Green Chemistry: The Missing Elements

John C. Warner

President and Chief Technology Officer
Warner Babcock Institute for Green Chemistry, LLC

President
Beyond Benign

john.warner@warnerbabcock.com

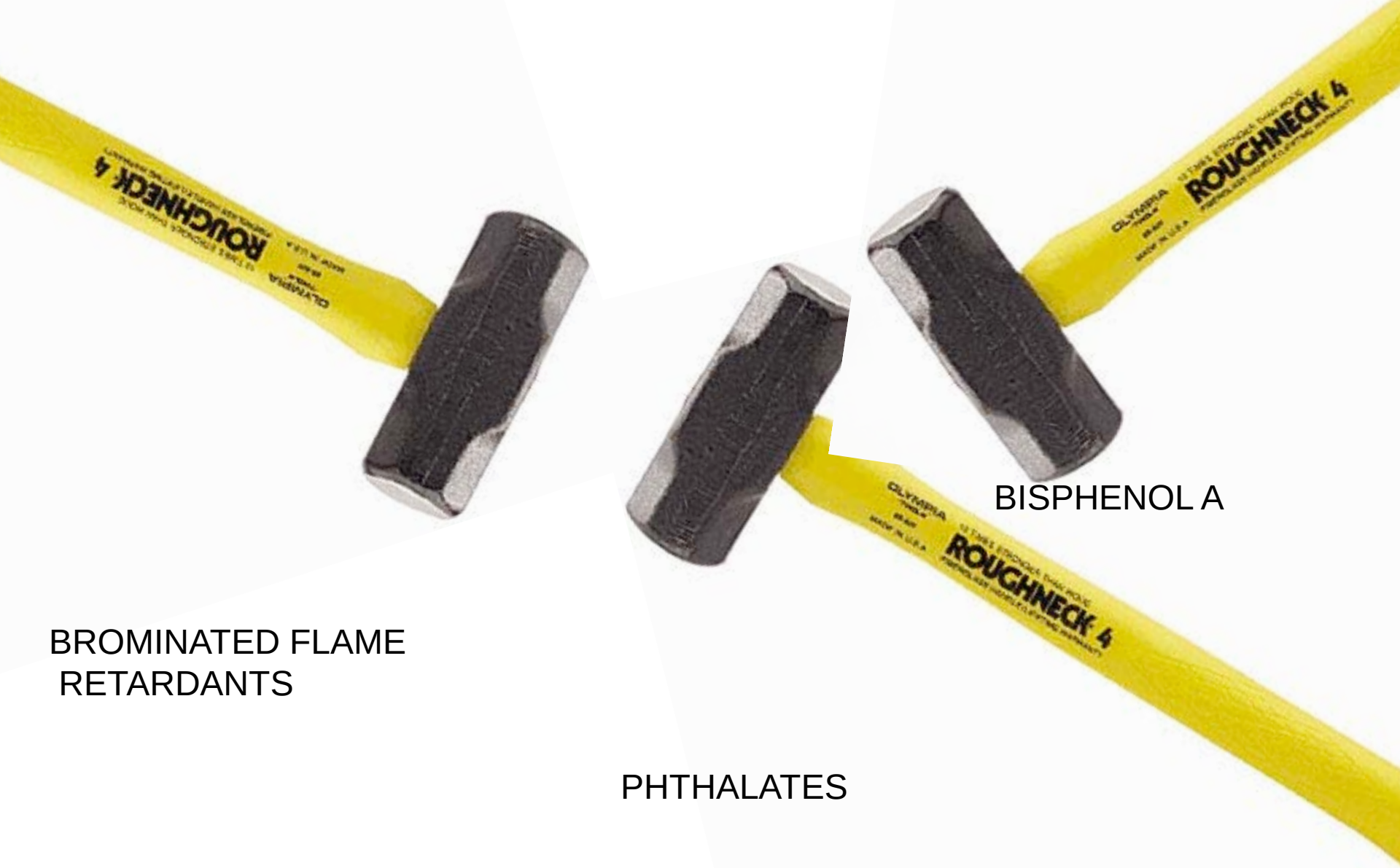
JohnWarnerOrg

warnerbabcock
institute for green chemistry

beyondbenign


BBC NEWS
Babie
The Wa
EPA Is Reconsidering
ton Post
hemical
The New York Times
Child obesity is link
to chemicals in plastic
TIME
The Poisoning of America
The Japan Times
Oceans awash in toxic seas of plastic
THE WALL STREET JOURNAL.
Yes, Bisphenol-A Does Enter the Body from Plastic Bottles
CNN.com
erious contaminati
from Africa's m
USA TODAY
5,000 evacuated after
hazardous Pa. acid spill
Chicago Tribune
Chicago's Toxic Air
THE SUNDAY TIMES
Household Dust Contains Highly Toxic Chemicals


WHACK A MOLE!



BISPHENOL A

BROMINATED FLAME
RETARDANTS

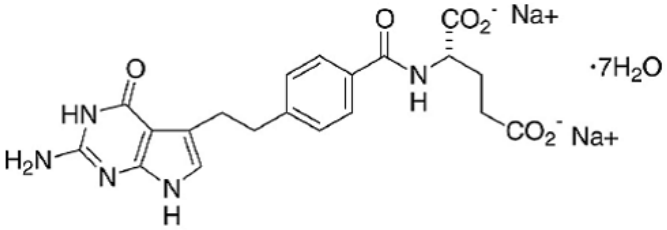
PHTHALATES

Asking the Right Questions

Why would a chemist make a hazardous material?

How do we train chemists?

Princeton University – 1984-1988

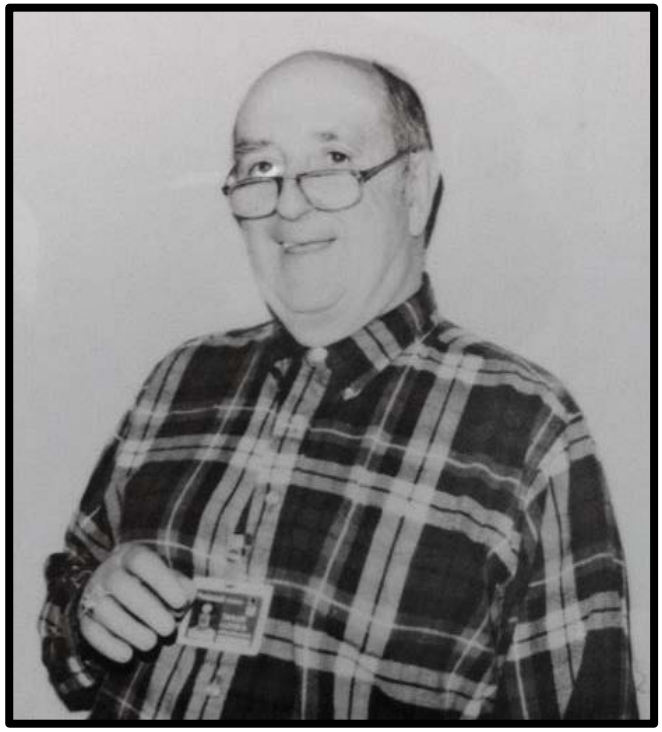


Professor E. C. Taylor

Natalie Warner
[1932 – 2002]

Polaroid Corporation – 1988-1997

Edwin Land



Lloyd D. Taylor

For over 180 years of "Modern Chemistry"…

But Nature…

Heat things under high temperature

Runs reactions at "room" temperature

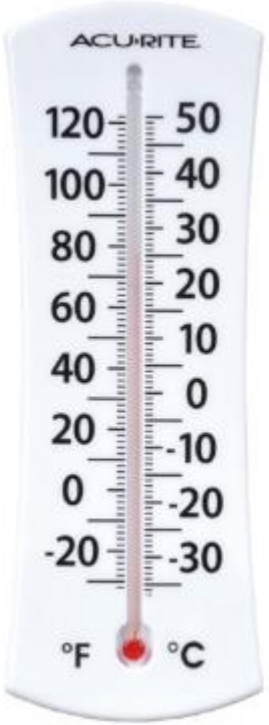
Apply high pressures

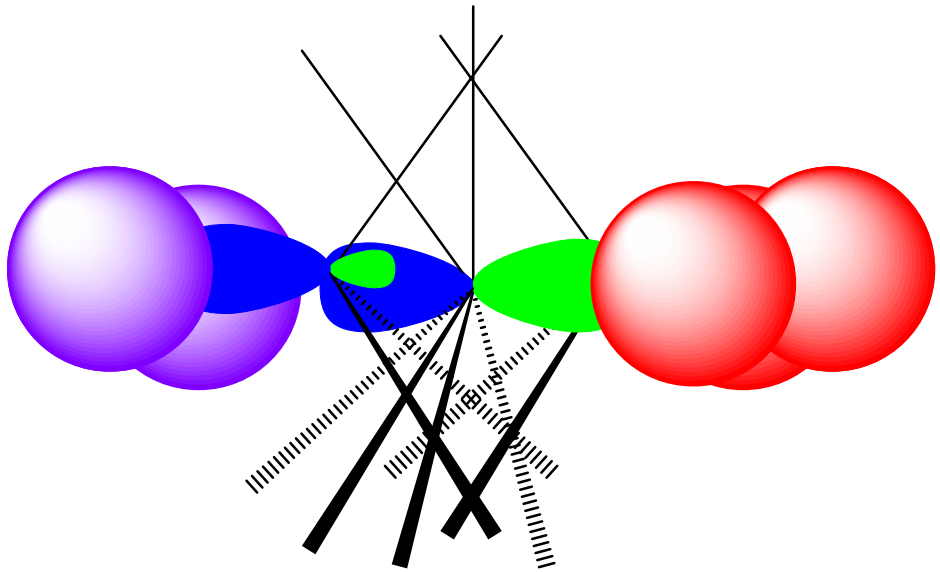
Runs reactions at ambient pressure

Use organic solvents

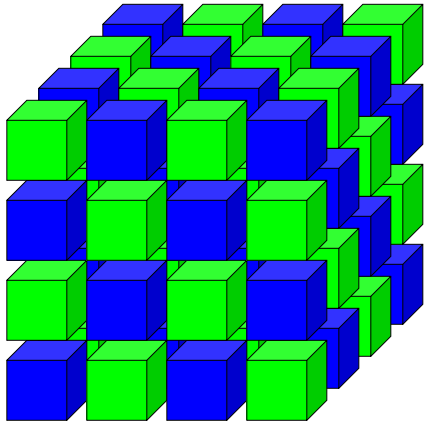
Uses water as a solvent

A thermometer is a molecular speedometer…





Non Covalent Derivatization



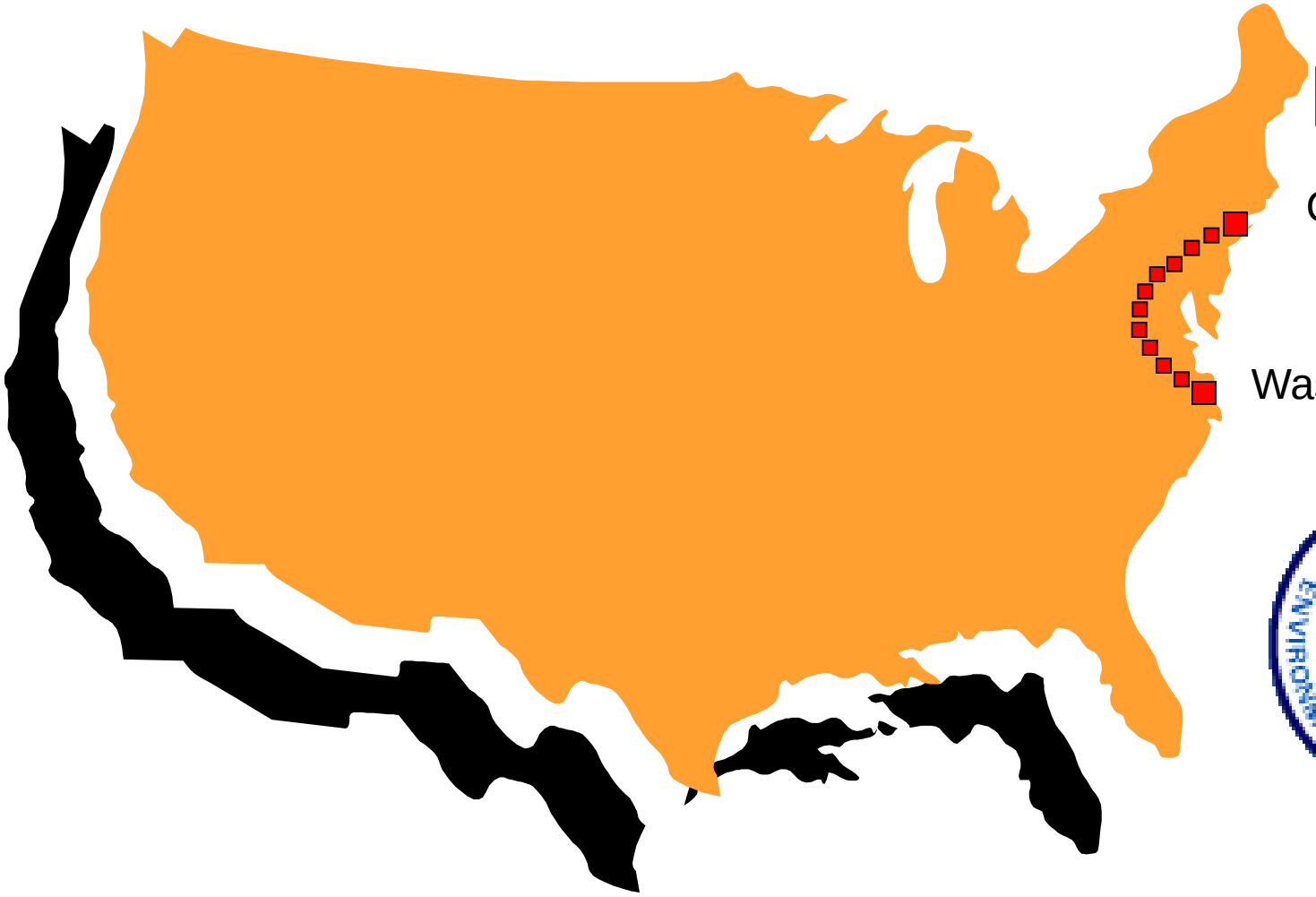
EPA Approval

Low **V**olume **E**xemption

Pre**M**anufacturing **N**otification

"Small particles"?

"Molecular Complexes"?



