

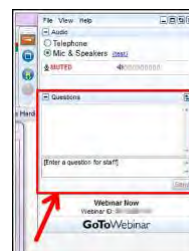
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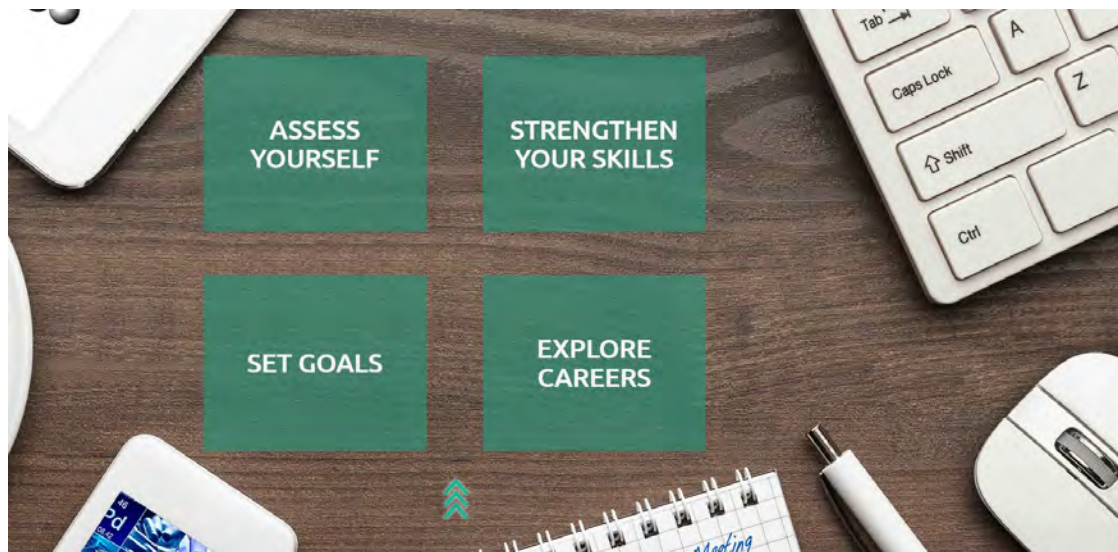
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## Free Resources from CCEW!

### Articles and Activities

- Grades 3-5 (from Science Activities in the Classroom)
  - Disappearing Statues  
See how acid rain eats away at hard materials.
  - Loose the Blues with CO<sub>2</sub>  
Test how much carbon dioxide is in the air using cabbage.
  - Roasting for Drink and Taste  
Use a carrot to learn why earthenware objects act differently in fresh and saltwater.
  - The Fate of Calcium Carbonate  
Calcium carbonate is a chemical found in eggshells, seashells, and many other materials. Observe how calcium carbonate reacts with common liquids.
  - Water Cycle Wristband  
Use colorful beads to help you remember the water cycle.
- Grades 6-8 (from Middle School Chemistry)
  - Carbon Dioxide Can Make a Solution Acidic  
Have students research the effects of too much carbon dioxide in ocean water.
  - Natural Resources & Synthetic Materials  
Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.
- Grades 9-12 (from AACT Chemistry Solutions)
  - Finding Chemistry Connections in Climate Change  
Resources to teach global warming and climate change in your chemistry classroom.
- ACS Student Chapters (from ACS Green Chemistry Institute)
  - From Lobster Shells to Plastic Objects: A Bioplastics Activity  
The official green chemistry activity for CCEW 2018. Do three or more green chemistry outreach or educational activities during the school year for a chance to win a Green Chemistry Student Chapter Award. More information here.



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### Videos



The ABCs of Ocean Acidification (Gordon College ACS Student Chapter)



Should You Pee on a Jellyfish Sting? (ACS Reactions)



How Bacteria Make It Rain (C&EN Speaking of Chemistry)



Do Mega Sharks Still Exist? (ACS Reactions)

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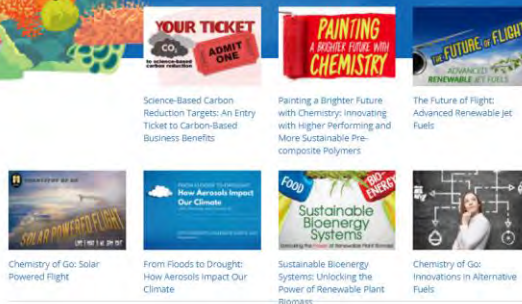
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## "Riding the Wave of Green Chemistry: How to Enhance Awareness of Plastics in the Ocean"



