Introduction to Green Chemistry

Institute for Green and Sustainable Science
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Marian University

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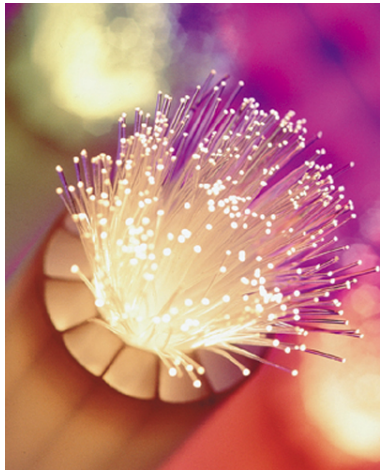
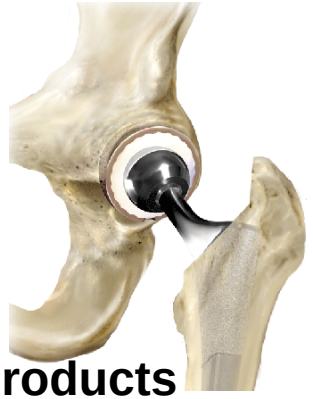
Overview

- The Benefits of Organic Chemistry
- Costs of a Chemical Society
- What is Green Chemistry?
- Why is Green Chemistry important?
- 12 Principles of Green Chemistry
- The Future of Green Chemistry

Benefits of An Organic World

- Organic chemistry and organic molecules play profound roles in our lives.





As individuals and as a society, we depend on these products

Benefits at What Cost?

- Global chemical sales totaled 1.5 trillion dollars in 1998.
  - This corresponds to the annual production of millions of tons of chemicals
- The production of chemicals leads to chemical emissions
  - In the United States in 1994, there were 2.26 billion pounds of 300 hazardous substances released into the environment

Early Chemical Industry

Union Carbide
1920's

Coke Plant Naphthalene
Settling Pans, 1916

Waste Disposal – land, air, water

Chemical Hazards – unknown, unconcerned

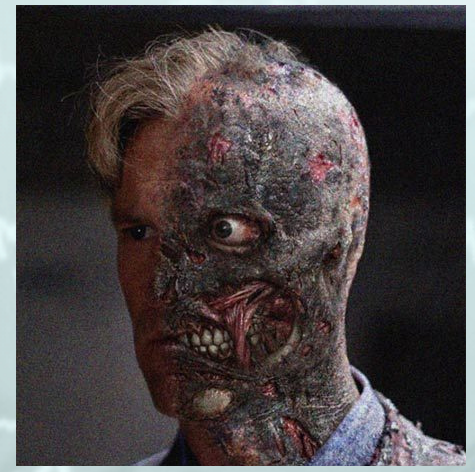
Safety – minimize personal exposure

Hazard Avoidance – Minimize Exposure

Washington University (St. Louis)
$55M Lab Science Building

Canadian Explosives
Research Laboratory (Ottawa)

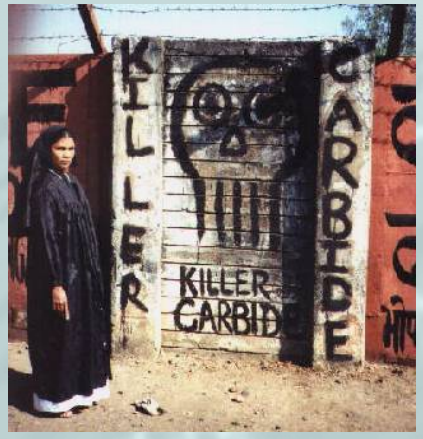
Accidents Can Happen



Accidents Can Happen

Bhopal, India (1984)

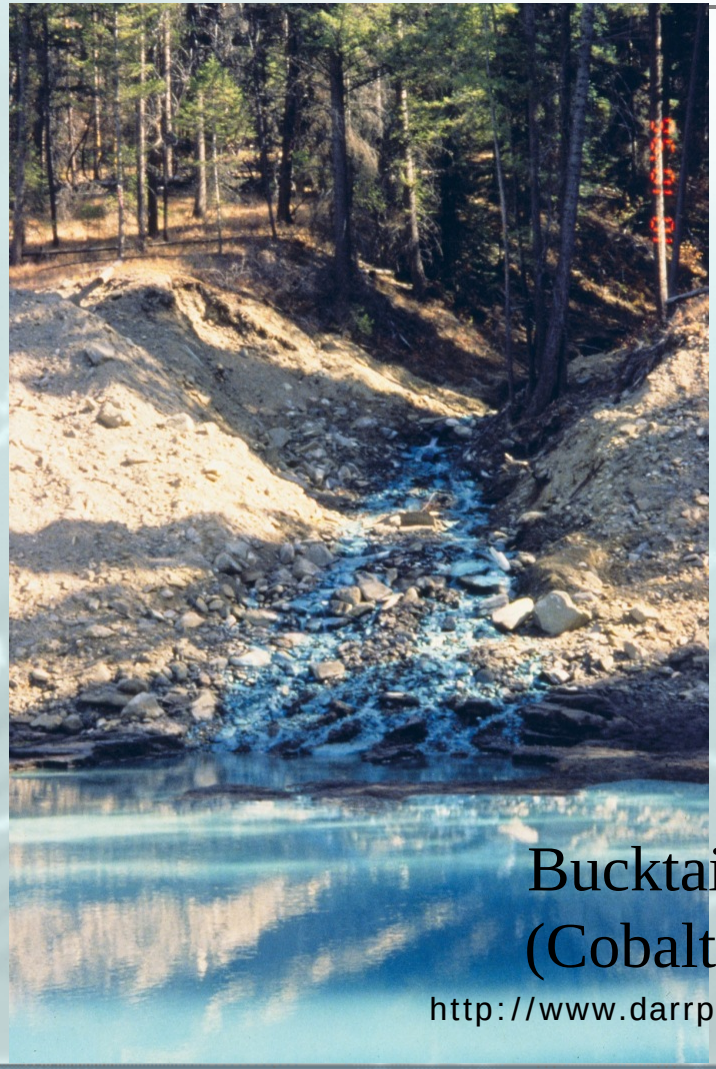
Cyanide spill



‘Dilution is the Solution to Pollution’

- Chemical emissions were essentially unregulated from the start of the Industrial Revolution through the mid 1950s
- Chemical release into the air, water, and land did not seem to matter
- Ignorance of:
  - Chronic toxicity
  - Bioaccumulation
  - Carcinogenicity

Early Waste Disposal



Bucktail Creek
(Cobalt, Idaho)

http://www.darrp.noaa.gov/northwest/black/

Valley of the Drums
Bullitt County, Kentucky

http://www.epa.gov/superfund/20years/ch3pg1.htm

A Legacy of Pollution

Love Canal
(New York)

