UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GREEN CHEMISTRY

INNOVATION

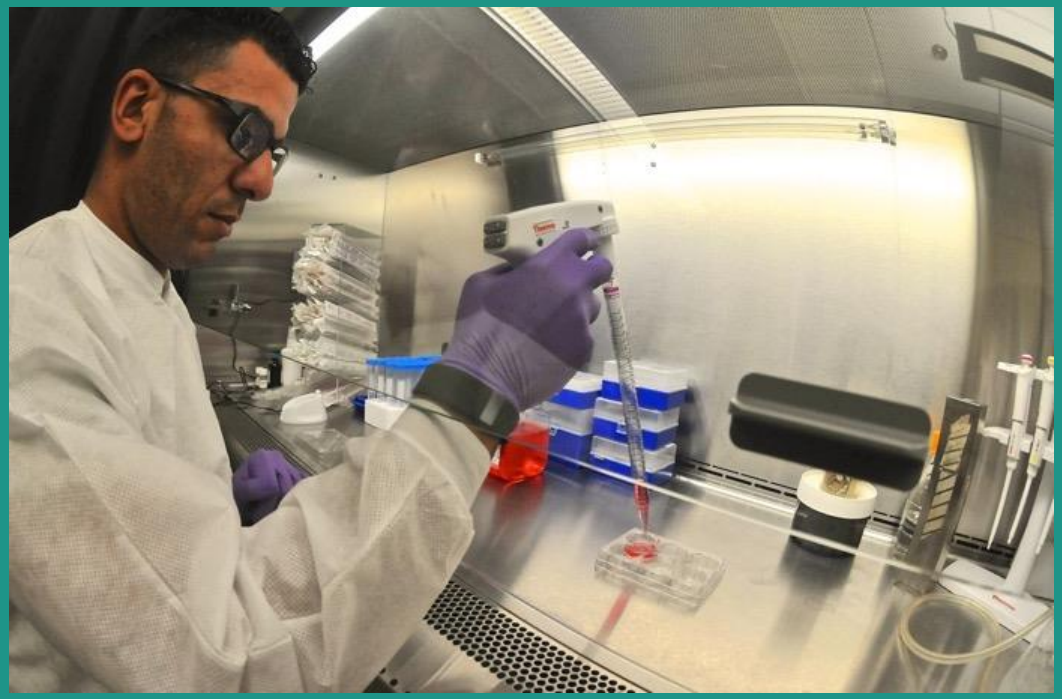


Image: Wikimedia Commons, Refining Innovation, Author: U.S. Army Photo by Sgt. Aaron Ellerman, 204th Public Affairs Detachment

DAY 4 SESSION III
4-DAY PRESENTATION

www.greenchemistry-toolkit.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GREEN CHEMISTRY

Topics To Be Covered

1. Transformative Innovation
   - What is it that we really want?
2. Nature as Inspiration
   - Design Challenges
3. Biomimicry
   - Color
   - Adhesives
   - Self-Cleaning
4. There is Still More We Can Learn from Nature

GREEN CHEMISTRY

Consider the function or service and NOT the product

Original product: Telephone Lines
What we really wanted is long distance communication.

Why not have a cellphone?

Images: WikiCommons

DECAF COFFEE INNOVATION

GREEN CHEMISTRY

Original product: Facility to decaffeinate coffee
What we really wanted is decaffeinated coffee.

Coffee decaffeination using methylene chloride

Why not have coffee beans that don't have caffeine?

Coffee beans without caffeine

Images: WikiCommons

COLORED FABRIC INNOVATION

GREEN CHEMISTRY

Original product: dye for cotton
What we really wanted is colored cotton

Dye produces various colors, but adds cost and waste issues

Why not have a naturally colored cotton?

Naturally colored cotton

Images: WikiCommons, http://www.knittersreview.com/

CLEAN CLOTHES INNOVATION

GREEN CHEMISTRY

Original product: detergent
What we really wanted is clean clothes

Detergent

Why not have self cleaning clothes?

Self-cleaning clothes

Images: WikiCommons

GRASS INNOVATION

GREEN CHEMISTRY

Original product: lawn mower
What we really wanted short grass

Lawn mower

Why not have a no-mow grass?

No-mow grass

Images: WikiCommons

WHAT DOES THAT MEAN FOR THE CHEMICAL INDUSTRY?

