Curriculum Overview

*Solutions Inspired by Nature: A Biomimicry Curriculum* connects science and design solutions through observation, questioning, building arguments and models, and a new scientific process called *biomimicry*. Through a series of hands-on, minds-on activities, students not only prepare for a trip to the Desert Botanical Garden, but they are exposed to a new way of problem solving inspired by nature. A concluding design challenge brings together all elements of learning into an engaging and thought-provoking group project that aligns with Common Core standards.

Materials

- Video of an art exhibit installation (links provided)
- Blindfolds – one for each pair of students in class
- Collection of natural objects (i.e., seed pods, seeds, branches, leaves, etc.)
- Pictures of biomimicry examples (Garden provided)
- Recycled material for post-activity (purchase kit from Garden or collect your own as a classroom)

Learning Objectives

*Upon completion of this curriculum, students will be able to…*

- Practice and demonstrate a variety of observation techniques
- Identify opportunities for biomimicry in a real-life setting by understanding that nature can inspire solutions to challenges
- Construct a model of a nature-inspired solution to a human problem
- Justify claims using supporting arguments
Pre-Field Trip

Explain to the students that they will be visiting the Desert Botanical Garden where they will have the opportunity to view desert adapted plants. By using their senses to observe their surroundings at the Garden, by asking questions, and by learning about adaptations, the students will brainstorm how these adaptive characteristics can inspire solutions to real-life, human challenges. For example, the saguaro cactus has internal and external structures that help it stand tall and thrive in extreme conditions. The structures of the saguaro could inspire humans to build stronger, taller, and/or more energy efficient buildings. The following activities can be used together or separate to introduce new concepts and prepare students for their field trip.

Art Installation Video

Show your students one or all of the installation videos. Ask students to carefully observe because they will need to refer back to this information later for a writing assignment. Tell them about the writing assignment and then show the video(s) again so they have an opportunity to take notes.

  This video is about Fred Lonberg-Holm’s Florasonic sound installation project at the Lincoln Park Nature Conservancy. He encountered many challenges and speaks about one very relatable challenge in the beginning. Please be advised that only the first 1:40 should be shown to students as additional audio content may not be appropriate.

- https://www.youtube.com/watch?v=h8cRzx-pnPw 3:52
  This time lapse video is about Daniel Goldstein and his studio’s installation of the large piece “Gathering Waves: A Hanging Sculpture”. It illustrates the complexities of transporting and hanging with such a large installation. No audio is required.

- https://www.youtube.com/watch?v=HdseJBKACRM 3:43
  This time lapse video is the creation of a sculpture from the 2013 International Ice Sculpting Competition in Maui, HI. There are many opportunities to discuss challenges with this piece, including melting, the public interference, weight, carving multiple pieces, etc. No audio is required.

Written Reflection

- Students write about personal challenges they have experienced vs. challenges seen during the art installation video(s)

Spend a few minutes discussing with your students what they saw during the installation. Ask your students to write about their personal experience building something or putting something together. What challenges did they experience? Lastly, have them compare their
personal experience with what they saw happen during the art installation video. Were there similar challenges? Were their experiences unique or similar?

Option: Students can write this as a narrative, informational text, or as a comparison essay.

### Biomimicry Introduction

Biomimicry is defined as a “science that studies nature’s models and then imitates them or takes inspiration from these designs and processes to solve human problems.” The word originated from the Greek *bios* meaning ‘life’ and *mimesis* meaning ‘imitation’ (Benyus, 1997).

Biomimicry is a change in thinking; humans learn from nature instead of learning about nature. Students should be encouraged to observe details and structures of plants and/or animals, ask questions about why those structures exist, and understand how they help the organism survive/function.

Biomimicry is not about designing a pair of slippers that look like butterflies. Instead, it is about studying what makes the color in butterfly wings and asking the question; how could humans make color in a similar, more sustainable way for computer or television screens.

You will find that it is ok not to know all the answers, as you and your students can hypothesize and learn together!

