FAIRCHILD
Discovery
PROGRAM

Biomimicry - Designed by Nature
Pre- and Post-Visit Activities
Grades 9-12

FTBG

Fairchild Tropical Botanic Garden

Welcome!

Dear Teacher:

Thank you for planning a field study at Fairchild Tropical Botanic Garden. The tour you have selected, **Biomimicry**, is designed to teach students about biomimicry, a new branch of science that looks to nature for inspiration in tackling contemporary, environmental problems.

Included in this document is a packet of activities. It can also be found online at: http://www.fairchildgarden.org/education/schoolprograms/discoveryprogram/. **This packet contains pre and post-visit resource materials to support and strengthen the learning experience. We encourage you to implement pre-visit activities as they will enhance and prepare students for the field study.**

Using pre-visit activities allows students to learn the vocabulary and key concepts. It also gives students time to think about what they will be learning during their field study and to start to formulate questions. Post-visit activities allow students to integrate, reflect, process and deepen their learning experience. The lesson plans correlate with the Next Generation Sunshine State Standards. **Please be sure that each teacher attending the field study receives an activity packet.** Feel free to make additional copies of this packet as needed.

The word list provided is especially important for students to study prior to their visit. An understanding of the vocabulary will be a great asset in comprehending the concepts discussed during the field study.

We look forward to your visit to Fairchild Tropical Botanic Garden and hope that you and your students will have an exciting and educational adventure.

Kind Regards,

Laura Tellez
Discovery Program Coordinator
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Introduction to Biomimicry

This unit has been prepared to help you and your students learn about biomimicry and to optimize the learning experience during your field study at Fairchild Tropical Botanic Garden. This multi-disciplinary unit features activities that introduce teachers and students to the concept of biomimicry and provide students a foundation in certain ecological concepts and environmental awareness. An introduction to mapping and Global Positioning System (GPS) is also included, as students will be using maps, compasses, and GPS units to navigate the garden during their visit.

Biomimicry — bio, meaning life, and mimesis, meaning to imitate — is a relatively new science that studies nature (its models, systems, processes and elements) and then imitates or takes creative inspiration from them to solve human problems sustainably.

Examples and Case Studies of Biomimicry include:

1. Architects have studied the ventilation in **termite mounds**. They are constructed with an effective ventilation system that maintains a constant temperature of 87 degrees Fahrenheit, while the external temperature varies between 37 and 104 degrees Fahrenheit. One building in Zimbabwe was designed based on the termite mound ventilation system and has proven to use 10% of the energy of a typical building its size.
2. The surface of a **lotus leaf**, although seemingly smooth, is rough on a microscale. Water droplets falling into the leaf bead-up. If the surface slopes slightly, water droplets roll off. Rough surfaces on a microscale tend to be more hydrophobic causing water droplets to roll-off instead of sliding-off. As water droplets roll-off, they pick up particles of dirt acting as a self-cleaning mechanism. The superhydrophobic surface of the lotus leaf allows it to stay dry even during a heavy storm. Scientists have developed non-toxic cleaning products and clothing modeled after the lotus leaf.
3. Some seeds, such as **cockleburs,** "hitchhike" on animals. These seeds have developed a hook and lock structure that allows them to attach themselves to passing animals. This mechanism allows the cockleburs to be carried and dispersed to a new location. These seeds inspired the invention of Velcro.
4. Structural color on **butterfly wings** and bird feathers can provide the model for non-toxic dyes for clothing. Certain organisms, including some butterflies and birds, portray a certain color and iridescence caused by the structure of the scales and feathers. which are stacked on top of each other in a way to catch and reflect light rays to portray iridescence.
5. The filtration system of **wetlands** filter out solids and chemicals. Wetlands are used as models for water treatment systems.

Resources:
"Biomimicry: Innovation Inspired by Nature," Janine M Benyus
http://www.odemagazine.com/doc/18/what_would_nature_do/
http://www.biomimicryinstitute.org/
http://www.biomimicryguild.com/
http://nationalzoo.si.edu/Publications/ZooGoer/1999/4/designsfromlife.cfm

Words for a Day at Fairchild

Bauxite: a soft, whitish to reddish-brown rock forms from the breakdown of clays and is a major source of aluminum. Bauxite consists mainly of hydrous aluminum oxides and aluminum hydroxides along with silica, silt, iron hydroxides, and clay minerals.

