Penn State RET in Interdisciplinary Materials

Teacher's Preparatory Guide

The Lotus Effect: Lithographic Reproduction of the Blue Morpho Butterfly

Purpose This lab is designed to help students understand the lotus effect and how the measurement of contact angles can indicate the level of hydrophobicity of a material. Students will also learn about the process of lithographic reproduction.

Objectives

- To produce PDMS molds of butterfly wings in an effort to compare the level of hydrophobicity of a replicated model to a real specimen
- To observe contact angle measurements greater than 150 degrees (superhydrophobicity) in specified locations on the butterfly wing
- To demonstrate how research can solve real world problems
- To show how past and current science researchers are using the "lotus effect" for improving the working and living conditions on the International Space Station

Time required about 8 class sessions (Each class session is approximately 50 minutes long)

Level Middle school

Benchmarks

SC.6.N.1.3
Explain the difference between an experiment and other types of scientific investigation, and explain the relative benefits and limitations of each.

SC.6.N.1.5
Recognize that science involves creativity, not just in designing experiments, but also in creating explanations that fit evidence.

SC.7.N.1.2
Differentiate replication (by others) from repetition (multiple trials).

SC.7.N.3.2

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Identify the benefits and limitations of the use of scientific models.

SC.7.N.1.5
Describe the methods used in the pursuit of a scientific explanation as seen in different fields of science such as biology, geology, and physics.

Teacher Background

Many naturally-occurring surfaces such as plant leaves and butterfly wings have unusual physical properties due to their structure at the micro- and nanoscale. For instance, the leaves of the lotus plant are extremely hydrophobic due to tiny bumps on its surface (sometimes called the "lotus effect"). Water beads up on these surfaces and rolls off, taking dirt with it, such that the lotus leaves are left clean and dry. Since such self-cleaning capabilities are appealing for consumer products, scientists have been studying natural surfaces such as the lotus leaf to learn new ways of building these capabilities into synthetic materials. It has been shown that lotus leaves and other natural materials can be used as templates for molding to generate replicates in synthetic materials that possess the structure-associated resistance to wetting. (Information was derived from the Keating Lab Group at Penn State University.)

Materials

- PDMS pre-cursor
- PDMS cross-linker agent
- Plastic cups
- Stirrers
- Petri dishes
- Electronic Balance
- Blue Oil based food coloring
- Butterfly wings (Blue Morpho and an assortment of wings)
- Cell phone camera
- Large binder clips
- Water
- Disposable Pippettes
- Protractor
- Optical microscope
- Meguiars car wax product
- Assorted small rings of PVC piping
- Assorted metal rings
- Exacto Knife
- Portable UV lights

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Advance Preparation/ Pre-Lab Activities

- Make sure to order the PDMS pre-cursor and the PDMS cross-linker agent
- Make sure to order the butterfly wings (Blue Morpho and assorted batch)
- Allow for students to read the following article, *New Water-Repellent Material Mimics Lotus Leaves* https://news.nationalgeographic.com/news/2003/02/0227_030227_lotusmaterial.html
- Allow for students to complete the Graphing Skills Gizmo Simulation Lab (www.explorelearning.com)
- Show the following video clip prior to the lab: www.youtube.com (The Lotus Effect: Breakthrough Junior Challenge 2016)

Safety Information

- Students need to wear gloves and safety goggles
- Be alert during use of sharp object (box cutter or razor blade)

Teaching Strategies

- Assign a pre-reading (refer to pre-lab activities)
- Review basic graphing skills (refer to pre-lab activities)
- Utilize innovative technology (polleverywhere.com)
- Think-Pair-Share (allow for students to discuss bell work question and laboratory assessment questions)
- Assign individual lab jobs (Principal Investigator, Materials Manager, Maintenance Manager, and Data Collector)
- Discuss lab objectives
- Ask higher order questions throughout the lab activity, for examples refer to: https://medicine.wright.edu/sites/medicine.wright.edu/files/page/attachments/QuestionTemplates.pdf) OR https://www.saydel.k12.ia.us/cms_files/resources/general%20HOTSQuestionCards.pdf

Resources

https://news.nationalgeographic.com/news/2003/02/0227_030227_lotusmaterial.html
www.explorelearning.com
https://medicine.wright.edu/sites/medicine.wright.edu/files/page/attachments/QuestionTemplates.pdf
https://www.saydel.k12.ia.us/cms_files/resources/general%20HOTSQuestionCards.pdf

https://www.youtube.com/watch?v=Cm9cQLUeVH4
nano4me.org

Directions for the activities

Warm-up (Engage): Bell work Question (polleverywhere.com)

Describe the difference between the terms hydrophobic and hydrophilic.