**Jane Wissinger**  
Professor of Chemistry, University of Minnesota, and Senior Principle Investigator, Center for Sustainable Polymers



**Reuben Hudson**  
Research Professor, Colby College

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# *Riding the Wave of Green Chemistry:* How to Enhance Awareness of Plastics in the Ocean



Jane E. Wissinger  
University of Minnesota



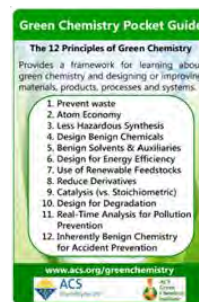
Reuben Hudson  
Colby College



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## Overview

- Experiments developed for the K-12 & college curriculum which introduce:
  - Plastics in society
  - Polymer basics
  - Green/sustainable chemistry solutions
  - (New) sustainable materials
- Feedback from students/teachers
- Resources



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# ENGAGING STUDENTS



## Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



**Today, how many kilograms of plastics does an average person in North America consume each year?**

- 5 kg (11 lbs)
- 25 kg (55 lbs)
- 50 kg (110 lbs)
- 75 kg (165 lbs)
- 100 kg (220 lbs)

[Worldwatch Institute: Vision for a Sustainable World: January 28, 2015,  
http://www.worldwatch.org/global-plastic-production-rises-recycling-lags-0](http://www.worldwatch.org/global-plastic-production-rises-recycling-lags-0)

## Plastics in Society – Attention Grabbers



### World Economic Forum: “Rethinking the future of plastics” January 2016

- Today, **95% of plastic packaging** material value, or \$80-120 billion annually, is **lost to the economy after a short first use**.
- More than 40 years after the launch of the first universal recycling symbol, only **14% of plastic packaging is collected for recycling**.
- In a business-as-usual scenario, **the ocean is expected to contain 1 ton of plastic for every 3 tons of fish by 2025, and by 2050, more plastics than fish (by weight)**.



[http://www3.weforum.org/docs/WEF\\_The\\_New\\_Plastics\\_Economy.pdf](http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf)

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## Plastics in the Ocean – Attention Grabbers



- Currently 250 million metric tons of plastic in the ocean; 5 trillion pieces
- Hazardous to marine life
- Studies show birds are ingesting (Midway-CNN video report)
- Studies show fish are ingesting
- We are ingesting marine life with microplastics



<https://cen.acs.org/materials/polymers/Fighting-ocean-plastics-source/96/116>

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# Plastics in the Ocean



Sperm Whale had 64 pounds of plastic & waste in its stomach

- Typical diet of giant squid
- This whale:
  - Plastic bags
  - Netting
  - Plastic water container
- Died of peritonitis and rupture of digestive system



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<https://www.cnn.com/2018/04/11/health/sperm-whale-plastic-waste-trnd/index.html>

## POLYMER CHEMISTRY GREEN/SUSTAINABLE CHEMISTRY



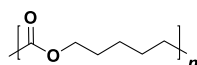
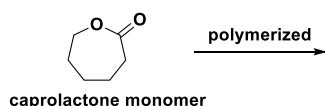
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# Polymer Basics and Unique Properties



## High School

- Definitions
- Size, variety
- Representations
- Tensile testing
- UV/Smartphone apps



For 14 Kg/mol,  $n = 122$

For 45 Kg/mol,  $n = 395$

For 80 Kg/mol,  $n = 697$

## Higher Education

- Classification of polymers
- Representations
- Copolymers (block)
- Calculation of  $M_n$
- $^1\text{H}$  NMR spectroscopy
- IR and  $^{13}\text{C}$  NMR
- UV spectroscopy

