National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

Coeur d'Alene, Idaho
31 March – 4 April, 2003

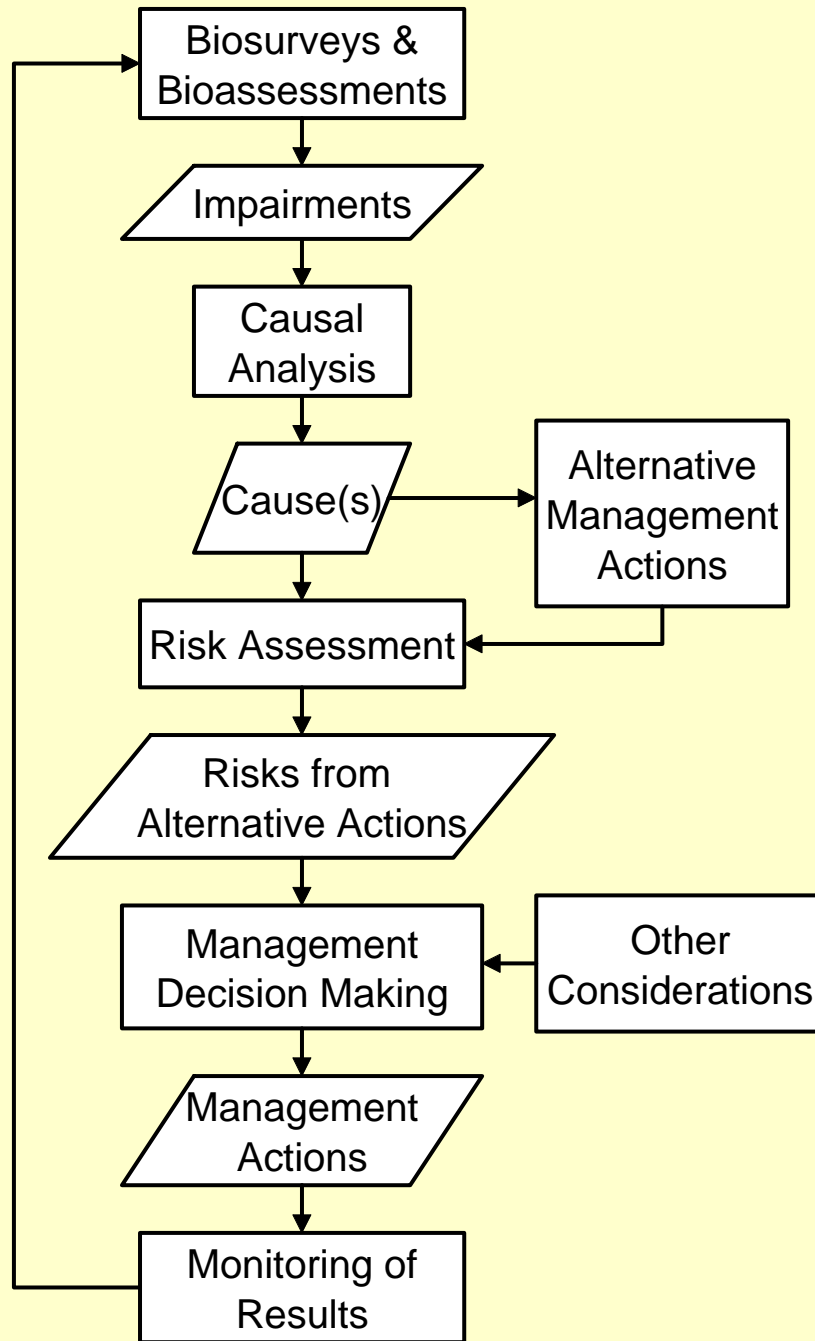# *Why a Formal Method for Causal Evaluation?*

Presented by

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Where are we going?

- **Place of causal analysis in environmental management**

- **Why a formal method?**

- **History of causal analysis**

- **Relation to Stressor Identification**

When is Causal Analysis Needed?