Polaroid

Cambridge, MA

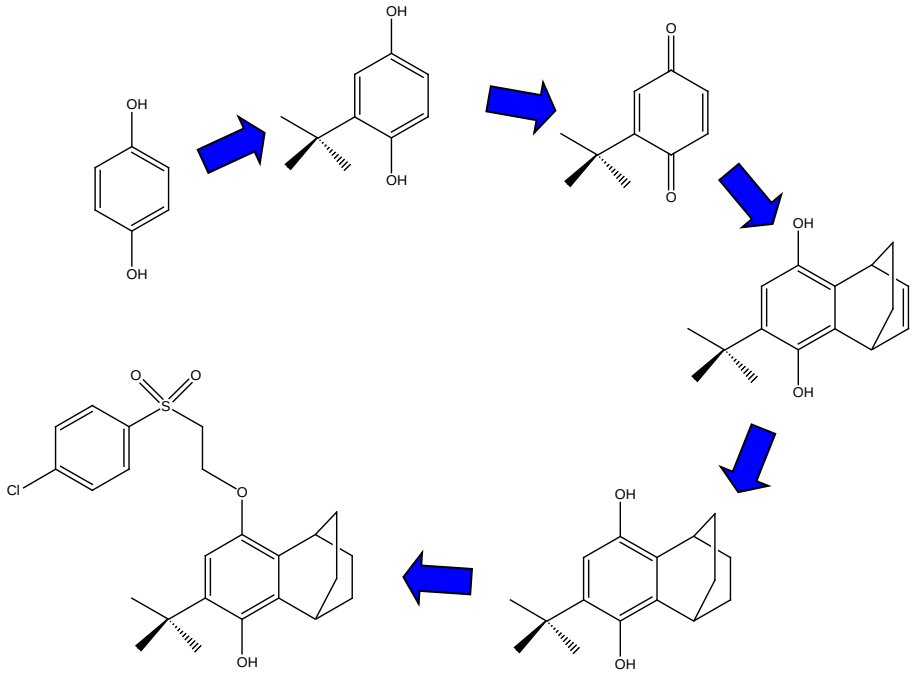
Washington, DC

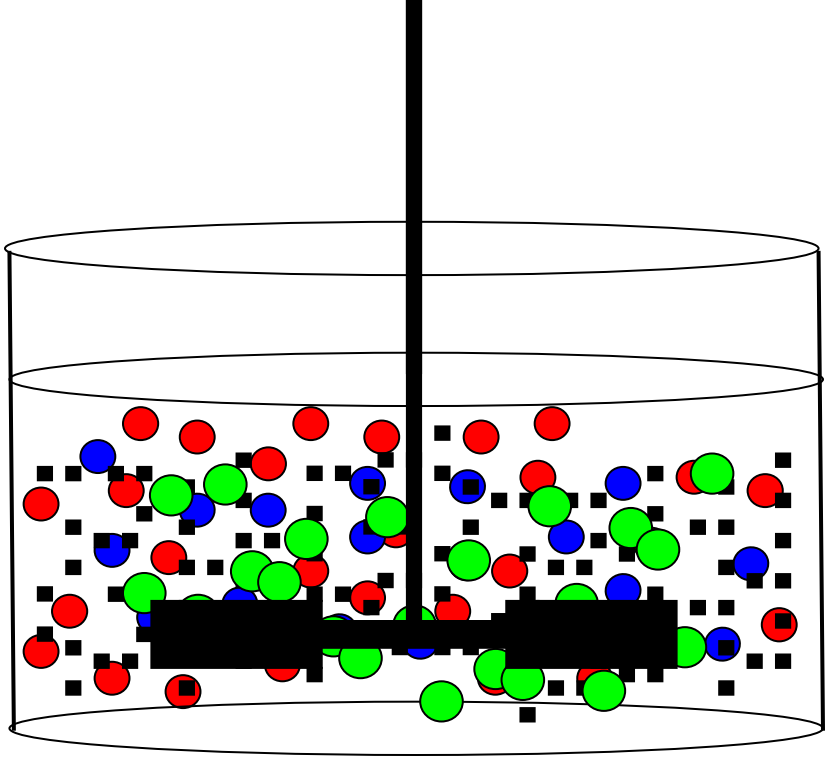
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

UMASS BOSTON

Paul Anastas

Office of Pollution Prevention and Toxics

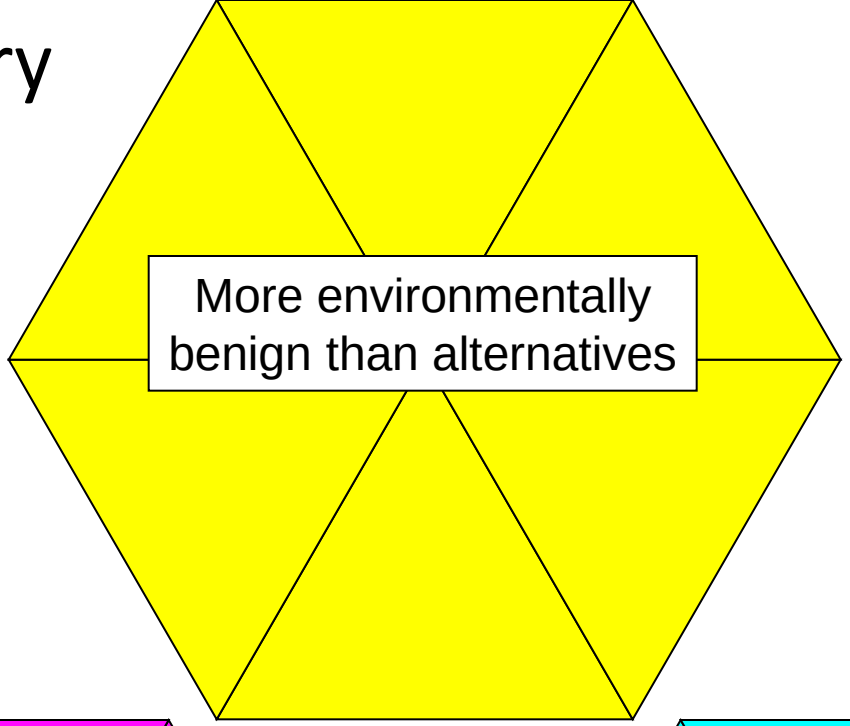


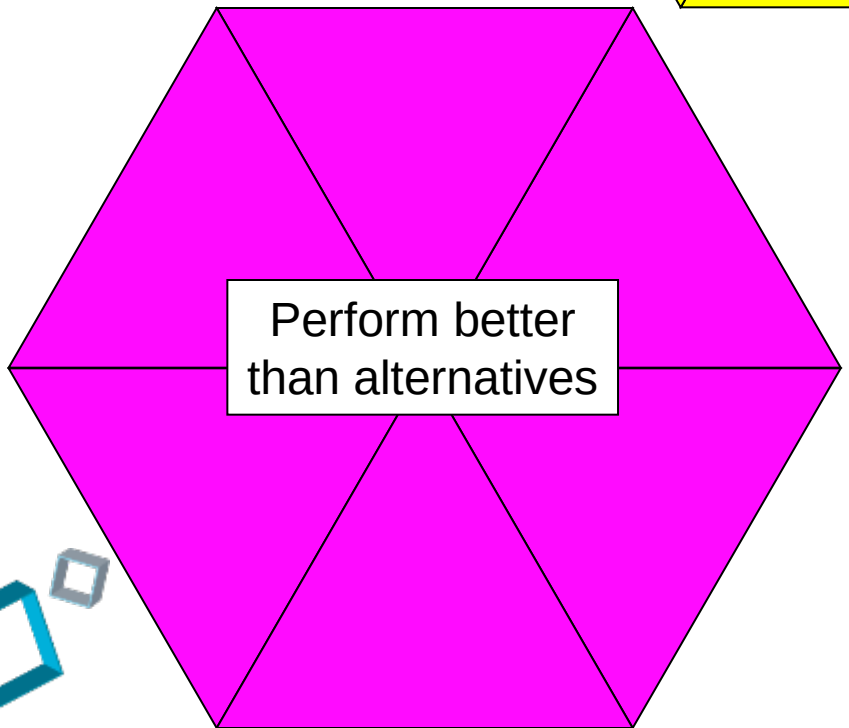


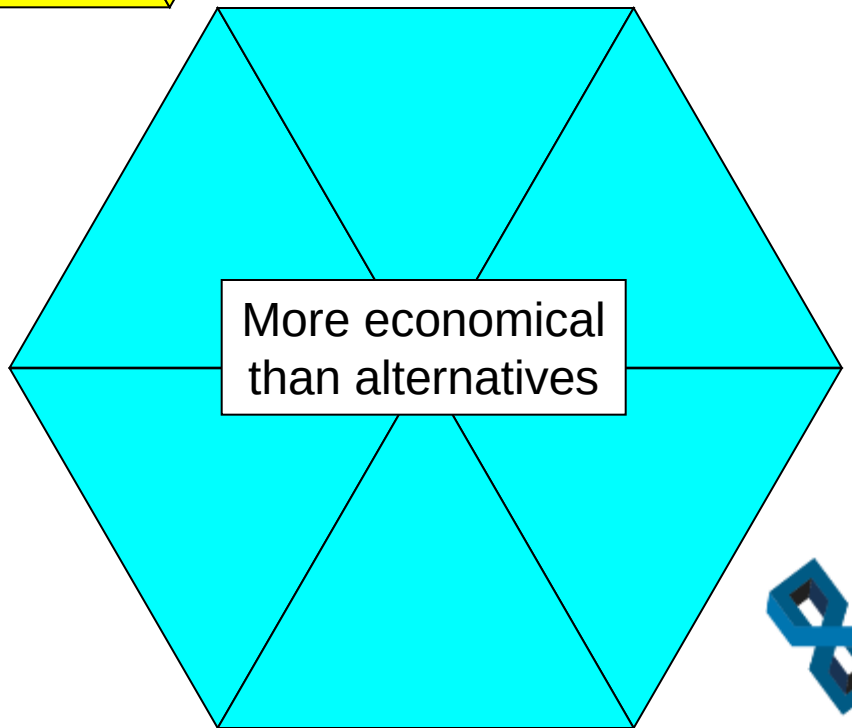
Old Technology
Several Solvents
High Energies
Hazardous Reagents

New Technology
Aqueous Conditions
Low Energies
Non-hazardous Reagents

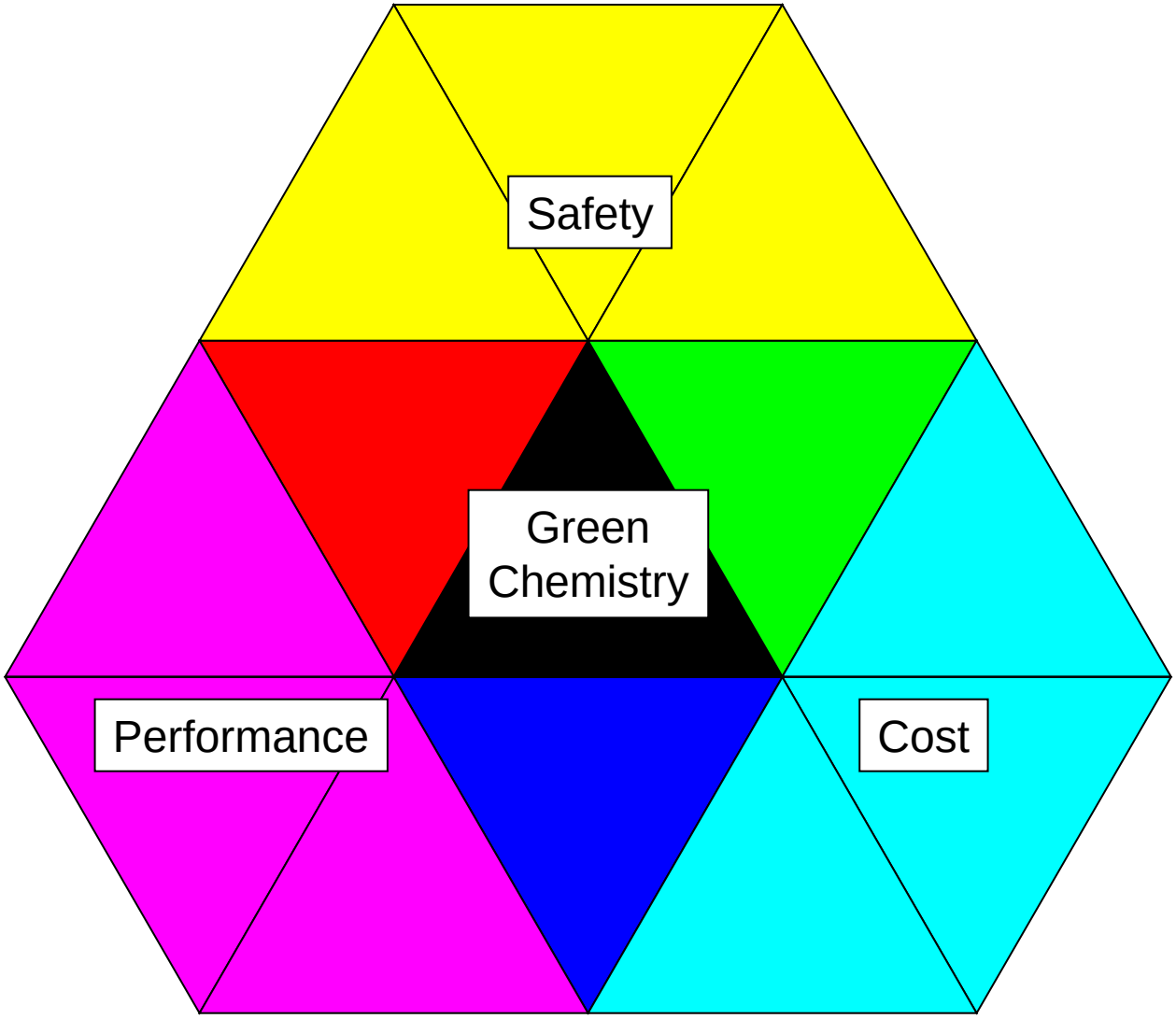
Green Chemistry







Green Chemistry



Green Chemistry is the *design* of chemical products and processes that reduce or eliminate the *use and/or generation* of hazardous substances.

The Twelve Principles of Green Chemistry

1. Prevention. It is better to prevent waste than to treat or clean up waste after it is formed.

2. Atom Economy. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Less Hazardous Chemical Synthesis. Whenever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals. Chemical products should be designed to preserve efficacy of the function while reducing toxicity.

5. Safer Solvents and Auxiliaries. The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.

6. Design for Energy Efficiency. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

7. Use of Renewable Feedstocks. A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

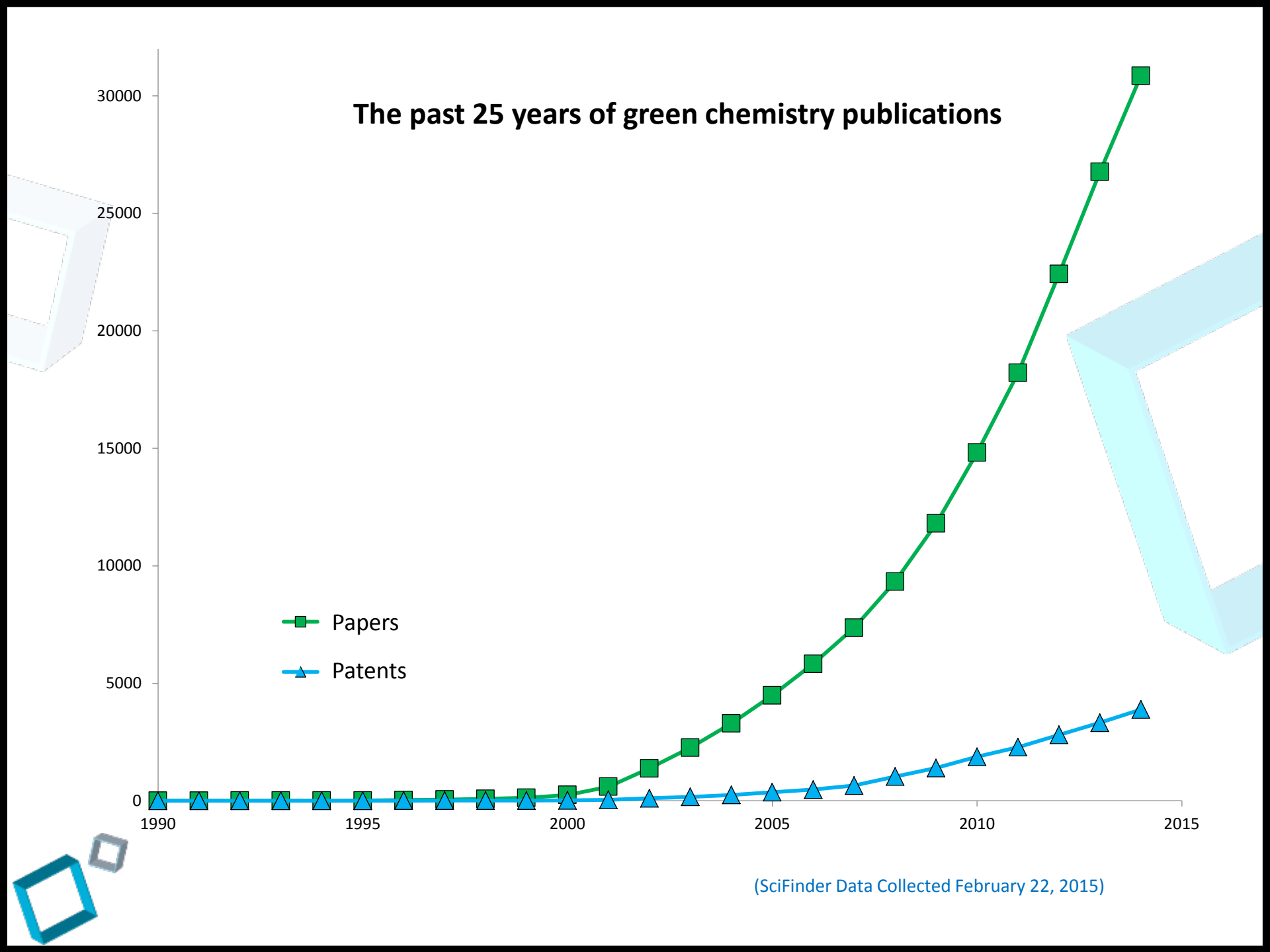
8. Reduce Derivatives. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible .

9. Catalysis. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

10. Design for Degradation. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

11. Real-time Analysis for Pollution Prevention. Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

12. Inherently Safer Chemistry for Accident Prevention. Substance and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.



(SciFinder Data Collected February 22, 2015)

EPA United States Environmental Protection Agency

Presidential Green Chemistry Challenge

The Presidential Green Chemistry Challenge

Awards Opportunities

The Pollution Prevention Act of 1990 established a national policy to prevent or reduce pollution at its source whenever feasible. The Pollution Prevention Act also provided an opportunity to expand beyond traditional EPA programs and devise creative strategies to protect human health and the environment. Green chemistry, or the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances, is a highly effective approach to pollution prevention. Green Chemistry applies innovative scientific solutions to real-world environmental situations, all through voluntary partnership programs. In order to successfully effect the technical and behavioral changes necessary to accomplish wide-spread pollution prevention through green chemistry, the benefits of the approach must be clearly demonstrated and communicated.