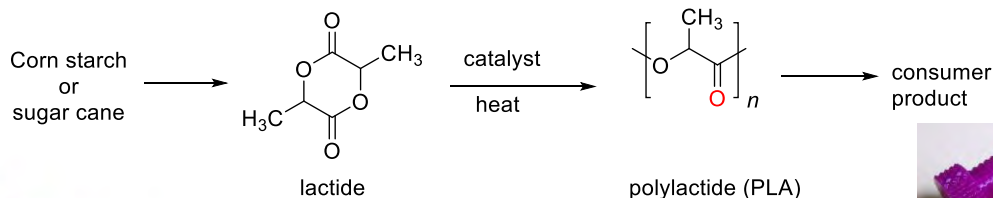


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# Green Chemistry Solutions



- 12 Principles – Prevent pollution!
- Use of renewable feedstocks
- Safer solvents/reaction conditions
- **Design for degradation** (biodegradable; compostable)



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<http://makingsociety.com/2013/08/materialmatters-series-n1-pla-plastic/>

# EXPERIMENTS HIGH SCHOOL/COLLEGE



**Bioplastic films** made from corn (yellow), potato (green), and tapioca (blue) **starch**

## Renewable Triblock Polymer Experiment



- Based on publication<sup>1</sup> and modified for organic chemistry laboratory
- Renewable monomers<sup>2</sup>
- Triblock for tunability and discovery-based<sup>3</sup>
- Interesting mechanical properties



<sup>1</sup>Martello, et al. *ACS Macro Lett* **2012**, *1*, 131-135.

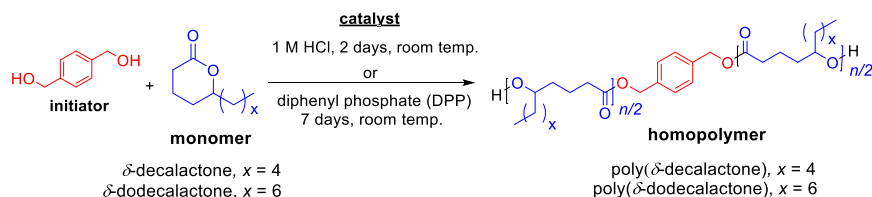
<sup>2</sup>Schneiderman, et. al. *J. Chem. Educ.* **2014**, *91*, p. 131-135.

<sup>3</sup>Fahnhorst, et al. In *Green Chemistry Experiments for the Undergraduate Laboratories*; ACS Symposium Series, **2016**, Chapter 8.

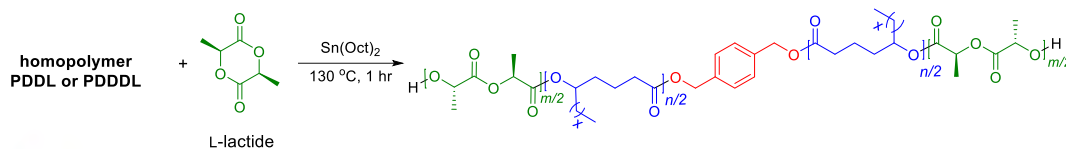
# Renewable Triblock Polymer Experiment



## Day 1: Synthesis of 2 different homopolymers

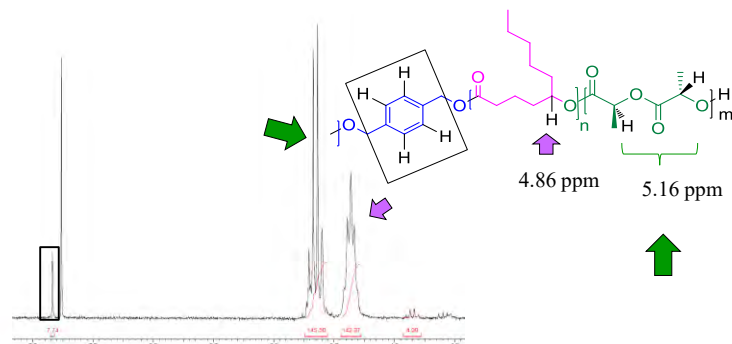


## Day 2: Triblock formation adding L-Lactide



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# Renewable Triblock Polymer Experiment



- Use initiator peaks to approximate  $M_n$  and integrations to determine size of each block polymer
- IR – distinct C=O
- $^{13}\text{C}$  NMR – distinct C=O



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## Renewable Triblock Polymer Experiment