For more information on Biomimicry, check out these links:

- [https://www.ted.com/talks/janine_benyus_biomimicry_in_action 17:42](https://www.ted.com/talks/janine_benyus_biomimicry_in_action)
  In this Ted Talk, Janine Benyus not only explains what biomimicry is, but also discusses real world products that are inspired by nature.

  This article from the Smithsonian presents some of the work they are doing with biomimicry of moths and butterflies as well as helping to explain biomimicry as a process.

  This article from BBC News provides an overview of biomimicry as well as providing some common examples from a more business and technology oriented perspective.

### Exploring Nature

- Adapted from the Biomimicry Institute’s ‘Seeing Function’ curriculum
- Students use their senses (other than sight) to observe a natural object. Using these observations they will build an argument with their partners about why natural objects have specific structures.
Students will work in pairs. One partner will be blindfolded while the other has a copy of the chart (p. 4) and a pencil. Each pair should be given the same two natural objects to examine. For example, all pairs have a leaf and a seed pod. It is recommended that the objects are hidden from view so the blindfolded partner’s first experience with the object is without sight (i.e. keep objects under a towel or in a bag).

**Option:** Have students collect a variety of natural objects to use instead of having matching pairs.

*Remind the non-blindfolded students to keep the blindfolded students safe at all times*

The blindfolded partner uses all of their senses other than sight to explore the object (sense of taste will be at the teacher’s discretion). Meanwhile, the other partner records on paper all of the words the blindfolded partner used to describe the object. For example, they might describe an object as lightweight, smooth, hard, has an earthy smell, etc. After several minutes, switch the blindfold and repeat roles with the second object.

Next, have the partners discuss what it felt like to use their senses other than sight. Did they enjoy it? Did they feel anxious? Have each partner guess what object they were observing. Then encourage discussion about the adjectives used to describe the object. What purpose do these characteristics serve, if any? How do they help the object or the larger natural object it belongs to? How might a similar structure help humans solve a problem? For guidance, suggestions are provided in the following chart.

For example, if a pair was examining a seed. What do you think makes it so hard? Maybe because it has a seed coat? Why might a seed coat be hard? To protect it from harsh weather conditions? To prevent water loss? So animals don’t eat them? How could having a hard coating help people? Could wearing hard protective gear help people who are attacked by animals? *Remember, at this point it is less about knowing the correct answer and more about thinking it through.*

Conclude this activity with a large group discussion to share observed structures and the importance of those structures.
<table>
<thead>
<tr>
<th><strong>Objects</strong></th>
<th><strong>Structures and Functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>From local plants or from the grocery store</td>
<td></td>
</tr>
<tr>
<td><strong>Seeds</strong></td>
<td>Hard coat – Protect from weather and prevent water loss</td>
</tr>
<tr>
<td>Examples include: Mesquite, Palo Verde, Cocklebur, Clematis, Dandelion, Nuts, Beans, Corn kernels</td>
<td>Prickly – Attach to animals to disperse the seeds</td>
</tr>
<tr>
<td></td>
<td>Feathery – Can be dispersed by the air</td>
</tr>
<tr>
<td></td>
<td>Light weight – Can be dispersed by floating in the water</td>
</tr>
<tr>
<td></td>
<td>Smooth – They have more starch and can store more water</td>
</tr>
<tr>
<td><strong>Seed pods</strong></td>
<td>Bumpy – Forms around the seed to protect it</td>
</tr>
<tr>
<td>Examples include: Texas Ebony, Palo Verde, Agave, Green Beans, Sugar Snap Peas</td>
<td>Cracked – To let the seed escape</td>
</tr>
<tr>
<td>*People allergic to peanuts are often allergic to Mesquite</td>
<td></td>
</tr>
<tr>
<td><strong>Leaves</strong></td>
<td>Small – To prevent water loss by minimizing pores</td>
</tr>
<tr>
<td>Examples include: Any living plant, Aloe, Creosote, and Palo Verde in particular, Lettuces, Spinach, Kale</td>
<td>Fuzzy – To protect the leaf from the sun</td>
</tr>
<tr>
<td></td>
<td>Waxy – To prevent water loss by having a water resistant coating.</td>
</tr>
<tr>
<td><strong>Branches/Stems</strong></td>
<td>Bumpy/Ridges – To grow leaves/branches from</td>
</tr>
<tr>
<td>Examples include: Any outdoor plant, Palo Verde in particular, Cinnamon (not ground), Broccoli stalks, Celery</td>
<td>Hard – Provide structure and support</td>
</tr>
<tr>
<td></td>
<td>Wet – water and nutrients transported through stem</td>
</tr>
<tr>
<td><strong>Roots</strong></td>
<td>Long – Absorb more rain water with more surface area</td>
</tr>
<tr>
<td>Examples include: Any living plant, carrots, jicama, celery root</td>
<td>Thin – Can grow easily in the soil</td>
</tr>
<tr>
<td></td>
<td>Pointed – Can grow deep to reach more water</td>
</tr>
<tr>
<td></td>
<td>Round – Can store water when it’s collected</td>
</tr>
<tr>
<td></td>
<td>Hairy – Has tiny roots to collect more water</td>
</tr>
<tr>
<td><strong>Other Suggestions</strong></td>
<td></td>
</tr>
<tr>
<td>Bird’s nests, Saguaro Boots, Honeycomb, turtle/tortoise shell, skulls, pelts</td>
<td></td>
</tr>
<tr>
<td>Object</td>
<td>Observations (while blind-folded)</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Seed</td>
<td>Hard, smooth</td>
</tr>
</tbody>
</table>
Comparison Reflection

