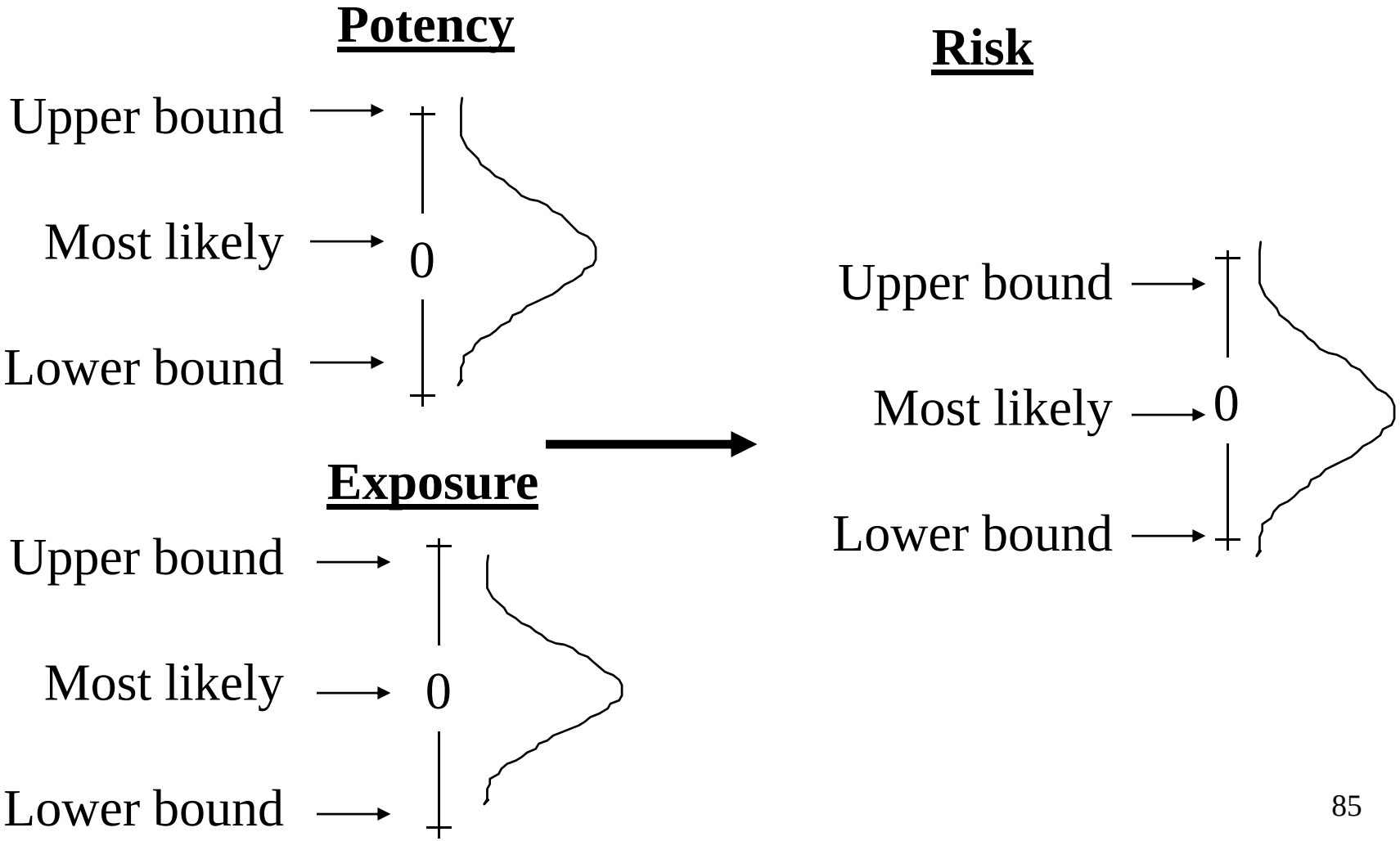
+

<u>Lack of Knowledge</u>

My Dog
LIBBY
as an object lesson
in Uncertainty
Analysis

UNITED STATES OF AMERICA

Uncertainty in Potency AND Exposure Contribute to Uncertainty in Risk

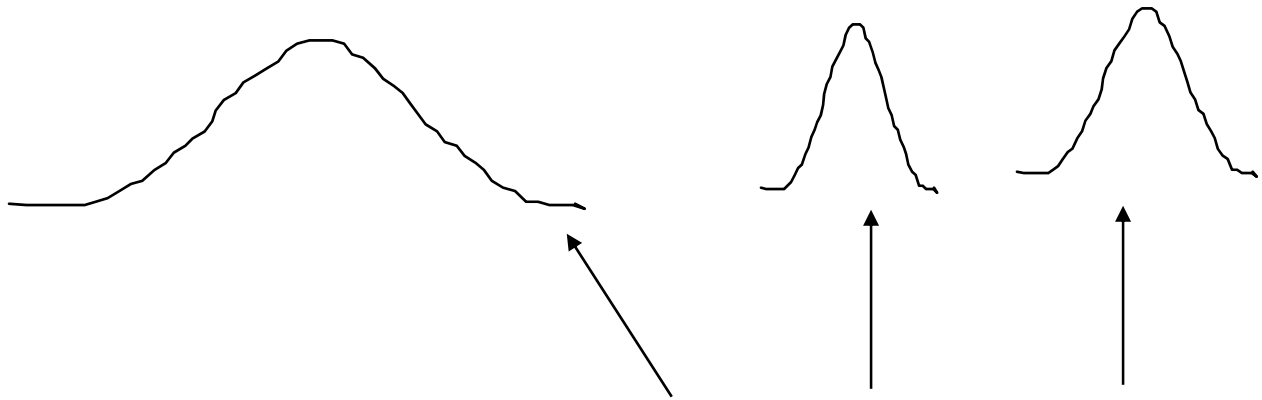


Simple Equilibrium Box Model

@ Equilibrium

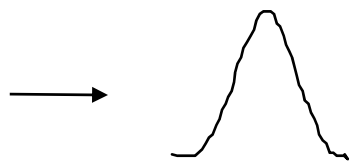
$$\textbf{Concentration} = \frac{\text{Generation Rate}}{\text{Ventilation}}$$

