A 20th Century Family History with Chemistry

- My grandfather graduated from high school in 1919, before the periodic table was used as a teaching tool; he spent 30 years in the Niagara Falls chemical industry as a research lab tech.

- My father graduated with an agricultural degree from Cornell in 1951; he spent 5 years working in Cornell's orchards testing pesticides in the 1950's.

- I graduated with an engineering degree from Cornell in 1979; in the 1980's I spent 5 years as an academic lab tech conducting environmental chemical analyses.
The Continuing Evolution of Science

Lab science in the 21st Century is an emerging complex system which highly values converging knowledge.
What do we know about Managing Risk in Complex Systems?

- First principles do not lead to reliable predictions about the system behavior.
- The behavior of the system is dependent on the history of the system.
- Managing risk in complex systems requires developing resilience-oriented strategies.
Safe Chemical Use requires a **System**, not a **Solution**

Managing lab hazards involves support programs integrated into a **resilient system** to control any residual chemical hazards.

1. Hazard reduction *(Green Chemistry)*
2. Engineering Controls *(Laboratory Ventilation Management Plan)*
3. Training and Oversight *(Chemical Hygiene Plan)*
4. Personal Protective Equipment *(Dupont SafeSpec, UCalifornia LHAT)*
5. Emergency Planning and Environmental Protection *(Institutional plans)*
The safety system is held together by the organization's Safety Culture

- The idea of safety culture emerged in the 1980’s, in the aftermath of Bhopal and Chernobyl.
- In the early 1990’s, Arie Rip, a Belgian chemist turned sociologist, broadened the idea of "safety culture" to include two types of Risk Cultures: Danger Cultures and Safety Cultures
- Lab risk culture is continuing to evolve under social pressure from government, professional and scientific organizations.

From Silbey, 2014
However, Risk Cultures are Complex Systems...
...as is Chemistry...

STARTING MATERIALS

- flask
- purging
- dinitrogen
- stirring and heating
- addition with stirring
- addition

PRODUCT

- air
- drying
- filter
- washing
- precipitation
- cooling
- ice bath

- pivaloyl chloride
- diethyl ether
- tert-butyl alcohol
- trifluoromethanesulfonic acid

Diagrams show the process of purging, addition, and washing with various reagents and conditions.
Lab Safety Information streams:
- Institutional data (lab rosters)
- Risk data collections (inventories, SDS’s)
- Control banding logic platforms
  - PPE Wizards
  - Lab ventilation wizards
  - ASHRAE lab design criteria
- The PDCA cycle can give us a handle on managing info in a complex system.
- However, the tension between organizational fears and desires will also be expressed in the EHS system.

Fear and Desire in Systems Design: Negotiating Database Usefulness
Tanu Agrawal
What's the Risk Experience in the Class Lab?

Blue = scores before labs began, Green = scores after lab ended

- Increased intimidation when entering organic chem lab; minor decrease after lab is done.
- This is likely to be the terminal chemistry lab experience for 80% of lab scientists

Kelli R. Galloway and Stacey Lowery Bretz*
Department of Chemistry & Biochemistry, Miami University, Oxford, Ohio 45056, United States
How do we alter complex systems?

**Identify and Exploit Leverage Points:**
System connections where effective interventions can be applied

Diagram simplified from Donella Meadows "Leverage Points: Places to Intervene in a System"
A Cultural Leverage Point: Shifting the Lab Safety Paradigm

Kuhn, 1962 *The Structure of Scientific Revolutions*

21st Century Risk Culture: Safety Culture focused on continuous improvement (incidents will occur but can be recovered and learned from)

20th Century Risk Culture: Danger Culture focused on "zero incidents" (i.e. zero learning opportunities)
Risk Assessment as a Cultural Tool

The Focus of the Risk Assessment Paradigm

Count of:
- Rework
- Defects
- Injuries

Danger culture

Safety culture
Bridging the Fear / Desire gap with interactive risk assessment strategies

The Illusion of Accountability: Information Management and Organizational Culture
Susan S. Silbey and Tanu Agrawal

Risk Assessment

RISK
COMMUNICATION
MAKE SURE
YOU LISTEN
AS MUCH AS
YOU TALK
IS A
TWO-WAY
STREET

The negotiated database system
The Hazard Management Logic

1. Recognize
   - Process Description Hazards

2. Assess
   - Prioritize Risks

3. Manage
   - Identify Hazard Control Practices

4. Plan and Protect
   - Emergency Preparedness / Environmental measures

5. Share
   - Store hazard assessment and LL available for data mining
The Relationship between the types of Risk Assessment

**Chemical Risk Assessment Methods in the Laboratory**

**GHS Danger Chemicals**
- Chemicals of Special Concern
  - water reagents
  - pyrophorics
  - potential explosives

These chemicals require **safety cases** that include:
- training requirements
- supervision expectations
- facility needs (specialized equipment)
- Personal Protective Equipment requirements

Developing the safety cases require JHAs (and possibly more) to be complete.