GREEN CHEMISTRY

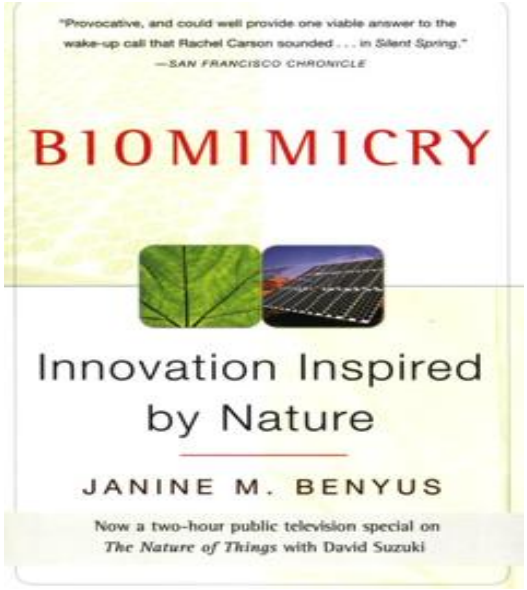
- Color without “dye”?
- Scent without “fragrance”?
- Adhesion without “adhesive”?
- Disinfection without “disinfectant”?
- Solvency without the “solvent”?
- Catalysis without the catalyst?
- Transformation without reaction?

Look to nature for inspiration

HOW NATURE DOES THINGS..

GREEN CHEMISTRY

- Nature runs on sunlight
- Nature uses only the energy it needs
- Nature fits form to function
- Nature recycles everything
- Nature rewards cooperation
- Nature banks on diversity
- Nature demands local expertise
- Nature curbs excesses from within
- Nature taps the power of limits



Janine Benyus, *Biomimicry*

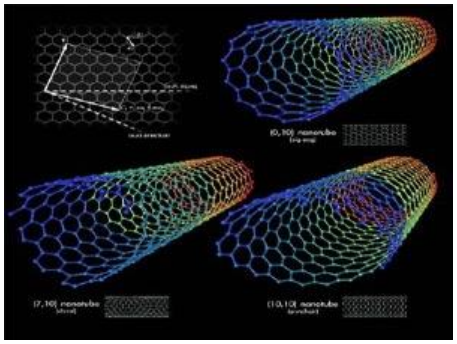
BIOMIMICRY IS NOT NEW…

GREEN CHEMISTRY

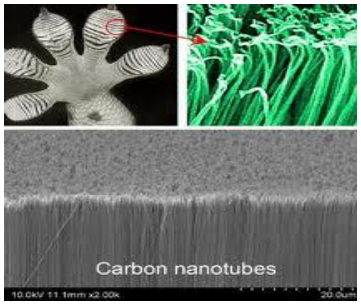
Images: FirstAir, WikiCommons, The Biomimicry Institute

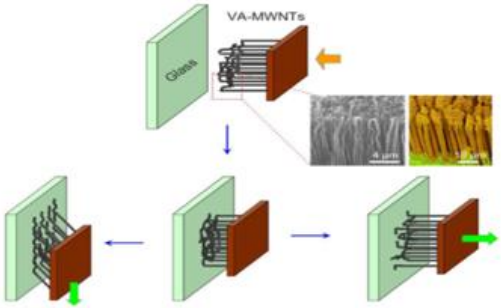
… BUT NOW IT IS MOLECULAR

GREEN CHEMISTRY



We can now imitate the nano-scale design features that give many natural materials some of their most interesting properties





Images: Pinterest (The Church – Micro), WikiCommons, Gecksin™

SOME DESIGN CHALLENGES

GREEN CHEMISTRY

- Filter particulates from air
- Filter water
- Create color
- Detect fire
- Retard fire
- Adhere or join
- Destroy macrobiotic pests / microbiotic pests
- Distribute data / information
- Distribute electricity

OVERVIEW OF INNOVATION

GREEN CHEMISTRY

- Thermal insulation
- Cool or heat (buildings, clothing)
- Remediate soil
- Self-assembling materials
- Prevent corrosion
- Prevent mineral build-up
- Prevent biotic build-up
- Generate energy
- Sterile, disposable packaging