Objective:

The Presidential Green Chemistry Challenge seeks to recognize outstanding accomplishments in green chemistry through an annual awards program in order to demonstrate the scientific, environmental, and economic benefits that green chemistry technologies offer.

Background:

The Presidential Green Chemistry Challenge was implemented as a voluntary EPA Design for the Environment (DfE) partnership with the chemical community. DfE partnerships encourage changes that both promote economic development and benefit industry by identifying cost-effective ways to prevent pollution.

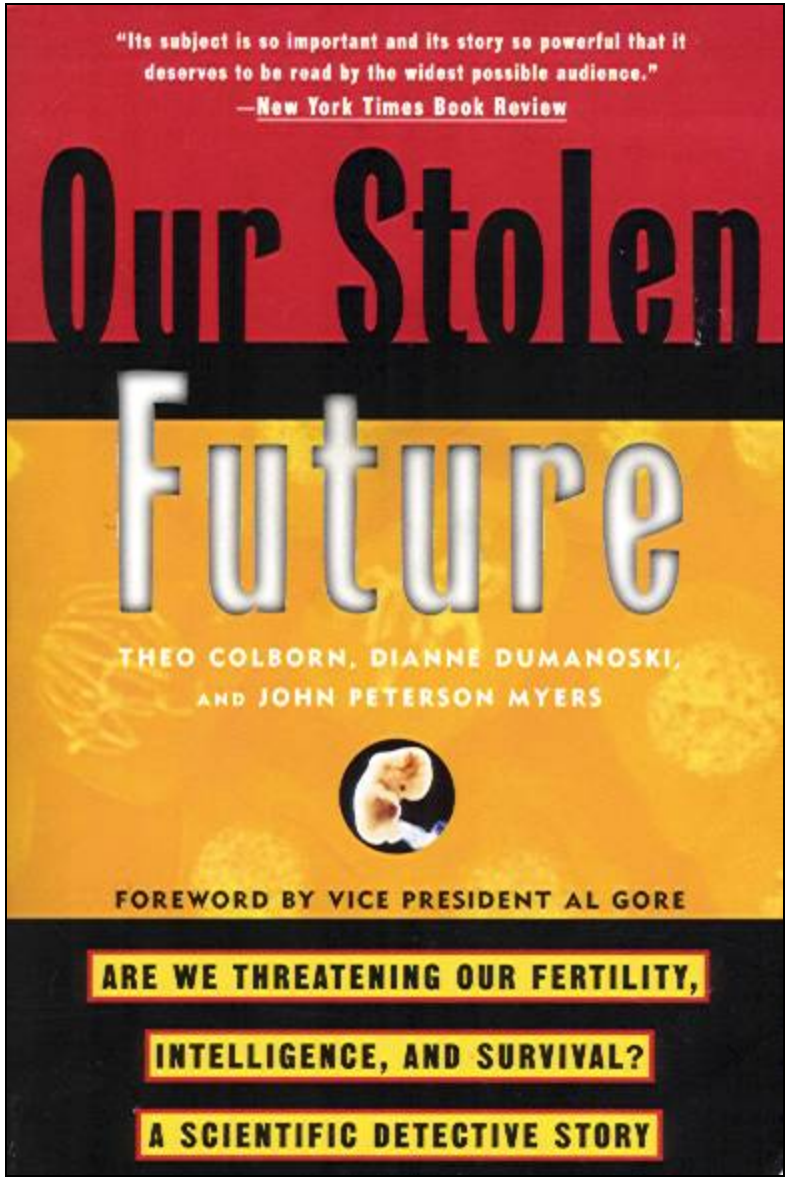
Description:

The Presidential Green Chemistry Challenge Awards Program is an opportunity for individuals, groups, and organizations to compete for annual awards in recognition of innovations in cleaner, cheaper, smarter chemistry. The Challenge Awards Program provides national recognition for outstanding chemical technologies that incorporate the principles of green chemistry into chemical design, manufacture, and use, and that have been or can be utilized by industry to achieve its pollution prevention goals.

Nominations received for the awards are judged by an independent panel of technical experts convened by the American Chemical Society. Typically, five awards are given annually to industry and government sponsors, an academic investigator, and a small business. For this program. Individual projects selected for support may be funded by EPA, NSF, or jointly by both agencies. This is at the option of the agencies, not the grantee.

Printed on paper that contains at least 50 percent postconsumer fiber.

	1996	1997	1998	1999	
Academic	Mark Holzapple	Joseph DeSimone	Barry Trost Karen Draths John Frost	Terry Collins	Chi H
Small Business	Donlar Corporation	Legacy Systems	PYROCOOL Technologies	Biofine	R
Alternative Synthetic Pathway	Pharmacia	BHC Company	Flexsys America	Lilly Research Laboratories	Roch
Alternative Solvents and Reaction Conditions	Dow	Imation	Argonne National Labs	Nalco Chemical Company	Bayer
Designing Safer Chemicals	Rohm and Haas	Albright and Wilson Associates	Rohm and Haas	Dow AgroSciences	Dow A



I have synthesized over 2500 compounds!!!!!

Every Year: (United States)

Chemistry and Chemical Engineering Graduates

15,000 Undergraduate Degrees

3,000 Masters Degrees

3,000 Doctoral Degrees

50.9 % Women Undergraduate Degrees (2004)

To get a degree in Chemistry…

No universities require any demonstration of knowledge regarding toxicity or environmental impact!

UMASS – 1996-2007

1997 Assistant Professor
1998 Associate Professor (Tenure)
1999 Director of Biochemistry
2000 Full Professor
2001 Chair Chemistry Department
2001 Director Green Chemistry PhD Program
2004 Professor Plastics Engineering (UML)

PHOTO BY ROB SHERMAN

INCUBATOR The University of Massachusetts, Boston, houses the first Ph.D. program in green chemistry.

GREEN CHEMISTRY EARNS A PH.D.

The University of Massachusetts, Boston, now offers a Ph.D. track in green chemistry

SINCE LAST FALL, THE UNIVERSITY of Massachusetts, Boston (UMB), has been accepting students into a new program called the green chemistry Ph.D. track. It is offered by the department of environmental sciences but administered by the department of chemistry.

The first of its kind in the world, the program is the brainchild of its director, UMB chemistry professor John C. Warner. Students in the program, he explains, will be trained much like other Ph.D. chemistry students, although their education will emphasize skills to design materials and processes that have minimal impact on human health and the environment. Areas of concentration include environmentally benign synthesis, environmental monitoring and detection, biodegradation, and bioremediation.

What makes the program different from anything else available so far, Warner says, is the requirement of courses in toxicology, environmental law and policy, environmental fate and transport, and industrial chemistry. Through these courses, he explains, "we broaden the students' understanding of environmental realities—such as what makes a molecule toxic, what laws have been established to govern synthetic procedures, and what happens in the environment—which conventional chemistry programs don't teach."

Terrence J. Collins, a chemistry professor at Carnegie Mellon University, notes that "we do not live in a sustainable civilization, sustainability meaning that what we do every day can be carried on to the indefinite future without causing damage." Collins was a recipient of the 1999 Presidential Green Chemistry Challenge Academic Award. The UMB program, he tells C&EN, is one way to call attention to the fact that "a sustainable civilization needs the intimate engagement of chemistry."

The UMB program "is timely, as there has been a distinct shift in focus in chemistry," says Janet Scott, deputy director of the Centre for Green Chemistry at Monash University, in Australia. "Even those who might not consider themselves 'green chemists' are beginning to focus on issues of sustainability and the design of benign products and processes to prevent pollution at the source. The chemical industry is beginning to demand a wider knowledge of and attention to issues of sustainability."

Mary Kirchhoff, assistant director of the Green Chemistry Institute, in Washington, D.C., agrees that the time is right for a green chemistry Ph.D. program. It might have been met with skepticism 10 years ago, when the term "green chemistry" first surfaced, she tells C&EN. Warner is the ideal person to lead such a program, she adds. "He's got the research credentials, the teaching credentials, the commitment to students, and the passion."

Particularly in organic synthesis, formal green chemistry training will force chemists to change how they think.

"One of the things that makes organic synthesis so exciting is that, if you draw a molecule, there are probably an infinite number of synthetic pathways that you can follow to make that molecule," Warner says. Traditionally, the focus has been on maximizing yields and stereoselectivities. Considerations of environmental and toxicological impact rarely come into play.

"IF ONE STEP in a synthetic sequence requires a hazardous reagent that's regulated by the federal government, that sequence could be more expensive than an alternative route that might give less yield," Warner explains. Regulatory and environmental realities often decide the economic viability of a synthetic route, he adds.

Chemists usually learn of such considerations when they're working for a company, Warner says. "Industry would like people to come in with some understanding of these issues, because there's economic benefit if processes designed in labs do not have to be reworked to satisfy regulatory requirements."

A green chemistry Ph.D. would be a big plus for chemists interested in process development, notes Berkeley Cue, vice president of pharmaceutical sciences at Pfizer Global Research & Development, Groton, Conn. "What we try to incorporate into the design of manufacturing processes—such as safety, efficient use of raw materials, minimal use of solvents, and online analysis—are aligned to the concepts that Warner and people like him are teaching," he explains. "We just didn't call it green chemistry. We called it process development."

Amy Cannon is the first student enrolled in UMB's green chemistry Ph.D. program. She's working on constructing solar energy devices in a more environmentally benign manner. Currently, she explains, producing solar cells consumes so much energy that a solar panel has to operate for years before it generates as much energy as was used to make it.

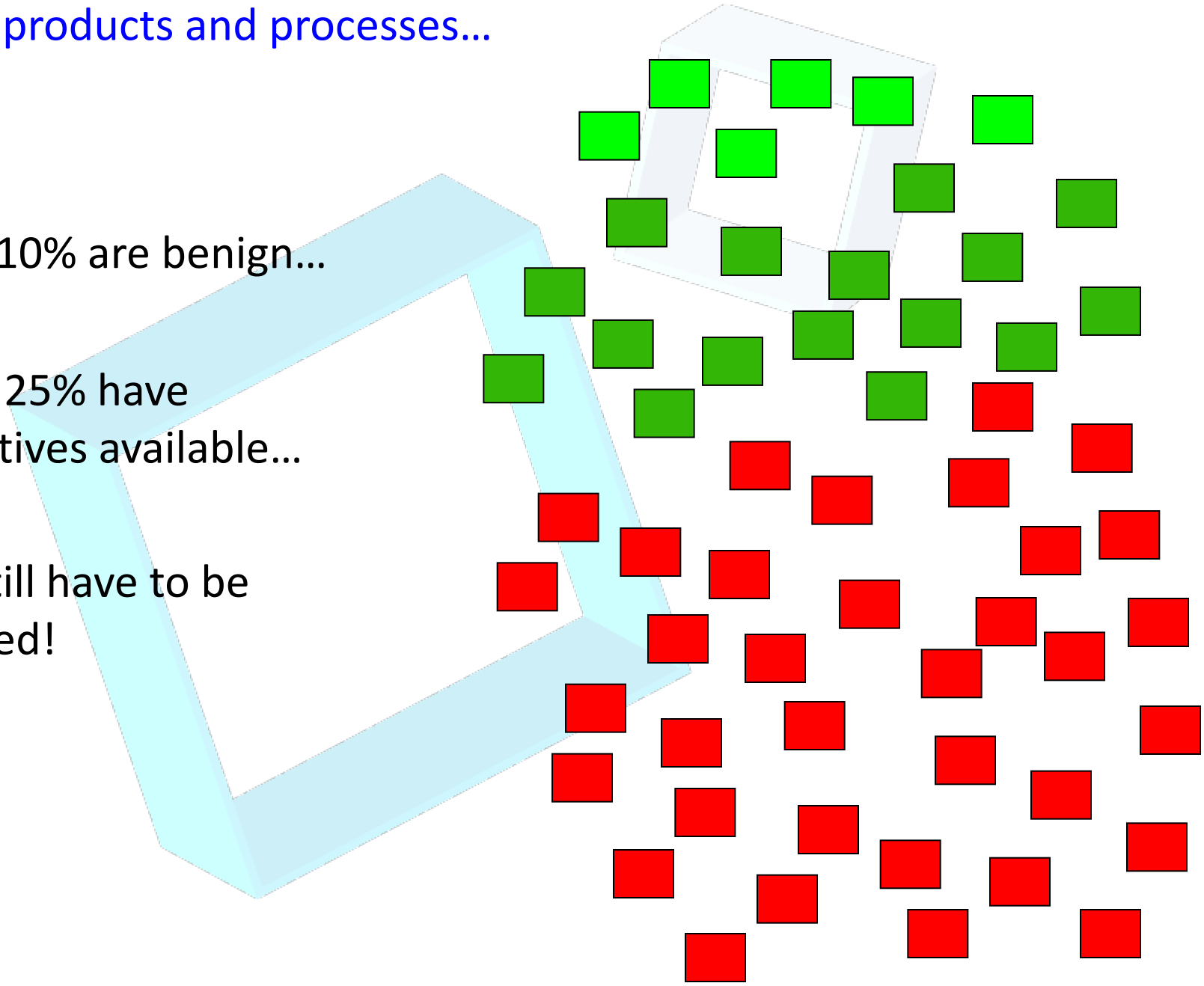
"Alternative energy is one of the most important areas in terms of sustainability," Cannon tells C&EN. Having just completed her master's degree under Warner's guidance, Cannon is passionate about green chemistry. "What could be better than this," she asks, "given that my big goal in life is to help save the world by doing what I can where I am?"—MAUREEN ROUHI

Of all the products and processes…

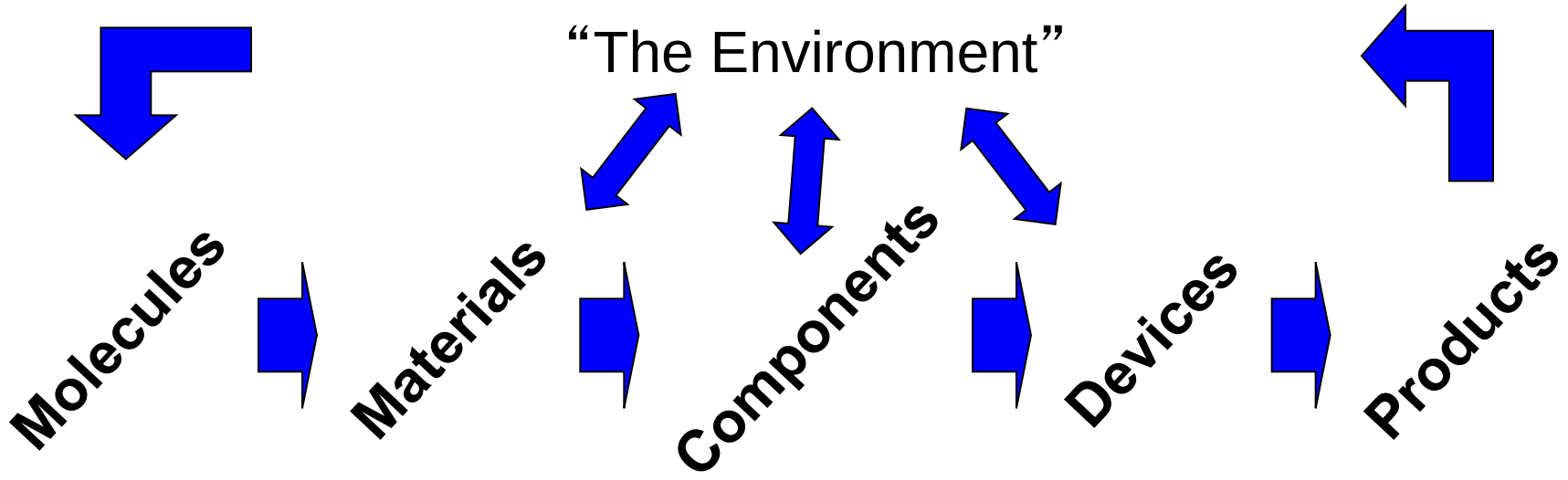
Maybe 10% are benign…

Maybe 25% have alternatives available…

65% Still have to be invented!



Where do products come from?