A Legacy of Pollution

Cuyahoga River, near Cleveland
1969

Cuyahoga River, 1952

Mixed Perceptions of Chemistry

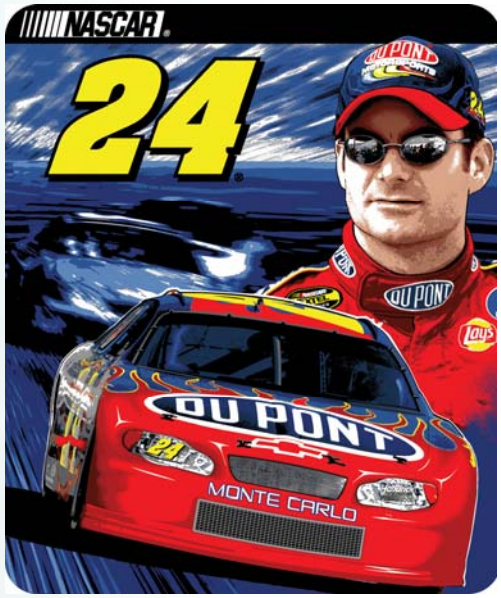
"Merchants of Death" (1930's)

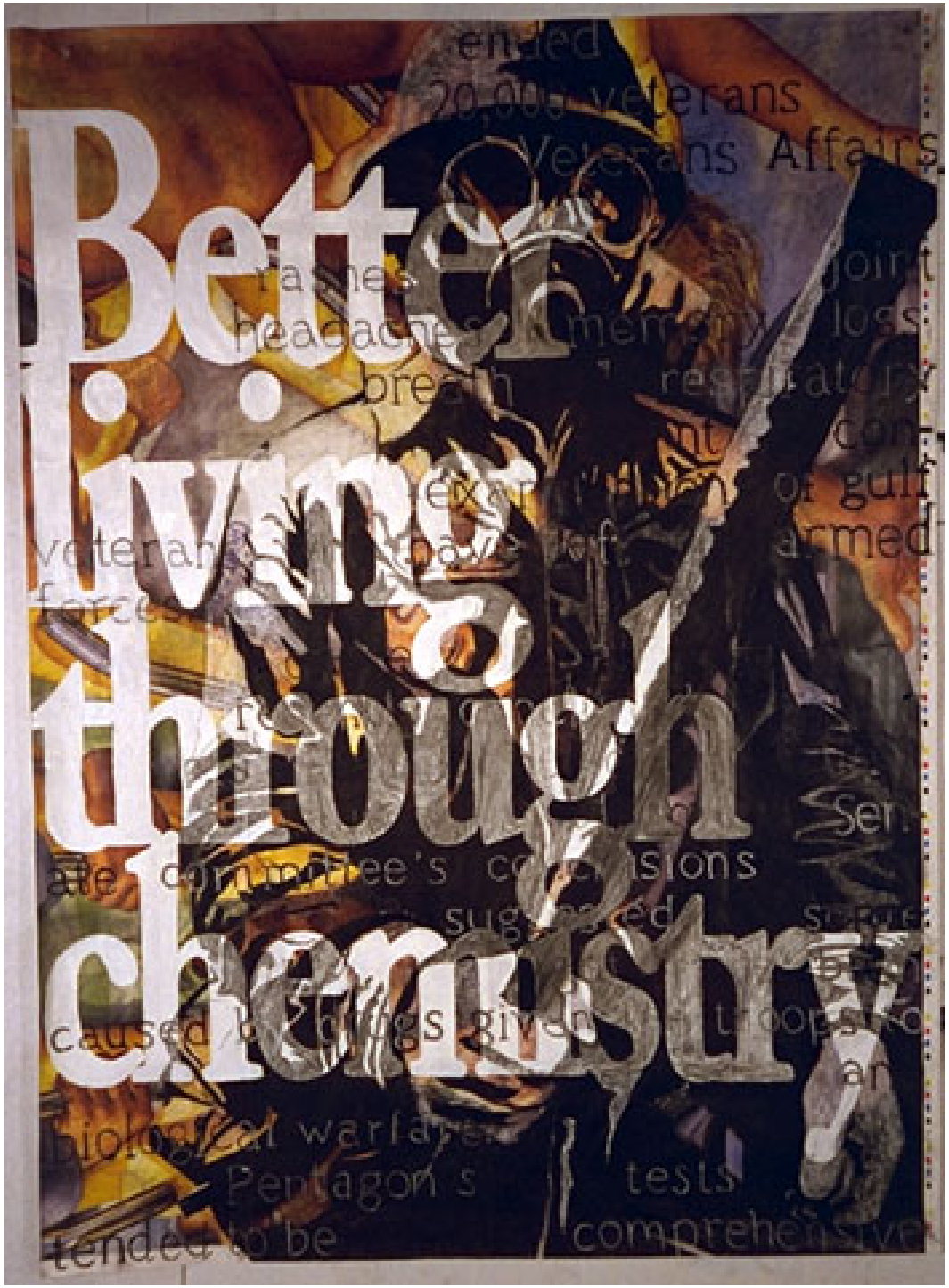
Better Things for Better Living … Through Chemistry (1935)

Better Things for Better Living (1980's)

DUPONT The miracles of science

(1999)