Biomimicry: a new science that studies nature (its model, systems, processes and elements) to imitate or take creative inspiration in order to solve contemporary human problems sustainably.

Compost: a mixture of various decaying organic substances, such as dead leaves or manure, used for fertilizing soil.

Consumer: an organism, usually an animal, that feeds on plants and/or other animals.

Decomposer: an organism, usually a bacteria or fungus, that breaks down the cells of dead plants and animals into simpler substances.

Ecological footprint: a measure of how much land and water an individual, a population or an activity requires to produce all the resources it consumes and to absorb all the waste it generates.

Food web: a series of organisms related by predator-prey and consumer-resource interactions.

GIS: Geographic Information System: a computer application used to store, view, and analyze geographical information.

GPS: Global Positioning System: a system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth.

Ore: a metal-bearing mineral or rock that can be mined at a profit.

Producer: an organism that is able to produce its own food from inorganic substances, for example a plant.

Reclamation: the conversion of wasteland into land suitable for use of habitation or cultivation.

Remediation: to contain, treat or remove contaminated water and/or soil.

Satellite: a device launched to orbit the Earth that collects scientific information.

Sustainable: able to be supplied with resources, sustenance or nourishment for an indefinite period of time without damaging the environment or depleting resources.

Pre-Visit Activity 1:
Biomimetic Shelter Project

Objectives

Students understand adaptations of plants and animals for specific environments. Students use critical and observational skills to learn from Nature's examples in addressing human challenges. Students learn about sustainability and how to apply its principles to make human systems more effective and efficient.

Next Generation Sunshine State Standards: SC912.L.17.11, SC.0112.L.17.12, SC.912.L.17.14, SC.912.N.4.2, SS.912.G.1.3, SS.912.G.3.1, SS.912.G.3.2, SS.912.G.5.2, LA.910.1.6.1, LA.910.1.6.2, LA.910.1.7.1, LA.910.1.7.2, LA.910.1.7.3, LA.910.1.7.6, LA.910.3.1.1, LA.910.3.1.2, LA.910.3.3.3, LA.910.3.3.4, LA.910.3.4.1, LA.910.3.4.2, LA.910.3.4.3, LA.910.3.4.4, LA.910.3.5.2, LA.910.3.5.3, LA.910.4.2.3, LA.910.5.1.1, LA.910.5.2.2, LA.910.5.2.3, LA.910.5.2.4, LA.910.6.2.1, LA.910.6.2.2, LA.1112.1.6.1, LA.1112.1.6.2, LA.1112.1.7.1, LA.1112.1.7.2, LA.1112.1.7.3, LA.1112.1.7.6, LA.1112.3.1.1, LA.1112.3.1.2, LA.1112.3.2.1, LA.1112.3.2.2, LA.1112.3.2.3, LA.1112.3.3.2., LA.1112.3.3.4, LA.1112.3.4.1, LA.1112.3.4.2, LA.1112.3.4.3, LA.1112.3.4.4, LA.1112.3.5.2, LA.1112.3.5.3, LA.1112.4.2.3, LA.1112.5.1.1, LA.1112.5.2.2, LA.1112.5.2.3, LA.1112.5.2.4, LA.1112.5.2.5, LA.1112.6.2.1, LA.1112.6.2.2, MA.912.A.2.7, MA.912.A.5.7, MA.912.A.10.1

Materials

- Arts and craft materials, paper, pencils and markers
- Library and/or computers with internet access to do research

Description

This activity can be done as a long-term project where students design a shelter for human habitation based on biomimicry principles. Students learn how to use natural systems to solve human problems. This project can be done by students individually or in small groups.

Procedure

1. Each student or group chooses a climate, a habitat and a location as the site for their shelter for human habitation design.
2. Students do research to find out what are some of the species in their chosen location and their adaptations to that specific environment.
3. Using the species adaptations as inspiration, students begin the shelter design process. Students use the adaptation survival strategies of species found in their climate, habitat and location as core principles in their shelter design.
4. The shelter design should address the physical structure, heating and/or cooling mechanisms and energy source for electricity use. If you have enough time and you would like to challenge your students, you can include water and food availability and storage as well.
5. The documentation of this project includes two parts: the visual representation and the written explanation.