Basic Research

Applied Research

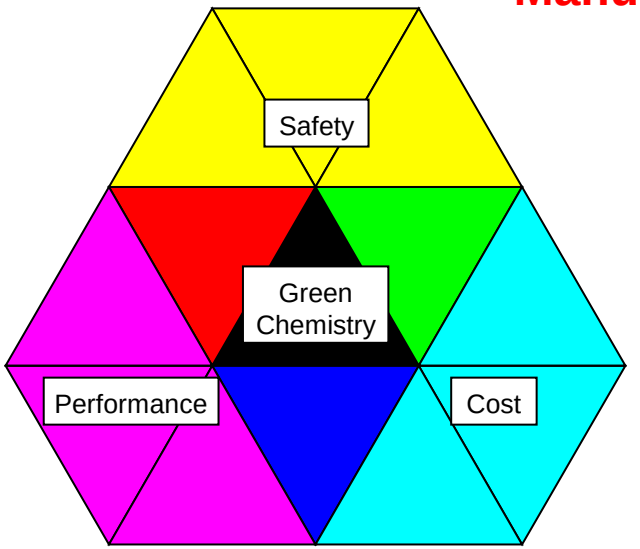
Development

Manufacturing

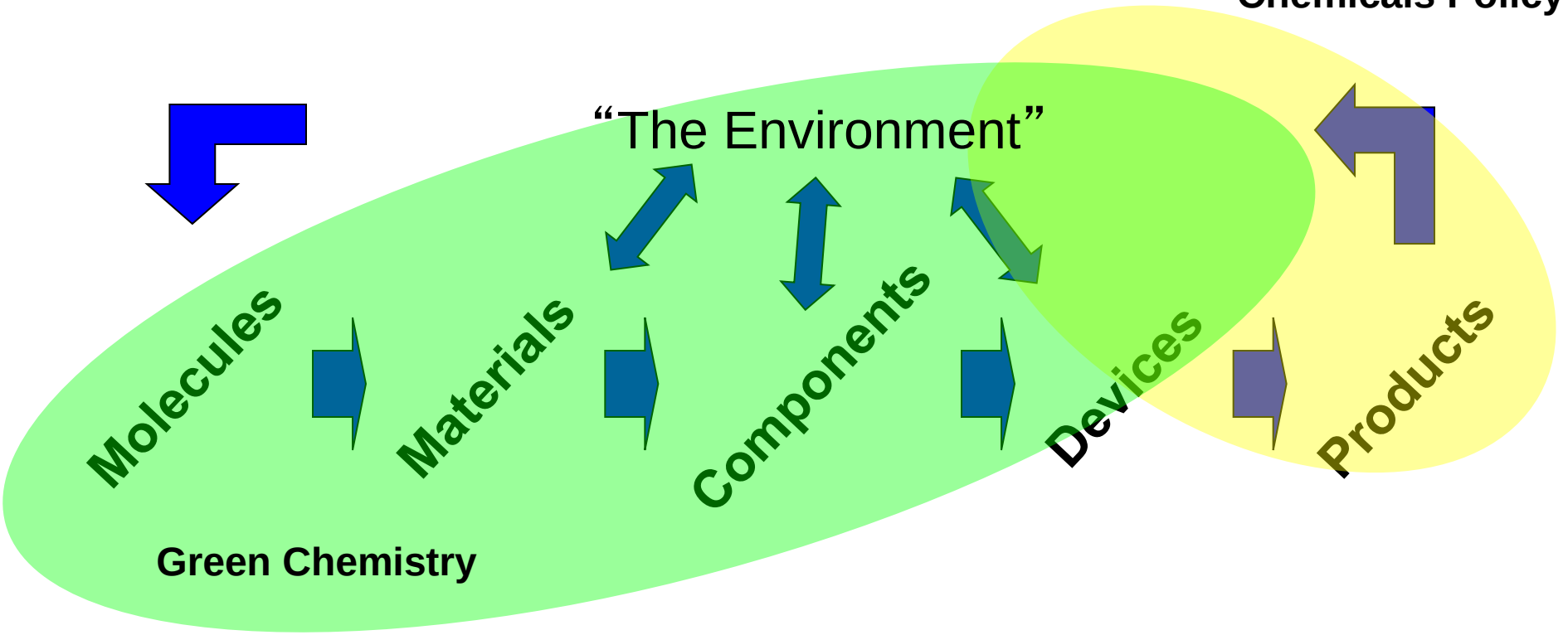
Performance

Economics

Social Implications



Chemicals Policy



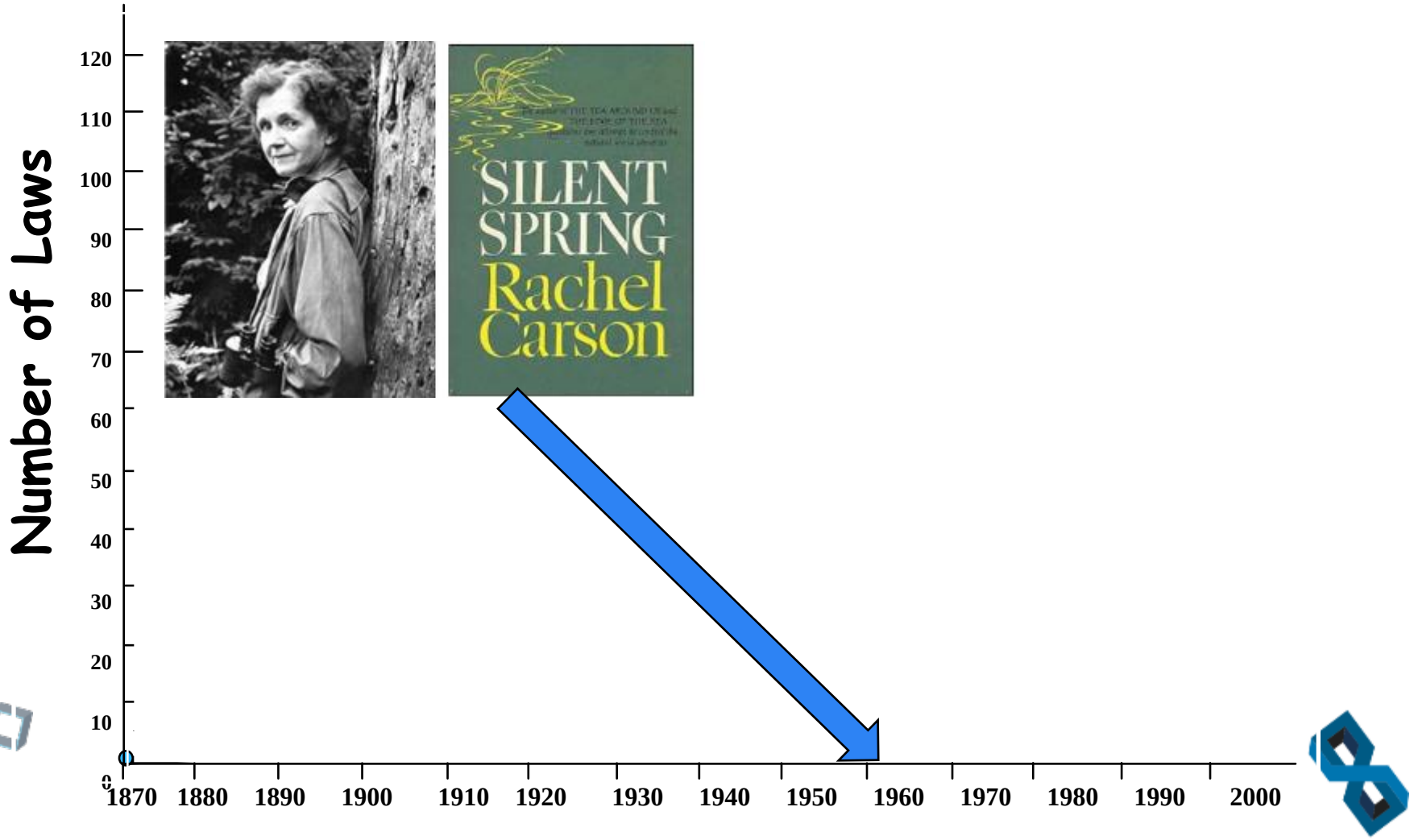
Chemists have ALWAYS cared about Human Health and the Environment.

Risk = Exposure x Hazard

The cost of using hazardous materials:

Storage
Transportation
Treatment
Disposal
Regulatory Costs
Liability
Worker Health and Safety
Corporate Reputation
Community Relations
New Employee Recruitment

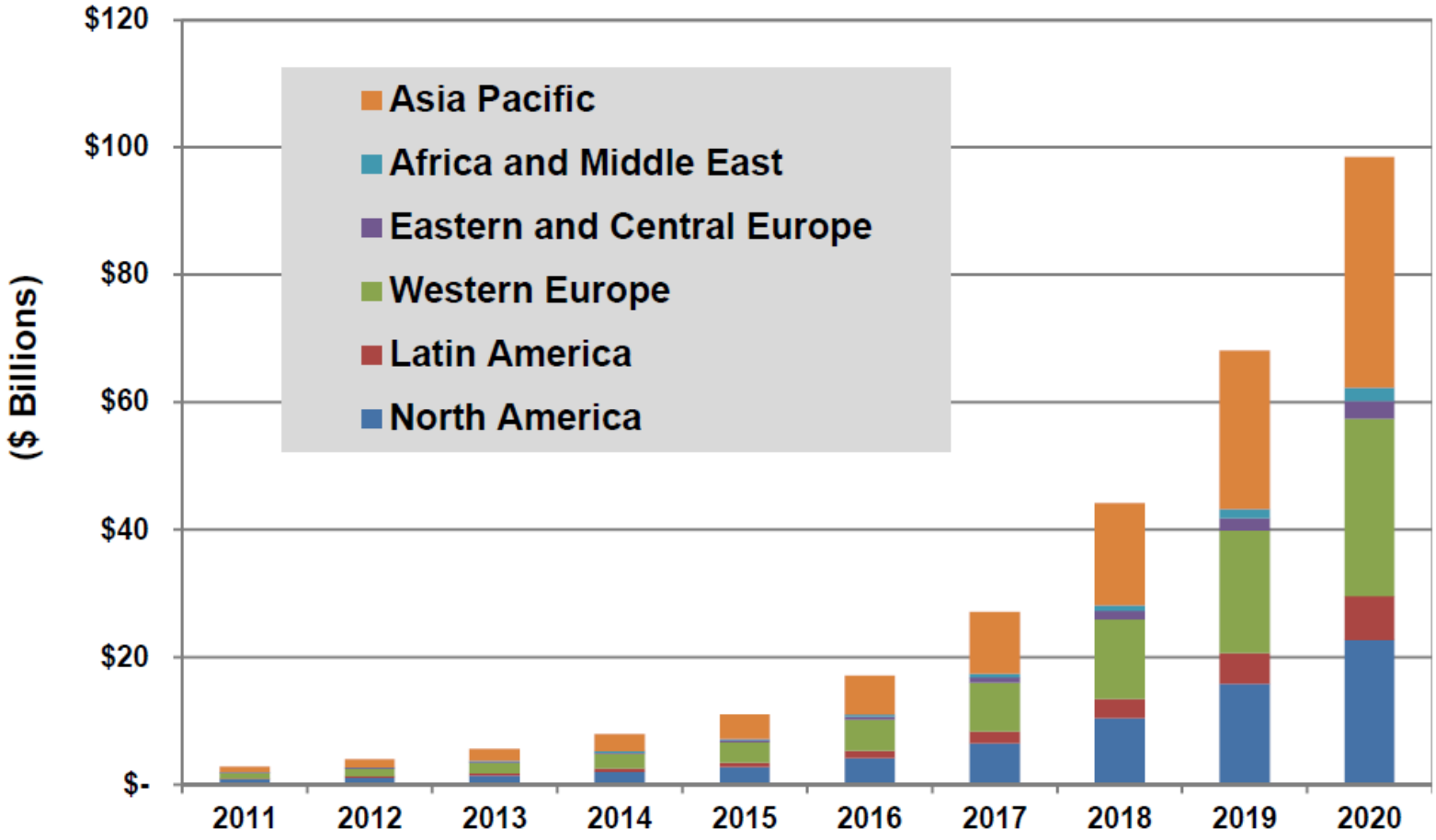
Environmental Regulations



Traditional Processes

Green Alternatives

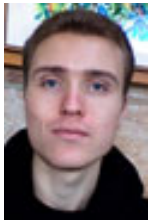
Chart 1.1 Green Chemical Market by Region, World Markets: 2011-2020



(Source: Pike Research)