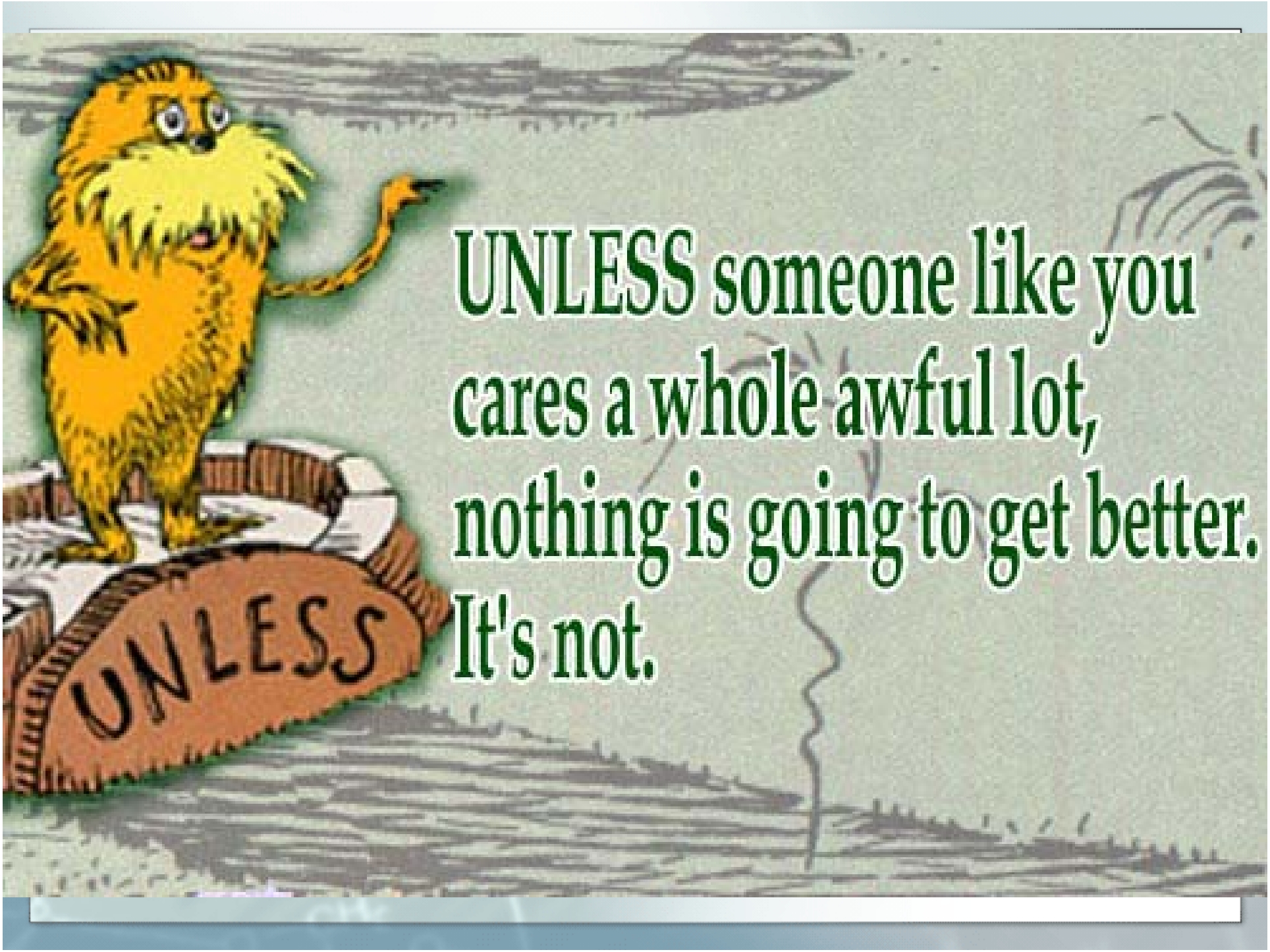




Better Living
Through Chemistry
Claude Moller
Mixed Media
69" x 51“
1994

What Can We Do?

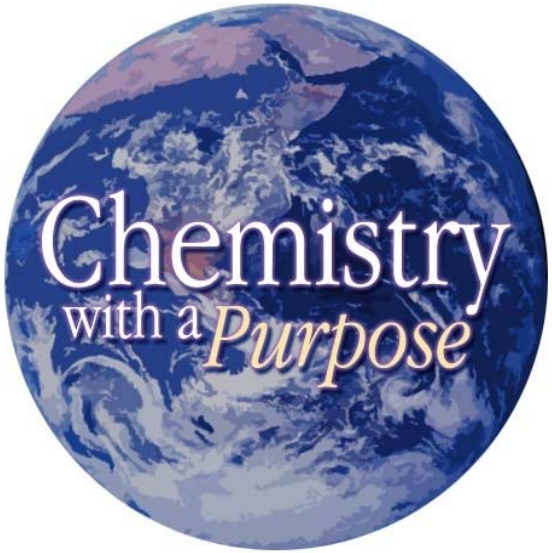
We Can't Just Ignore the Problem


UNLESS
UNLESS someone like you
cares a whole awful lot,
nothing is going to get better.
It's not.

Role of Chemistry

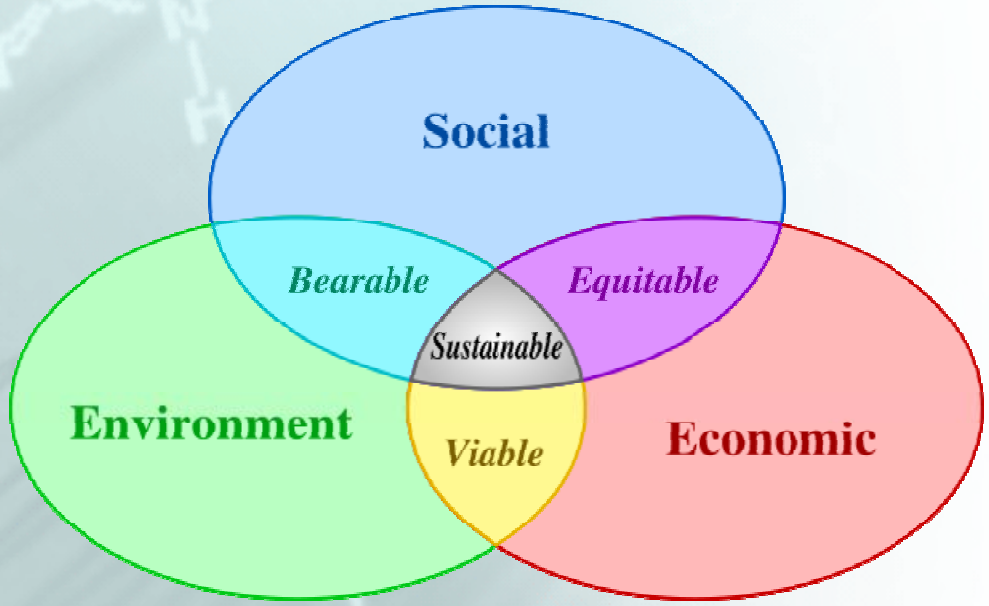
- Chemistry is the scientific discipline which addresses the structure, composition, reactivity, and energetics of substances from bulk properties to the level of atoms and molecules

- As chemists, we are uniquely situated to address the global need to discover, develop, and utilize sustainable practices.



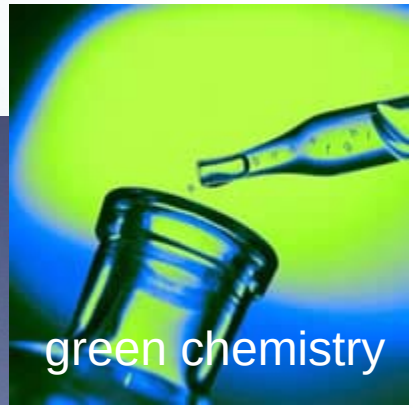
What is Sustainability?