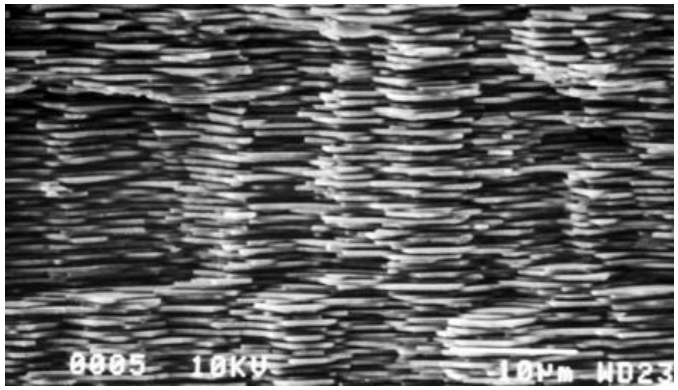
"After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret of survival."

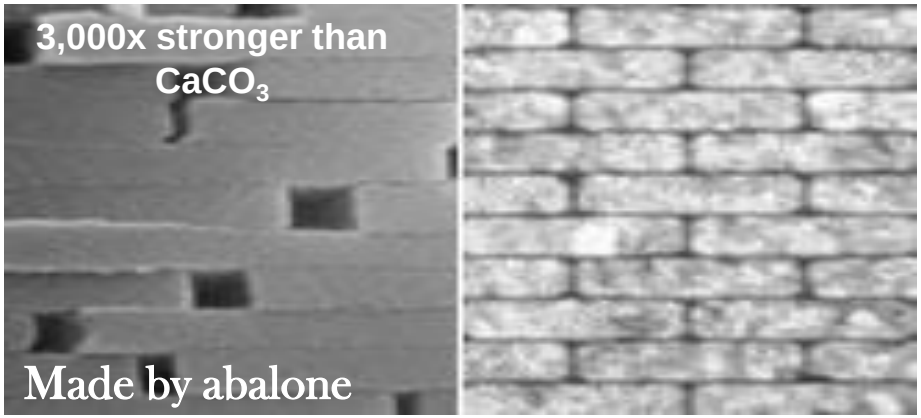
- Janine Benyus

HIGH TECH MATERIALS

GREEN CHEMISTRY

Image: Flickr (Lisa Ann Yount)