$$\mathbf{C} = \frac{G}{Q}$$

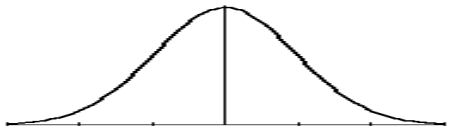


$$G = \frac{(MW)(MTC)(VP)(AREA)}{T_L}$$

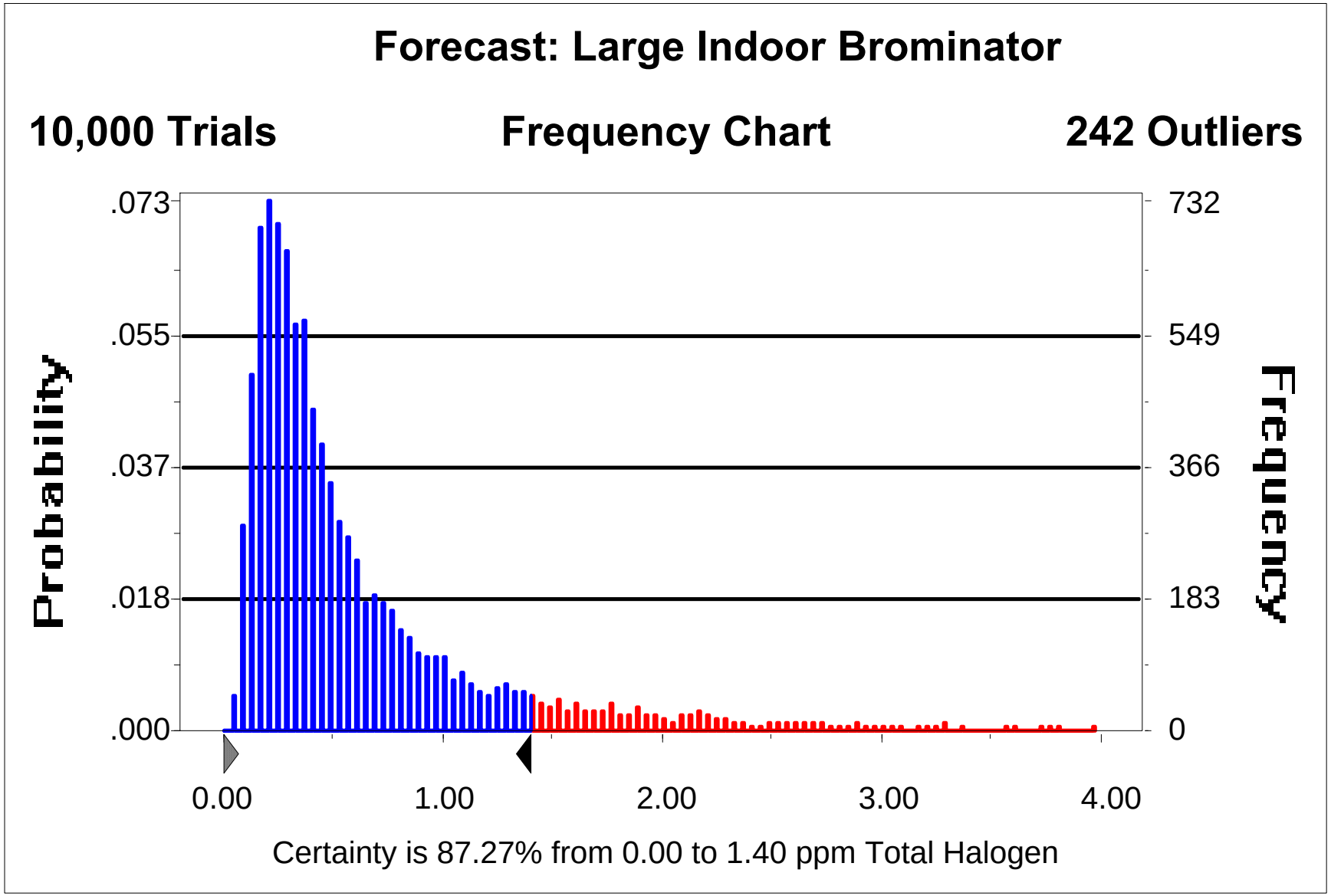
$Q =$



$$C = \frac{G}{Q} =$$

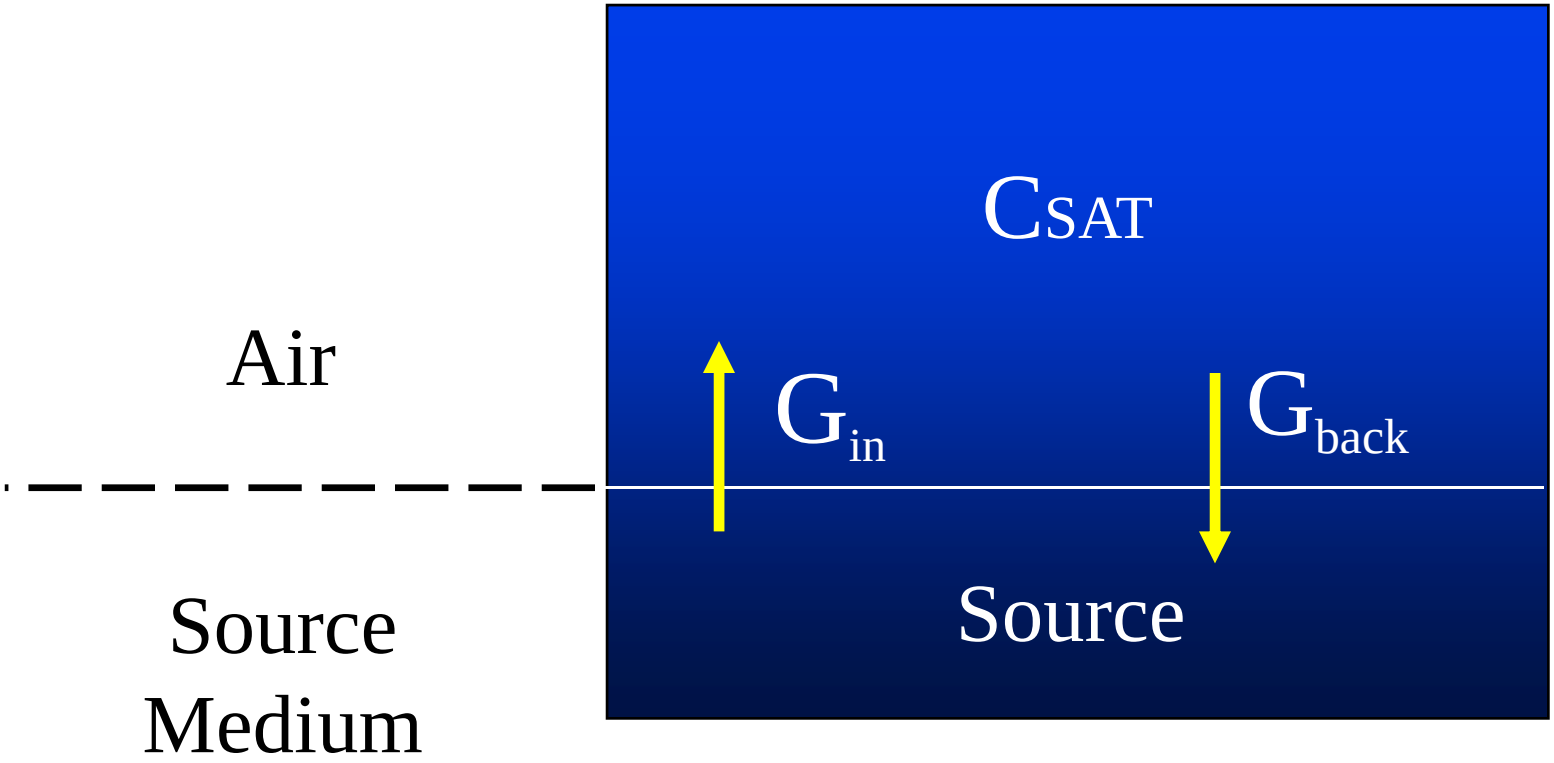


Combined Distribution


Forecast: Large Indoor Brominator
10,000 Trials
Frequency Chart
242 Outliers
Probability
Frequency
.073
.055
.037
.018
.000
732
549
366
183
0
0.00
1.00
2.00
3.00
4.00
Certainty is 87.27% from 0.00 to 1.40 ppm Total Halogen

Inhalation Modeling Specifics

ZERO VENTILATION or SATURATION MODEL



G = mass transfer rate (wt/time)

ZERO VENTILATION EQUATIONS

$$C_{ppm} = \left(\frac{(VP_{TORR})}{760} \right) 10^6$$

$$C_{mg/m^3} = C_{ppm} \left(\frac{MW}{24.45} \right)$$

Ascribed Aerosol

$$C_{aerosol} = 10 - 15 \ \frac{mg^3}{m}$$

SOLUTION vapour PRESSURE

$$C_{SAT} = \frac{mg}{m^3}$$

$$C_{SOLN} = \frac{mg}{m^3}$$ concentration in the bulk liquid

$$\frac{C_{SAT}}{C_{SOLN}} =$$ **Dimensionless** Henry's Law **<u>CONSTANT</u>**

Valid For:

- Ideal solutions at all concentrations
- Solutes at low solute concentration in non-ideal solutions.