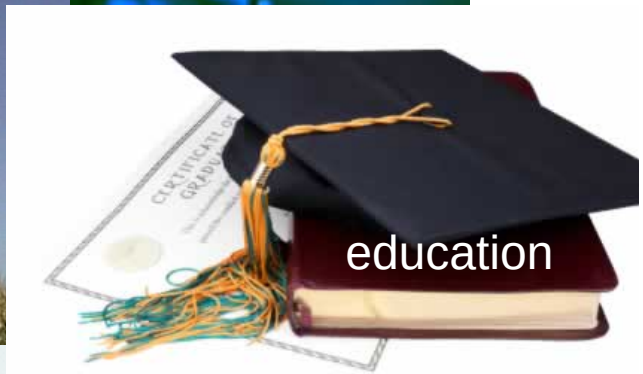
- Sustainability can be defined as the ability of society to utilize natural resources without impairing the ability of future generations to do the same.



Areas of Sustainability

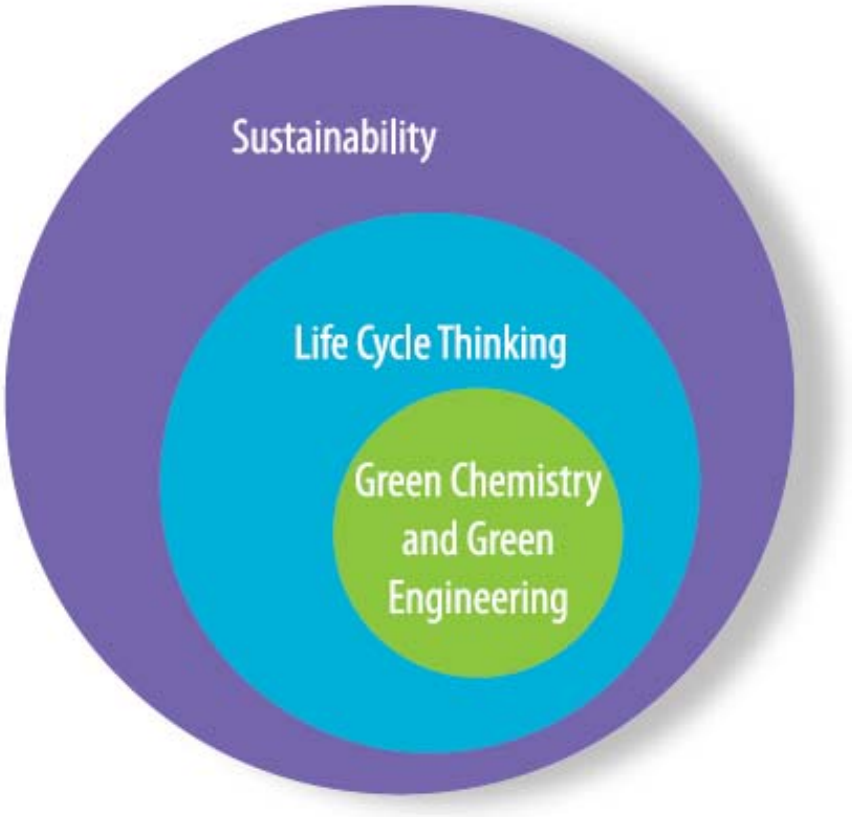
- In 2006 the NSF recognized four major areas of importance within sustainability:





http://www.chem.uiowa.edu/research/sustainability/

Green Chemistry: An Essential Component of Sustainability

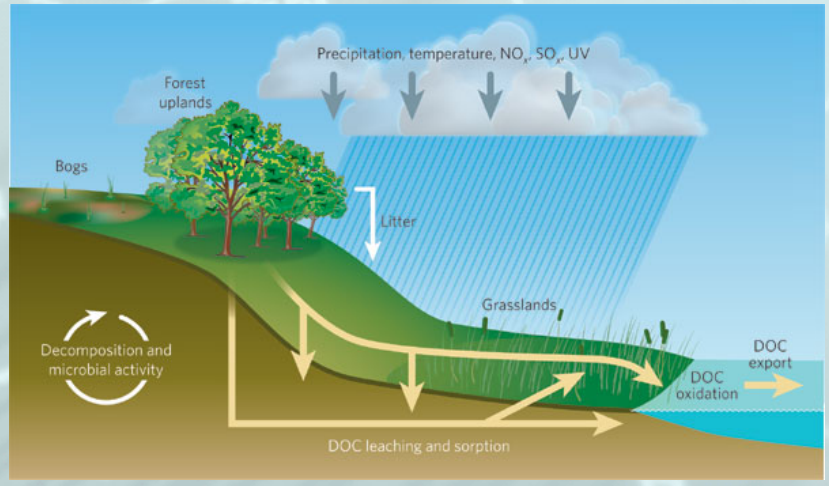


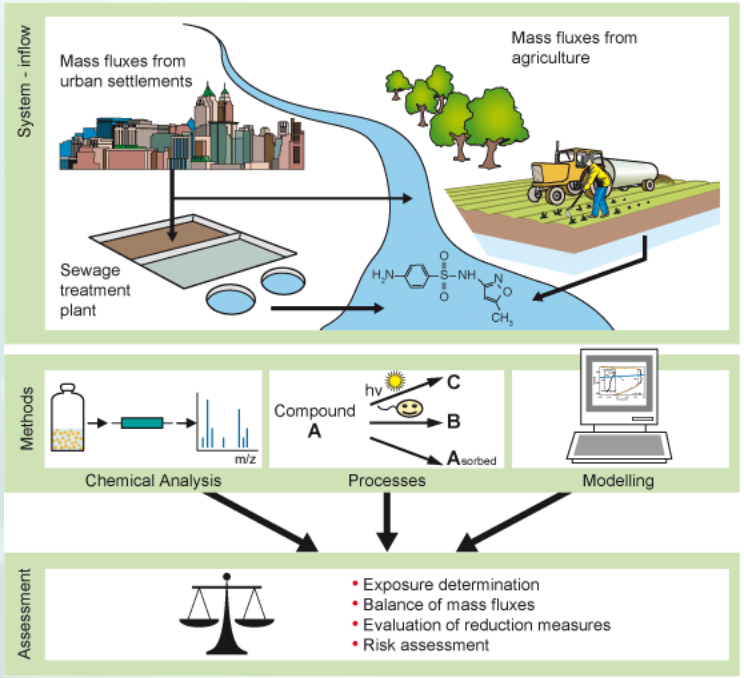
What is Green Chemistry?

- Green chemistry can be thought of as an overarching philosophy of chemistry
- Chemical choices - minimizing the hazards and maximizing efficiency
- Green chemistry is fundamentally about waste prevention at the level of atoms and molecues
- Chemistry with respect, not disregard, for health and the environment

Environmental Chemistry ?