Students design mechanical/physical property testing

- **Flexibility (% PLLA)**
- **Strength** - 1 inch x 0.5 inch strip (~0.5 g) could hold 290 g of clamps and others
- **Degradation** - place in aqueous NaOH solution for minutes, retest strength

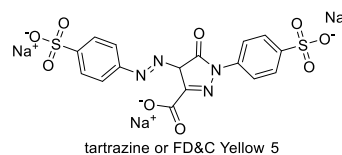
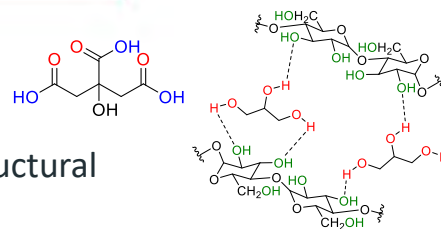
- **Adhesion**



## Dyeing to Degrade: A Bioplastics Experiment



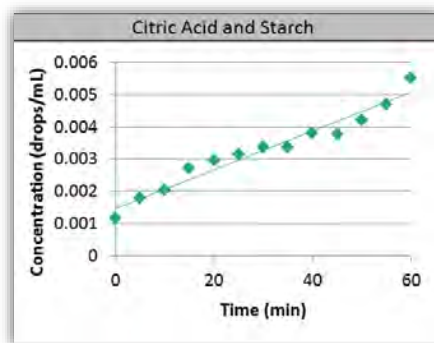
- Renewable, non-toxic components
- Citric acid, glycerol, tapioca root starch
- Three combinations results in three different structural polymers
- FDA approved yellow dye 5 allows degradation studies



# Dyeing to Degrade: A Bioplastics Experiment



- Degradation in aqueous 1 M NaOH (dye stable)
- Release of dye followed by UV Spectrometer or Smartphone App
- Beer's Law plots, graphing, Le Chatelier's principles, polymer structures, plastics in society



 Center for  
Sustainable Polymers

*manuscript in preparation*

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## Polymeric Medical Sutures: An Exploration of Polymers and Green Chemistry<sup>4</sup>



**Part 1:** Drawing Sutures Using Polycaprolactone (PCL)



**Part 2:** Tie-Ability and Tensile Strength Testing



**Part 3:** Testing Degradability of Sutures

### Connection:

Absorbable sutures → biodegradable polymers

Non-absorbable sutures → non-degradable polymers

 Center for  
Sustainable Polymers

<sup>4</sup>Knutson, C. M. et al. "Polymeric Medical Sutures: an Exploration of Polymers and Green Chemistry," *J. Chem. Educ.* **2017**, 94 (11), 1761-1765.

<https://csp.umn.edu/labs/>

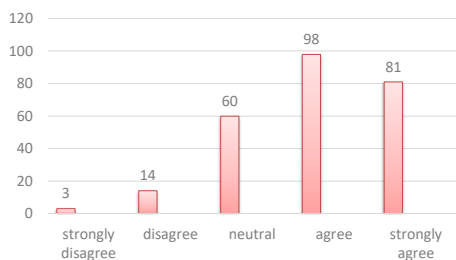
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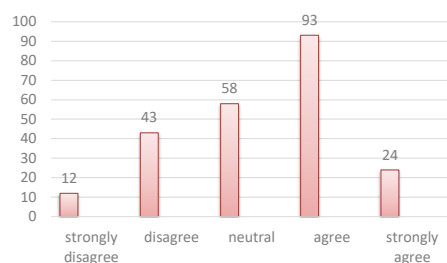
## Student Feedback



*"I enjoyed learning about renewable and degradable polymers by performing this experiment."* (Fall 2017, 256 responses)



*"The material associated with the sustainable polymer experiment enhanced my awareness of plastics in the ocean."* (Spring 2018, 230 responses)