Adapted from Introduction to the Biomimetic Shelter Project prepared by Torrey McMillan

6. The **visual representation** should include a concise interpretation. Students can draw, build or otherwise visually represent their shelter in the context of the environment they chose. Ask students to include brief explanations of the design features and where they drew inspiration for them. Students should also describe the various design decisions they made and why they made them. The visual representation should show the design of the shelter, the way in which energy will be obtained and how natural resources will be collected, how waste will be managed, etc.
7. The written explanation should include:
   a. **Location description** including: climate, topography, ecology and geology.
   b. **Problem definition:** What problems does this specific location require that you solve to have an effective and efficient shelter?
   c. **Observation and abstraction:** What models from Nature solve your defined problems in ways suitable to your location? Did you notice any patterns in your solutions? Which species "solved" the problems you identified and how did they do so?
   d. **Application:** How did you apply the lessons learned from Nature in your shelter design?
   e. **Reflection:** What are the design flaws in your shelter? Which parts do you think will work well? Why? How viable do you think it is to build your shelter given current technologies and costs?
8. You can introduce your students to self-directed learning, which is a process in which a person takes responsibility and initiative for their learning. You can use the following assesment criteria found on the next page as a guide.

Resources

http://www.biomimicryinstitute.org/education/k-12/curricula.html

Adapted from Introduction to the Biomimetic Shelter Project prepared by Torrey McMillan
http://www.biomimicryinstitute.org/education/k-12/curricula.html

Pre-Visit Activity 1: (Continued) Assessment Criteria

Self-directed Learning:
- Did you turn in all pieces of the assignment on time?
- Did you make good use of in-class time to work?
- Did you seek help if and when you needed it?
- Did you challenge yourself with the project, holding yourself to a high standard?
- Did you manage your time well, spreading the work load for the project out over multiple days and work sessions?

Information Processing:
- Did you read the assignment carefully and follow-through with the specific details of what was required?
- Did you identify the information you needed?
- Did you access information from multiple, reliable sources?
- Did you accurately assess the quality and reliability of your sources?
- Did you extract key ideas and information in response to each of the sections of the project?

Knowledge Application:
- Did you use biomimicry principles in your design process, representing the steps in your written work?
- Did you explain the basic site characteristics for your shelter location, including climate, topography, ecology and geology?
- Did you identify native species to your chosen location and models from Nature that can help you solve your design problems explaining the solutions to the problems you have identified?

Complex Thinking:
- Did you apply biomimicry principles to the design process of your shelter?
- Were you able to identify the problems presented by your site to generate a problem definition from which you could look for solutions in Nature?
- Did you draw reasonable abstractions from your observations and research of Nature's solutions to your design problems?
- In the face of challenges when locating information, did you think creatively about alternative sources, new ways to conceive the problem you were trying to address, or other locations/species that might have solved similar problems in different locations?

Effective Communicator:
- Did you cite your sources using a proper format?
- Is your writing free of grammatical and spelling errors?
- Does your writing flow logically? Is it well organized and structured? Do your paragraphs have topic sentences and supporting details within?
- Did you include all the sections of the project and are they clearly delineated? Did you use formatting to help guide the reader through the information?
- Is your visual representation easy to interpret? Does it have the required annotations?
- Did you include your name on your work? Did any emails you sent to turn in work have the assignment title and due date in the subject line?

Adapted from Introduction to the Biomimetic Shelter Project prepared by Torrey McMillan
http://www.biomimicryinstitute.org/education/k-12/curricula.html

Pre-Visit Activity 2: Ecological Footprint

Objectives

Students understand the impact of their decisions and behavior on the environment.
Students apply basic math skills to use collected data to create and solve real-world math problems.

