SNNI
SAFER NANOMATERIALS AND NANOMANUFACTURING INITIATIVE

ONAMI
OREGON NANOSCIENCE AND MICROTECHNOLOGIES INSTITUTE

Greener Chemistry and Nanotechnology in Oregon

Professor Jim Hutchison
Department of Chemistry, University of Oregon
Director, ONAMI Safer Nanomaterials and Nanomanufacturing Initiative (SNNI)

hutch@uoregon.edu
http://greenchem.uoregon.edu
http://www.greennano.org

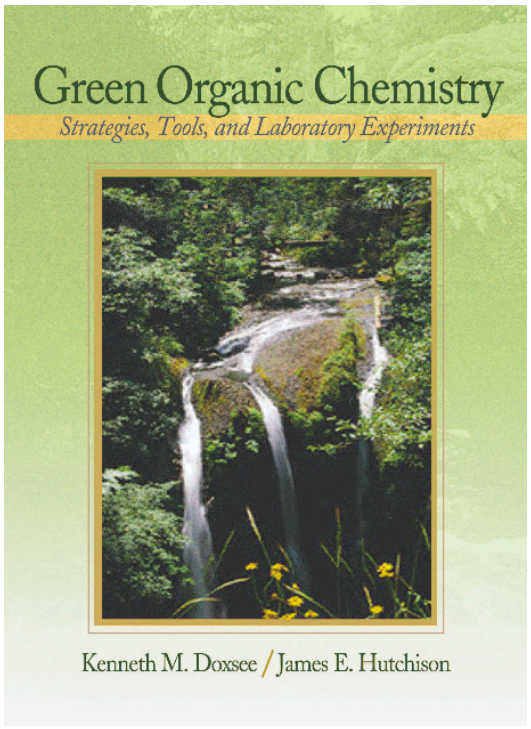
OSU Oregon State University

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

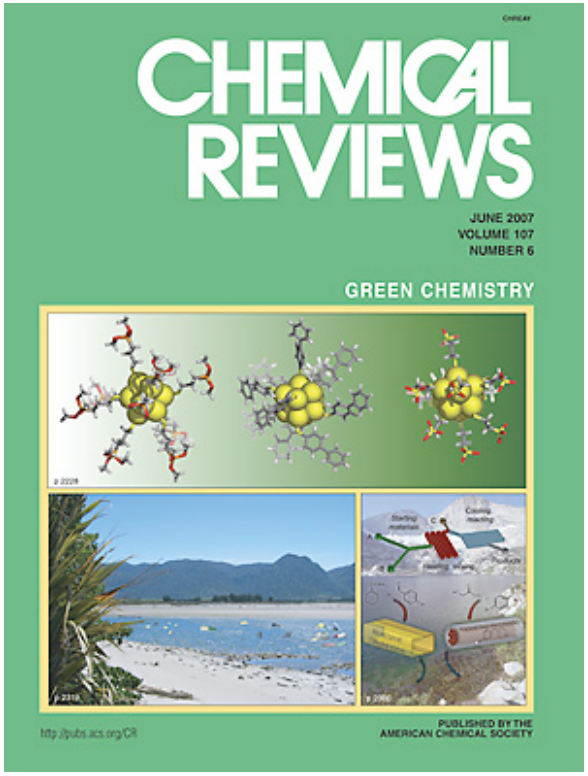
PORTLAND STATE UNIVERSITY

UNIVERSITY OF OREGON

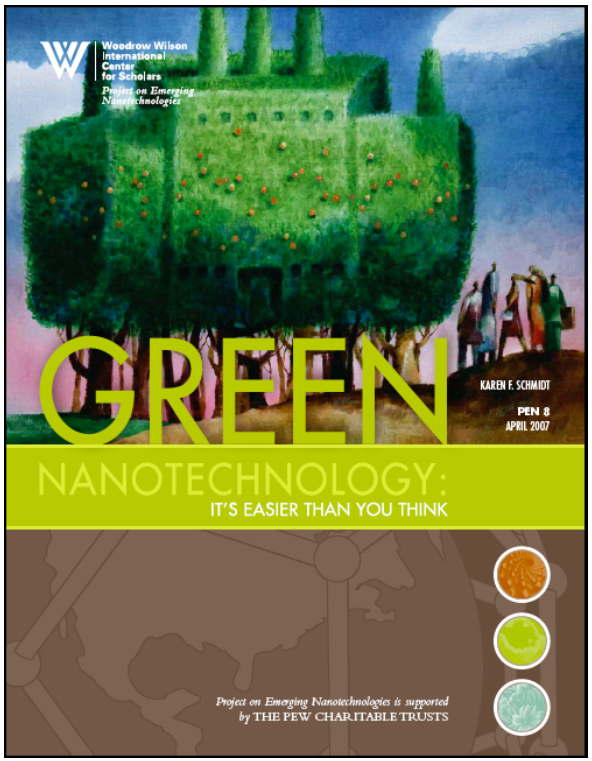
Green Chemistry and Nanoscience at Oregon