Introduction (Engage): Brief video clip (explaining lotus effect and introduction of lesson vocabulary)

https://www.youtube.com/watch?v=Cm9cQLUeVH4

Lab Procedure (Explore):

Day 1

Make Observations of Blue Morpho Butterfly Wing and organize butterflies into petri dishes

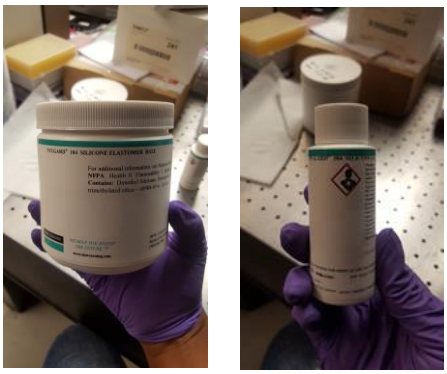
Day 2

Create PDMS:

1. Pour an unspecified amount of PDMS pre-cursor into a small plastic cup and weigh out the amount of an electronic balance (tare the balance prior to adding the PDMS pre-cursor)

2. Whatever the weight is then weigh out a 1/10 of that weight when adding the crosslinking agent. For example, if the weight of the PDMS pre-cursor is 35.0 g. then you need to add about 3.5g. of crosslinker agent to the substance. Remember to tare the balance before adding the crosslinker agent.

3. Stir the solution vigorously. You can also tap the cup of PDMS on the counter to get rid of any air bubbles in the solution. At this point, you will also add the oil based food coloring.



Polydimethylsiloxane (PDMS)

Day 3

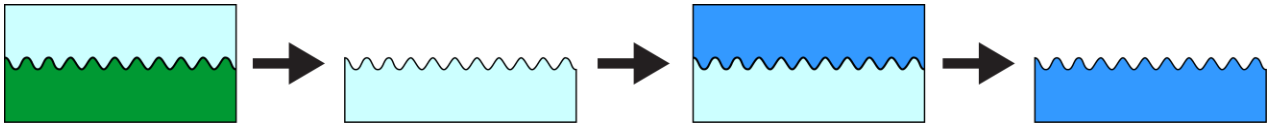
Create negative molds of butterfly wings (allow for about 2 days to cure)

Day 5

Place molds out in the sun and spray with Meguiars car wax product. This should make the surface of the molds hydrophobic which will allow for the new PDMS to be easily removed. These molds should be outside for at least 24 hrs.

Day 6

Create positive molds of butterfly wings (allow for about 2 days to cure).



Schematic Cartoon of the Lithographic Reproduction Process

Day 8

Measure Contact Angles of butterfly wings and molds

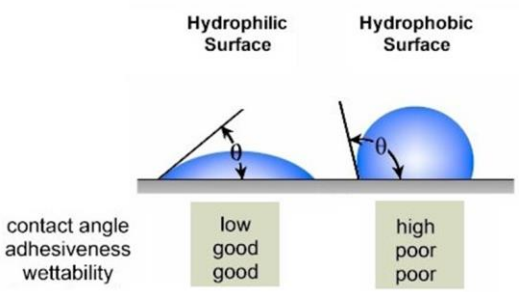
1. First, using a pipette you measure out 10 microliters of water and place the drop on an area of the butterfly wing.

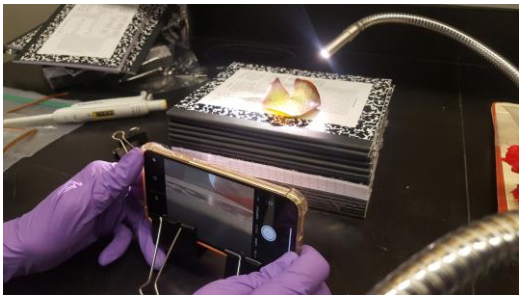
2. Next, you take the cellphone and attach binder clips to it to make a tripod camera.

3. Align the camera lens to the image (butterfly wing with drop of water)

5. Take a picture and repeat the entire process 4 more times.

6. Then using a protractor, measure the contact angle of the water droplet photo. Make sure to input all date into the data table.





Jenkinson D. Ultra-Ever Dry [Internet]. Science Brainwaves. 2013 [cited 2018 Jul 31];Available from: http://www.sciencebrainwaves.com/ultra-ever-dry/

Mini-Formative Assessment (Explain and Evaluate): Kahoots

Cleanup:

Each lab group should have an assigned maintenance manager that ensures that all lab tables have been cleaned and any trash has been properly disposed.

Extensions (Extend):

1. Create a scaled drawing of a prototype of a self-cleaning product
2. Build and create/ design a self-cleaning product prototype using a specific list of materials
3. LIVE skype video conference with Dr. Christine Keating and Charlie Crowe (regarding the Lotus Effect)
4. Utilize the RAIN (Remotely Accessible Instruments for Nanotechnology Education) by accessing nano4me.org
5. Discuss how a self-cleaning product could be useful on the International Space Station

Student Worksheet

The Lotus Effect: Lithographic Reproduction of the Blue Morpho Butterfly

Introduction

The lotus effect is a phenomenon that is observed on the lotus plant and on butterfly wings. This is where naturally-occurring surfaces such as the lotus plant exhibits hydrophobicity on its leaves (due to the physical structures). Butterflies also exhibit this phenomenon as they emerge from chrysalis. During this lesson, you will create lithographic molds of a variety of butterfly wings, specifically the Blue Morpho using a polymer called PDMS. You will be comparing the level of hydrophobicity of the PDMS molds and the actual butterfly wing specimens by taking contact angle measurements and analyzing the data collected in this lab. The goal is to reproduce the microscopic physical structures on the wings that are responsible for the lotus effect.