<u>Next Generation Sunshine State Standards</u>: SC.912.L.17.8, LA.910.5.2.1, LA.910.5.2.3, LA.1112.5.2.1

Vocabulary

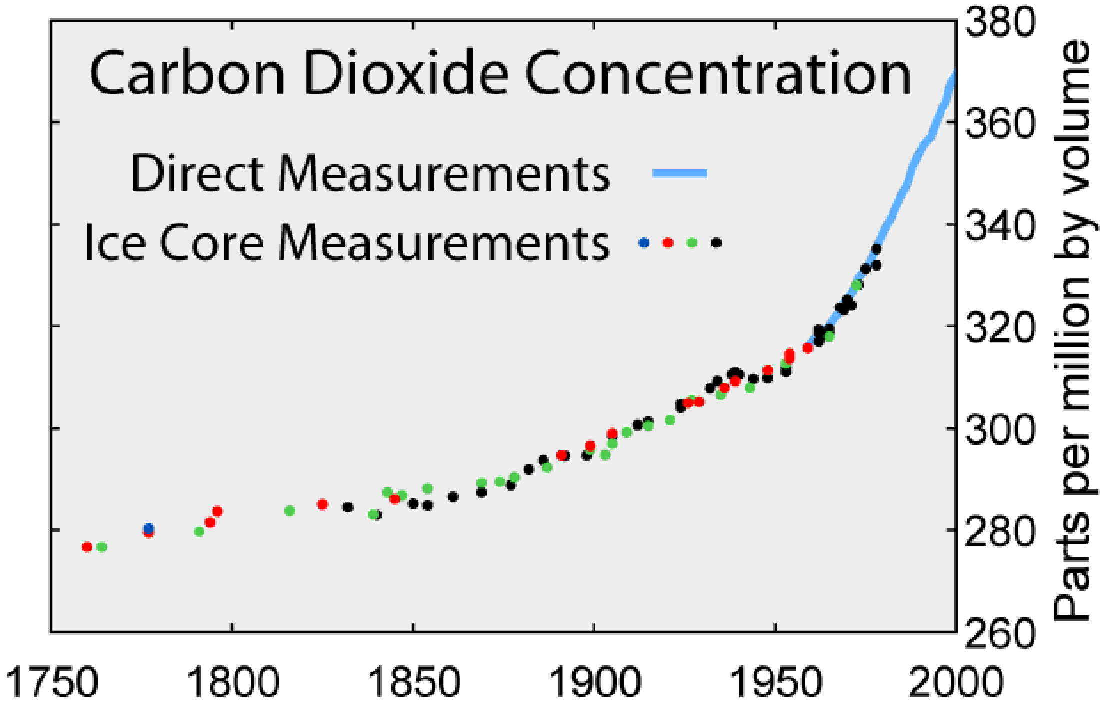
Ecological Footprint   Sustainable   Compost

Materials

- Computers with internet access

Procedure

1. Have students calculate their ecological footprint on a website such as: http://www.myfootprint.org
2. List 3 things they and their families could do to reduce their ecological footprint.



Source: http://www.stuffintheair.com/global-warming-carbon-dioxide.html

3. (Optional) Print the above graph for students and ask them to answer the following questions:
   - What does this graph show us about CO2 levels over time?
   - How could you explain the steep increase in CO2 levels since 1950?

Post-Visit Activity 1: Waste Audit

Objectives

Students learn to use the correct mathematical formulas to solve real-world problems.
Students illustrate data using graphs.
Students explain how accumulating garbage harms the environment and identify specific steps they can take to reduce waste and environmental pollution.

Next Generation Sunshine State Standards: LA.910.5.2.1, LA.910.5.2.3, LA.1112.5.2.1, MA.912.A.2.1, MA.912.A.2.2

Procedure

1. Have students weigh the collective trash and recycling from their lunches.
2. Have students calculate the following:
   - How many pounds of garbage did we produce at lunch?
   - How many pounds of garbage would this become in 1 week of school? 1 month? 1 year?
   - Do the same calculations for the recycling.
   - What percent of the total waste was recycled from your school lunch?

3. Ask students to create a graph illustrating the weight of garbage and recycling that would be thrown out over the course of a year.
4. Ask students to create a line graph illustrating the time period required for each material in your lunch to decompose (i.e. one line for plastic, one for paper, etc.).
5. Print out the table on the next page and hand out to students.
6. Ask students to fill in the grid.
7. Ask students to create a bar chart illustrating the time period for each of the materials to decompose.