Education



Research



Policy

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Why we pursued green chemistry in our teaching laboratory at UO

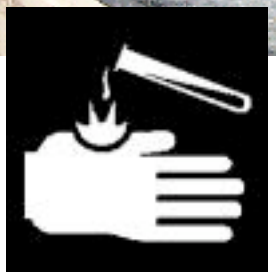


Table 1 Starting Material Employed in Classic Organic Laboratory Syntheses 1902-1980

Date	Author	Acetanilide	4-Bromoacetanilide	Benzoin
		Starting Materials Required (grams)		
		Aniline	Acetanilide	Benzaldehyde
1902	Levy, 4th ed.	46.2		50.0
1915	Cohen, 3rd ed.	25.0	5.0	25.0
1933	Adkins	28.0	13.5	10.0
1941	Fieser, 2nd ed.	18.2	13.5	25.0
1963	Adams	20.0	13.5	16.0
1980	Drust	10.0	5.2	10.0

Adapted from: From Microscale Organic Laboratory by D.W. Mayo, R.M. Pike and S.S. Butcher, 1985

Preparing students to pursue chemical research that brings solutions to sustainability challenges

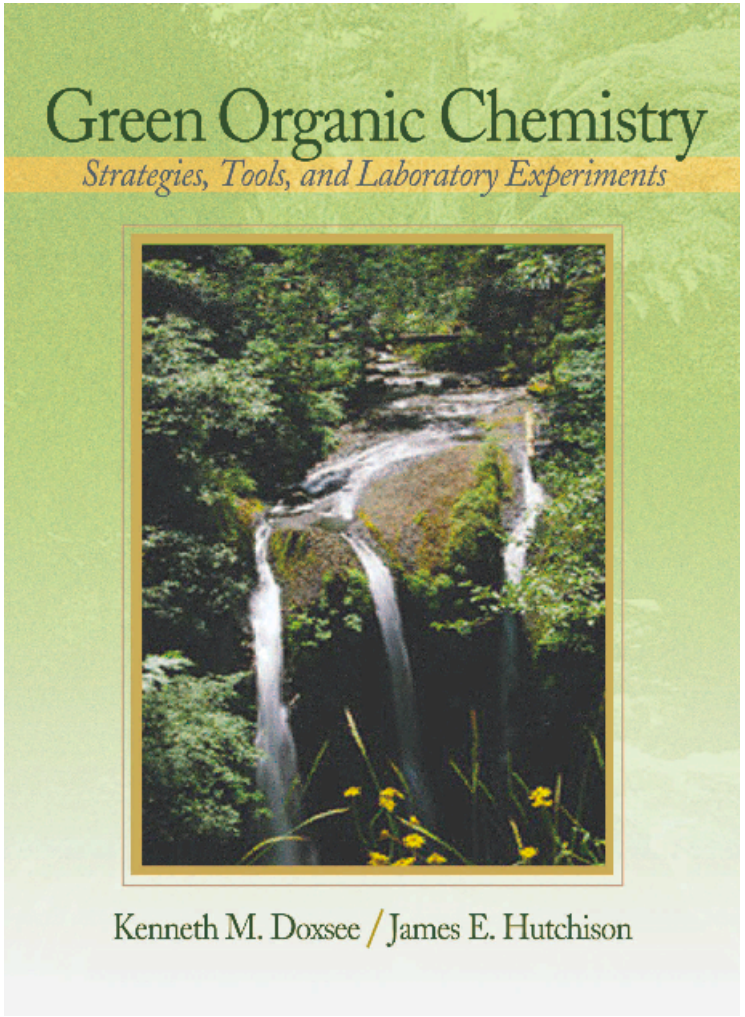
Green Organic Chemistry Laboratory Manual

19 Green Organic Chemistry Experiments

Plus….

- Introduction
- Identification of Chemical Hazards
- Chemical Exposure and Environmental Contamination
- Evaluation of Chemical Hazards
- Introduction to Green Chemistry
- Alternative Solvents
- Alternative Reagents
- Reaction Design and Efficiency
- Alternative Feedstocks and Products

Target audience: Sophomore-level organic chemistry laboratory



2004 Brooks-Cole

Preliminary study suggests broad benefits for institutions

Initial survey of: Simmons, St. Olaf, Worchester State, Gordon, and Hendrix Colleges; Suffolk U.; Bridgewater State U.; Lane and Central Oregon CC; Bend HS (OR); and UO