Bell work:
Describe the difference between the terms hydrophobic and hydrophilic.

Video Reflection:
Watch the following video, The Lotus Effect: Breakthrough Junior Challenge 2016 and record any vocabulary terms from the clip.

Observations:

Using the two column chart, list the butterfly species that you have in your lab group and record your observations.

Name of Butterfly Species	Observations

Make a Prediction:

_____

_____

_____

Materials:

_____

_____

_____

List Variables (Control, Constants, Independent, and Dependent):

_____

Procedure/Plan:

_____

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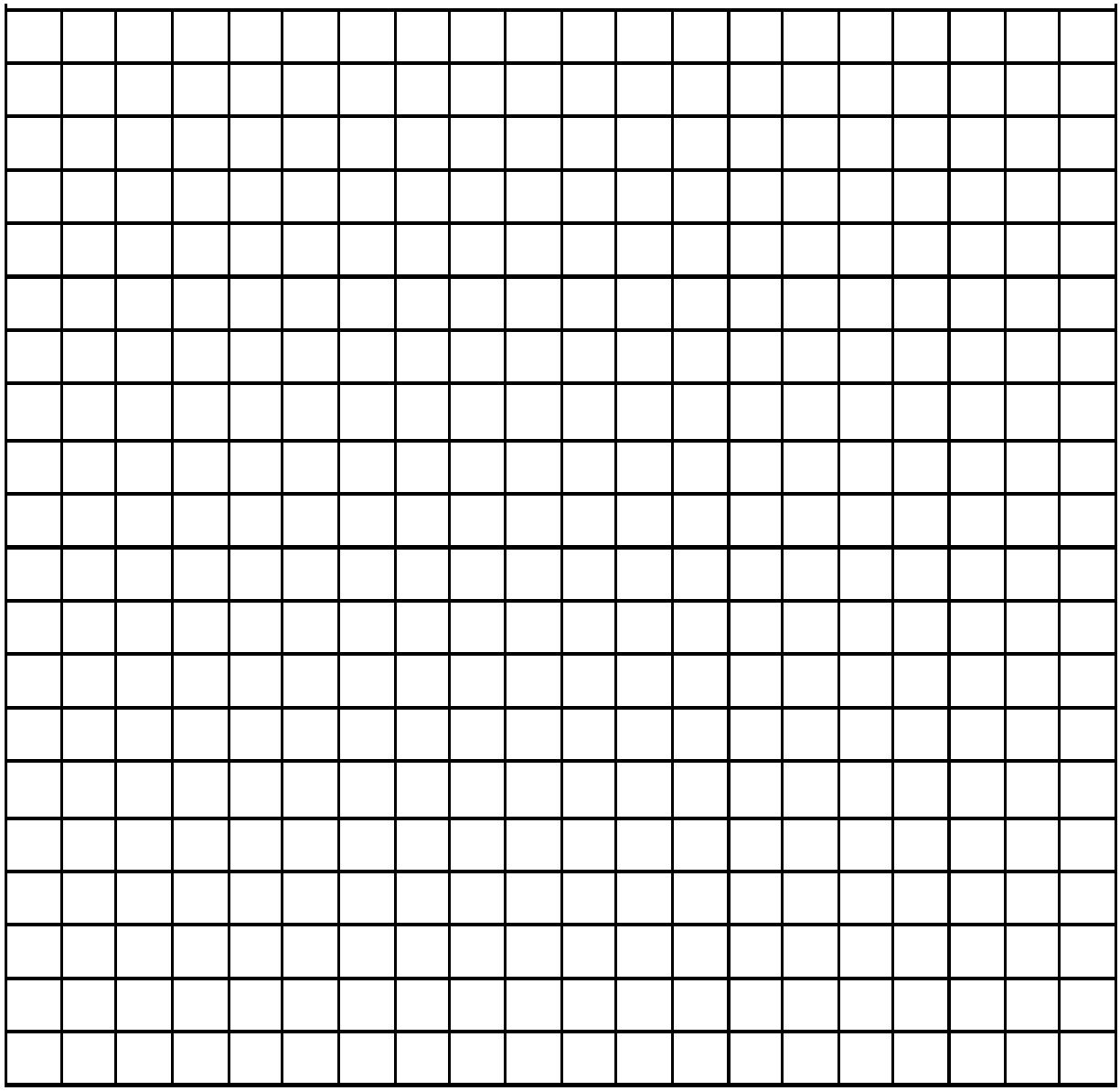
Collect and Interpret Data:

Name of Butterfly Species	Contact Angle Measurement	Contact Angle Measurement	Contact Angle Measurement	Average of Contact Angle Measurements

Graph Data:



Draw Conclusions:

1. List 3 things you learned from the lab activity.

2. After analyzing the data from the lab activity, what were some patterns or trends that you noticed?

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