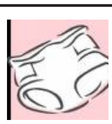
Resources

http://www.thatdanny.com/2008/06/06/how-long-does-it-take-a-plastic-bag-or-a-glass-bottle-to-decompose/
http://www.deq.state.or.us/lq/pubs/docs/sw/OregonGreenSchoolTools.pdf
http://www.epa.gov/epaoswer/non-hw/composting/index.htm

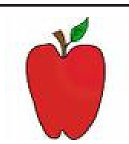
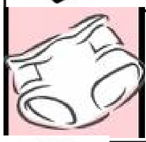
Name ______________________________________ Date ____________________

Table Illustrating Time Period for Each Material to Decompose

Fill in the table using the information provided by your teacher or from your own research:

Material		**Decomposition Timeframe**					
		<1 year	**5-10 years**	**10-20 years**	**20-100 years**	**100+ years**	**Never**
	**Leaves**						
	**Apple Core**						
	**Paper**						
	**Milk Carton**						
	**Cigarette Butt**						
	**Plastic Bag**						
	**Disposable diaper**						
	**Soda can**						
	**Glass Bottle**						
	**Styrofoam**						

Teacher Answer Key

Material		Decomposition Timeframe					
		<1 year	**5-10 years**	**10-20 years**	**20-100 years**	**100+ years**	**Never**
	**Leaves**	1-3 months					
	**Apple Core**	2 months					
	**Paper**	2.5 months					
	**Milk Carton**		5 years				
	**Cigarette Butt**			10-12 years			
	**Plastic Bag**			10-20 years	20-100 years	100+ years	
	**Disposable diaper**				75 years		
	**Soda can**					200-500 years	
	**Glass Bottle**					500 years	
	**Styrofoam**						X

Post-Visit Activity 2: How Can Recycling Aluminum Help Rainforests?

Objectives

Students will understand how aluminum is processed, the environmental impacts of bauxite mining, and the importance of recycling.

Next Generation Sunshine State Standards: LA.A.1.4.1; LA.A.1.4.2; LA.A.1.4.4; LA.A.2.4.1; LA.B.1.4.2LA.B.2.4.3; SC.D.2.4.1; SC.G.2.4.1; SC.G.2.4.2; SC.G.2.4.6

Vocabulary

Bauxite   Reclamation   Remediation   Ore

Hyacinth Macaws, Native to the Rainforests in Central and South America

Materials

- Atlas with world map
- Examples of products containing aluminum (aluminum foil, soda can, food sieve)
- Copies of "Bauxite and Aluminum Mining Worksheet"
- Examples of products containing iron (nail, magnet, tool, or pictures of car/refrigerator)

Background

Aluminum is the second most used metal (after iron). The ore from which aluminum is produced is called bauxite. Bauxite undergoes refining steps to become alumina first and then aluminum. Aluminum may be stored in sheet-rolls or in ingots until it is re-melted in a processing plant to take its final shape.

The United States produces one fourth of all aluminum produced in the world. Although there are bauxite deposits in Arkansas, the alumina being processed in the U.S. comes from major producing countries such as Australia, Guinea (West Africa) and Jamaica.

Bauxite is an ore comprised of several aluminum oxides, which form in nature by extensive chemical weathering of certain type of rocks (e.g. volcanic). Chemical weathering is more intense in warm, humid regions. For this reason, bauxite deposits are found within tropical rainforests in broad, shallow layers under the soil. Bauxite can also be found in formerly tropical regions, which is the reason why bauxite deposits are found in Arkansas.

Because the ore is spread as a layer beneath the soil, it is mined in open pits. Open mining is a highly destructive extraction technique that damages and disturbs the delicate nature of rainforest habitats and promotes the loss of rainforest soils. The need for land reclamation in mining areas and the benefits of recycling aluminum are greatly illustrated in this activity.