<u>Key initial findings - Basis for a more in-depth study</u>

Energy - Reduction in fume hoods (from 22 → 5) saves UO ~ $90,000/year

Capital costs - UO project reduced renovation costs by 33%

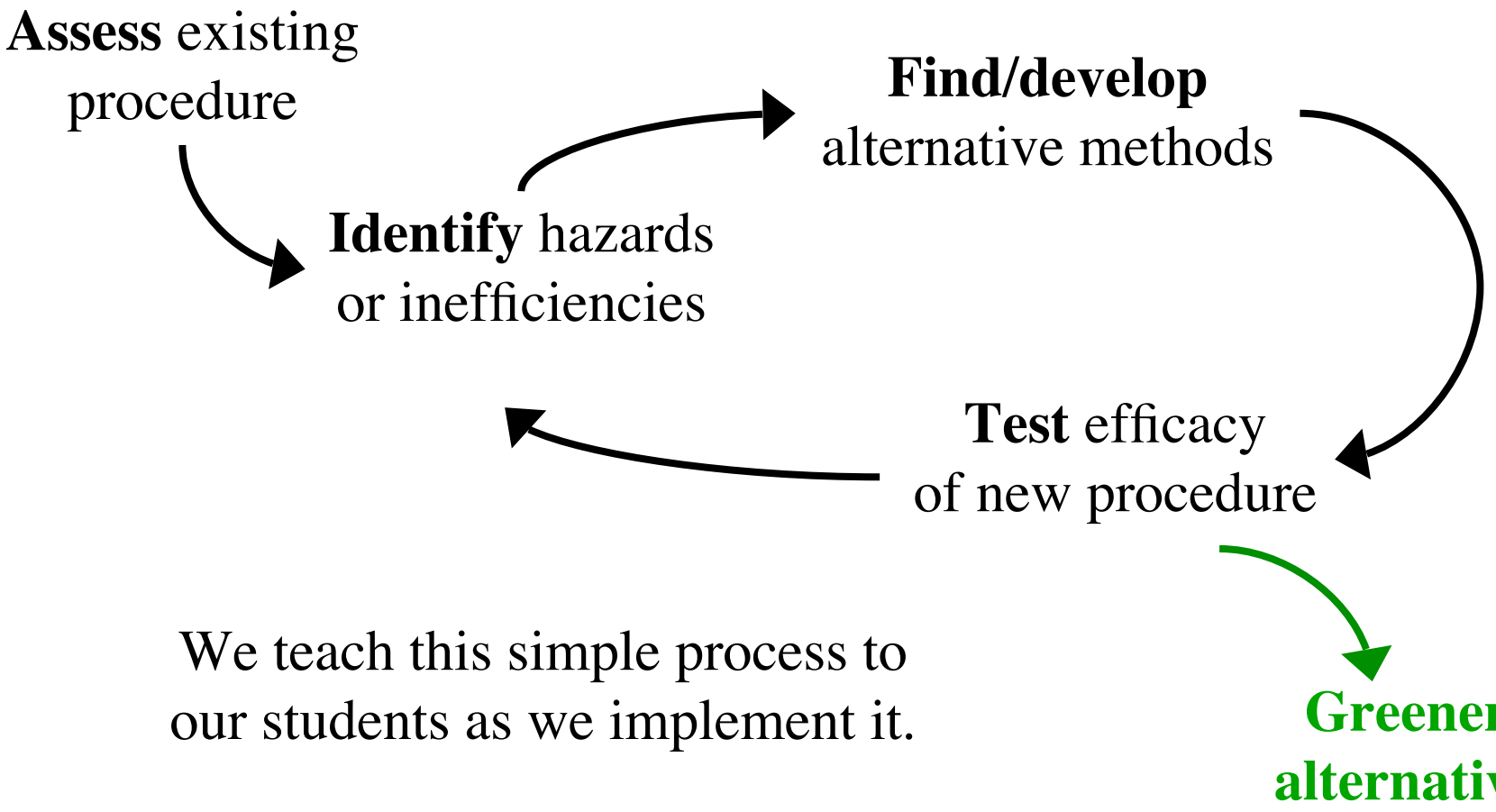
Recruiting - Benefits seen in recruiting faculty (2 -> 10 at UO), graduate students (60% of accepted applicants at UO) and undergraduates

Student engagement - Many examples of enhanced student interest

Faculty professional development - Renewed excitement, tenure, prestigious fellowships, collaborative projects, awards

Facilities improvement - New organic chemistry labs (UO, Northwestern, St. Olaf)

A framework for continuous improvement of greener laboratory procedures



We teach this simple process to our students as we implement it.

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Reed, S.M.; Hutchison, J.E. *J. Chem. Ed.* **2000**, *77*, 1627-1629.

1997: Green chemistry education efforts

Workshops for Faculty: 2001-present

Thinking about going GREEN ?