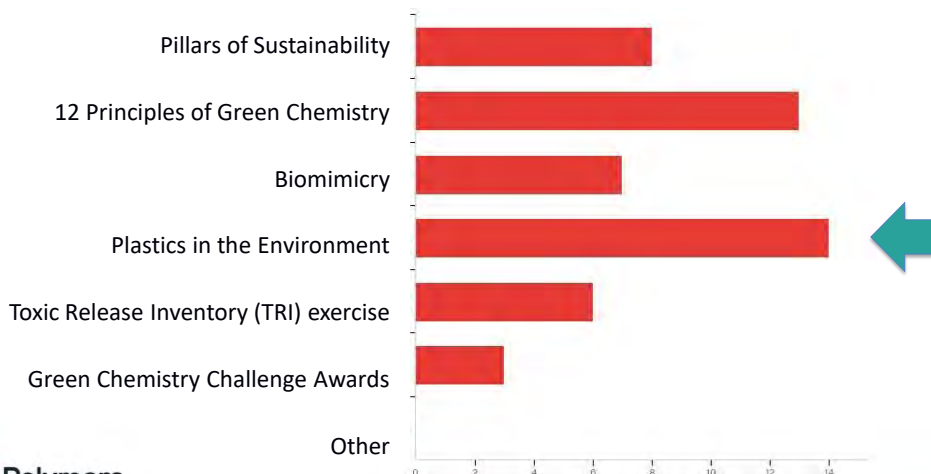
*"I think this was an interesting way to introduce the concept of sustainability as increased waste and plastic use is a current issue that is good for us to learn about."* – Ochem student 2014



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## Green & Sustainable Chemistry Workshop for High School Teachers – Summer 2017

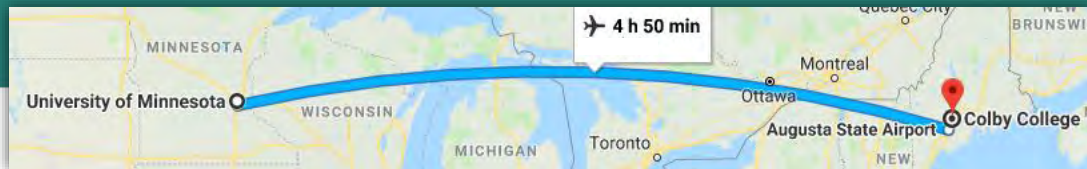
*Which green chemistry/sustainability lecture content are you likely to add to your curriculum?*



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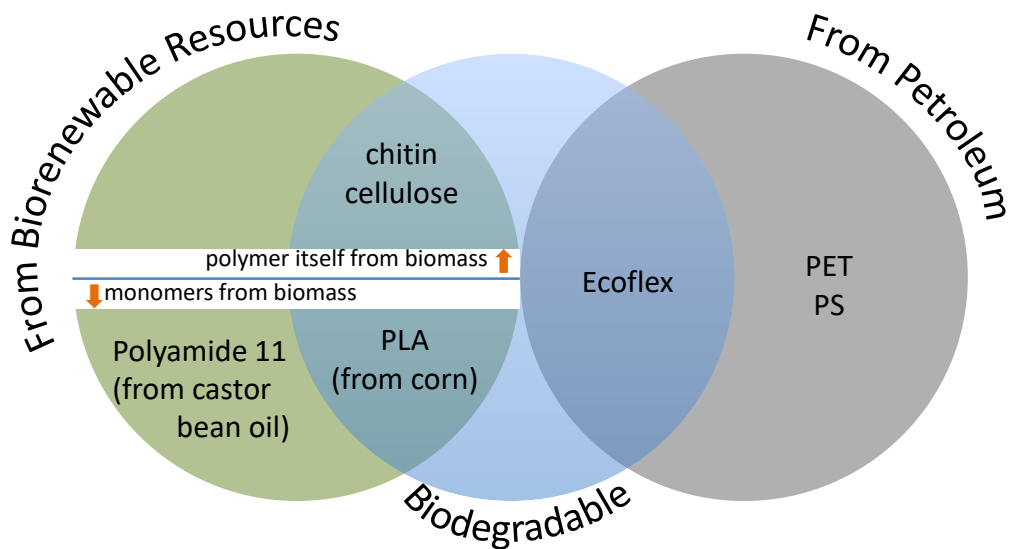


# REUBEN HUDSON



## K-12 Outreach: Lobster Shells to Plastic Objects





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## Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



**Of the 320 million tons of plastic produced each year, what percent is sourced from biomass?**

- 1 percent
- 2 percent
- 5 percent
- 10 percent
- 25 percent

<https://www.european-bioplastics.org/market>

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# Earth Abundant



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# Inexpensive



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## Audience Challenge Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