Adapted from : Rainforests, Recycling, and Bauxite, Mélida Gutiérrez. http://www.cnas.missouristate.edu/eyh/bauxite%20paper.pdf

Post-Visit Activity 2:How Can Recycling Aluminum Help Rainforests? (Continued)

1. Show students the products containing aluminum and those containing iron.
2. Discuss the different properties of each (aluminum is light-weight, less strong than iron, rust resistant, able to take different shapes, will not react with water, and non-magnetic). Ask them to brainstorm more products containing aluminum (aluminum siding, screen doors, pots and pans, etc).
3. Explain why bauxite is formed as a "residual" ore in warm, humid regions.
4. Let students locate the major bauxite producing countries on a world map and see how their occurrence coincides with tropical rainforests.
5. Read the description of "typical bauxite mining and aluminum processing" (next page) and have students answer the questions listed on the worksheet.

Teacher Answer Key

1. **What problems do you see with the mining of bauxite?**
   Destruction of rainforest habitat and top soil.
2. **Name some things that could be saved by recycling aluminum.**
   Rainforest habitat, soil and wood, money to buy and transport bauxite, electricity, reduced greenhouse gases emissions.
3. **Describe how an open pit mine can be reclaimed.**
   Collection of soil and water samples help assess any pollution created by bauxite mining. If pollution is detected, remediate until chemical(s) concentration(s) are at non-threatening levels. Some of the remediation technologies are: excavation, pumping and treating and soil vapor extraction. Choose the most appropriate remediation technology taking into account that remediation can be a long-term process that may take several years depending on the level of damage, pollution and the chemicals detected at the chosen site for remediation. After remediation is completed, the ground can be covered with material and top soil, followed by planting of new grass and trees. It is important to remember that there are other indicators of pollution that are not found in water and soil samples, such as the health conditions of humans, animals and plants. Recurrence of certain disease(s) can be related to environmental pollution.
4. **Soil devoid of vegetation in the rainforest is washed away by rains in a matter of days. How would this affect your reclamation efforts above?**
   Top soil will have to be purchased and transported from somewhere else increasing the cost of reclamation.
5. **Mention how the steps described in your answer to questions 1 to 3 above would change if aluminum is recycled instead of mined.**
   Open pit mines will not have to be dug in tropical regions; bauxite and alumina will not have to be transported; electricity will not have to be used so much; landfill space will be saved.
6. **What are some reasons that more people do not recycle?**
   People may not know about the benefits of recycling; recycling centers may not be centrally located; the community may not have recycling programs in place.
7. **Brainstorm about some ways to encourage recycling (a) at home, and (b) in your school.**

Resources

- Braus, Judy, 1991. Geology: The Active Earth, Ranger Rick Nature Scope Series, McGraw Hill.
- http://minerals.usgs.gov/minerals/pubs/commodity/bauxite/
- http://www.world-aluminium.org/Sustainability/Recycling

Name ______________________________ Date ____________________

Bauxite and Aluminum Processing

Read the text below and answer the questions that follow.

Most bauxite is mined in open pits. First, bulldozers clear away trees, rocks and topsoil. The ground is then loosened with explosives and the soil and bauxite lumps are loaded into trucks and transported to a place where the next step will take place.

The bauxite and soil mixture is crushed and washed to remove some of the clay and sand waste. Then, it's dried out through a heating process (wood from the rainforest is likely the heating source).

Crushed, washed bauxite is transported to a refinery where it is transformed into alumina by a series of chemical reactions. Alumina is a fine white powder. Alumina is loaded into a ship and transported to a smelter in an industrialized country.

In the smelter, alumina is placed into a large pot and heated at high temperatures to remove the oxygen. Molten aluminum is transported into a cast house, where other materials are added to make the product stronger, and then poured into molds to form blocks of aluminum called "ingots". These processes are extremely electricity intensive.

Ingots are transported into the final plant where the aluminum will be re-melted, hammered or molded into its final shape.

Questions

1. Can you write a description of the processing path for aluminum cans that get recycled?

2. What problems do you see with the mining of bauxite?

3. Name the positive impacts of recycling aluminum and how it would affect the environment.

4. Reclamation is the process of restoring disturbed land to its original condition.
Describe how an open pit mine can be reclaimed.

5. Soil devoid of vegetation in the rainforest is washed away by rains in a matter of days. How would this affect your reclamation efforts above?

6. How would the steps described in your answers to questions 1 to 3 change, if aluminum was recycled instead of mined?

7. Why do you think people do not recycle? How could that be changed?

8. Brainstorm about some ways to encourage recycling (a) at home, and (b) in your school.