8th annual

Green Chemistry in Education Workshop

June 15, 2008

Hands-on workshop focusing on implementing green chemistry in the organic lab curriculum:

- try out new experiments
- learn approaches to incorporate green chemistry in your curriculum
- network with other educators in your region

Application deadline for 2009 workshop: March 15, 2009

Sponsored by the UO, the NSF and the NSF-sponsored Center for Workshops in the Chemical Sciences

For more information see: http://greenchem.uoregon.edu

Today: Universities and colleges across the US (and around the world) are teaching green chemistry

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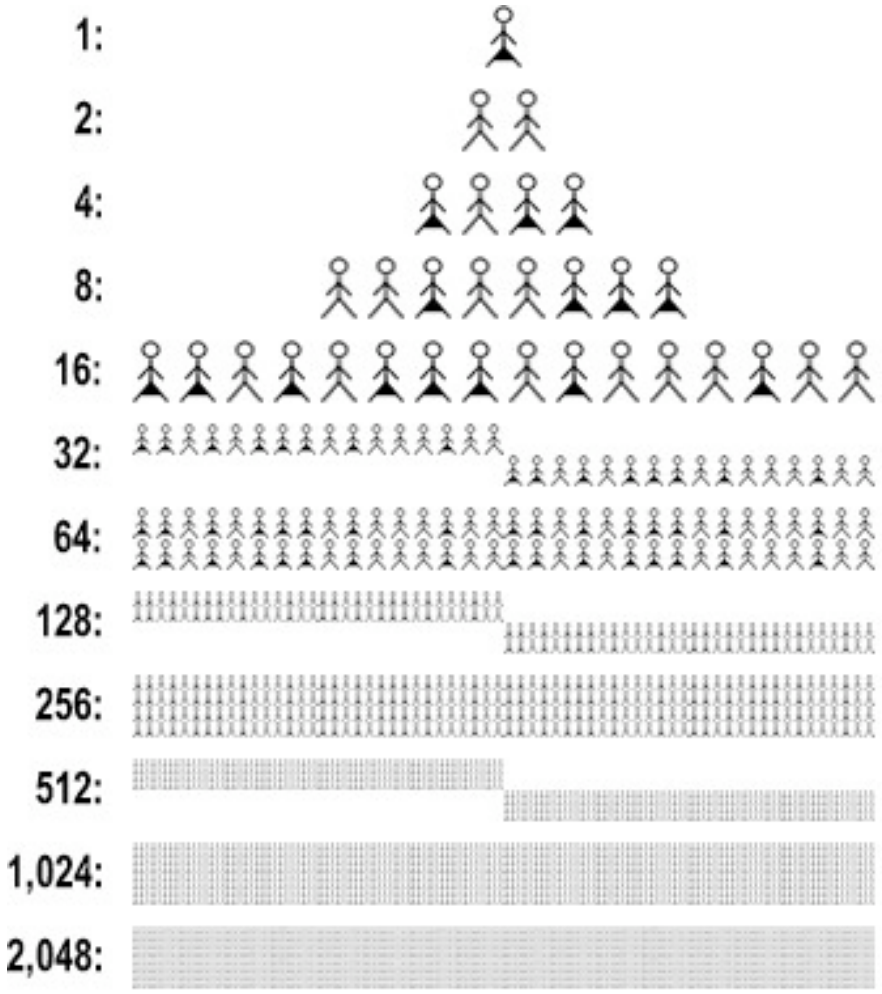
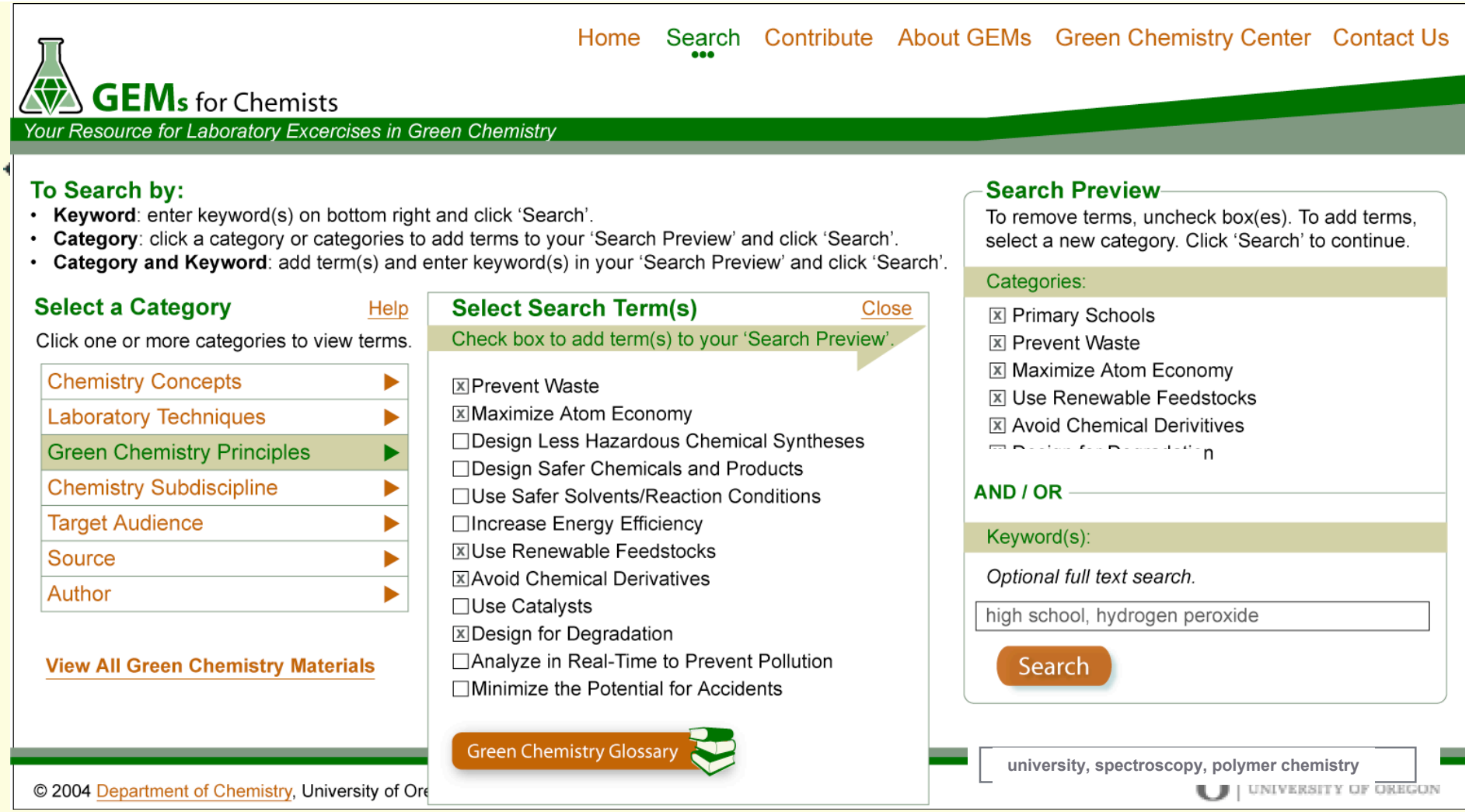
The Green Chemistry Education Network (GC EdNet)