- Students observe a natural organism and the man-made design it inspired. Completing a Venn diagram with the class will help them compare and contrast characteristics.

Draw a large Venn diagram on the board. Explain to your students that you are going to discuss real-life examples of biomimicry -- man-made technology that was inspired by a structure and its function in nature. Fully complete the activity with one of the following biomimicry examples before moving to the next.

- Burr and Velcro
- Kingfisher and the Japanese Bullet Train
- Boxfish and Concept Car

Begin by showing your students the first example of biomimicry. Have them describe each image aloud as you fill-in both sides of the Venn diagram. Then discuss what they have in common, placing those characteristics in the center of the diagram (completed diagram for reference p. 8). The center or overlapping characteristics should help students determine what structures and functions from the organism inspired what structures and functions in the man-made object. For example, the form or shape of the burr and its quick fastening properties inspired the invention of Velcro as an easy fastening alternative.

Option: Have students work in pairs or small groups to complete Venn diagram. Then discuss findings as a whole class.

After examining the images and completing the Venn diagram, have your students read the provided informational text. Discuss if the text supports the conclusion the class reached through the Venn diagram. Lastly, discuss whether it is a good idea to model man-made solutions after functions and structures in nature. Alternatively, ask students if they can think of other man-made solutions that could have been inspired by nature and why they believe that.
Burr and Velcro
Burr and Velcro

Reading Sample:

One summer day in 1948, a Swiss amateur-mountaineer and inventor decided to take his dog for a nature hike. The man and his faithful companion both returned home covered with burrs, the plant seed-sacs that cling to animal fur in order to travel to new ground. With a burning curiosity, the man ran to his microscope and inspected one of the many burrs stuck to his pants. He saw all the small hooks that enabled the seed-bearing burr to cling to the tiny loops in the fabric of his pants. George de Mestral raised his head from the microscope and smiled, thinking, "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 French words ‘velour’ meaning fabric and ‘crochet’ meaning hook. It will rival the zipper in its ability to fasten."

Mestral's idea was met with resistance and even laughter, but the inventor stuck by his invention. Together with a weaver from a textile plant in France, Mestral perfected his hook and loop fastener. By trial and error, he realized that nylon when sewn under infrared light, formed tough hooks for the burr side of the fastener. This finished the design, patented in 1955. The inventor formed Velcro Industries to manufacture his invention. Mestral was selling over sixty million yards of Velcro per year. Today it is a multi-million dollar industry.
Kingfisher and Japanese Bullet Train
Reading Sample:

“In Japan, they have these very fast bullet trains. They were getting so fast that the typical bullet shape was causing a loud booming sound when these trains would exit typical train tunnels,” stated biomimicry expert, Sunni Robertson of the San Diego Zoo.