- It is distinct from environmental chemistry which focuses on the chemical phenomena in the environment





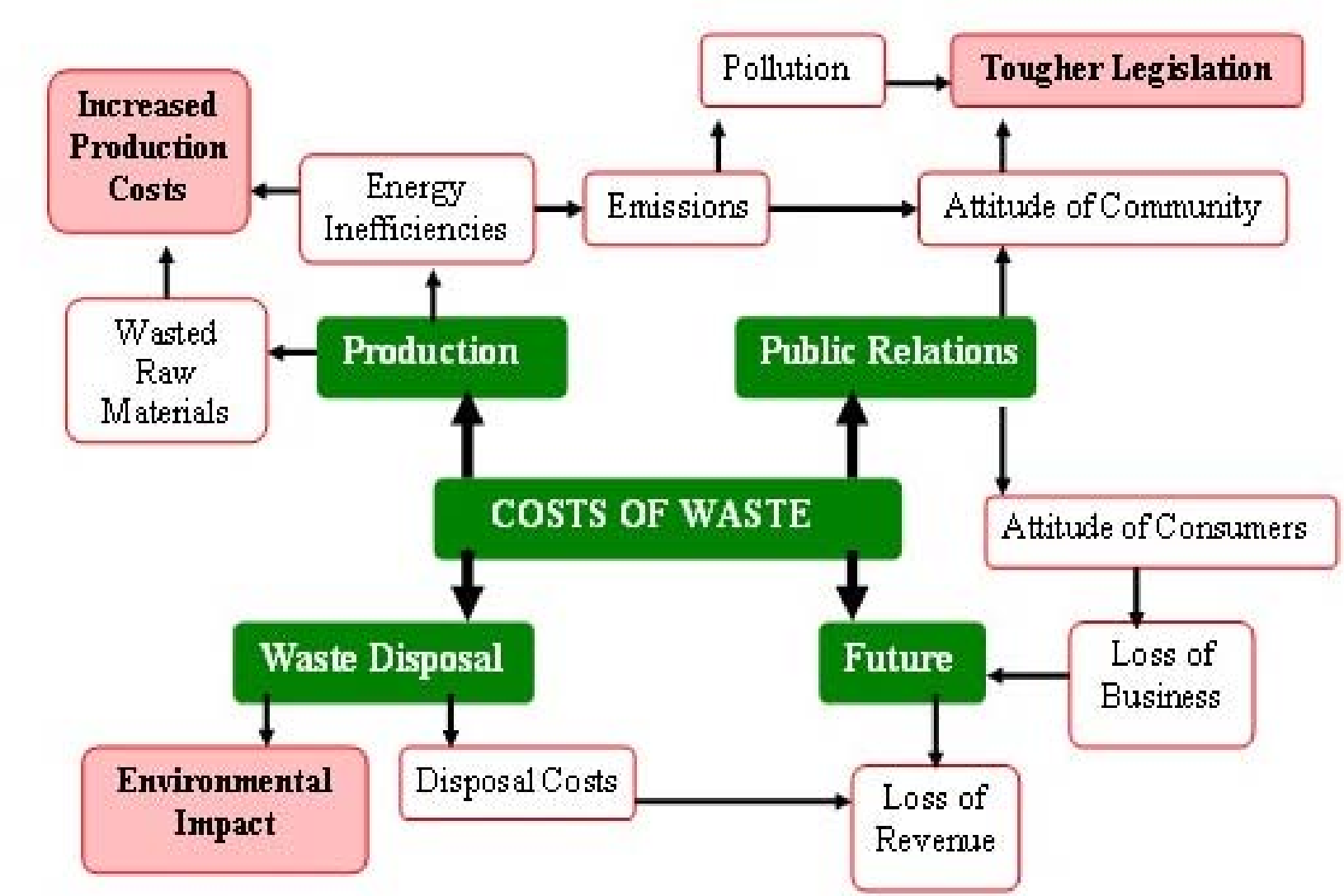
Risk is a function of hazard and exposure

$$\text{Risk} = f\,[\text{hazard, exposure}]$$

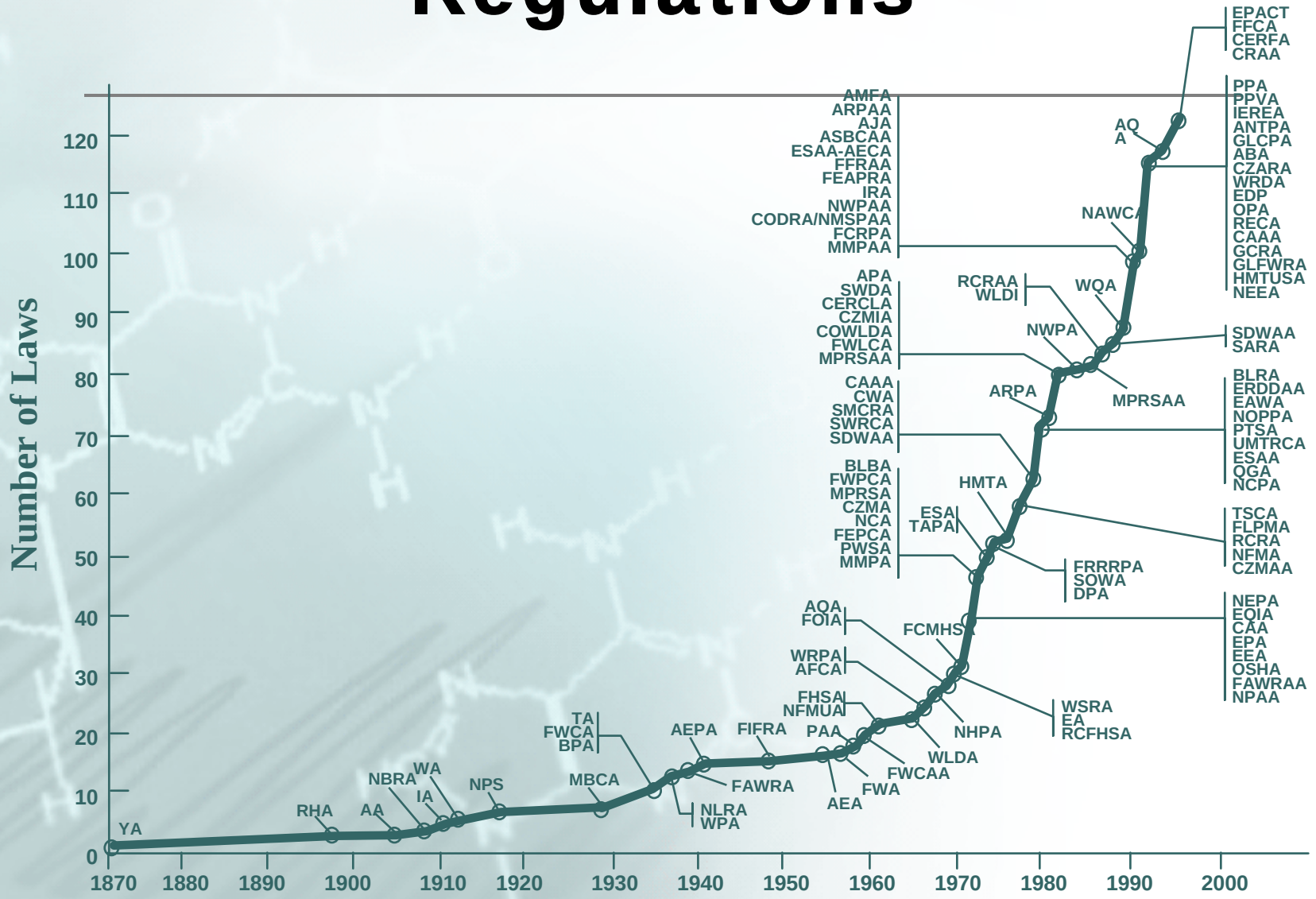
By reducing intrinsic hazard, risk can be minimized even in the event of accidental exposure.