Tapping the energy of interested faculty and students is the key to dissemination (and change)

http://www.gcednet.org/



# of requests to the server = 65,000 per month: Up ~four-fold since 2005

# of unique IP addresses = 6,000 per month: Up six-fold since 2005

visits (# of 30 minute visits) = 300 per month: Up two-fold since 2005

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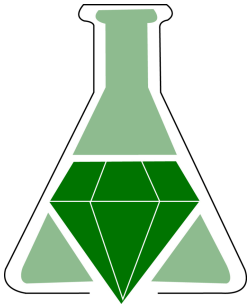
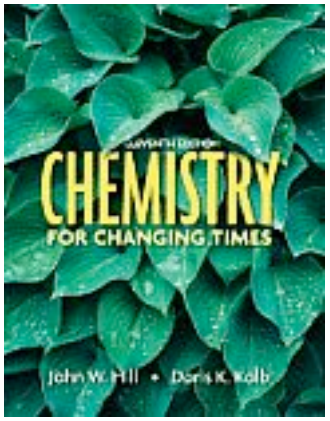
Today there is a thriving, distributed green chemistry education community

Workshops and Summer Schools



GEMs
(database)

***G**reener **E**ducation **M**aterial**s** for Chemists*

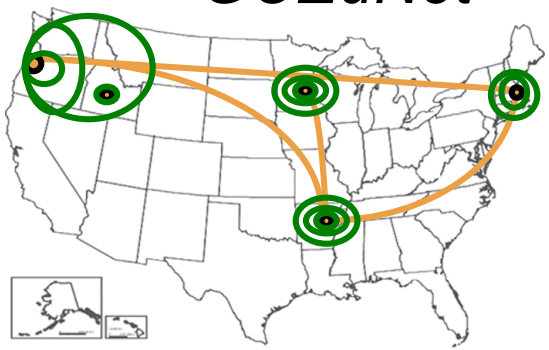


Textbooks

Partnerships

- Guided Inquiry
- Vernier and Fisher
- Science Museums
- University Initiatives

GCEdNet



Ambassador Sites

SAFER NANOMATERIALS AND NANOMANUFACTURING INITIATIVE

Nanotechnology for society and the environment

Clean, sustainable chemical production

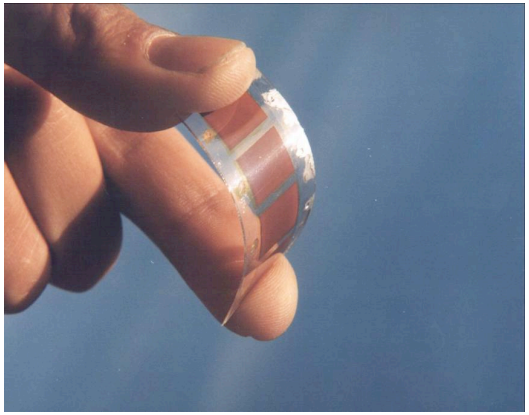
Abundant clean energy from the sun

Drinkable water for everyone around the world

Catalysts for greener production of chemicals and fuels

High performance batteries for transportation

Benign coatings that reduce cleaning or protect surfaces



Material Safety Data Sheet for Carbon Nanotubes

Section 1: Product Identification

Chemical Name: Carbon Fullerene
Formula: Carbon
Synonyms: Carbon Nanotubes
CAS Number: 7782-42-5 (Graphite)

Section 2: Composition and Information on Ingredients

Synthetic graphite Up to 100%
Metallic impurity Balance

Section 3: Hazards Identification

Potential Health Effects
Eye Contact: May cause eye irritation
Skin Contact: No known hazards, but may be mildly irritating
Inhalation: May cause irritation to respiratory tract
Ingestion: No known hazards, but may irritate gastrointestinal tract
Acute and Chronic High concentration of dusts may be irritating to eyes, skin,