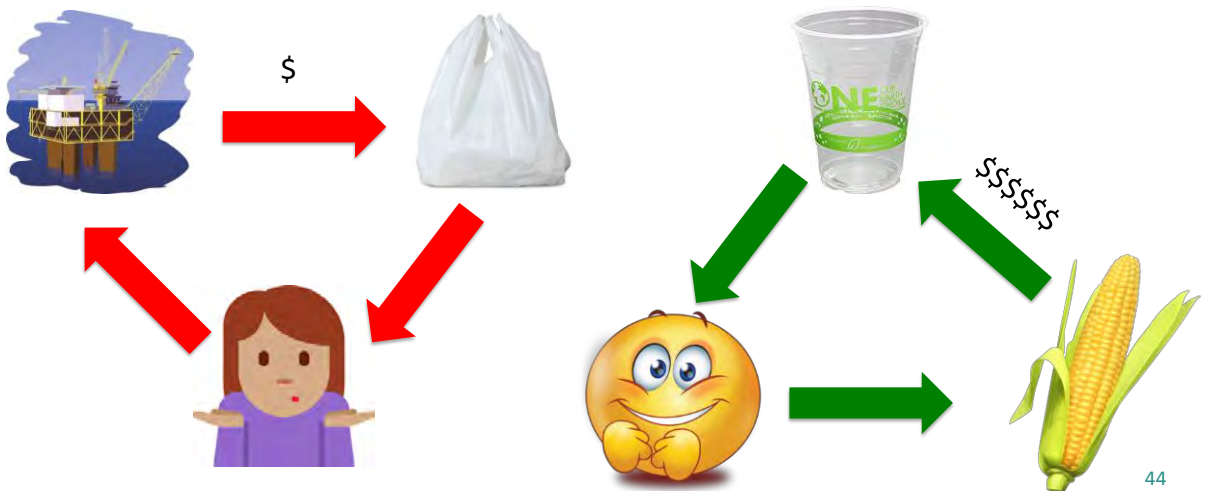


**Which of the following polymers is most expensive (kilogram scale, Alibaba):**

- low density poly propylene
- polystyrene
- chitin
- poly lactic acid

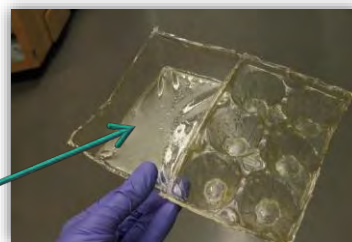
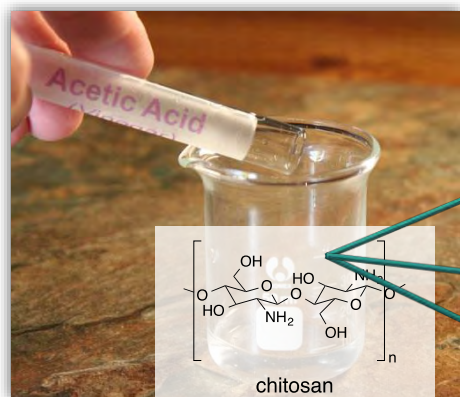
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## Economics of Bioplastics



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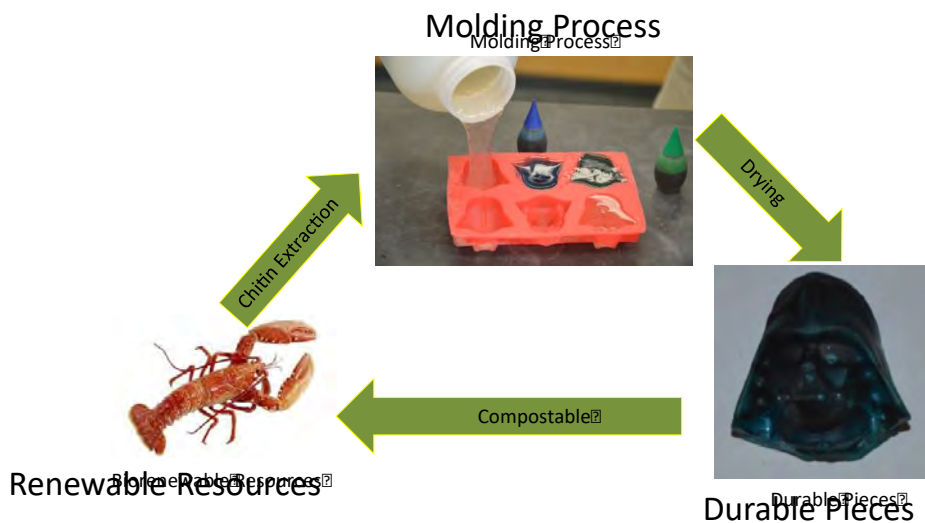
## Processing – in the lab



Macromol. Mater Eng., 2014, 291 (1), 932-938.