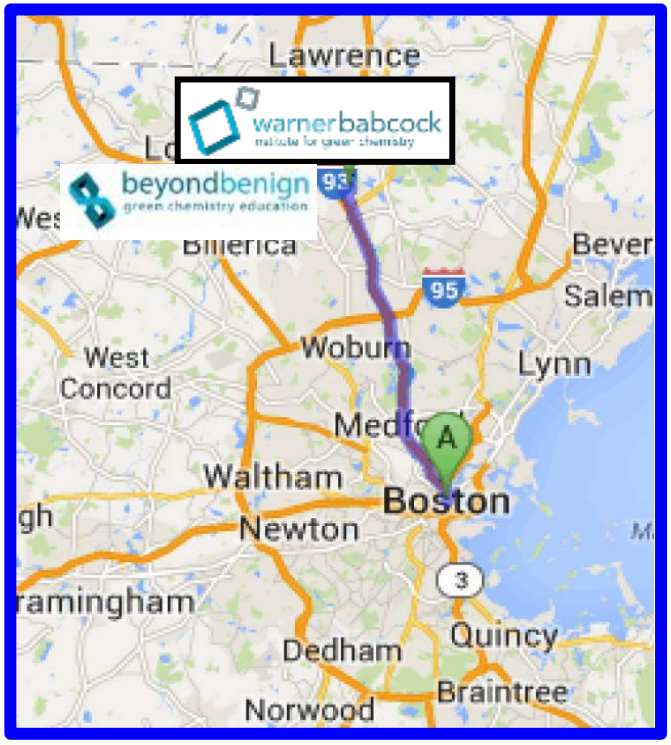
2007 onward…

John Warner Amy Cannon

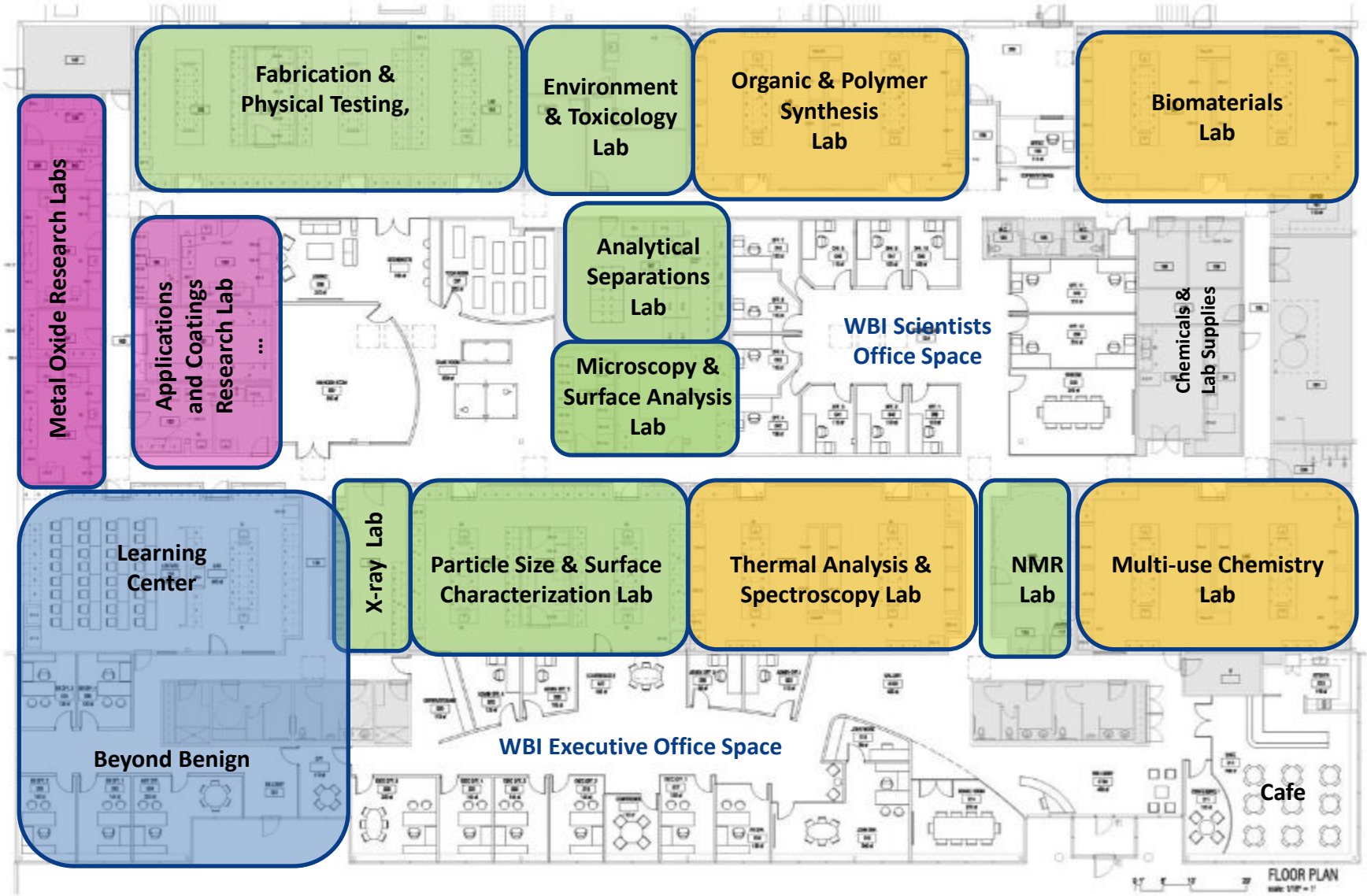


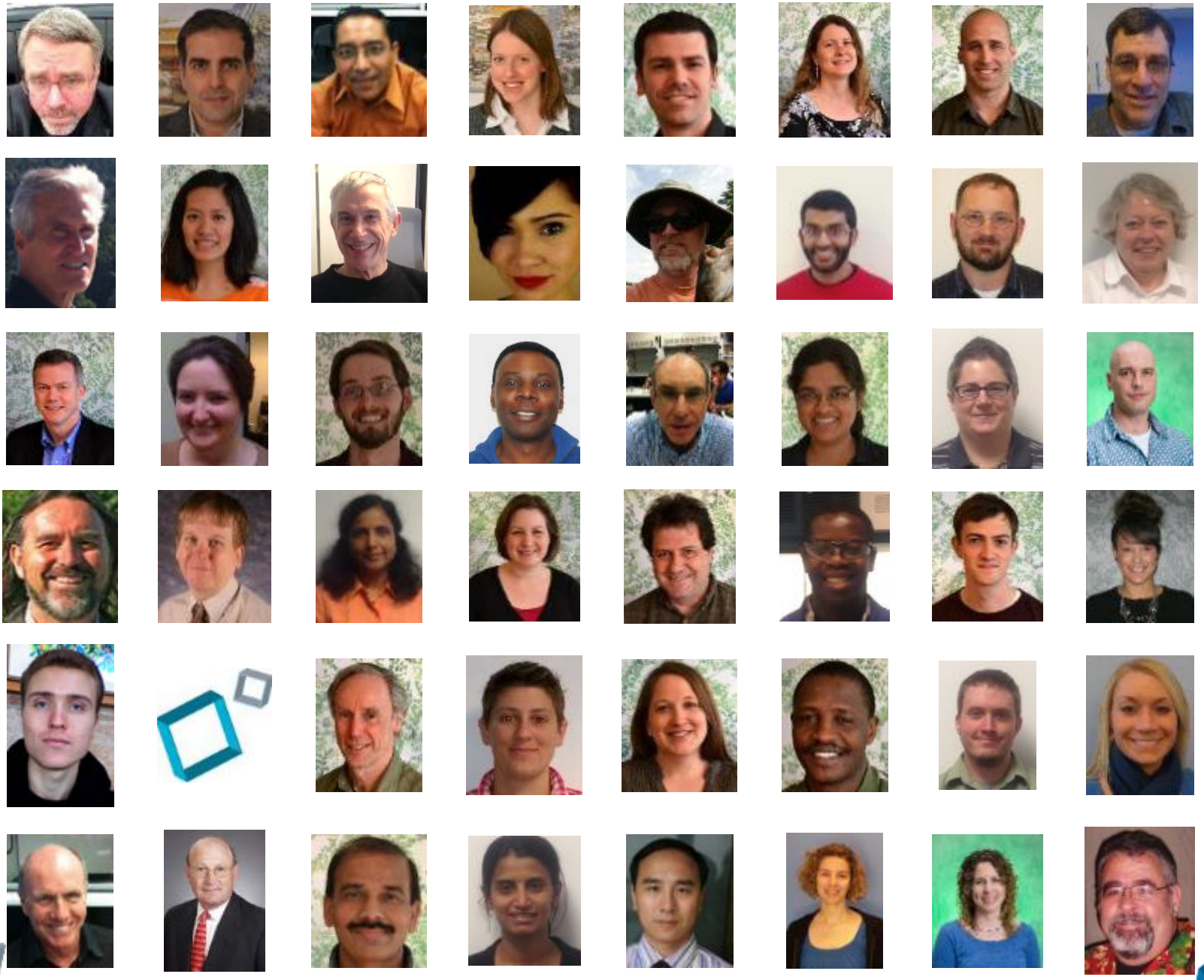
James & Jim Babcock

Joe Pont, CEO



100 Research Drive
Wilmington, MA 01887

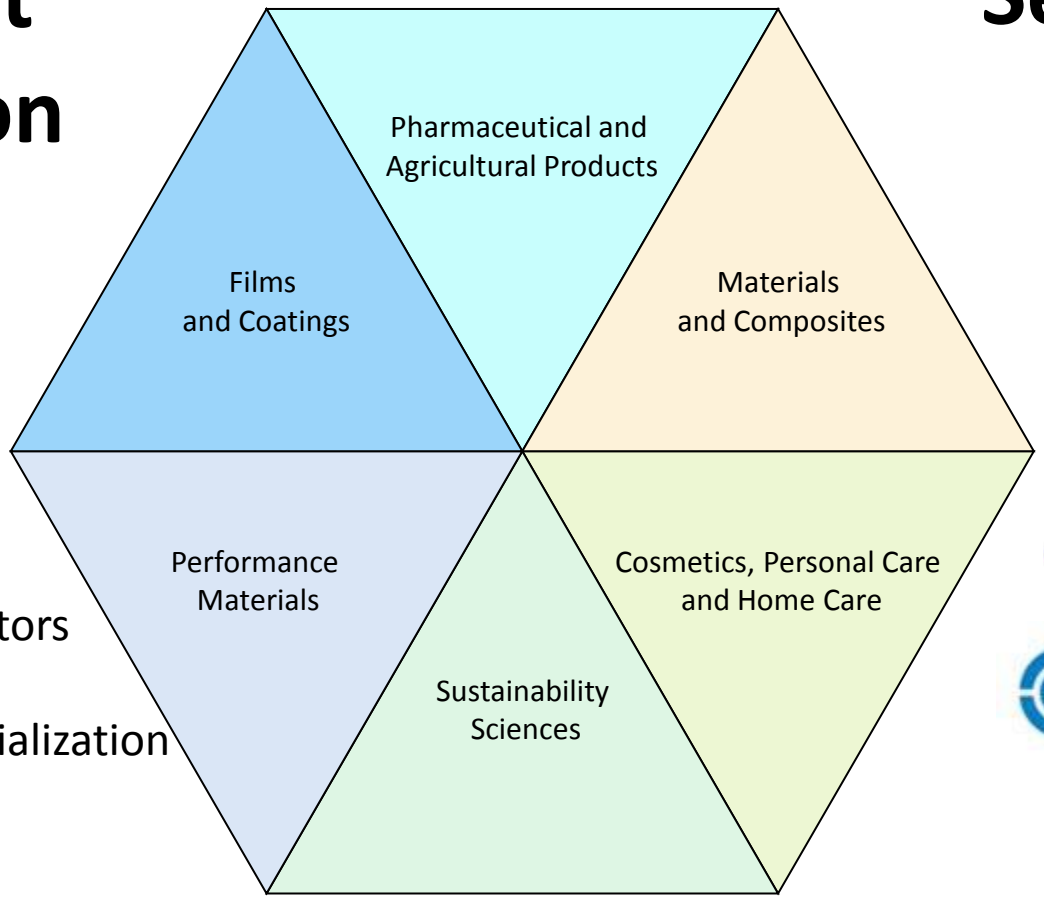

Fabrication & Physical Testing,
Environment & Toxicology Lab
Organic & Polymer Synthesis Lab
Biomaterials Lab
Metal Oxide Research Labs
Applications and Coatings Research Lab
...
Analytical Separations Lab
Microscopy & Surface Analysis Lab
WBI Scientists Office Space
Chemicals & Lab Supplies
Learning Center
X-ray Lab
Particle Size & Surface Characterization Lab
Thermal Analysis & Spectroscopy Lab
NMR Lab
Multi-use Chemistry Lab
Beyond Benign
WBI Executive Office Space
Cafe
FLOOR PLAN



warnerbabcock
institute for green chemistry

Contract Invention

Self-Funded Invention



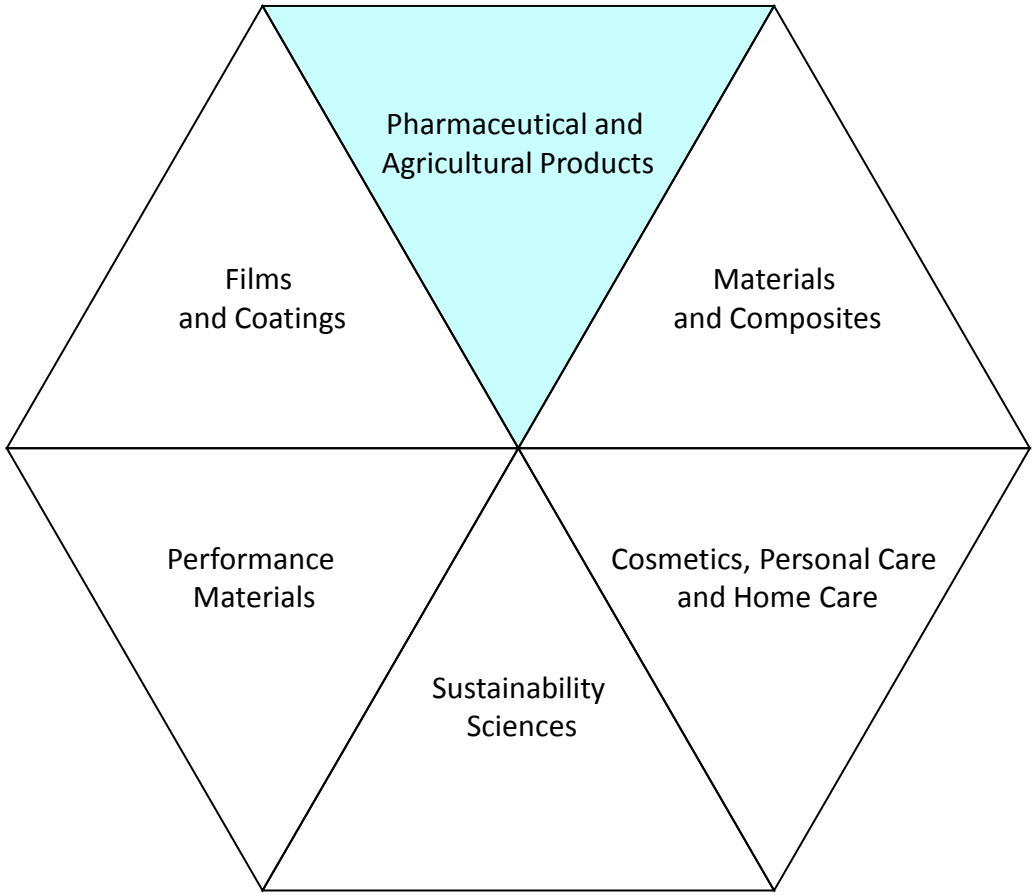
Invent for collaborators

Help with commercialization

COLLABORATIVE AGGREGATES LLC

COLLABORATIVE MEDICINAL DEVELOPMENT LLC

Pharmaceuticals and Agricultural Products

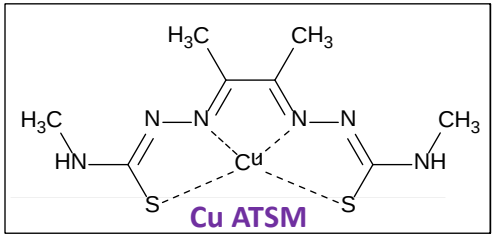


Parkinson's/ALS Disease Therapeutic

COLLABORATIVE MEDICINAL DEVELOPMENT LLC

PROCYPRA THERAPEUTICS LLC

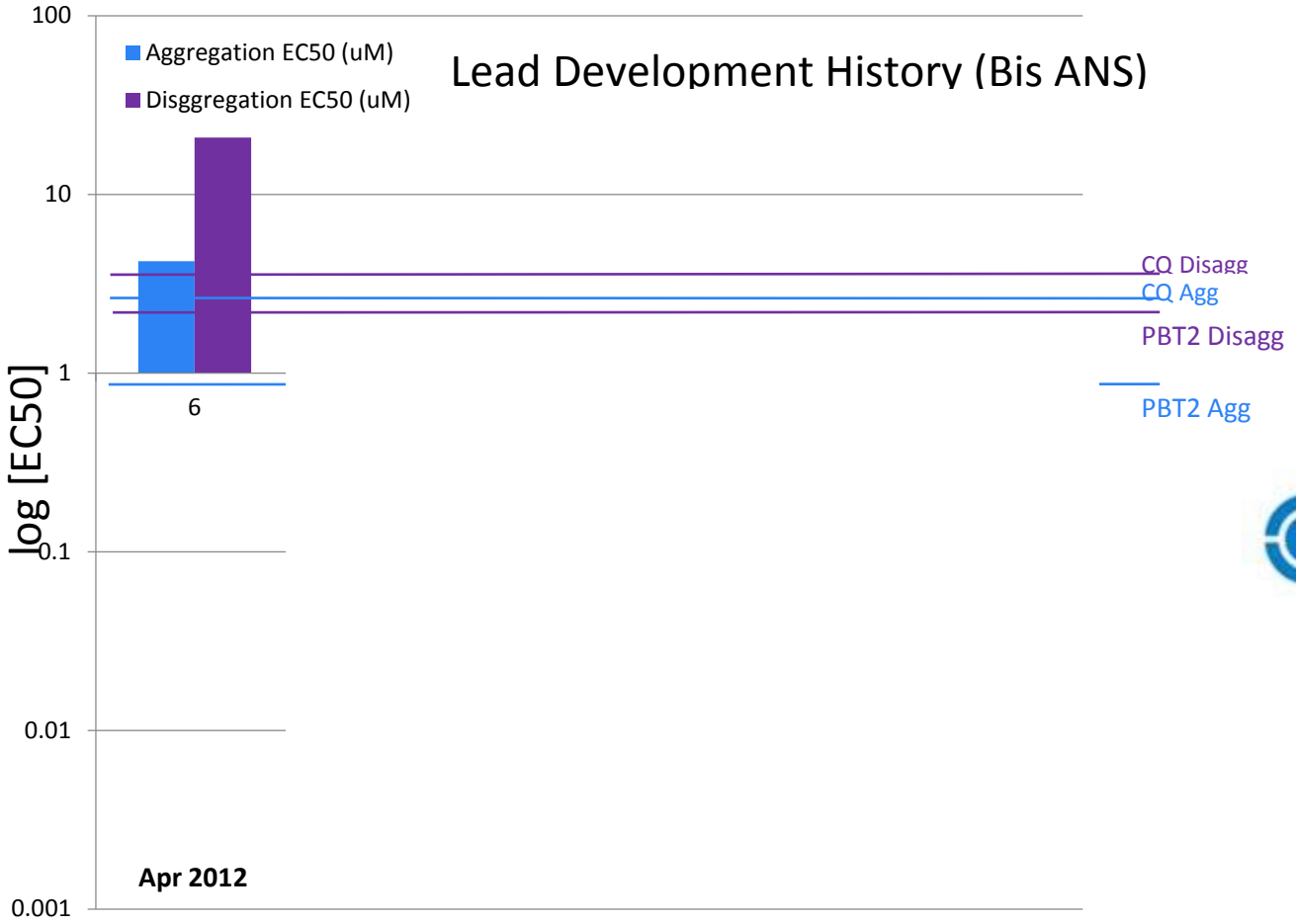
THE MICHAEL J. FOX FOUNDATION FOR PARKINSON'S RESEARCH



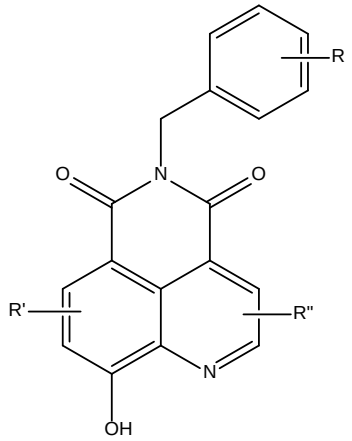
Cu ATSM

"Non-Covalent Derivatives of Metal Complexes and Methods of Treatment"
Warner, John C., Cheruku. Srinivasa R.; *US Pat Application* No. 61/932,348 January 28, **2014**.
"Copper (II) bis(N-alkyl-hydrazinecarbothioamide) Complexes as Non-Covalent Derivatives for the Treatment of CNS Conditions"
Warner, John C., Cheruku. Srinivasa R.; *US Pat Application* No. 61/902,682 November 11, **2013**.