Health Effects: mucus membranes and respiratory tract.

Section 6: Accidental Release Measures

Spill Procedures: Sweep or vacuum according to normal housekeeping practices.

Section 8: Exposure Controls and Personal Protectio n

Respiratory Protection: Use of a dust mask is recommended.
Skin Protection: Impervious gloves and protective clothing to prevent skin contact.
Ventilation: A local or general exhaust system is recommended.

What about the *production* of nanoscale products?

The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices

ERIC D. WILLIAMS,*,† ROBERT U. AYRES,‡ AND MIRIAM HELLER§

United Nations University, 53-67 Jingumae 5-chome, Shibuya-ku, Tokyo, Japan, INSEAD, Boulevard de Constance, Fontainebleau, 77305 Cedex, France, and National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230

For a 2-g DRAM chip:

Chemical input ~72g
Energy (fossil fuels)
~1,600 - 2,300 g
Water ~ 20,000 g
Gases ~ 500 g

Environ. Sci. Technol. **2002**, *36*, 5504−5510

Bottom-up manufacturing has potential to improve materials efficiency, however…

"Discovery scale" production of nanoparticle building blocks

- Low yields
- Toxic reagents
- Inefficient functionalization
- Wasteful purification

E-factor of 6,000 to 15,000

Nanotechnology for society and the environment

Clean, sustainable chemical production

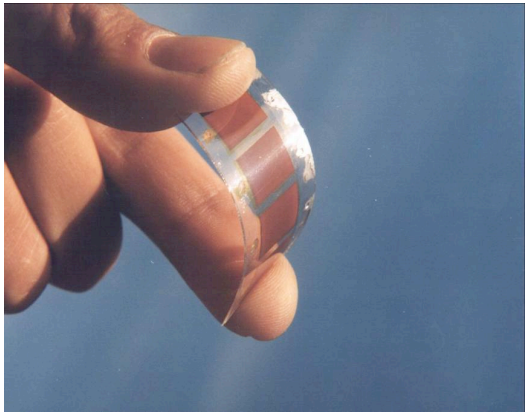
Abundant clean energy from the sun

Drinkable water for everyone around the world

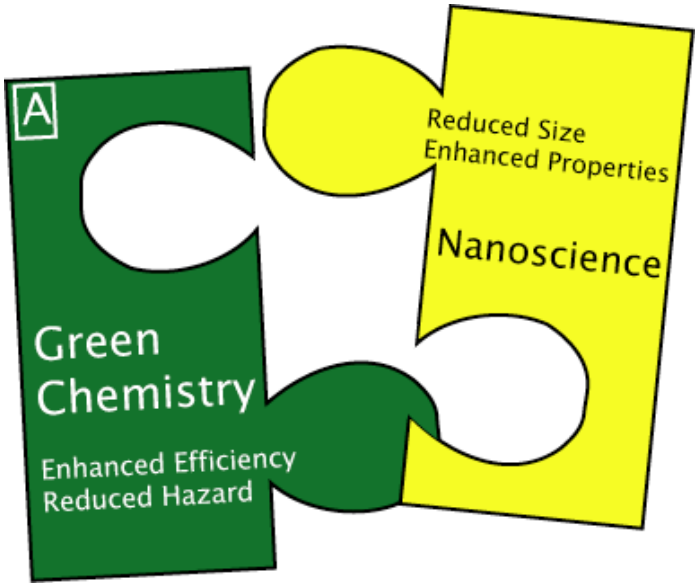
Catalysts for greener production of chemicals and fuels

High performance batteries for transportation

Benign coatings that reduce cleaning or protect surfaces



Applying green chemistry to nanomaterials and nanomanufacturing



Higher performance
Cheaper
More convenient
Greener

McKenzie and Hutchison "Green nanoscience," *Chemistry Today*, **2004**, 30.
Dahl, Maddux and Hutchison "Toward Greener Nanosynthesis,"
*Chem. Rev.***2007**, *107,* 2228.