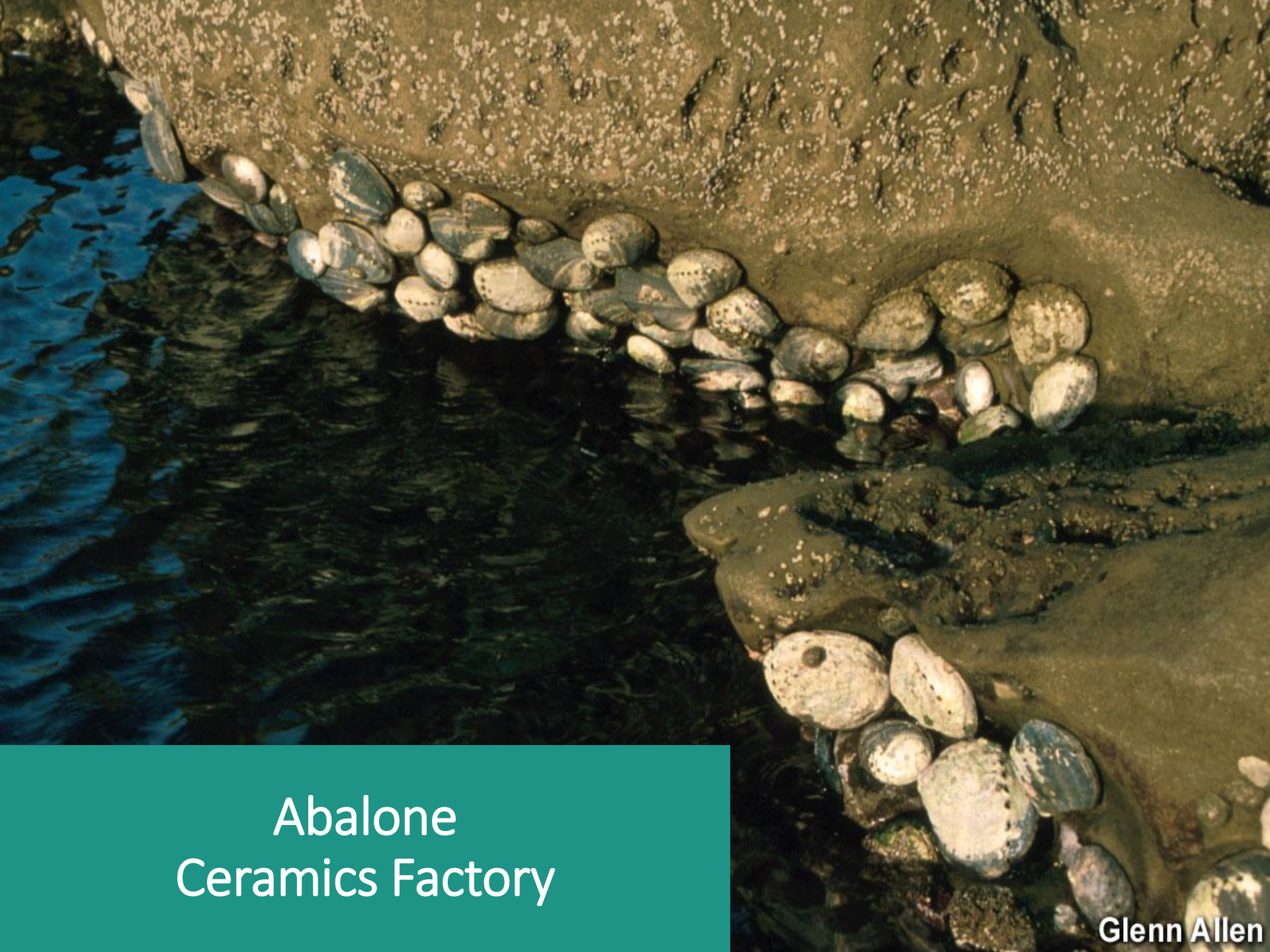


HOW WE MAKE THINGS?

GREEN CHEMISTRY

Image: Pixabay

"Heat, beat, and treat"



Abalone Ceramics Factory

PEACOCK

GREEN CHEMISTRY

Image: Pixabay

How many chemical pigments are needed to produce this assortment of colors?

None! Color is produced through optical interference arising from the surface structure of the feathers

TEXTILES

GREEN CHEMISTRY

Image: www.eveandersson.com/

How many pigments used here?

TEXTILES

GREEN CHEMISTRY

Textiles Enzymes

- Cellulase Enzymes
- Textile Processing Enzymes

Textile Pretreatment Chemicals

- Desizing Agents
- Detergents Agents
- Optical Brighteners Agents

[+] View All

Textiles Finishing Chemicals

- Emulsifiers
- Paraffins
- Polyethylene Waxes

[+] View All

Textiles Dyeing Chemicals

- Anti Creasing Agents
- Defoaming Agent
- Dispersing Agents

[+] View All

Textiles Coating Chemicals

- Butadiene Polymer
- Styrene Polymers

Textile Dye Chemicals

- Acrylic Dye
- Cotton Dye
- Denim Dye

[+] View All

Textile Pigment

- Carotenoids
- Chrome Oxide Pigment
- Fluorescent Pigment

[+] View All

Textile Colorants

- Direct Dyes
- Disperse Dyes
- Reactive Dyes

[+] View All

Textile Polymers

- Acrylic Polymers
- Polyvinyl Alcohol

Finishing Chemicals

- Flame Retardants

The textiles sector uses thousands of chemicals.
Many of them toxic.