Alzheimer's Disease Therapeutic



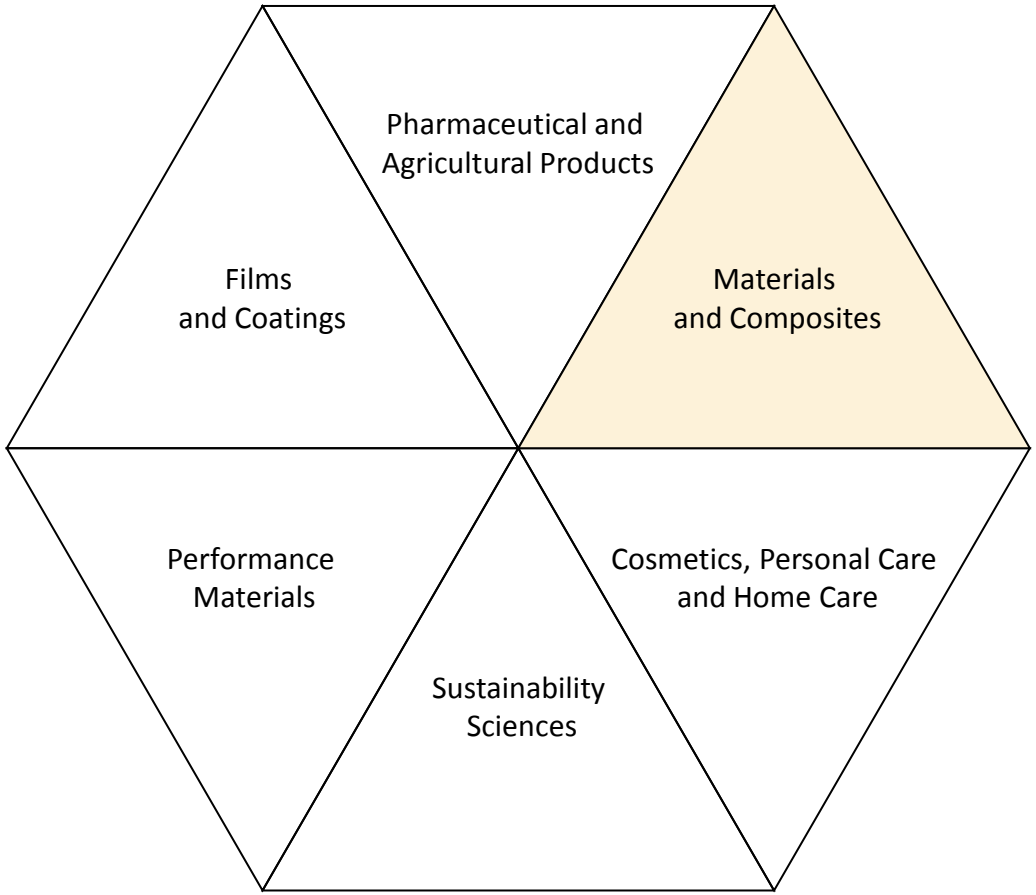
COLLABORATIVE MEDICINAL DEVELOPMENT LLC

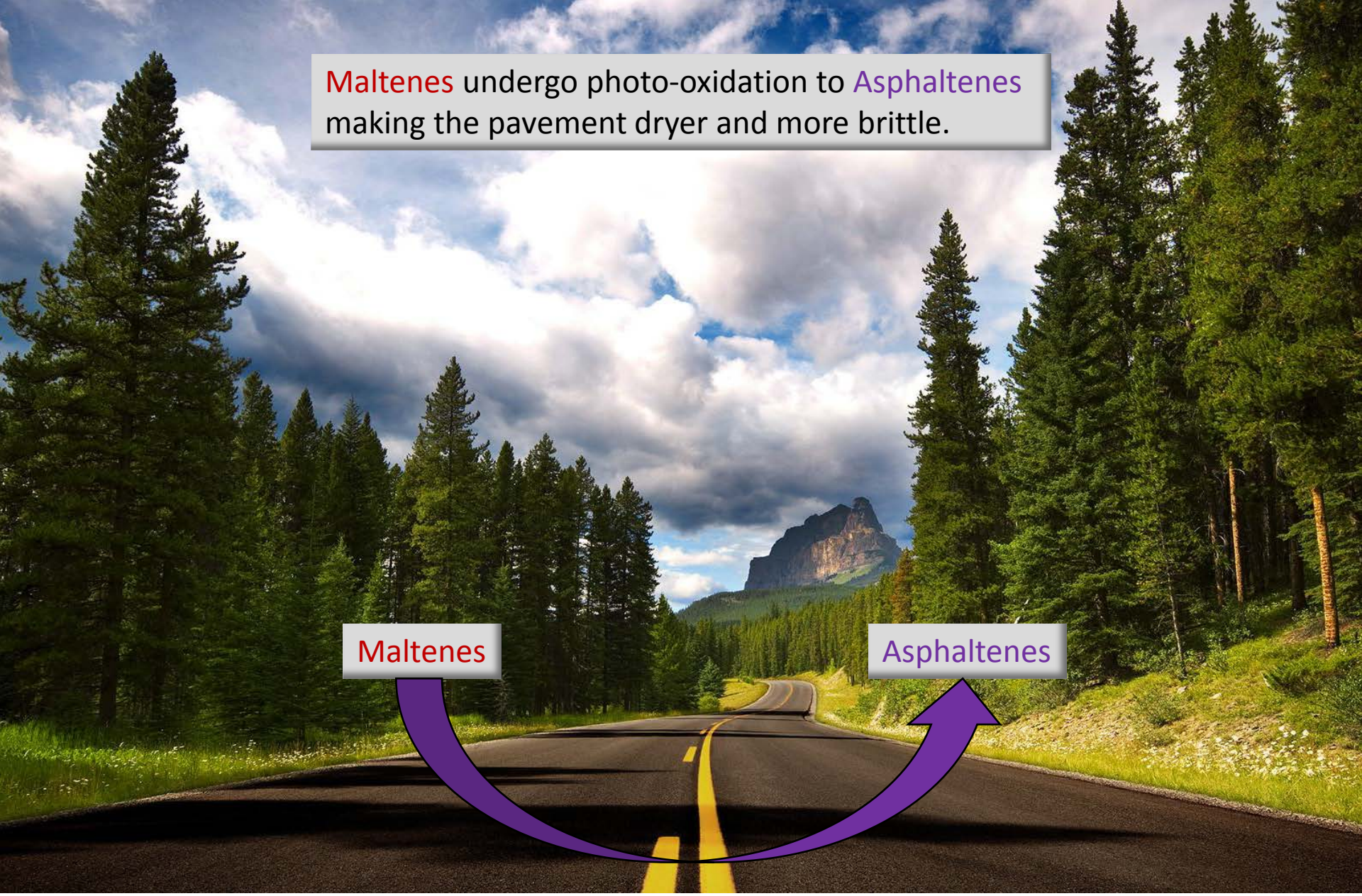


"Dihydro-6-Azaphenalene Derivatives for the Treatment of CNS, Oncological Diseases and Related Disorders" Warner, John C. et al., US PCT Application No.: PCT/US13/62429. September 27, **2013**.

Cthulhunol

Materials and Composites

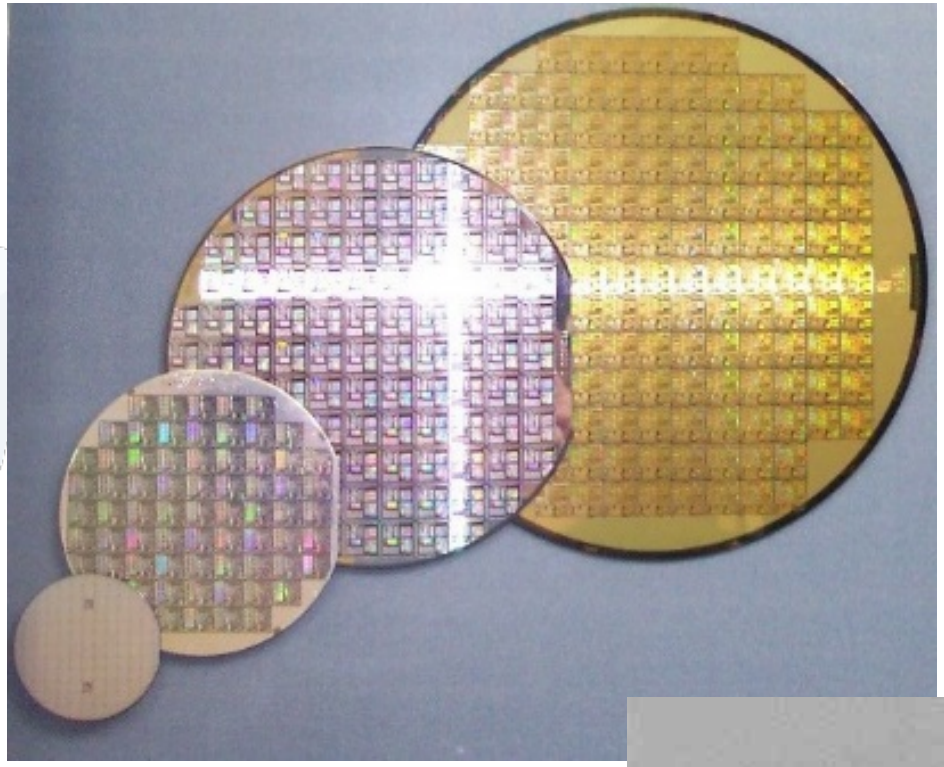



Maltenes undergo photo-oxidation to Asphaltenes making the pavement dryer and more brittle.
Maltenes
Asphaltenes

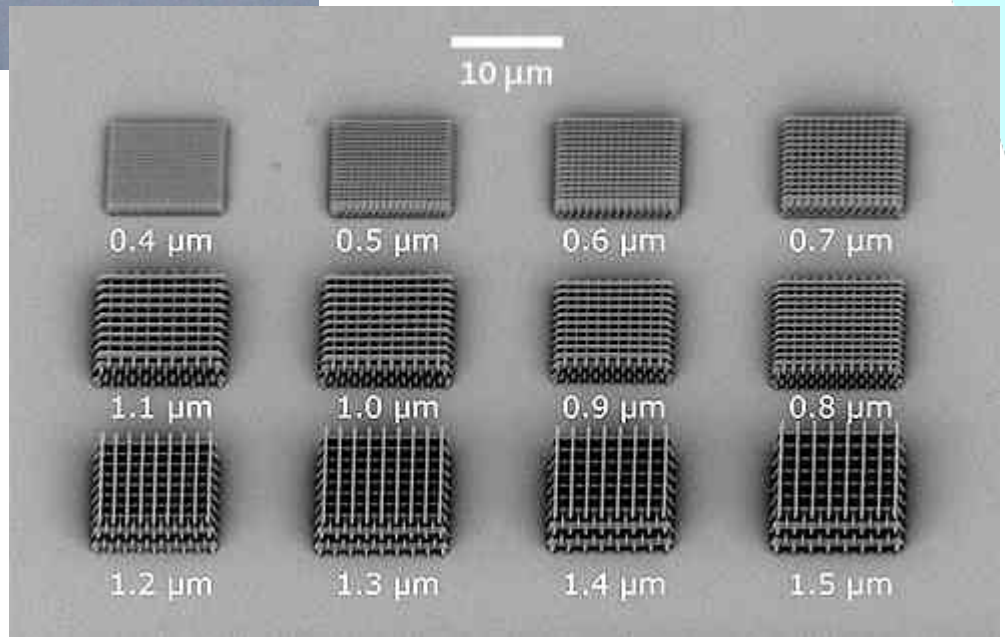
This is world's oldest known photograph made in 1825

It was made by
Joseph Nicéphore Niépce

He exposed a metal sheet coated with asphalt to light in a camera for 8 hours. The areas irradiated by light washed off!



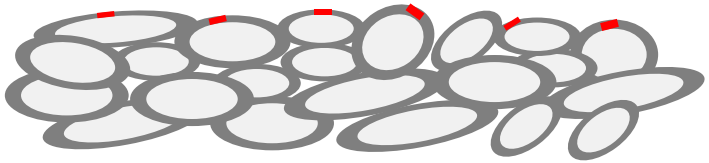
Polaroid


10 µm
0.4 µm
0.5 µm
0.6 µm
0.7 µm
1.1 µm
1.0 µm
0.9 µm
0.8 µm
1.2 µm
1.3 µm
1.4 µm
1.5 µm

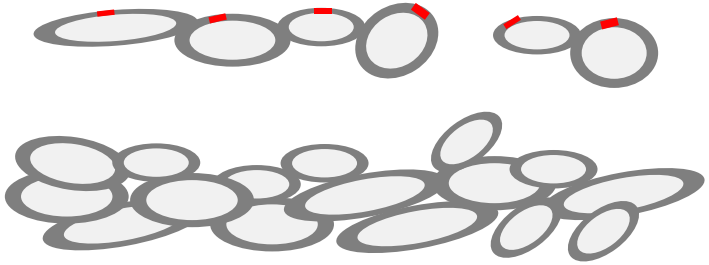
JCW's Patents Involving Photo-imaging Systems at the time

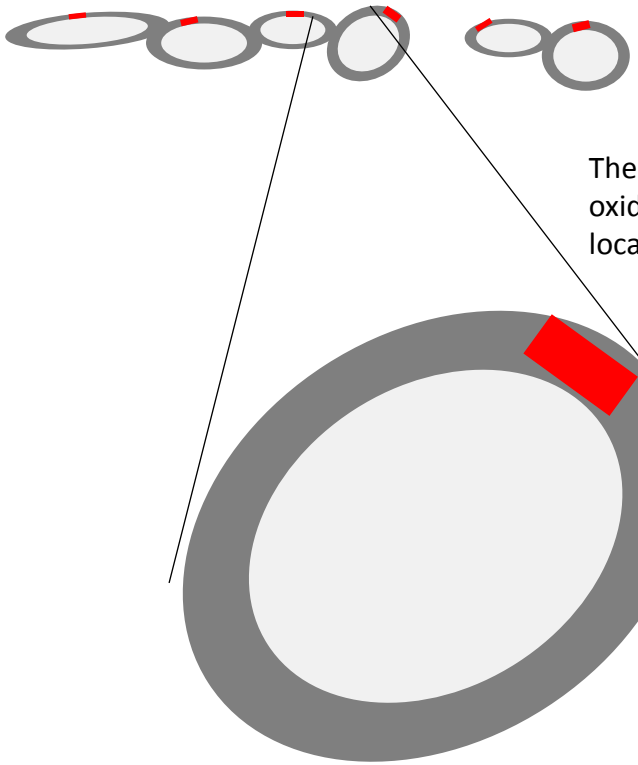
1. "Photoinduced Copolymer Functionalized Substrates" Warner, John C.; Cannon, Amy S.; Dye, Kevin PCT Int. Appl. WO 2007139810. Filed May 23, 2007. Published December 6, 2007.
2. "Methods of solubilizing and recycling biodegradable polymers containing photoreactive moieties using irradiation" Warner, John C.; Morelli, Alessandra; Ku, Man Ching US Patent 6,946,284. Filed November 15, 2002. Published September 20, 2005.
3. "Metal Oxide Films" Warner, John C.; Morelli, Alessandra US Pat. Appl. US 20030054207. Filed July 17, 2002. Published March 20, 2003. PCT Int. Appl. WO 2003008079. Filed July 17, 2992. Published January 30, 2003.
4. "Support containing lewis acid, dye precursor, acidic material and thermal stabilizer." Dombrowski, Edward J.; Guarrera, Donna J.; Jones, Robert L.; Mischke, Mark R.; Warner, John C.; Yang, Jiyue US Patent 5,750,464. Filed April 22, 1997. Published May 12, 1998.
5. "Thermographic Recording Films." Dombrowski, Edward J.; Jones, Robert L.; Warner, John C.; Yang, Jiyue US Patent 5,750,463. Filed April 22, 1997. Published May 12, 1998.
6. "Acid-Catalyzed Thermal Decomposition of Secondary Acid Generator and Formation of Second Acid; Copper Compound and Reactive Material Used to Decompose Superacid Precursor" Marshall, John L.; Baker, Rita Shon S.; Takiff, Larry C.; Telfer, Stephen J.; Warner, John C. US Patent 5,741,630. Filed April 25, 1994. Published April 21, 1998.
7. "Copolymers having pendant functional thymine groups" Grasshoff, J. Michael; Taylor, Lloyd D.; Warner, John C. US Patent 5,708,106. Filed May 3, 1996. Published January 13, 1998.
8. "Photograph Development" Guarrera, Donna J.; Mattucci, Neil C.; Mehta, Avinash C.; Taylor, Lloyd D.; Warner, John C. US Patent 5,705,312. Filed Nov. 25, 1996. Published January 6, 1998.
9. "Photograph System" Guarrera, Donna J.; Mattucci, Neil C.; Mehta, Avinash C.; Taylor, Lloyd D.; Warner, John C. PCT Int. Appl. WO 1997029405. Filed January 21, 1997. August 14, 1997. DE 69701493. Filed January 21, 1997. Published April 27, 2000. EP 0820607. Filed January 21, 1997. Published January 28, 1998.
10. "Images by Exposure to Actinic Radiation; Solvent Removal of Non-Exposed Areas" Grasshoff, J. Michael; Taylor, Lloyd D.; Warner, John C. US Patent 5,616,451. Filed May 24, 1995. Published April 1, 1997.
11. "Process for Fixing an Image, and Medium for Use Therein" Ehret, Anne; Marshall, John L.; Baker, Rita Shon S.; Takiff, Larry C.; Telfer, Stephen J.; Warner, John C. US Patent 5,582,956. Filed April 28, 1994. Published December 10, 1996.
12. "Low-Volatility, Substituted 2-Phenyl-4,6-bis[Halomethyl]-1,3,5-triazine for Lithographic Printing Plates." Fitzgerald, Maurice J.; Kearney, Frederick R.; Liang, Rong-Chang; Schwarzel, William C.; Guarrera, Donna, J.; Hardin, John M.; Warner, John C. PCT Int. Appl. WO 1996034315. Filed April 19, 1996. Published October 31, 1996. CA 2189459. Filed April 19, 1996. Published October 31, 1996. DE 69609136. Filed April 19, 1996. Published August 10, 2000. EP 0767932. Filed April 19, 1996. Published April 16, 1997.
13. "Low-Volatility, Substituted 2-Phenyl-4,6-bis[Halomethyl]-1,3,5-triazine for Lithographic Printing Plate Preparation" Fitzgerald, Maurice J.; Kearney, Frederick R.; Liang, Rong-Chang; Schwarzel, William C.; Guarrera, Donna, J.; Hardin, John M.; Warner, John C. US Patent 5,561,029. Filed April 28, 1995. Published October 1, 1996.
14. "Vinylbenzyl Thymine Monomers and Polymers and Products Prepared from Same" Grasshoff, J. Michael; Taylor, Lloyd D.; Warner, John C. PCT Int. Appl. WO 1995031755. Filed May 10, 1995. Published November 23, 1995. CA 2185144. Filed May 10, 1995. Published November 23, 1995. EP 0759193. Filed May 10, 1995. Published February 26, 1997. DE 69504652. Filed May 10, 1995. Published October 15, 1998.
15. "Process for Fixing an Image" Ehret, Anne; Marshall, John L.; Baker, Rita Shon S.; Takiff, Larry C.; Telfer, Stephen J.; Warner, John C. PCT Int. Appl. WO 95029067. Filed April 25, 1995. Published November 2, 1995. CA 2186514. Filed April 25, 1995. Published November 2, 1995. DE 69506396. Filed April 25, 1995. Published January 14, 1999. EP 0757628. Filed April 25, 1995. Published February 12, 1997.
16. "Vinylbenzyl Thymine Monomers and their use in photoresists" Grasshoff, J. Michael; Taylor, Lloyd D.; Warner, John C. US Patent 5,455,349. Filed May 13, 1994. Published October 3, 1995.
17. "Imaging Medium and Process." Fehervari, Agota F.; Gaudiana, Russell A.; Kolb, Eric S.; Mehta, Parag G.; Taylor, Lloyd D.; Warner, John C. US Patent 5,424,268. Filed May 13, 1994. Published June 13, 1995.
18. "Thermally-Processable Image Recording Materials Including Substituted Purine Compounds." Ford, Maureen F.; Guarrera, Donna J.; Mischke, Mark M.; Pai, Ramdas; Warner, John C. US Patent 5,411,929. Filed June 30, 1994. Published May 2, 1995.
19. "Copolymeric Mordants and Photographic Products and Processes Containing Them" Grasshoff, J. Michael; Taylor, Lloyd D.; Warner, John C. US Patent 5,395,731. Filed May 13, 1994. Published March 7, 1995.
20. "Process and Composition for Use in Photographic Materials Containing Hydroquinones." Taylor, Lloyd D.; Warner, John C. US Patent 5,338,644. Filed December 23, 1992. Published August 16, 1994.
21. "Process and Composition for Use in Photographic Materials Containing Hydroquinones." Taylor, Lloyd D.; Warner, John C. US Patent 5,177,262. Filed July 19, 1991, Published January 5, 1993. EP 0523470. Filed July 3, 1992, Published February 3, 1993. CA 2070450. Filed June 4, 1992, Published January 20, 1993. DE 69218312. Filed July 3, 1992, Published April 24, 1997. JP 06230540. Filed July 16, 1992.