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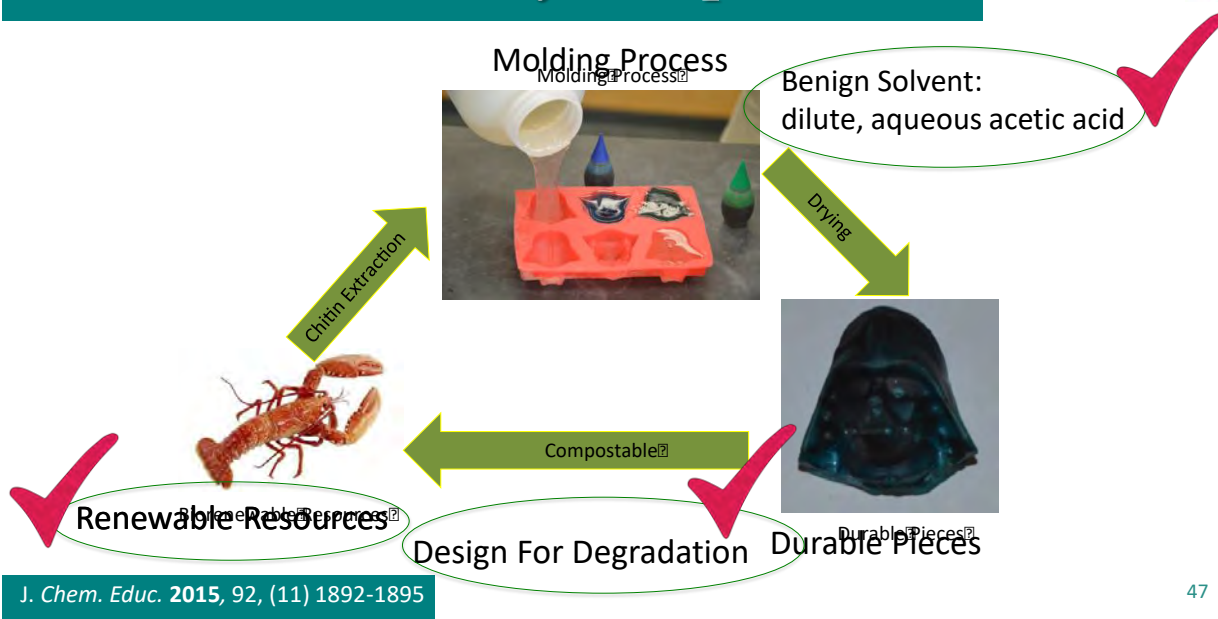
## Processing – in the classroom



J. Chem. Educ. 2015, 92, (11) 1892-1895

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# Green Chemistry Perspective