- **Implementing biological standards**
- **Investigating fish kills**
- **Contaminated sites**
- **Interpreting biological monitoring results**
- **Recovery plans for T&E species**
- **Any other case of observed effects**

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   ┌───▶│   Biosurveys &  │
   │    │  Bioassessments │
   │    └─────────────────┘
   │             │
   │             ▼
   │        ╱ Impairments ╱
   │             │
   │             ▼
   │        ┌──────────┐
   │        │  Causal  │
   │        │ Analysis │
   │        └──────────┘
   │             │
   │             ▼                    ┌──────────────┐
   │        ╱ Cause(s) ╱ ───────────▶│  Alternative │
   │             │                    │  Management  │
   │             │                    │   Actions    │
   │             ▼                    └──────────────┘
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   │     │Risk Assessment│◀─────────────────┘
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   │     ╱  Risks from      ╱
   │     ╱ Alternative Actions ╱
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   │     ┌──────────────┐             │    Other     │
   │     │  Management  │◀────────────│Considerations│
   │     │Decision Making│            └──────────────┘
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   │       ╱ Management ╱
   │       ╱   Actions  ╱
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   └─────│ Monitoring of│
         │    Results   │
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Why use a formal method?

- **To convince skeptical stakeholders**

- **To increase a manager's confidence that costly remedial or restoration efforts are targeted at factors that can truly improve biological condition.**

- **To identify causal relationships that are otherwise not immediately apparent.**

- **To prevent biases or lapses of logic that may not be apparent until a formal method is applied.**

"*The first principle of science is that you must not fool yourself--and you are the easiest person to fool*"
   --Richard Feynman

This is Harder Than Rocket Science

- **Causation is one of the most difficult and controversial concepts in philosophy**
- **Only one reliable method**
  - **Randomized, replicated, controlled experiment**
  - **Lesson of hormone replacement**
  - **Not available to us**
- **But we all think we know how to do it**
  - **Hard wired to jump to conclusions**
  - **Creaking wood at night means intruder!**
 - **Causal analysis says thermal contraction**

History of Causality

- **Galileo Galilei: causes must be**
  - **Necessary: Never E without C**
  - **Sufficient: Always E when C**
- **Hume: all we know is:**
  - **Time order: C precedes E**
  - **Association: E when C**
  - **Consistency: Always E when C**
- **Mill: no causality without experiment**
  - **Must manipulate C and observe E**
- **Pearson: Probabilistic causality**
  - **Frequency of E given C = probability of causation**
- **Fisher: probabilistic analysis of experiments**
  - **Probability of E given imposed C**

Causation in Epidemiology

- **Conventionally probabilistic**
  - **Does smoking cause cancer?**
  - **Contingency table**
    - **400 smokers**
    - **400 nonsmokers**