Sunlight and air damage asphalt.



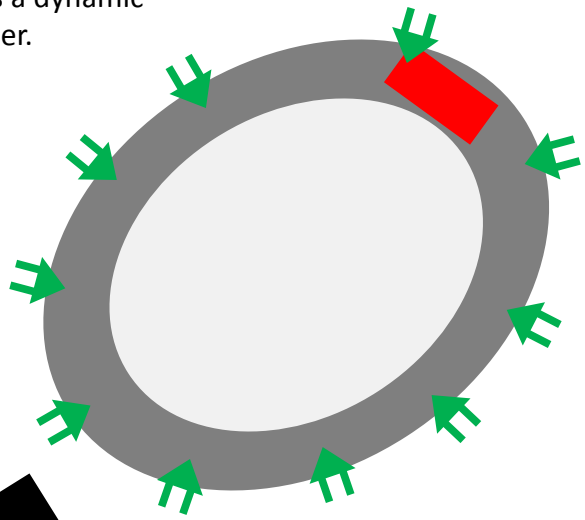
To repair this damage, the top layer is removed and replaced.

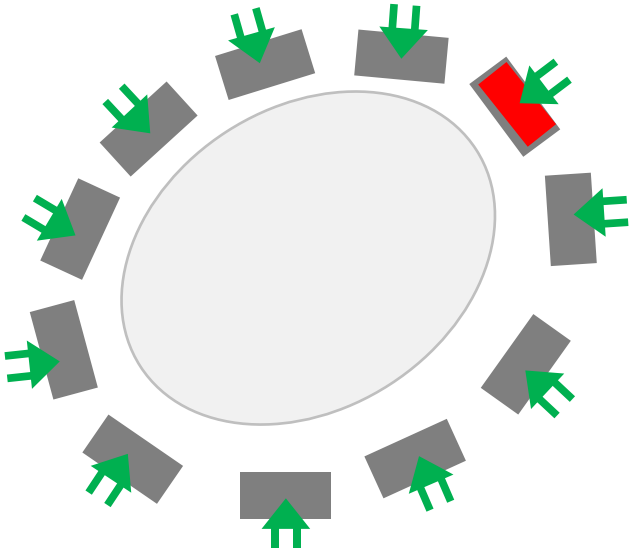




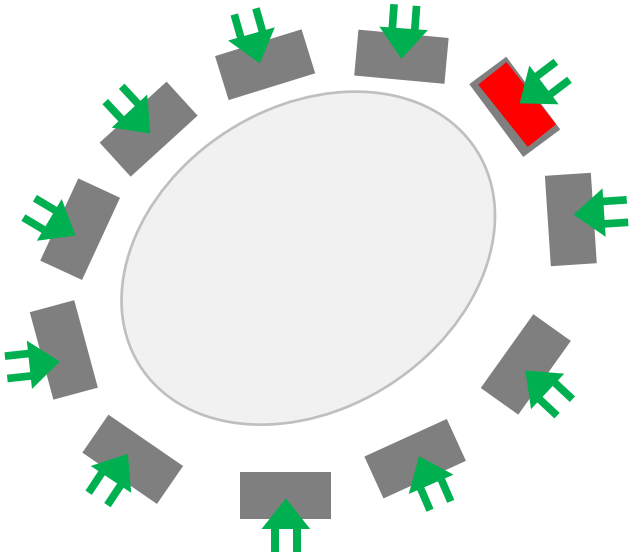
There is only a small amount of oxidized asphalt, but because it is localized it hurts the performance.

Delta-S is a dynamic rheology modifier.

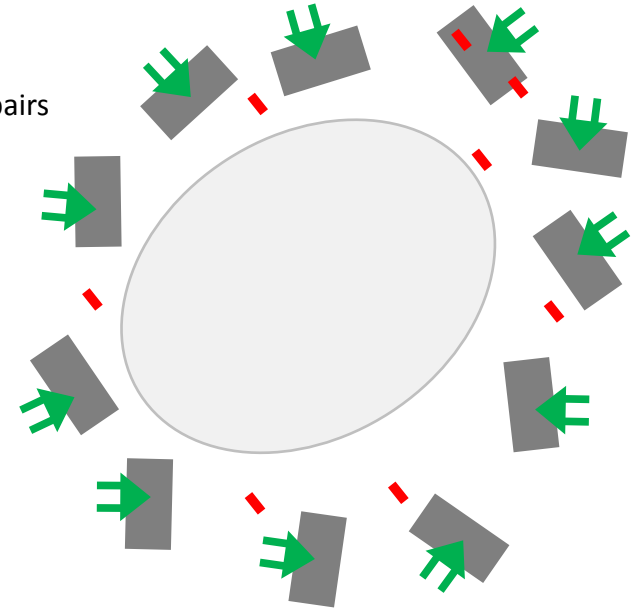




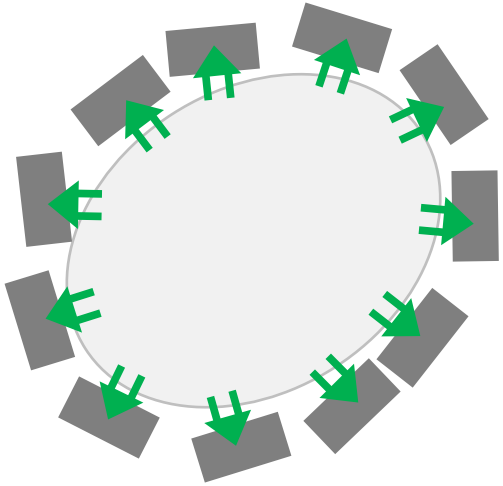
It first helps lift of the damaged asphalt from the aggregate



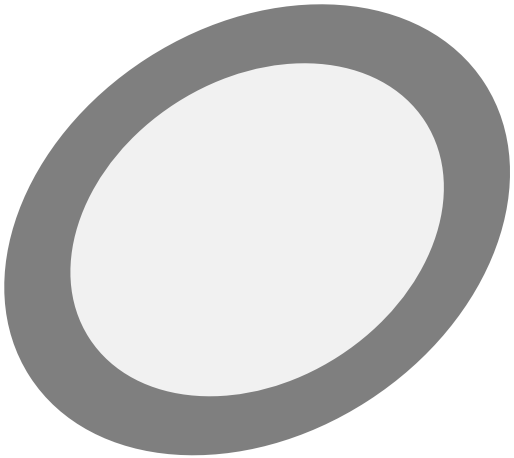
It then distributes and repairs the oxidative damage.

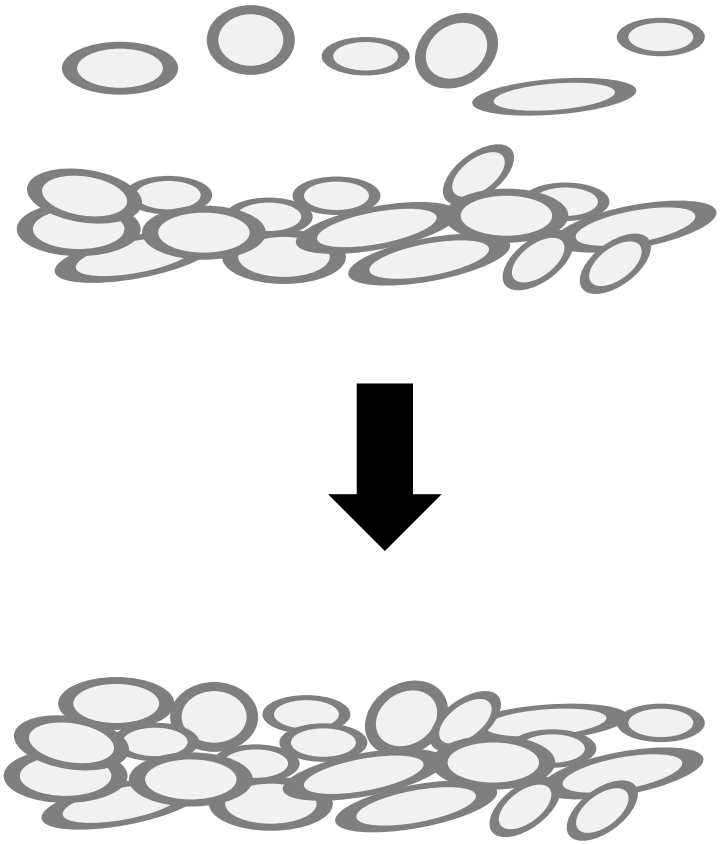


If this is all that Delta-S did, the material would remain soft and never harden.



But the dynamic rheology modifier then reverses behavior and helps re-establish the bonding of the asphalt to the aggregate.





The aggregate is returned to its original state, but now has Delta-S built in to add added future stability.

Construction Materials: Asphalt Paving

COLLABORATIVE AGGREGATES LLC

November 25, 2013

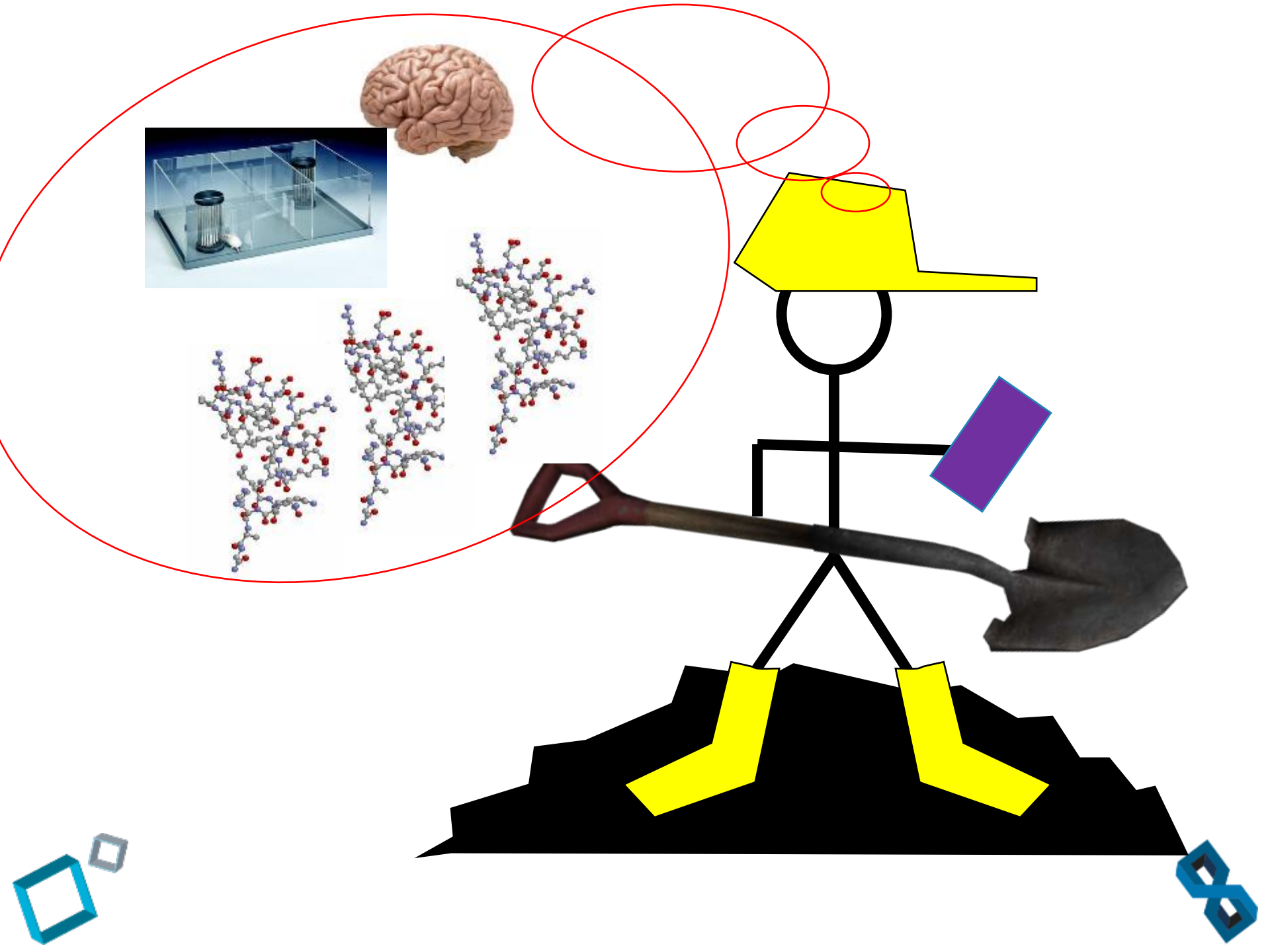
> 50% Recycled Material < 20°F

COLLABORATIVE AGGREGATES LLC

Delta-S

"Asphalt Binder Additive Compositions and Related Materials" Warner, John C., Muollo, Laura R.; Walker, Rowan L., Bianchini, J. R. PCT Int. Appl. WO 2015070180. May 14, **2015**.

"Composition to Rejuvenate Asphalt" Warner, John C., Muollo, Laura R., Walker, Rowan L. *US Pat Application* No. 61/902,706, November 11, **2013**.