SOLUTION VAPOR PRESSURE

Raoult's Law

$$VPP = (VP_O)(X)$$

Where:

VPP = vapour Pressure over solution

VP_O = vapour Pressure of Pure Compound

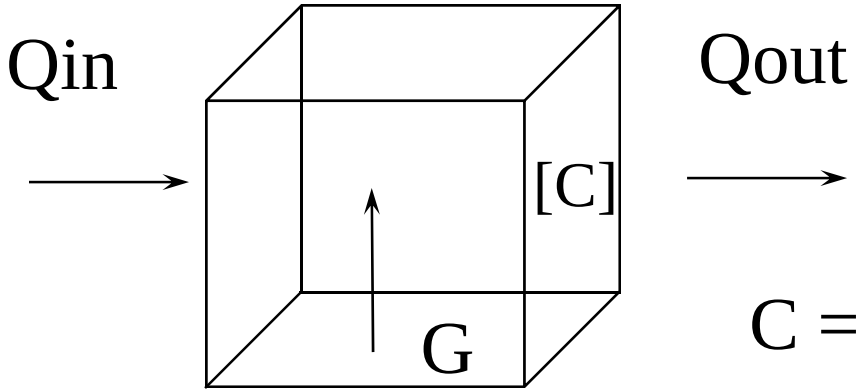
X = Mole Fraction of Compound

Valid for:

- **Ideal solutions at all concentration**
- **Solvents at low solute concentrations of non-ideal solutions**

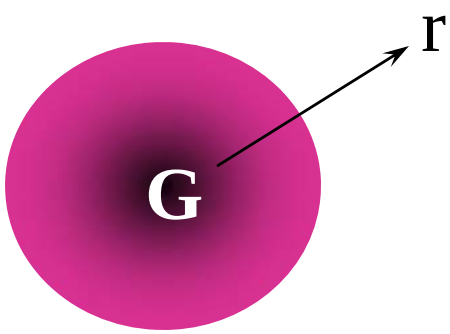
Two Types of Airborne Concentration Models