	Cancer	No Cancer
Smokers	**40**	**360**
NonSmokers	**2**	**398**

Fisher Strikes Back
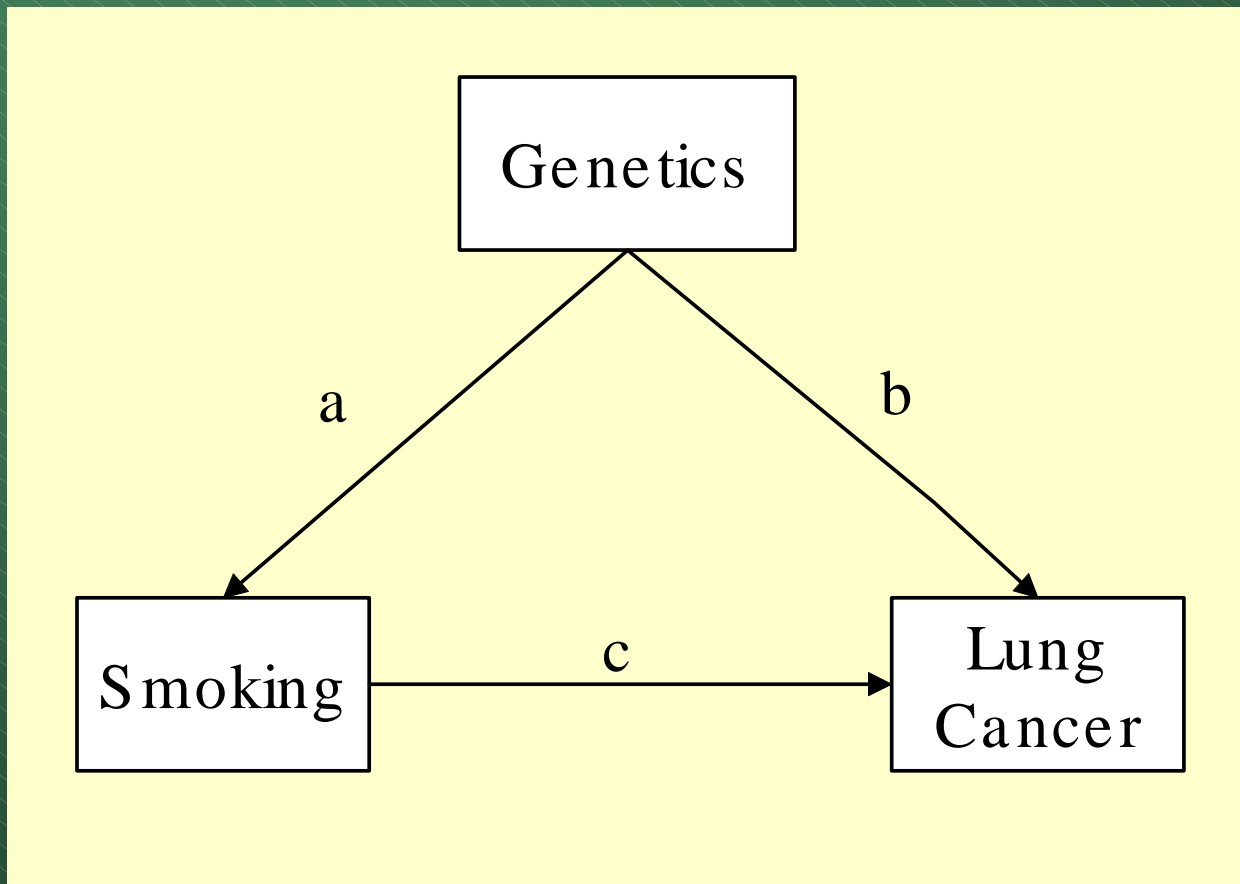
Hill to the Rescue

- **His criteria:**
  - **Strength**
  - **Consistency**
  - **Specificity**
  - **Temporality**
  - **Biological Gradient**
  - **Plausibility**
  - **Coherence**
  - **Experiment**
  - **Analogy**
- **Established causality based on strength of evidence**

Current State of the Art

- **Hill's criteria and variants**
  - Susser, Fox, etc.
- **Popperian disproof**
  - Based on experiment (Mill, Platt)
  - Based on observation (Galileo)
- **Fisherian disproof**
  - Only for experiments
- **Probabilistic Association**
  - Frequentist or Bayesian
- **Koch's Postulates (single chem. or pathogen)**
  - Association of C and E
  - Isolation of C from E
  - Experimental Association of C and E
  - Experimental Isolation of C from E

Synthesis

- **Hume was right**
  - Its all association
  - But, not all associations are equal
- **Experimental Association**
  - Reliable due to control, replication & randomization
  - Results may be uncertain due to variance
  - Results may not be relevant
- **Observational Association**
  - Results may be directly relevant
  - Not reliable: no control or randomization
- **Mechanistic Association**
  - Associations at lower level of organization
  - Reductionism

