## Why Do We Need Good Science?

<table>
<thead>
<tr>
<th>Decision</th>
<th>Does a Real Hazard Exist?</th>
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<tr>
<td></td>
<td>True</td>
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<tr>
<td>Act</td>
<td>Improved health</td>
</tr>
<tr>
<td>Don’t Act</td>
<td>Health deteriorates</td>
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Do We Have Good Science?

Yes and No

Maybe?
Does Good Science Encompass Only Process or Also Outcome?

**Process**
- Methods
- Study Design
- Statistical Power
- Appropriate Extrapolation

**Outcome**
- Maximum Benefit
- Minimum Costs
- Minimal Risk of Adverse Impacts
Regulatory Science Functions in a Challenging Context

- Legislation
- Regulatory Deadlines
- Funding Limitations
- Staffing Limitations
- Cognitive Bias
- Time Constraints
- Available Methods
- And More!
Amongst the Challenges - Specialization

• With rare exceptions, American universities and colleges have dissolved their curriculum into a slurry of minor disciplines and specialized courses. While the average number of undergraduate courses per institution doubled, the percentage of mandatory courses in general education dropped by more than half.

→ Regulatory science offers an opportunity to re-integrate basic scientific questions into their broader, social and public health context.
Today’s Agenda

• Good Science and Contested Science
• Three Cases
  – Chloroform
  – Perchlorate
  – The Delta
• Good Science Considers the Broader Context
• Parting Thoughts
GOOD SCIENCE AND CONTESTED SCIENCE

Epidemiology: Case-control study: what are differences in health effects associated with this factor?

Exposure assessment: how much is associated with water versus other exposure routes?
Default Approach for Cancer Risk Assessment – Simplifies Extrapolation

Response

Model assumes no threshold

Increasing Risk

Dose of Interest
Micrograms per liter

Experimental Region

High doses
grams per liter
Good Science– Version 2.0

Toxicology: Single-compound studies that examine mechanism or mode of action

Epidemiology: what factors influence the responses of sub-populations?

Exposure assessment: how much of exposure makes it to the target organ (i.e., role of metabolism)?
Different Extrapolation Models Produce Different “Acceptable Levels”

Models assuming **no threshold** effect

Model assuming a **threshold** effect

Increasing Risk

Response

Dose of Interest

Micrograms per liter

Experimental Region

High doses

grams per liter
Toxicology: multiple compounds with same mode of action

Epidemiology: how significant is the health effect in the population? What other factors influence this health effect?

Risk management: what non-water interventions are possible?
Good Science and Honesty

• ...if you're doing an experiment, you should report everything that you think might make it invalid — not only what you think is right about it; other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked — to make sure the other fellow can tell they have been eliminated.

  Details that could throw doubt on your interpretation must be given, if you know them. You must do the best you can — if you know anything at all wrong, or possibly wrong — to explain it.

  "Cargo Cult Science" in Surely You're Joking, Mr. Feynman!
CHLOROFORM AND DISINFECTION BY-PRODUCTS
The Case of Chloroform – I

1974 – Detected in drinking water.

1979 – Regulated for first time.

1986 – EPA Guidelines for Carcinogen Risk Assessment
- Linear dose-response
- No threshold

1996 – EPA draft Proposed Guidelines for Carcinogen Risk Assessment
- Mechanisms matter
- Should consider departing from default assumptions
The Case of Chloroform – II

1998 – EPA proposes a Maximum Contaminant Level Goal of 300 ppb, then withdraws it after ensuing controversy – retains “0”

2000 – Court of Appeals rejects “0”:

- Finding the agency's December 1998 rule adopting a zero MCLG for chloroform to be arbitrary and capricious and in excess of statutory authority, we vacate the rule.
  
- In promulgating a zero MCLG for chloroform, EPA openly overrode the 'best available scientific evidence', which suggests that chloroform is a threshold carcinogen.
# Implications Contested

<table>
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<th>Direct Application</th>
<th>Not So Fast</th>
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<tr>
<td>Thresholds exist for carcinogens therefore should not regulate so stringently</td>
<td>All exposures are adding to the normal background so incrementally increase risk regardless</td>
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<tr>
<td>Health effects are unlikely with chloroform so should not regulate</td>
<td>Chloroform is a proxy for other DBPs that may cause bladder cancer</td>
</tr>
<tr>
<td>Only regulate DBPs for which there is health effects data</td>
<td>Control for chloroform is similar to that for other DBPs.</td>
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PERCHLORATE RISK OR TARGET HEALTH RISK?
How Perchlorate is Framed Matters to Risk Management Choices

Perchlorate

NO₃, Cl, Br, ClO₃, BrO₃

Iodide deficiency

Inhibit iodide uptake
EPA Enlisted Science Advisory Board for Perspectives in July 2012

• Approaches for Deriving Maximum Contaminant Level Goals for Drinking Water

• Four issues
  1. Sensitive Life Stages
  2. Physiologically-Based Pharmacokinetic Evidence
  3. Epidemiological Evidence
  4. Integration of Information

• But what about the 2010 Inspector General’s Report?