The booming, it turned out, had to do with the shape of the front of the train.

“The reason this booming was happening, they discovered, is that this cushion of air was building up in front of that speeding train, going 300 kilometers an hour. The sound was waking up people who lived nearby. It disturbed the wildlife.” Eiji Nakatsu, an engineer with JR West and a birdwatcher, used his knowledge of the splash-less water entry of kingfishers to decrease the sound generated by the trains.

“He had witnessed a kingfisher diving down through the air, going into the water and creating very little splash.” Kingfishers move quickly from air, a low-resistance (low drag) medium, to water, a high-resistance (high drag) medium. This is similar to the train tunnels. The kingfisher's beak provides an almost ideal shape for such an impact. The beak is streamlined, steadily increasing in diameter from its tip to its head. This reduces the impact as the kingfisher essentially wedges its way into the water, allowing the water to flow past the beak rather than being pushed in front of it.

Because the train faced the same challenge, moving from low drag open air to high drag air in the tunnel, he thought, ‘I wonder if I could apply this principle to the shape of the front of the bullet train.’ And so, Nakatsu modeled the front of the train like the kingfisher’s face. It has a pointy part to it just like the beak of the kingfisher. And, sure enough, when they tried out that new model, it moved through without creating the boom. And it saved them 10-15% more energy because it was more aerodynamic.”
Boxfish and Concept Car
The yellow boxfish, with fins that appear too small to propel its large body through water, is an unlikely source of inspiration for a car. The well-known car company, Mercedes-Benz, thought differently. Their engineers saw the box-shaped fish as an outstanding example of hydrodynamic design and used its shape as inspiration for a new concept car in 2005. What resulted was a light-weight, energy efficient and safe vehicle for consumers.

With its sleek design, the concept car consumes 20 percent less fuel than other cars in its class. The boxy shape of the fish not only provides hydrodynamic movement through the water, but it also allows for the fish to escape unharmed when bumping into other underwater organisms. The car engineers mimicked the same design resulting in a vehicle that is 40 percent stiffer than the average car, helping to prevent dents. It also weighs 30 percent less, which improves the overall efficiency of the car.
Post-Field Trip

Biology to Design Challenge

Biomimicry can start with an inspiration found in nature that can help solve a human challenge; or scientists may be working to solve a human challenge first and look to nature for inspiration. This culminating challenge will focus on the nature inspiration coming first.

- Begin by dividing your classroom into small groups
- Give each group a Challenge Kit from the Garden filled with recycled materials or collect your own recycled materials and divide evenly amongst the groups
- Write the following desert-related challenges on separate pieces of paper (one per group number, some may repeat) and have each group pick a challenge at random
  - Contain/conserve/contain water
  - Protect/shade from the sun
- Have each group use the knowledge they gained from the field trip to the Garden, notes from their Data Collection Journal, and the recycled materials to construct a sustainable solution to their environmental challenge. Make sure they think about what these organisms/traits can help humans to do better.
- For example, is there something a desert plant does to store water that humans could do too? Your students might be inspired by the barrel cactus and construct a design for a house that could collect and store water after a big rain. Remember, these models do not actually have to DO what they are modeling, just represent it.
- Once completed, each group will present their model to the entire class. The presentation should include a fully developed supporting argument.

Optional: Provide students with real, nature-inspired solutions to their chosen challenges as a conclusion or to help motivate their design process. Examples are listed below.

- Contain/Store Water: Succulent Inspired House
  The house has plastic curtains that collect and store the rainwater then distribute it throughout the house. The roof has a funnel/rosette shape to direct the water into the bladder-like curtains.