- BOX



C = Constant in Box

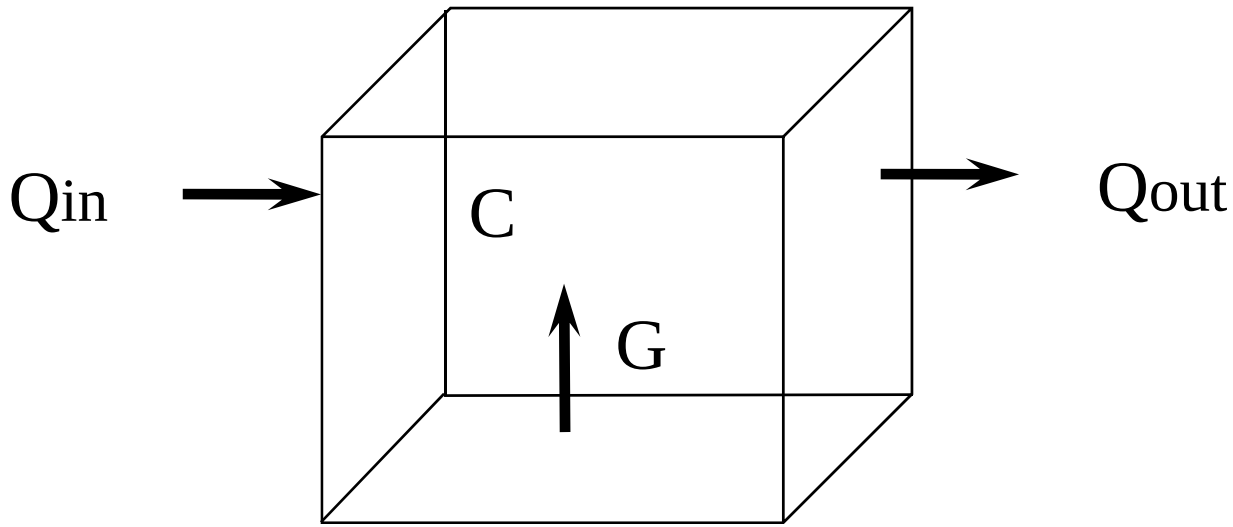
- DISPERSION or Gradient



$$C = f(r)$$

General Ventilation Model
Without Sinks or Backpressure

Box of Air with Volume = V



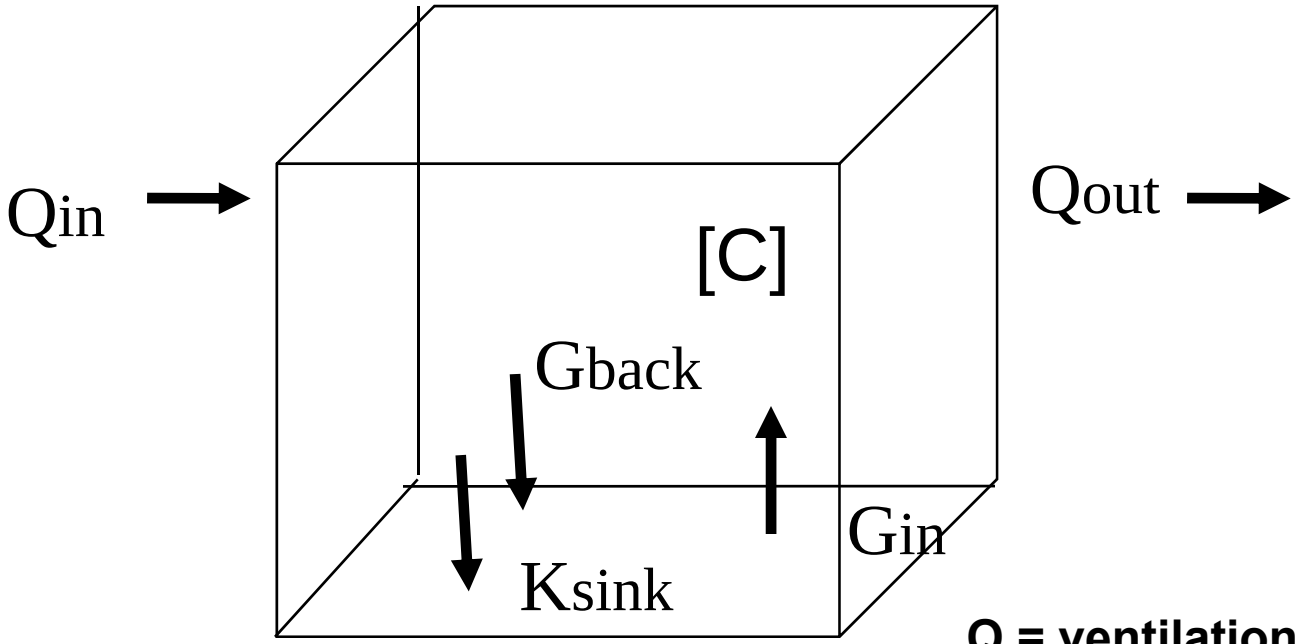
$$VdC = Gdt - QCdt$$

Q = Ventilation (m^3/hr)

G = Contaminant Source Rate (mg/hr)

C = Concentration in Box (mg/m^3)

Well Mixed Box
– complete and complicated



Q = ventilation rate(vol/time)

$$VdC = (G_{in} - G_{back})dt - Q(m)Cdt - K_{sink}Cdt$$

General Ventilation Model

Q_{in}, Q_{out}	=	Ventilation (vol/time) (m^3/hr)
m	=	Mixing Efficiency (0 to 1)