• The OIG Analysis also confirmed that EPA’s perchlorate RfD is conservative and protective of human health, but limiting perchlorate exposure does not effectively address this public health issue. Potentially lowering the perchlorate drinking water limit from 24.5 ppb to 6 ppb does not provide a meaningful opportunity to lower the public’s risk.

• By contrast, addressing moderate and mild iodide deficiency occurring in about 29% of the U.S. pregnant and nursing population appears to be the most effective approach to increase total iodide uptake to healthy levels during pregnancy and nursing, thereby reducing the frequency and severity of permanent mental deficits in children.
Notable Precedent of Folic Acid

- Folic acid deficiency was found to be a significant risk factor for neural tube defects during pregnancy.
- The Food and Drug Administration took action
  - Required fortification of foods that could be purchased under WIC
  - Industry found it easier to supplement cereals and breads across the board.
ECOSYSTEM HEALTH: THE DELTA
The Pelagic Organism Decline

Delta Smelt

Striped bass

Longfin Smelt

Threadfin Shad


Source: Sommer et al. (2007) in Ted Sommers ppt

Competing Objectives
+ “Co-Equal”

Water Supply
- Municipal (~ 23 M people) and Industrial
- Agriculture ($2B)

Ecosystem
- Habitat: over 700 species
- Fisheries: 80% of commercial species live or migrate through

Habitat
(0.5 M people)

Tourism
(12 M people annually)

Land subsidence and flood control
### Competing Narratives: Is It Flow or Is It More Complex?

<table>
<thead>
<tr>
<th>Classification</th>
<th>Examples</th>
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| **Water Movement/Hydrology**    | - Export pump effects  
- Salinity location changes  
- Residence times               |
| **Toxicants/Nutrients**         | - Microcystis blooms  
- Nutrient loading  
- Pesticides                |
| **Food Web Changes**            | - Asian clam impacts on food availability  
- Reduced zooplankton  
- Non-native fishes and plants |
| **Habitat Changes**             | - Wetland reduction  
- Channelized rivers  
- Floodplain loss         |
Competing “Solutions”

- Increase flow
- Increase habitat
- Reduce ammonium
- By-pass Delta
GOOD SCIENCE CONSIDERS THE BROADER CONTEXT
There Are a Variety of “Environmental” Exposures

Food  Air  Beverages
Relative Exposures Provide Insight as to Where the Best Risk Reduction Might be Obtained
Cancer and Reproductive Effects

Genetic Predisposition

Environmental Exposures

- Metabolism-Activation
- Elimination

Food

Water

Air

Other Beverages

Tap Water

Organic
- TCE
- PCE
- THMs
- HAAs

Inorganic
- Arsenic
- Bromate
- Chromium

Indoor

Outdoor
Health Outcomes Depends on a Mixture of Factors

- Sleep
- Diet
- Exercise
- Stress
- Genetics
- Income
- Other
PARTING THOUGHTS
Available Health Effects Information Suggest That Blurry Lines Are More Appropriate
Reality of Trade-offs Should Make Us Cautious of Thinking That “Problems” Are Easily Solved

...the level or levels or treatment techniques shall minimize the overall risk of adverse health effects by balancing the risk from the contaminant and the risk from other contaminants the concentrations of which may be affected by the use of a treatment technique or process that would be employed to attain the maximum contaminant level or levels

Source: 1996 Amendments to the Safe Drinking Water Act
Recognize That Resource Allocation Decisions Are Everybody’s Problem

“The ... reason that it matters whether the nation spends too much to buy a little extra safety is that the resources available to combat health risks are not limitless.”

Stephen Breyer, US Supreme Court Justice, in *Breaking the Vicious Circle: Toward Effective Risk Regulation*
Remember That Context Not Only Matters, But Can Open Up Superior Risk Management Alternatives

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<thead>
<tr>
<th>Narrow Question</th>
<th>Broad Question</th>
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<td>Do THMs cause birth defects?</td>
<td>What can I do to have a safe pregnancy?</td>
</tr>
<tr>
<td>Does perchlorate in water increase adverse developmental outcomes?</td>
<td>What controllable factors most influence thyroid function?</td>
</tr>
<tr>
<td>How much treatment do we need for Cryptosporidium?</td>
<td>What are the major infection routes and what can be done?</td>
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<tr>
<td>How can lead in overnight samples of drinking water be minimized?</td>
<td>What are the principal sources of lead exposure and how can the most vulnerable best be protected?</td>
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QUESTIONS?