Is Green Chemistry Expensive?

Waste = Lost Profit


Pollution
Tougher Legislation
Increased Production Costs
Energy Inefficiencies
Emissions
Attitude of Community
Wasted Raw Materials
Production
Public Relations
COSTS OF WASTE
Attitude of Consumers
Waste Disposal
Future
Loss of Business
Environmental Impact
Disposal Costs
Loss of Revenue

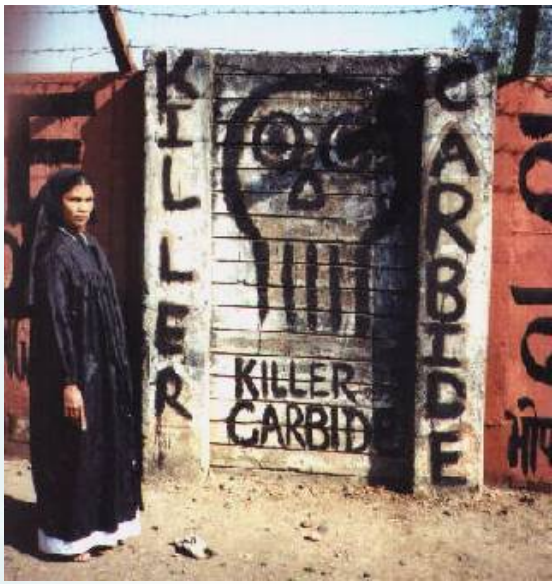
Regulations



The Rise of Regulation

- The last 40 years has seen:
  - Public recognition of pollution
  - The creation of the EPA
  - Proliferation of environmental regulation
  - Recognition of the need for environmental stewardship
- Much has been done – even more to do

Public Relations



“Environmental” Control is Expensive

There are an estimated 85,000 fume hoods in California, and more than 500,000 in the United States.

A single fume hood running 24 hours a day uses as much energy as an entire house

Berkeley Lab researchers estimate that a new fume hood technology could save 360 gigawatt-hours of electricity in California, and 2,100 GWh in the United States. At $0.08 per kWh, the annual electricity savings per hood is about $1,000 (close to 8,500 kWh saved per hood).”

http://www.lbl.gov/Science-Articles/Archive/fume-hood-elec-movie.html

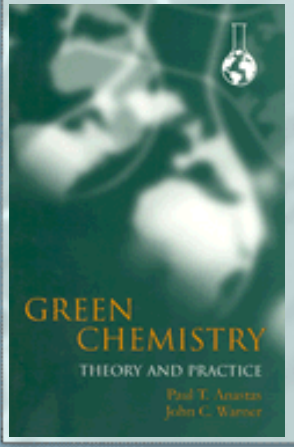
12 Principles of Green Chemistry

John Warner and Paul Anastas

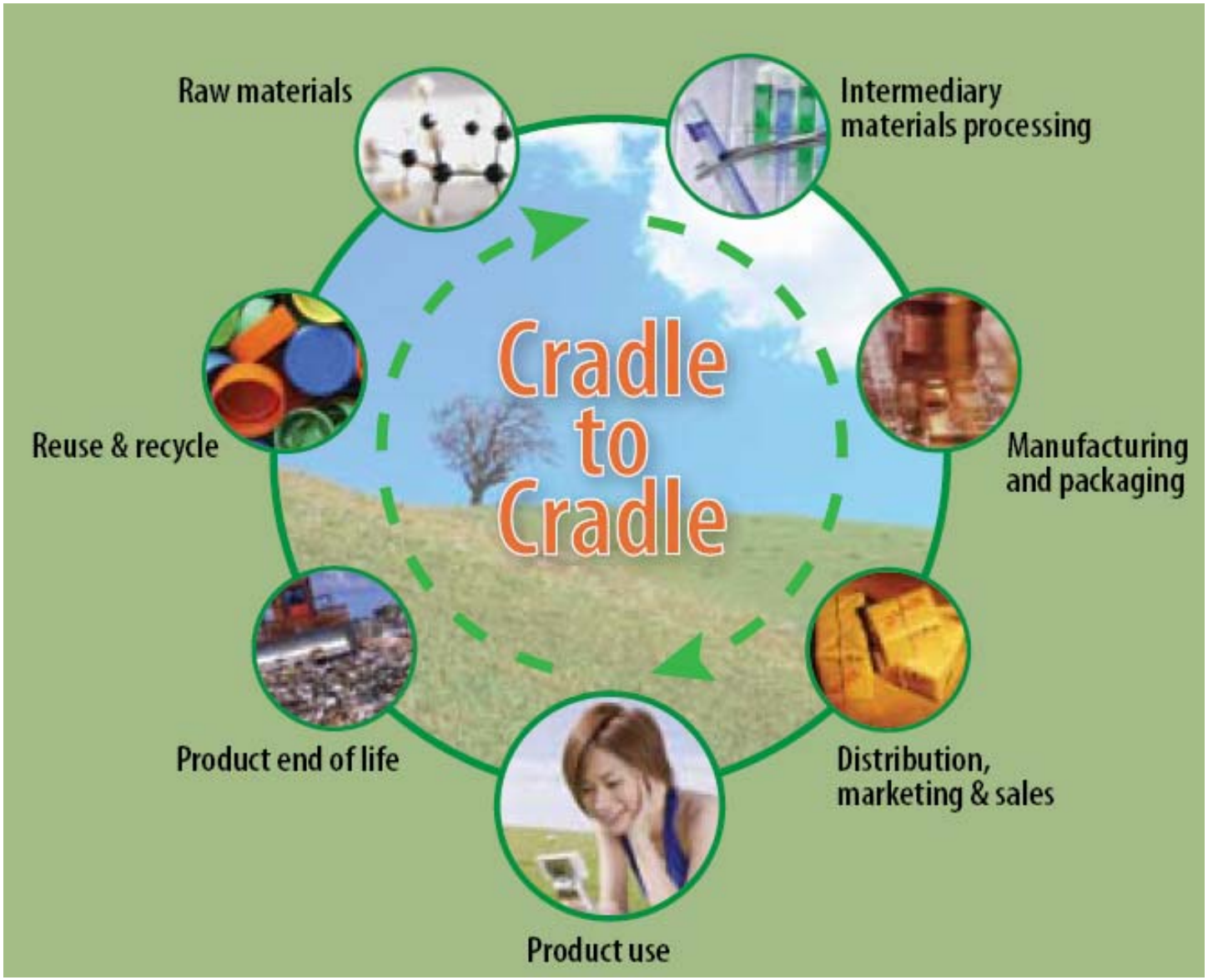
1. **Prevention**
2. **Atom Economy**
3. **Less Hazardous Chemical Synthesis**
4. **Design Safer Chemicals**
5. **Safer Solvents and Auxiliaries**
6. **Design of Energy Efficiency**