G_{in}	=	Source Rate into "box" from Evaporation or Injection (mass/time (mg/hr))
G_{back}	=	"Backpressure" from Partial Pressure in the "Box" Retarding Further Evaporation
K_{sink}	=	Overall Nonventilatory Loss or Sink Rate (vol/time)(m^3/hr)

K_{sink} is Probably more Complicated

$$K_{sink}\, C\, dt = K_{absorb}\, (C)\, (A)\, dt - K_{desorb}\, (M)\, (A)\, dt$$

M = Mass/Area in Sink, mg/m^2

A = Surface Area of Sink, m^2

K_{absorb} = Absorption Rate, m/hr

K_{desorb} = Desorption Rate, hr^{-1}

Re: Tichenor, et al: Indoor Air, 1, 23-25 (1991)

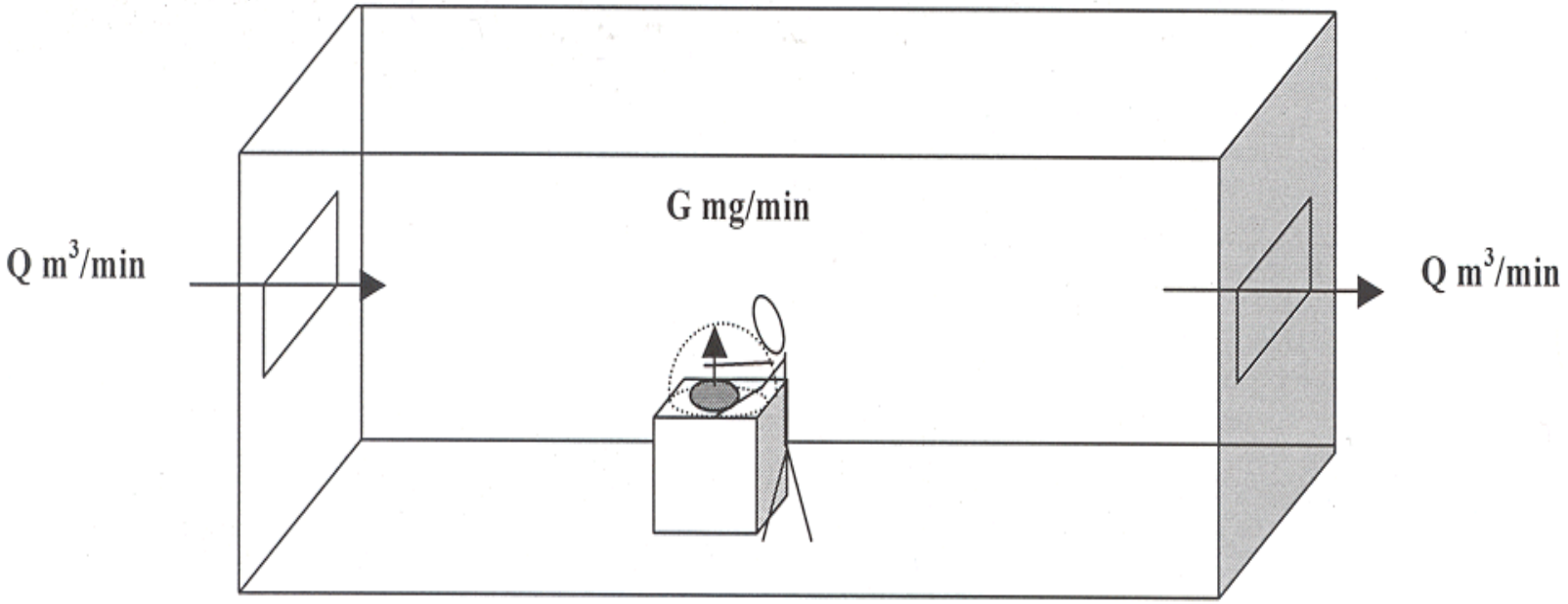
Mathematical Solution to Simplified WMB Model