DISPLAY TECHNOLOGY

GREEN CHEMISTRY

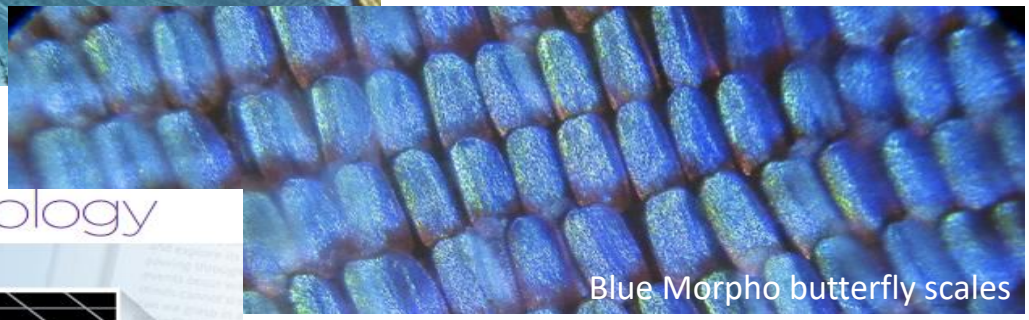


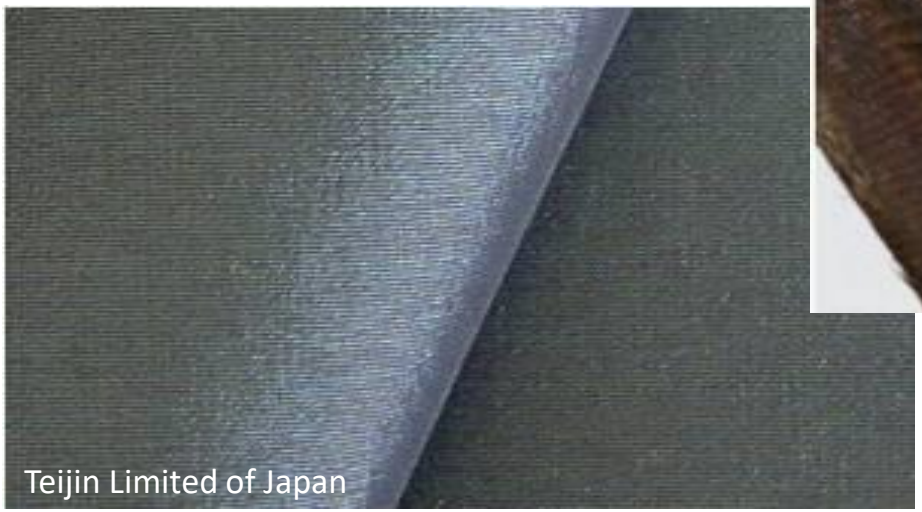
Image: mirasol™

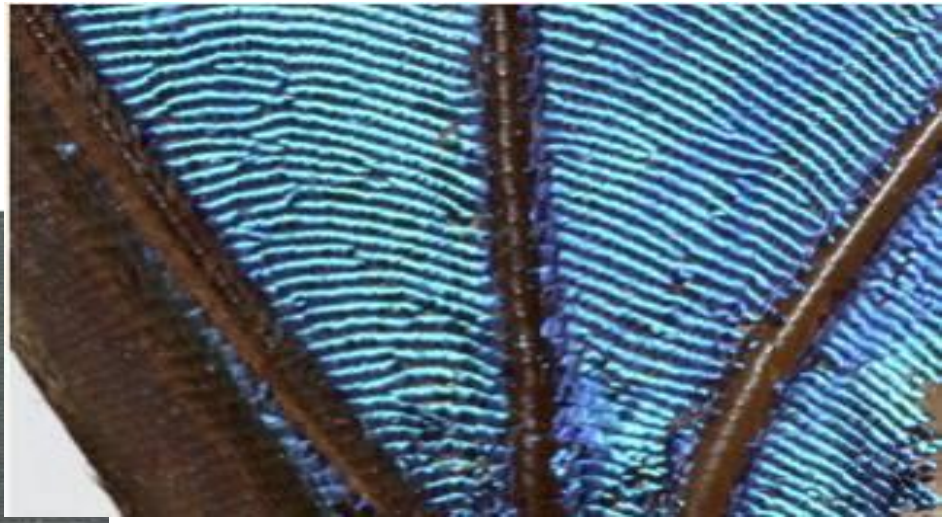
IMOD = InterferometricMODulation

MEMS-based innovation that is *bistable* (low power consumption) and *highly reflective* (display can be see in direct sunlight)

COLOR WITHOUT CHEMICALS

GREEN CHEMISTRY





Morphotex Fibers

- No dyes or pigments
- Color based on varying thickness and structure of fibers
- Reduced energy consumption and chemical release by eliminating dye processes