**GHS Warning Chemicals**
- Control Banded Chemicals
  - solvents
  - corrosives
  - acutely toxic chemicals
  - regulated carcinogens

Use of these chemicals can rely on control bands that address:
- education and training needs
- oversight protocols
- facility needs (ventilation)
- waste disposal protocols
- emergency planning
Key Resources for the Risk Assessment Process

- To support safe science while protecting emergence, safety information must be **scalable, transferable and sustainable**.
- These goals entail describing the safety use case using **ontology** and **curation** tools and applying the logic developed established by the CH&S community to the use of these tools.

<table>
<thead>
<tr>
<th>Stakeholders</th>
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<tbody>
<tr>
<td><strong>Bench chemists</strong></td>
</tr>
<tr>
<td><strong>Peer chemists</strong></td>
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<tr>
<td><strong>Chemistry librarians</strong></td>
</tr>
<tr>
<td><strong>Chemical information professionals</strong></td>
</tr>
<tr>
<td><strong>Chemical Health and Safety (CH&amp;S) professionals</strong></td>
</tr>
<tr>
<td><strong>Environmental Health and Safety (EHS) professionals</strong></td>
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</tbody>
</table>

<table>
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<tr>
<th>Information Channels Used by the Stakeholders</th>
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<tbody>
<tr>
<td><strong>Raw Information:</strong> experimental process information and raw data</td>
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<tr>
<td><strong>Published Literature:</strong> peer reviewed articles, methods and data</td>
</tr>
<tr>
<td><strong>Curated Chemical Information:</strong> chemical literature managed to support assessment of data quality and maintain accessibility</td>
</tr>
<tr>
<td><strong>Chemical Health and Safety Assessments:</strong> information organized to support chemical risk management</td>
</tr>
<tr>
<td><strong>EHS Oversight Process:</strong> information designed to support management of chemical hazards</td>
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</tbody>
</table>
**An Emerging Risk Assessment Model**

### iRAMP: A Web-Based Model for Laboratory Chemical Risk Assessment

**Leah McEwen**, Chemistry Librarian, Cornell University  
**Ralph Stuart**, Chemical Hygiene Officer, Keene State College  
Secretaries, ACS Division of Chemical Information and ACS Division of Chemical Health and Safety

### Stakeholders

- **Bench chemists** plan and execute large-scale processes with hazardous chemicals.  
- **Peer chemists** oversee bench chemists in planning projects  
- **Chemistry librarians** help develop chemical information literacy skills and resources  
- **Chemical Information professionals** provide access to chemical information and best practices for maintaining it  
- **Chemical Health and Safety (CH&S) professionals** identify and control chemical hazards for a chemical or process  
- **Environmental Health and Safety (EHS) professionals** guide and promote safe and sustainable chemical practices

### A Conceptual Model

**Goal:** A flexibly structured ecosystem of data, domain expertise and workflow tools mapped to the essential connections between the research process and laboratory safety planning in academic labs.

**Stage 1:** The opening section provides an overview of the workflow, access to a search engine of key chemical safety information sources and links to helpful websites.

**Stage 2:** The RAMP process is managed through a combination of electronic information and the professional judgement of the user.

**Stage 3:** The closing sections enable the user to identify administrative elements of the safety case being developed and to document Lessons Learned as part of the work.

### Information Resources

**Chemical Specific**

**Process**

**Sources of information:**

- Prudent Practices in the Laboratory  
- ACS Committee on Chemical Safety publications  
- Journal of Chemical Health and Safety  
- Not Voodoo X  
- recent lab incidents from Google  
- DCHAS-L archives

### The Hazard Management System

**Documentation of safety planning is a key element of a laboratory safety culture.**

Proactive risk assessment of laboratory processes enables effective supervisor and institutional oversight; improves the quality of the work being conducted; and provides evidence of adherence to prudent practices if a problem arises during the work.

### The Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

**HAZARDS IN RESEARCH LABORATORIES**

**Identifying and Evaluating Hazards**

**Hazard Analysis Methods**

**Engineering Controls**

**Adjust the Chemistry to Minimize the Hazards**

**Personal Protective Equipment**
Early Fruits of iRAMP

• We proposed the development of an LCSS format for chemical safety data to PubChem in February; 3200+ LCSS's will be released tomorrow.

• Next steps:
  • Develop descriptors which can data mine the literature to identify process hazards
  • Develop a crowd annotation system for EHS professionals
  • Develop a Chemical Safety Ontology
Three Take Home Messages

1. The lab safety paradigm is changing; the administrative stress around fear and desire is a sign of this change.

2. EHS logic as an organizational tool is more valuable than our data; this logic will support, not replace, our professional judgment.

3. It's time to make friends with the chemistry librarians.