ONAMI Safer Nanomaterials and Nanomanufacturing Initiative (SNNI)

Merge green chemistry and nanoscience

Greener nanomaterials

More efficient, safer nanomanufacturing processes

High performance, yet pose minimal harm to human health or the environment

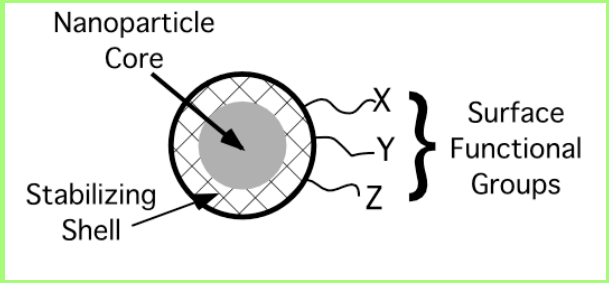
Nine ONAMI Teams - 30 Faculty/Sr. Researchers (chemists, biologists, toxicologists, physicists, materials scientists and engineers)

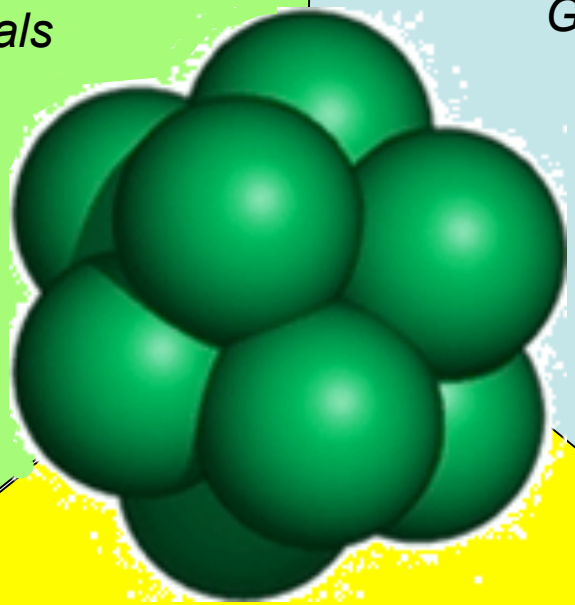
Partnership between ONAMI and the Air Force Research Laboratory.