12 Principles of Green Chemistry

7. **Use Renewable Feedstocks**
8. **Reduce Derivatives**
9. **Catalysis**
10. **Design for Degradation**
11. **Real-Time Analysis for Pollution Prevention**
12. **Accident Prevention**



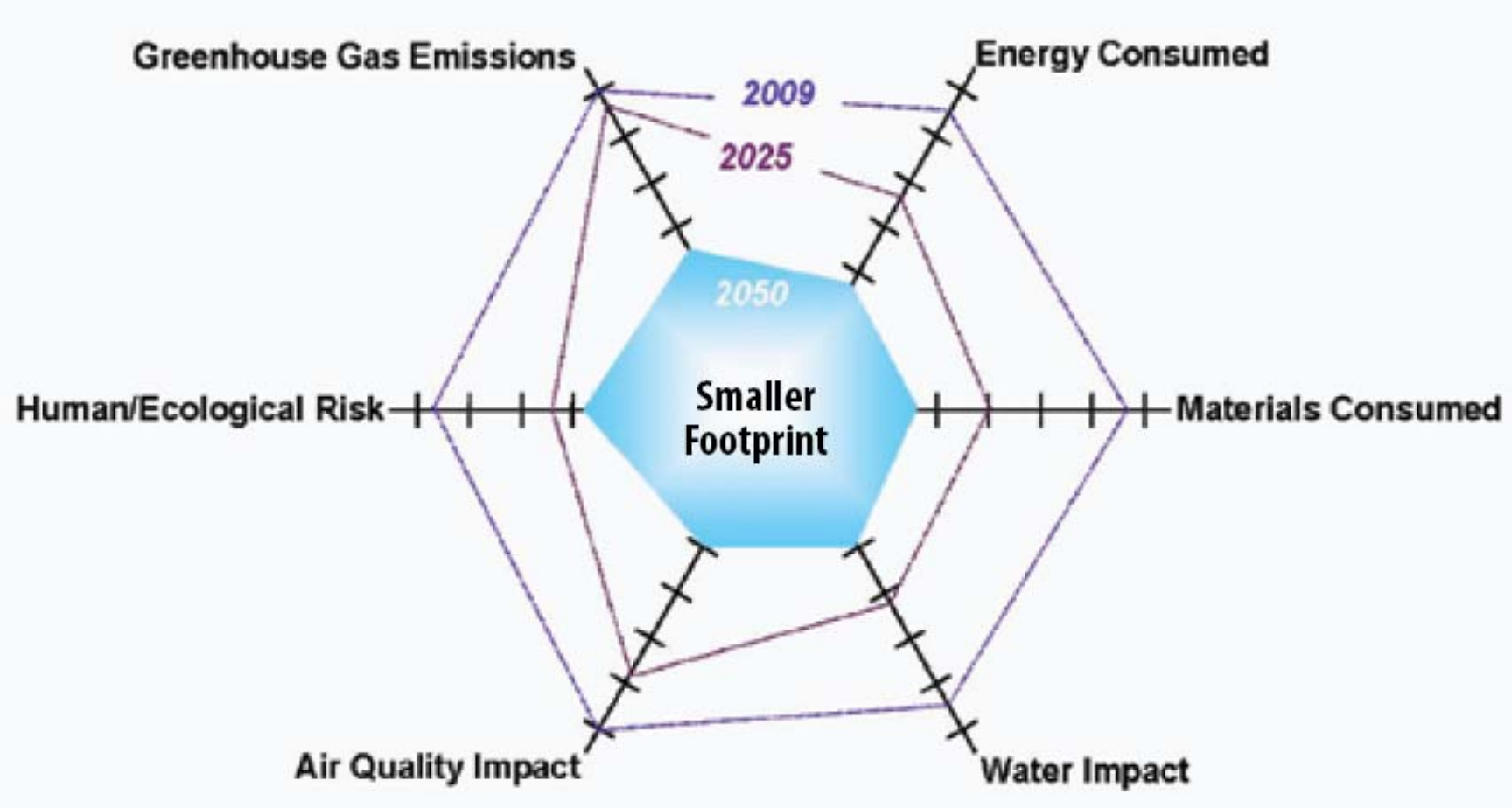
Anastas, P.T.; Warner, J. C. *Green Chemistry: Theory and Practice*; Oxford University Press: New York, 1998; p 30.