$$C = \frac{G_{in}}{Q} + \left(C_0 - \frac{G_{in}}{Q} \right) e^{\frac{-Q}{v} t}$$

$$\text{at steady state} \quad C_{eq} = \frac{G_{in}}{Q}$$

C_0 = concentration in the box at t = 0

Two Box Model



Two Box Model

Change in Mass = Mass Gain – Mass Loss

Near Field: $VNF \cdot dCNF = [G \cdot dt + \beta \cdot CFF \cdot dt] - \beta \cdot CNF \cdot dt$

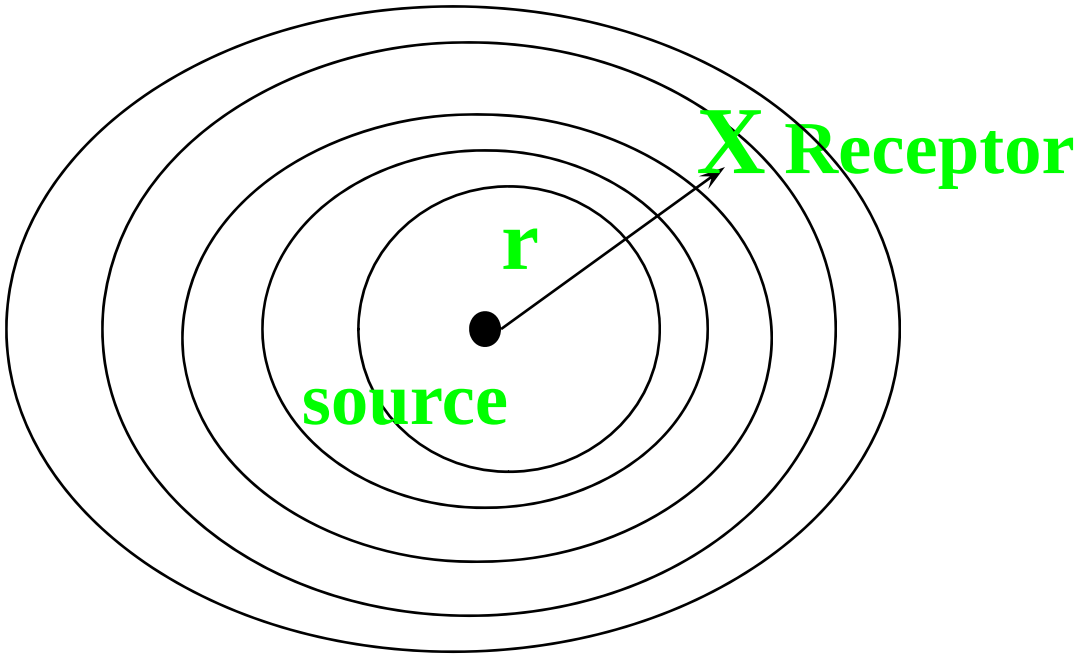
Far Field: $VFF \cdot dCFF = \beta \cdot CNF \cdot dt - [\beta \cdot CFF \cdot dt + Q \cdot CFF \cdot dt]$

Where:

CNF = the near field concentration (mg/m^3)
CFF = the far field concentration (mg/m^3)
VNF = the near field volume (m^3)
VFF = the far field volume (m^3)
G = constant mass emission rate (mg/min)
β = air flow rate (m^3/min) between the near and far fields

Ref: Two-Box Model.doc on your course CD for more details.

Dispersion Models



Eddy Diffusion Model (no advection)

$$C = \frac{G}{2\pi D \bullet r} \, erfc\left[\frac{r}{\sqrt{(4D \bullet t)}}\right]$$

where D_T = eddy diffusivity

r = sample point distance from source

t = elapsed time since start of release

G = continuous emission rate

"erfc" = error function complement or (1 - erf)

ASSUMPTIONS: random air movement, point source
hemispherical emission pattern

NOTE: Divide by 2 for spherical pattern

Steady State Eddy Diffusion Model (with advection)