Image: asknature

ARCHITECTURE

GREEN CHEMISTRY

Photo by Bryony Schwan, License: Attribution

Eastgate Building in Harare, Zimbabwe

90% less energy for ventilation than a comparable conventional building

Image: www.morpho-biomimicry.be/

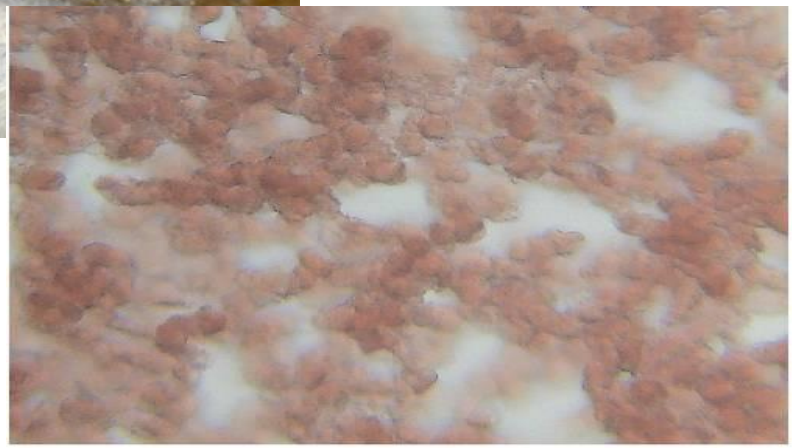
ARCHITECTURE

GREEN CHEMISTRY

Image: WikiCommons

SELF-HEALING MATERIALS AND SYSTEMS

GREEN CHEMISTRY



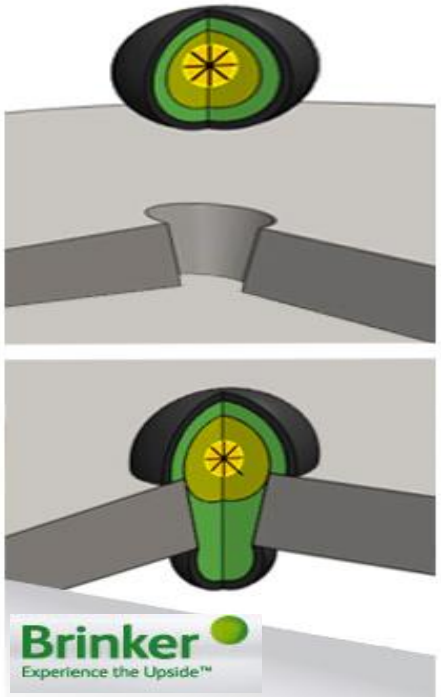
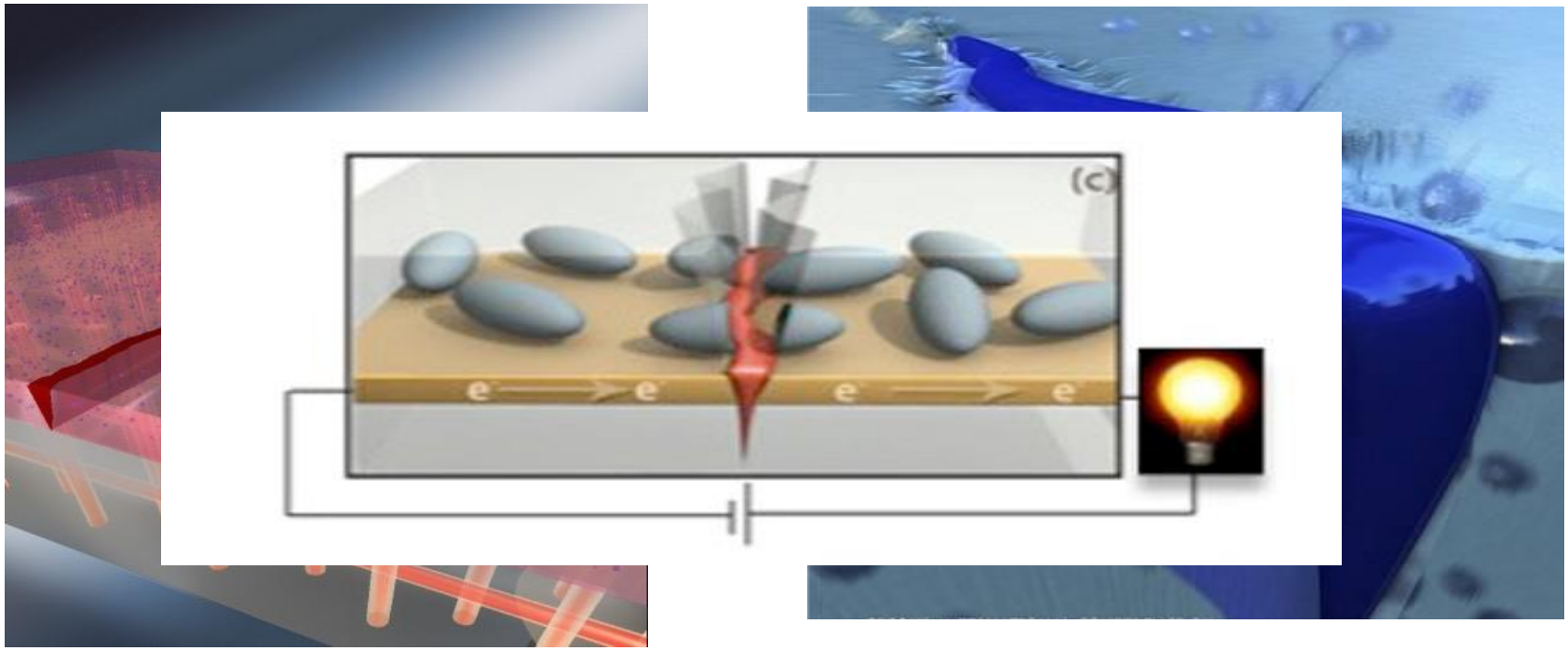