Mechanistic Response to Fisher
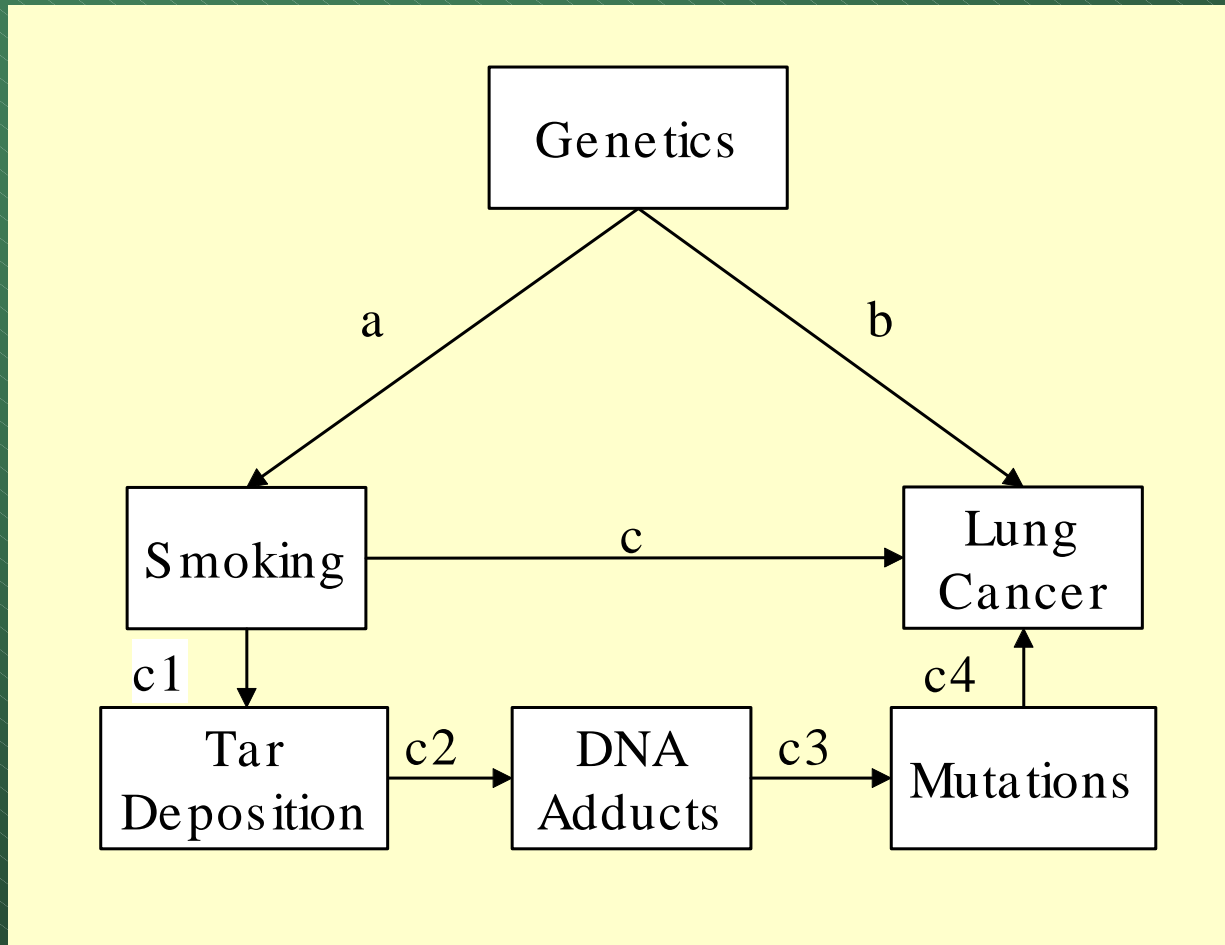
Alternatives to Association for Identifying Causes

- **Deduction from theory**
  - Our theories are not that good
  - Computational toxicology some day
- **Consensus**
  - Stakeholder processes
- **Regulatory constraints**
  - The cause is the one we can hammer

Our Causal Strategy

- **Logically eliminate when can**
- **Diagnose when can**
- **Use strength of evidence for the rest**
- **Do not claim proof of causation**
- **Identify the most likely cause**
- **Use a consistent process**
- **Document the evidence and inferences**