Formaldehyde Free Wood Composites

COLLABORATIVE AGGREGATES LLC

Alberta Innovates Technology Futures

"Lignocellulosic Compositions and Methods of Making Same" Warner, John C. et al. US Patent Filed

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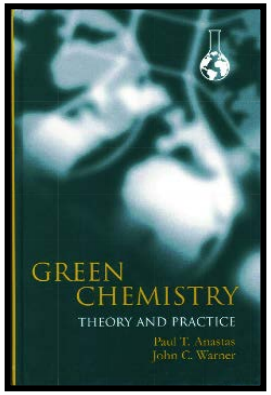
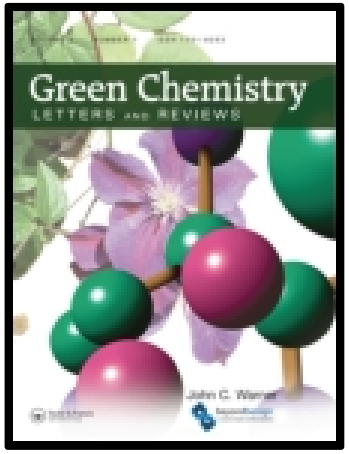


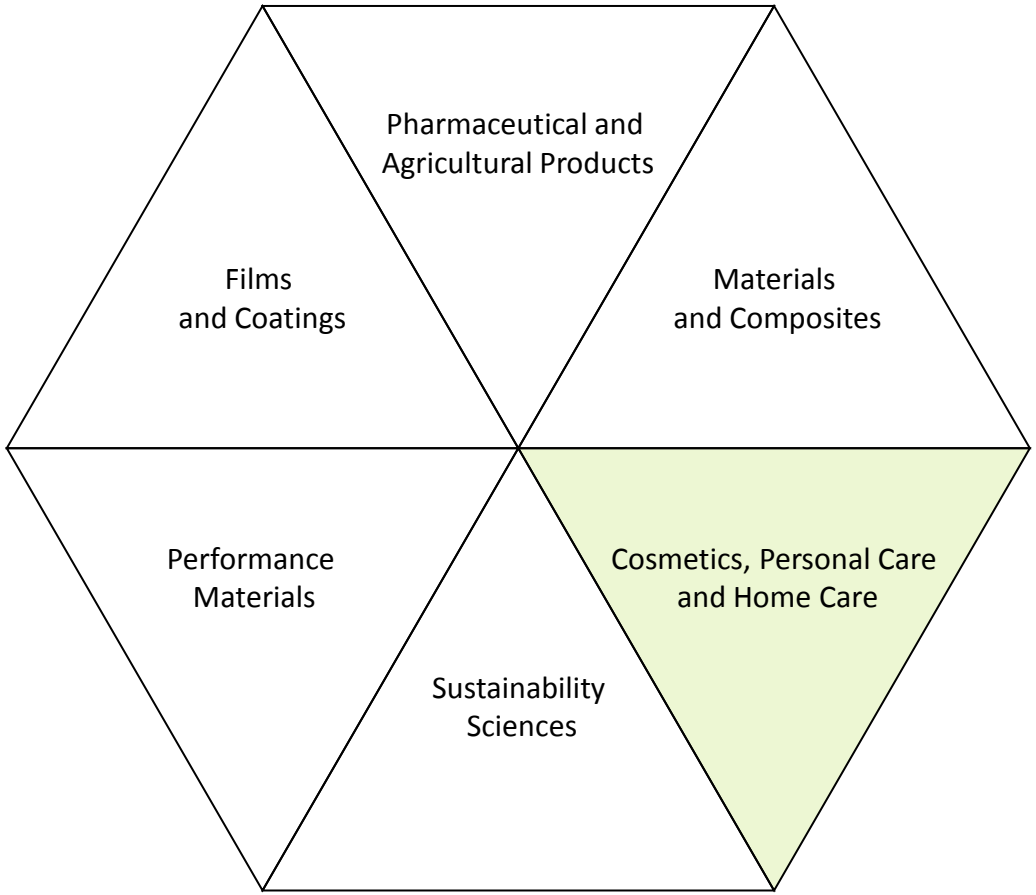


beyondbenign

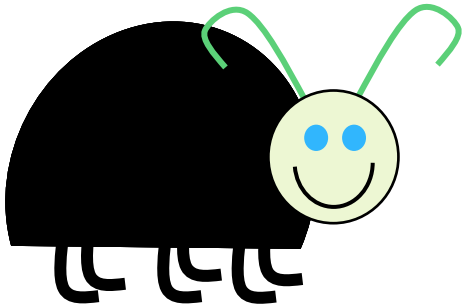
john.warner@warnerbabcock.com

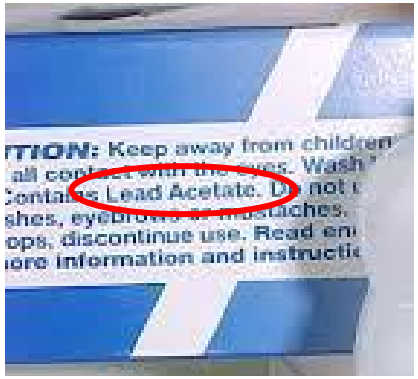
JohnWarnerOrg

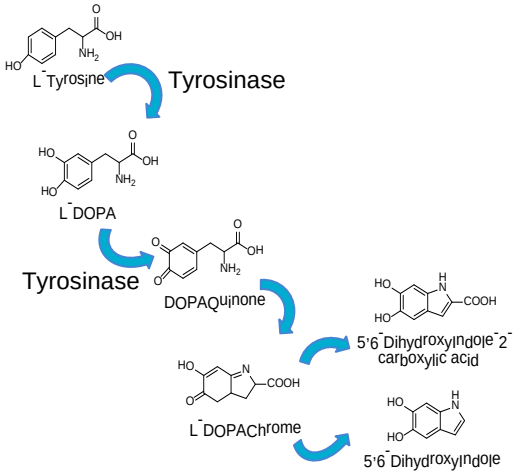
Cosmetics, Personal Care and Home Care



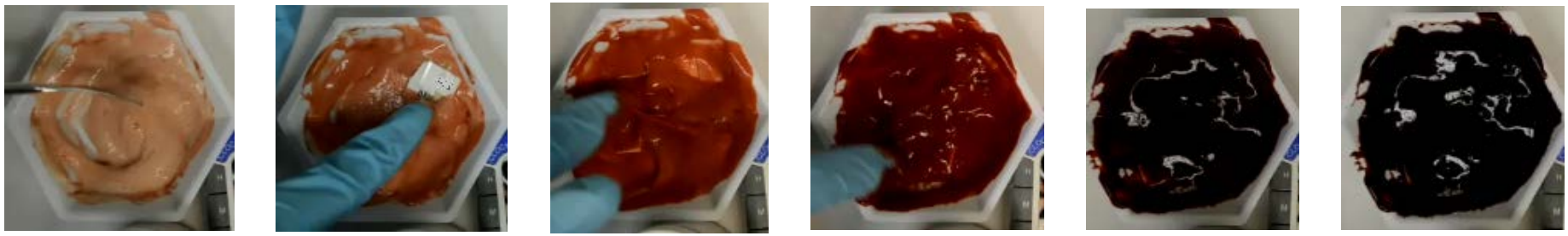
Hair Color Restoration

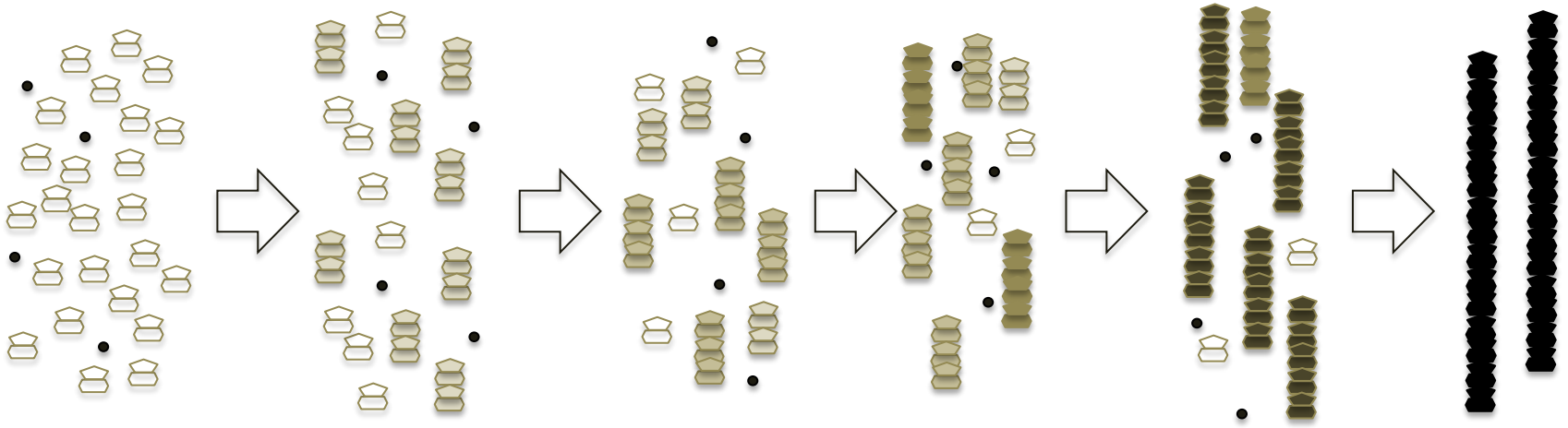


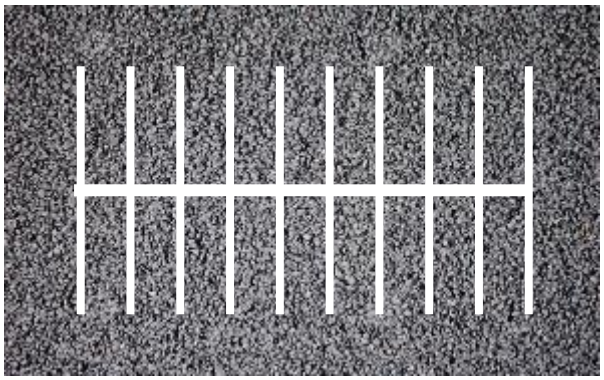


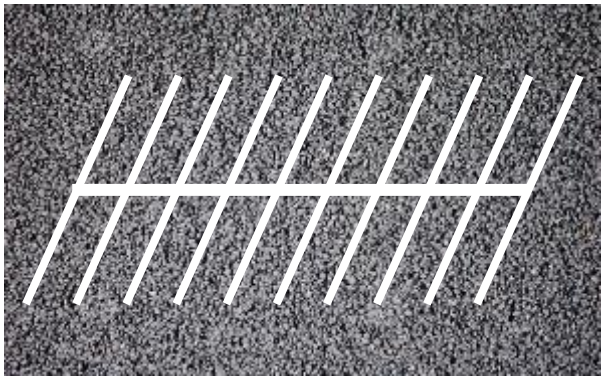


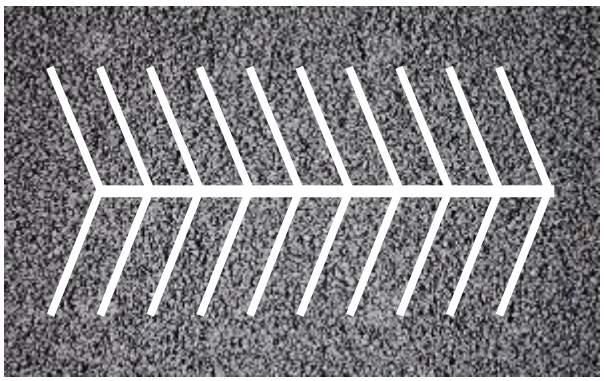
"Formulation and Processes for Hair Coloring" Warner, John C.; Muollo, Laura; Stewart, Amie. US Patent 8,828,100. Filed Oct. 14, 2013. Published September 9, 2014.











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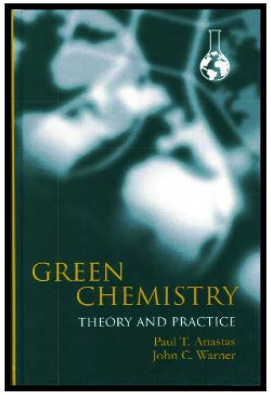
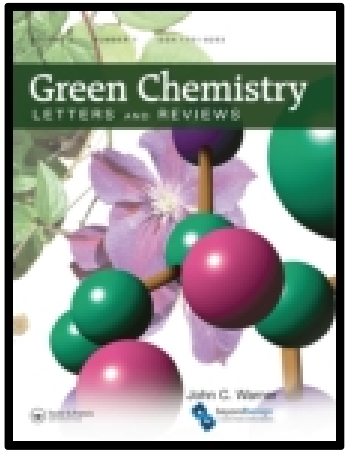


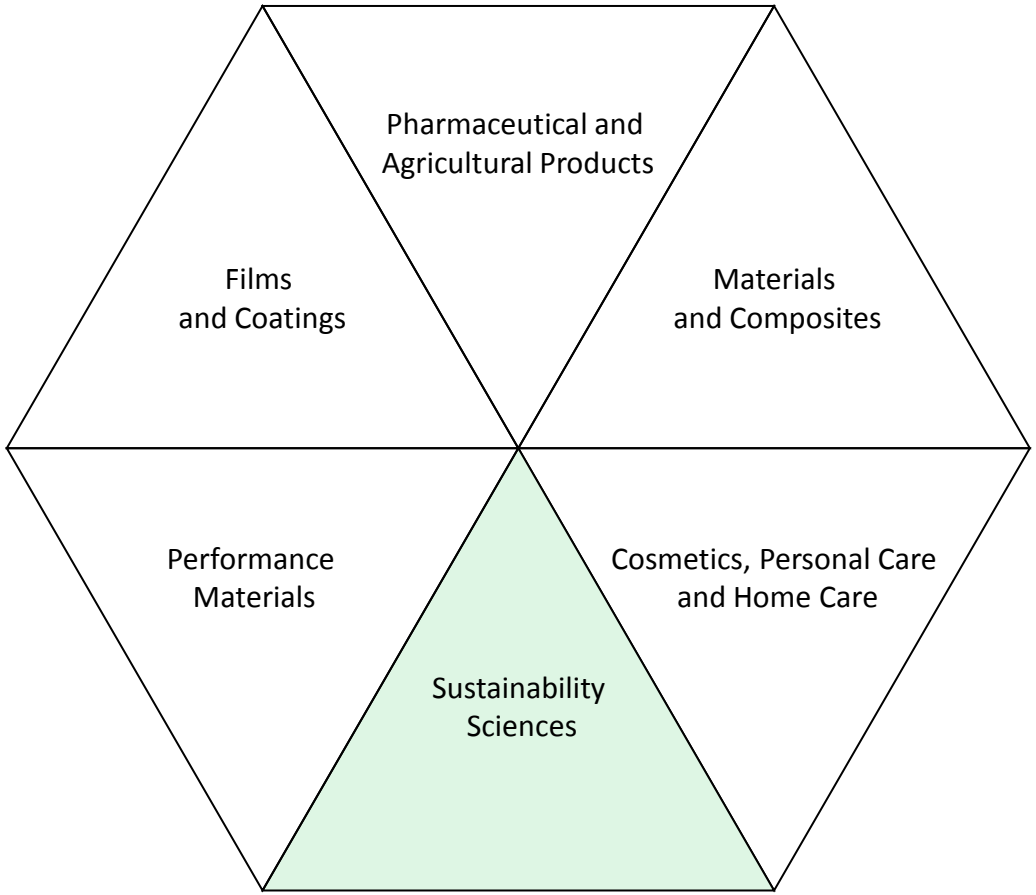


beyondbenign

john.warner@warnerbabcock.com

JohnWarnerOrg

Sustainability Sciences



Ocean Plastics Recycling and Reclamation

June 29, 2015

United Nations

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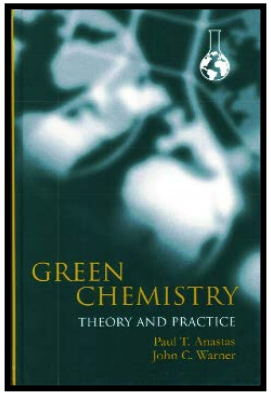

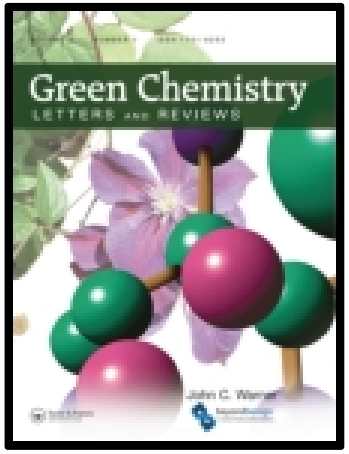

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john.warner@warnerbabcock.com

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