Image: Pixabay, Brinker

SELF-HEALING MATERIALS AND SYSTEMS

GREEN CHEMISTRY



UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

VELCRO

GREEN CHEMISTRY

"I will design a unique, two-sided fastener, one side with stiff hooks like the burrs and the other side with soft loops like the fabric of my pants. I will call my invention 'velcro' a combination of the word velour and crochet. It will rival the zipper in its ability to fasten."

- George de Mestral, 1945

3M

Image: WikiCommons

ADHESIVES

GREEN CHEMISTRY

Mussels
Photo by Sarah Nuehring, License: Attribution Non-commercial Share Alike

Blue Mussel

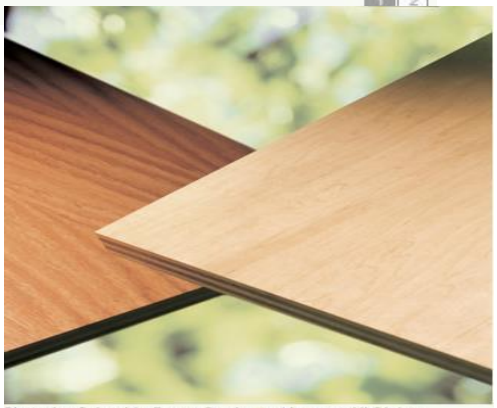


Photo by Columbia Forest Products, License: All Rights Reserved

- **soy-based**
- **formaldehyde-free**

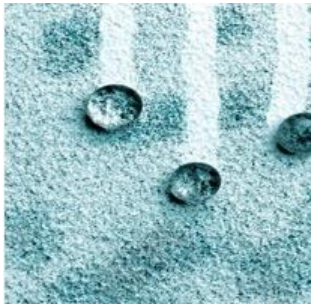
ADHESIVES

GREEN CHEMISTRY

Image: WikiCommons, Geim, A. K. et al. *Microfabricated adhesive mimicking gecko foot-hair*. Nature Materials

CLEANING

GREEN CHEMISTRY

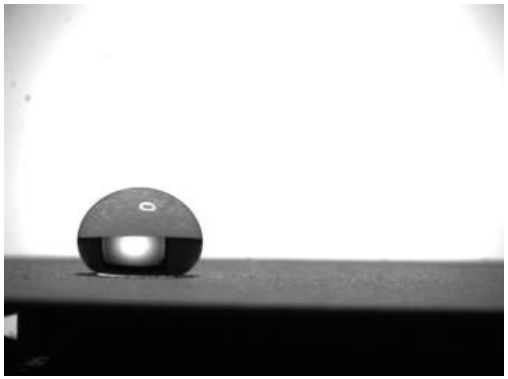


StoCoat Lotusan®

Other uses:

- Clothing waterproofing
- Teflon alternatives
- Glass coating

Lotus Effect



Superhydrophobicity

- The surface structure of lotus leafs minimizes adhesion of dirt particles to the surface