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# Why we care

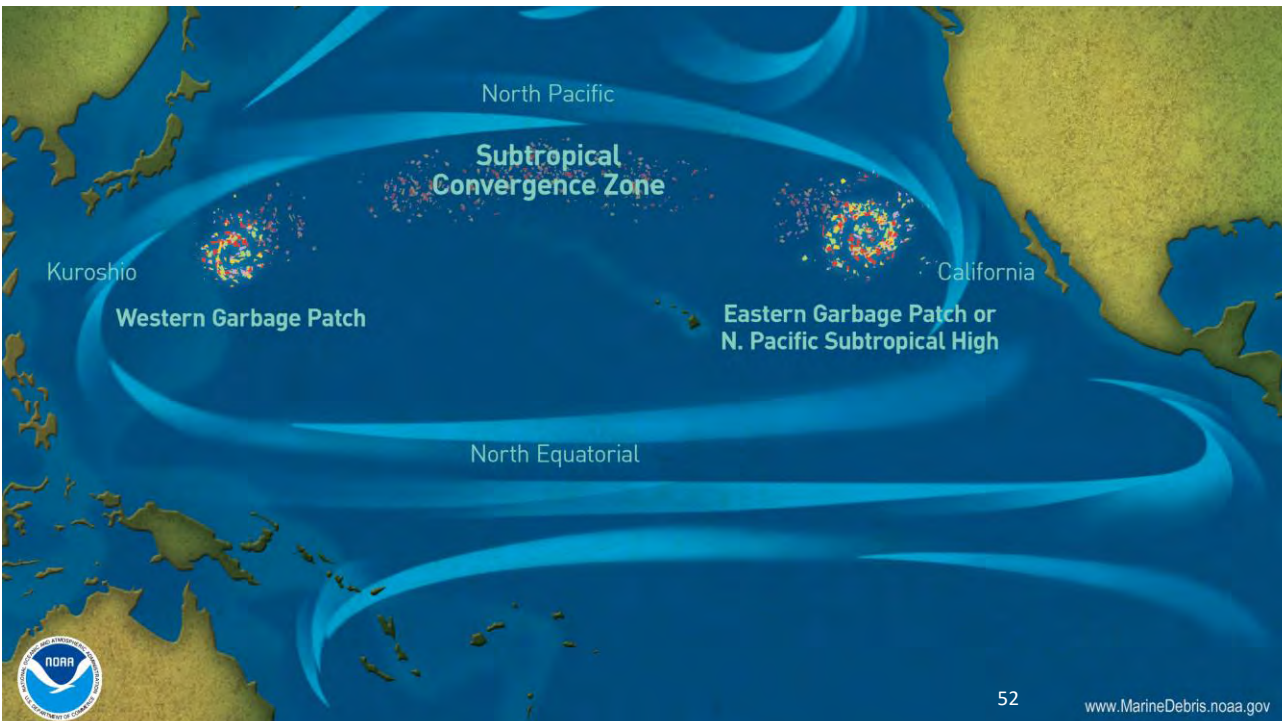


How does trash make it to the ocean?

How can the ocean stem tide of trash?



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[www.MarineDebris.noaa.gov](http://www.MarineDebris.noaa.gov)

## Conclusions: Polymer content for all levels

- Topic **relevant and engaging** to all levels
- **ACS major accreditation** includes macromolecules
- Tunable properties enable **inquiry based pedagogies**
- Exploring mechanical properties covers **engineering principles** (next generation science standards)
- Awareness → Science → Solutions



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## More to think about

- Reduction of single-use items
- More infrastructure for collecting/recycling waste
- 'Mining' oceans for discarded plastic to recycle or recover energy



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# Acknowledgements

## Experiment Development:

### Triblock

Debbie Schneiderman  
Grant Fahnhorst  
Dr. Michael Wentzel  
Zachary Swingen  
Christa Blaquiere  
Chad Gilmer  
Tomohiro Kubo

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Dr. Perry Wilbon  
Cassandra Knutson  
Constance Anderson  
Dr. Angela Perkins

### Medical Sutures

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Ming Yu  
Cassidy Javner  
Dr. Mark Distefano

### Lobster Bioplastics

Jeff Katz  
Sam Glaisher  
Alex Bishop

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Center for Sustainable Polymers (NSF Center for Chemical Innovation)

Margaret A. Cargill Scholarship Fund (Augsburg College)

Department of Chemistry, University of Minnesota

NSF Science, Education and Engineering for Sustainability Fellowship

Department of Chemistry, Colby College

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*“Riding the Wave of Green Chemistry: How to Enhance Awareness of Plastics in the Ocean”*



**Jane Wissinger**  
Professor of Chemistry, University of Minnesota, and Senior Principle Investigator, Center for Sustainable Polymers



**Reuben Hudson**  
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Sustainable Bioenergy Systems: Unlocking the Power of Renewable Plant Biomass

**Chemistry of Gas: Solar Powered Flight**  
Chemistry of Gas: Solar Powered Flight

**From Floods to Drought: How Hazards Impact Our Climate**  
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*“Riding the Wave of Green Chemistry: How to Enhance Awareness of Plastics in the Ocean”*



**Jane Wissinger**  
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