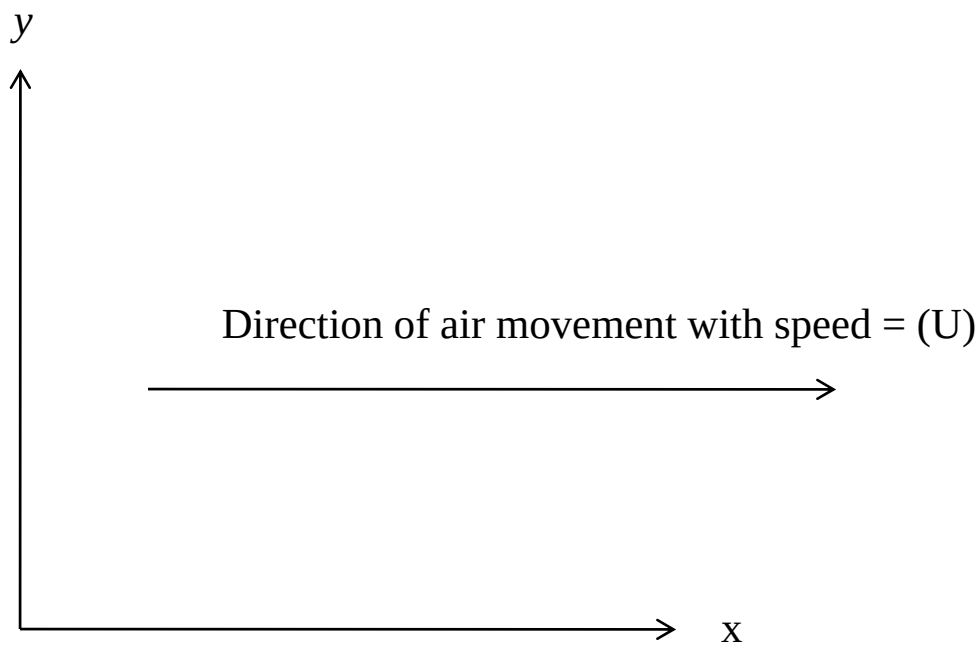
$$C(x,y,z)_{ss} = \frac{G}{G_f \pi D_T \sqrt{x^2+y^2+z^2}} \, exp\left(-\frac{U}{2D_t}\left(\sqrt{x^2+y^2+z^2}-x\right)\right)$$

G_f = geometric factor for source sphere, hemisphere, quarter sphere, eighth sphere

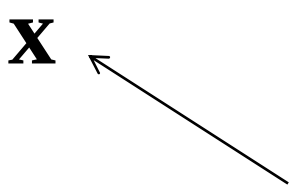
x,y,z = coordinates positioning the person's breathing zone relative to the point source.

U = downstream wind speed in the x direction.

Eddy Diffusivity Coordinates



Note : z direction is out of the page (i.e., above the bench top)



Example : x,y,z = 0,-1,1 would position the receptor here 1 m to the “south” of the source and 1 m above it
With the direction of air from left to right

Inhalation Models on NOT complete without CONTACT

1. Model (*i.e.*, estimate) Airborne Concentration in a Volume of Air

2. One needs to "Time" the Person in This Volume to Estimate Exposure

The “problem” with airborne dust or aerosol modeling

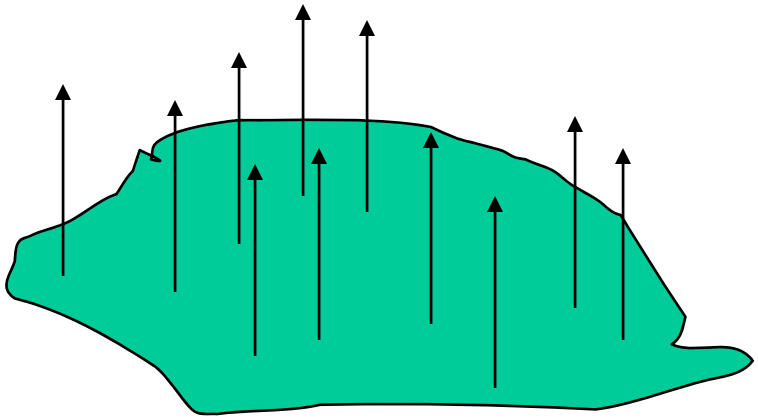
- The Generation rate can not be estimated with “first principle” submodels
- Requires rough estimates or experimental characterization which is limited to the specific class of emission being considered.
- Research is sorely needed.

ESTIMATING SOURCE STRENGTH
(Submodling)

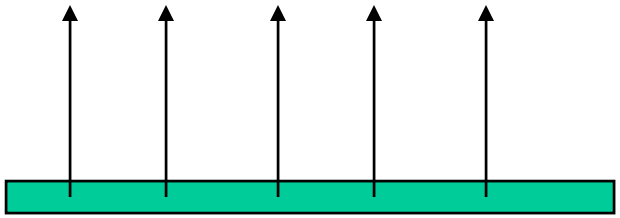
- Diffusion v. Injection
- Diffusion
  - vapourization
    - From pure liquid
    - From mixture
    - From solid matrices
- Injection
  - Drum filling
  - Spraying

Diffusion of Vapors

Passive movement from areas of high concentration to air at initially low concentration