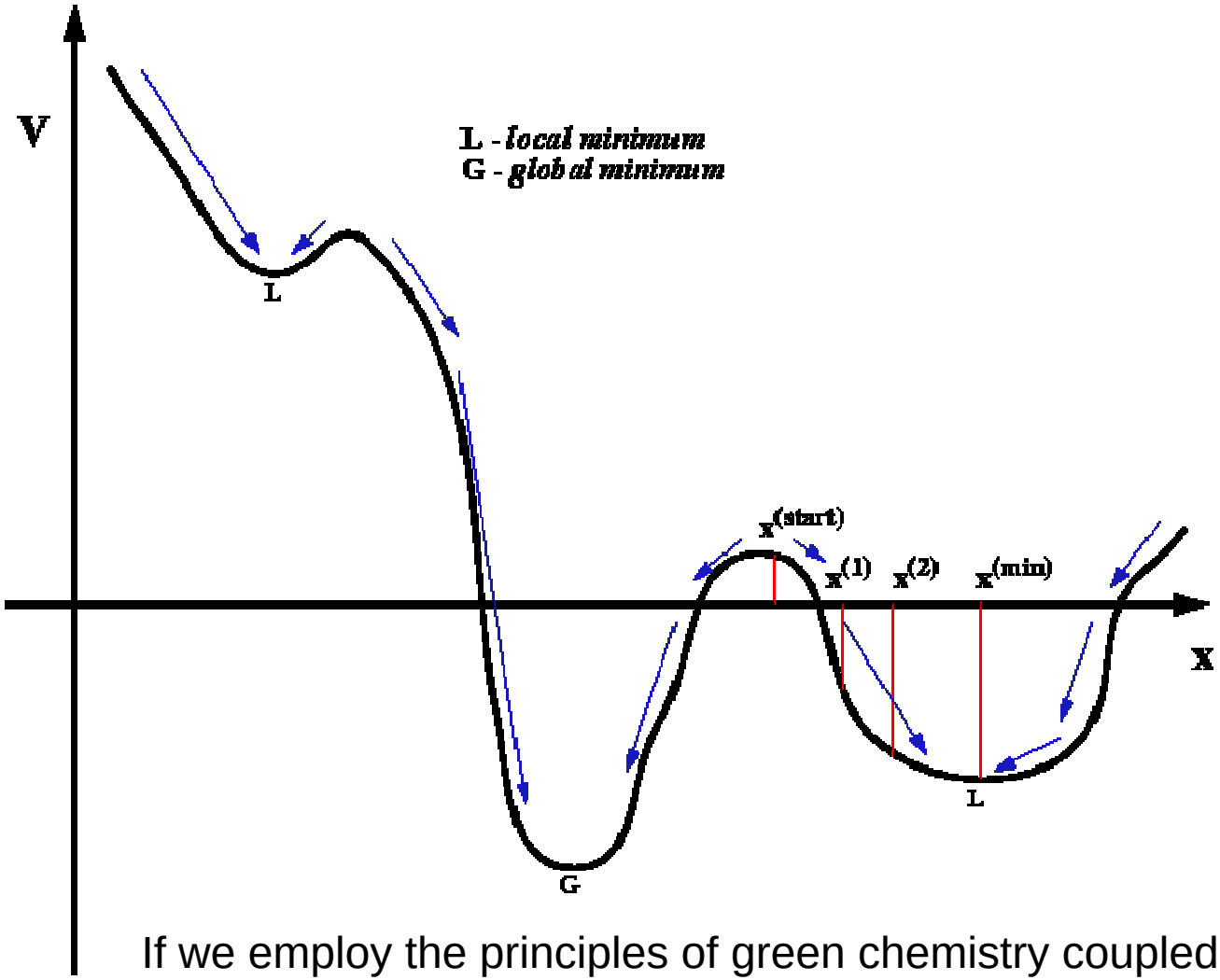
Braungart and McDonough Cradle-to-Cradle: Remaking the Way We Make Things (2002)

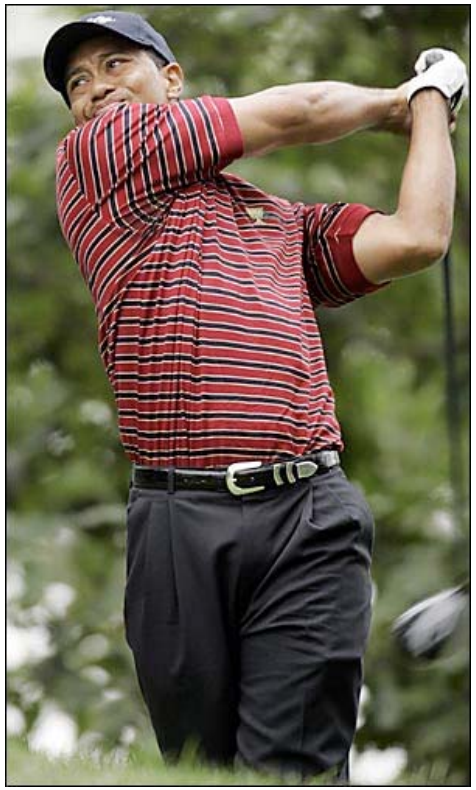

Trash or Feedstock?

Use of Conceptual Metrics to Reduce a Product's Environmental Footprint



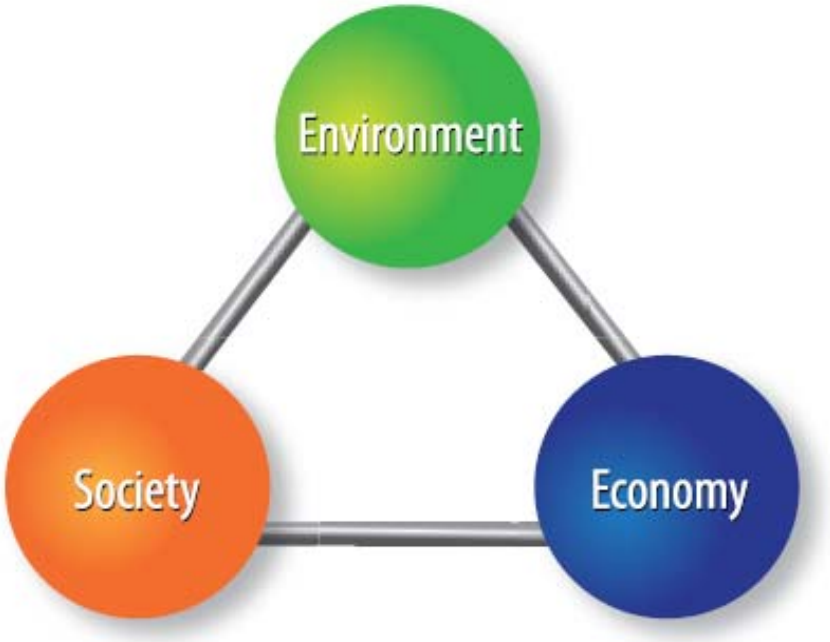
Green Chemistry - a Driver for Innovation





If we employ the principles of green chemistry coupled with new metrics for performance, we have the opportunity to make significant new discoveries

Triple Bottom Line



When economic, social and environmental benefits are integrated and balanced, sustainability can be maintained.

Green Products?

Note - the Clorox product line depicted may or may to be green – need metrics!

- Greenwashing is a term that describes misleading claims about the environmental safety and effects of a product or service.
- The use of appropriate metrics will stem the greenwashing of products

Does Green chemistry have a Direct Impact on Your Life?

Direct Impact on Your Life

Green Chemistry can make your community a cleaner, safer place

- Reducing local pollution
- Reducing transportation of hazardous materials
- More affordable products

Where does the Future lay?

Future Educational Challenges

1. Cultivate an understanding of basic principles of chemistry, environmental sciences, toxicology and sustainability

Future Educational Challenges

2. Foster interest in careers in science, chemistry, engineering and other related disciplines

Future Educational Challenges

3. Build a workforce equipped with the scope and breadth of knowledge and skills to advance green chemistry and an intellectual environment that catalyzes the development of new ideas and technological innovations

Future Educational Challenges

4. Develop a well-informed citizenry capable of actively engaging in demanding and supporting green products and processes and avoiding unsafe chemical use and disposal practices


Questions?