Image: StoCorp, WikiCommons

ORGANIZED CHAOS…

GREEN CHEMISTRY

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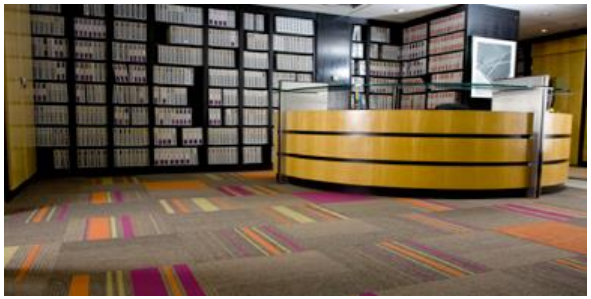
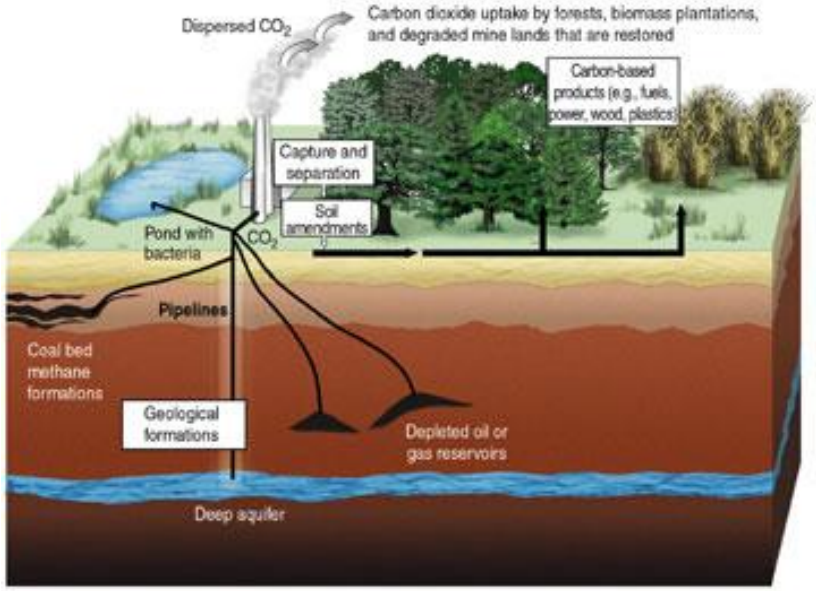
Fall leaves
Photo by Brett Harkey, License: Attribution Non-commercial Share Alike



Interface FLOR™

CARBON SEQUESTRATION

GREEN CHEMISTRY



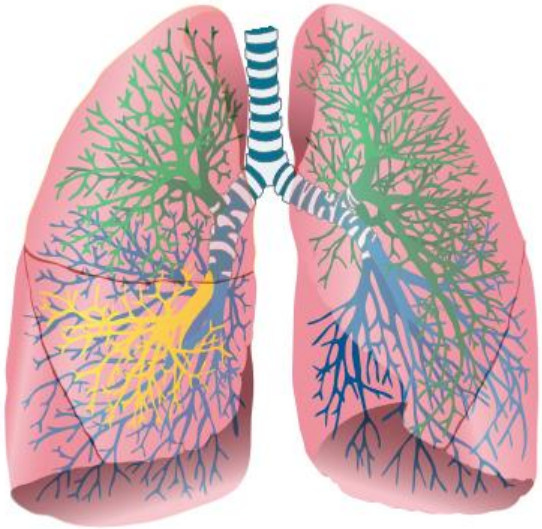


Image: WikiCommons

STILL MORE TO BE LEARNED

GREEN CHEMISTRY

Images: WikiCommons

"Pond scum may be a synonym for 'primitive', but the tiny organisms that compose it easily beat the human state of the art when it comes to capturing energy from the sun. Some purple bacteria answering to that unflattering description use light energy with almost 95% efficiency – more than four times that of the best man-made solar cells."

- University of Southern California news release, August 22, 1994

STILL MORE TO BE LEARNED

GREEN CHEMISTRY

"If the age of Earth were a calendar year and today were a breath before midnight on New Year's Eve, we showed up a scant fifteen minutes ago, and all of recorded history has blinked by in the last sixty seconds."

- Janine Benyus

Images: WikiCommons

TOPICS TO BE COVERED

GREEN CHEMISTRY

1. Transformative Innovation
   - What is it that we really want?
2. Nature as Inspiration
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THANK YOU!

QUESTIONS?

This training material was developed in close collaboration with the Center for Green Chemistry and Green Engineering at Yale University.

www.greenchemistry-toolkit.org