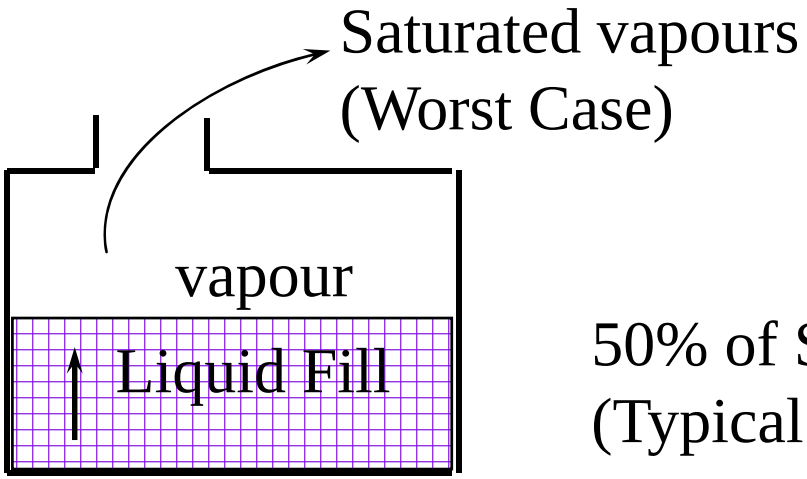


Pure Liquid or Mixture



Solid Matrix

Estimating Source Rate (G) from Drum Filling (Injection)



$$\left(\frac{\text{Drum}}{\text{Hr}}\right)\left(\begin{array}{c}\text{Drum}\\ \text{Volume}\end{array}\right)\left(\begin{array}{c}\text{\% of}\\ \text{Saturation}\end{array}\right)\left(\begin{array}{c}\text{Saturation}\\ \text{Concentration}\end{array}\right) =$$

$$\text{G}\ (\text{wt per hour into room air})$$

Taxonomy of Sources from 2005 JRC Verbania/Intra Italy Workshop on Sources

- **vapour emitted from** DRY SOURCES**,**
- **vapour from** WET SOURCES**,**
- PARTICULATE MATTER SOURCES **(solid and liquid aerosol),**
- COMBUSTION SOURCES **(particulate and vapour), and**
- CHEMICAL REACTION SOURCES **(particulate and vapour)**.

Reference available online:

http://web.jrc.ec.europa.eu/pce/documentation/eur_reports/Global%20CEM%20Net%20Workshop%202%20SOURCES.pdf

Software Demo

- Crystal Ball Uncertainty Analysis – Excel Spreadsheet add-in
- IH-Mod spreadsheet from AIHA (called EASCIHMOD on web site)

Software Resources

- AIHA web site for latest version of IH-Mod (called EASCIHMOD on the site)
- http://www.decisioneering.com/
  - Decisioneering Crystal Ball software 303-534-1515
- http://www.wsdinc.com/products/p1009.shtml
  - Palisades @RISK software 800-286-4106

Crystal Ball and @Risk do the same thing.

Crystal Ball Software Demo

Case Study
Laboratory Bench Top Spill

Spill Volume = 0.2 liter (200 grams)

Surface Area = 0.2 m^2

Evaporation rate = 1000 mg/min

Room Volume (V) = 200 m^3

Near Field Volume (Vn) = 1 m^3 (arms length = 2.5 ft = 0.78 m)

Ventilation rate (Q) = 20 m^3/min

Air exchange rate = Q/V = ??? air change/hr

Air movement (β) = 5 m^2/min (basic on 2.6 m/min air movement in and out of the 1 m^3 Vn.

Eddy Diffusivity (D_T) = 1 m^2/min

Your Task

- Watch me show you how to run IH-Mod
- Watch me run the Well Mixed Box Model
- Run the 2 box model in IH-Mod with the same scenario
  - Vary (play around with) the inputs
  - Discuss the results and differences
- Run the Eddy Diffusivity with Advection on the same scenario. Please the person perpendicular to the airflow at x = 0m, y = -0.5m, z = 0.5m (*i.e.,* over the spill cleaning it with the air movement from left to right).
  - Vary (play around with) the inputs
  - Discuss the results and differences

Doing the analysis is almost easy – getting the inputs is hard

- Submodels to are critically needed to characterize and estimate.
  - Source rate(s) as a function of time.
  - Ventilation and dispersion (β and D)
  - Non-ventilatory losses from sorption or degradation.

Conclusions

SO WHAT DO WE HAVE?

- **A DYNAMIC TENSION BETWEEN THE ORGANIZATIONAL AND SOCIETAL COSTS AND BENEFITS OF :**
  - **CONTROL**
  - **SAFETY**
  - **RA KNOWLEDGE**

SO WHAT DO WE NEED?

- Validated models of **toxicity** and **exposure** (perhaps best developed in public works projects).
- An Informed and Empowered Clients and Charges that can take the information provided and determine the level and balance of risk/benefit that they can endorse.

What's Does It Get Us?

- Charges that are well-served.
- Rational and cost effective analysis and recommendations.
- "Surprised and delighted" clients.
- The security of full employment born of having an important and portable skill set.

References

- **AIHA Pub: *Mathematical Models for Estimating Occupational Exposure to Chemicals*, 2nd Edition – due out this year!**
- **AIHA Pub: *Risk Assessment Principles for the Industrial Hygienist*, 2000.**
- **Papers and articles supplied with this PDC.**

Mathematical Models for Estimating Occupational Exposure to Chemicals

2nd edition

Edited by Charles B. Keil, PhD, CIH
Catherine E. Simmons, CIH
T. Renée Anthony, PhD, CIH, CSP

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