ONAMI SNNI Research Thrust Groups

Thrust Group I

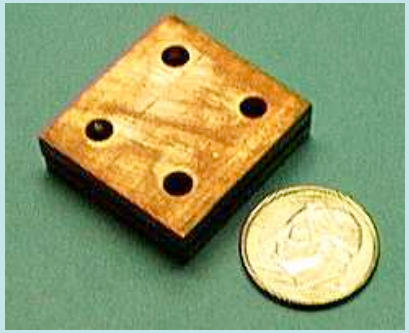
Designing Safer Nanomaterials





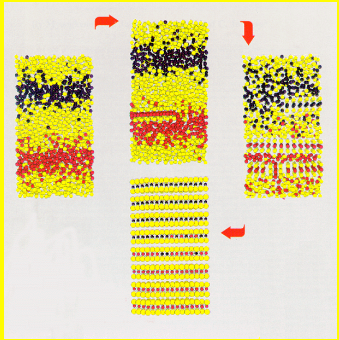
Thrust Group II

Greener Nanomanufacturing of Engineered Nanoparticles

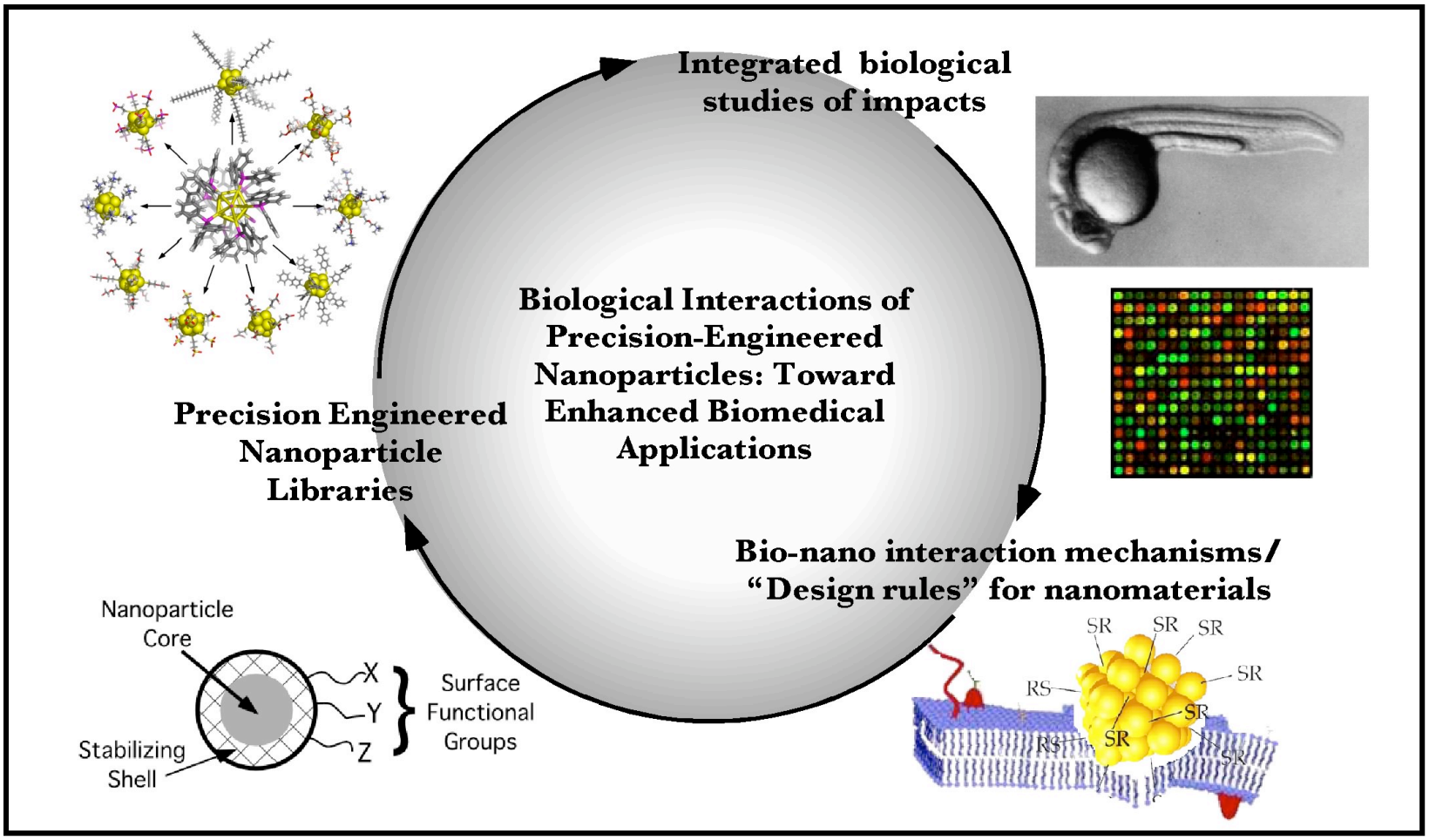


Thrust Group III

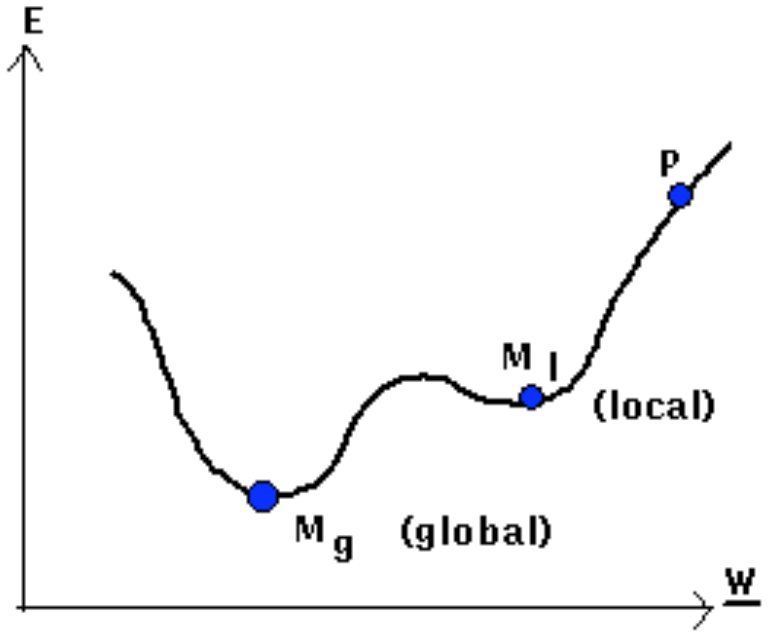
Interfacing Nanoparticles to Nano- and Macro-Structures for Device Applications



Iterative process for designing greener nanoparticles



Green chemistry can be a *driver* for invention (and innovation)



Drive design

Proactively address EHS concerns

Align goals regarding performance, cost and safety