  For photos and more information: http://www.evolo.us/architecture/succulent-house-collects-rainwater-through-use-of-biomimicry-murmur/

- Conserve/Use less Water: Fungus Symbiosis Inspired Agriculture
  Moen’s innovation team was inspired by the Fibonacci series which improves efficiency and is often found in nature. The company applied this same pattern to their showerheads in order to provide a product with full coverage of water at any setting.
• **Collect Water: Beetle Inspired Material**
  The Stenocara beetle’s back is covered in small bumps that collect condensation and funnel the water to the beetle’s mouth. Researchers were inspired to create a material the collects water from the air for human use.


• **Protection from Sunlight: Cactus Building**
  This energy efficient structure’s design was inspired by a cactus. It is constructed of smart shades that open and close depending on the strength of the sun.

What to do Next

Share Your Work
Please share your students’ nature inspired design models with the Desert Botanical Garden.

- Email photos or anything else to formaled@dbg.org
- Be sure to include your school and grade!

What to do with containers and leftover stuff?
We hope you and your students enjoyed learning about desert ecology, design, and biomimicry. We understand that there may have been more items in your containers than you needed. As a lesson in sustainability and protecting our environment, the Desert Botanical Garden Education Department prefers that the items are not immediately discarded into the trash. Please reuse and repurpose materials to keep them out of the landfill. Here are some ideas...

- Share the extra items with other teachers, the art teacher, or teacher organizations (such as Treasures for Teachers)
- Donate them to afterschool programs or other youth organizations at your school
- Ask the students what they would like to do with the extra items
- Use the materials for a future modeling project
- Let students keep some of the more interesting items
- Plant seeds, a seasonal vegetable, or native plant in your plastic pot containers
- Recycle anything you can (i.e., remove the twine and recycle the cardboard container pieces)
- Make a mural and use the items to spell out a word like “recycle.”
References


**Burr Example Images**–
http://justseven.blogspot.com/2010/04/wild-velcro-plant.html


**Kingfisher Example Images** -


**Boxfish Example Images** –
http://biomimicrykth.blogspot.com/2012/05/boxfish-car.html

http://www.designboom.com/contemporary/biomimicry.html
Art Installation Video and Written Reflection

Blindfold Exploration
Fifth – AZ.5.W.4, 5.W.8, 5.SL.1
Sixth – AZ.6.W.4, 6.W.8, 6.SL.1, 6-8.RST.7
Seventh – AZ.7.W.4, 7.SL.1, 6-8.RST.7
Eighth – AZ.8.W.4, 8.SL.1, 6-8.RST.7

Comparison Reflection
Fifth – 5.RI.2, 5.RI.3, 5.RI.7, 5.RI.8, 5.RF.3, 5.RF.4, 5.SL.2, 5.L.4
Sixth – 6.RI.2, 6.RI.4, 6.RI.7, 6.SL.2, 6.L.4, 6-8.RST.1, 6-8.RST.4, 6-8.RST.7, 6-8.RST.9
Seventh – 7.RI.37.RI.7, 7.SL.2, 7.L.4, 6-8.RST.1, 6-8.RST.4, 6-8.RST.7, 6-8.RST.9
Eighth – 8.RI.7, 8.SL.2, 8.L.4, 6-8.RST.1, 6-8.RST.4, 6-8.RST.7, 6-8.RST.9

Biology to Design Challenge
Fifth – 5.SL.4, 5.SL.5
Sixth – 6.SL.4, 6.SL.5
Seventh – 7.SL.4, 7.SL.5
Eighth – 8.SL.4, 7.SL.5

Arizona Career and College Ready Standards - MATH

Art Installation Video and Written Reflection
Fifth – N/A
Sixth – N/A
Seventh – N/A
Eighth – N/A

Blindfold Exploration
Fifth – N/A
Sixth – N/A
Seventh – N/A
Eighth – N/A

Comparison Reflection
Fifth – N/A
Sixth – N/A
Seventh – N/A
Eighth – N/A

Biology to Design Challenge
Fifth – 5.MP.1, 5.MP.4
Sixth – 6.MP.1
Seventh – 7.MP.1
Eighth – 8.MP.1