Biomimicry:

A bite-sized introduction

Advance Copy, v.1

BIOMIMICRY INSTITUTE

Lesson 3

Learning to Connect Function with Design

Duration: 1-2 class periods (~50 min each)	*Grades: 6-12*
What students do: Students are introduced to and learn about what functional design is and why it's important in doing biomimicry, through a slide deck, discussion, and activities.	
Learning objectives: 1. Students learn what functional design is and why it's important. 2. Students gain experience identifying and communicating about functional design. 3. Students gain experience sharing their work.	
Materials: • Slide deck for Lesson 3 • An aluminum beverage can (optional)	

Getting Ready

- Review the provided slide deck, suggested discussion questions, and included activities.
- Identify a suitable outdoor space for your students to observe nature and/or, if remote, how you will guide them in finding an appropriate location.

Procedure

Check in

Have students share some recent entries from their biomimicry journals.

Presentation and discussion

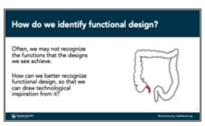
Begin presenting/providing the slide deck to students and facilitate a discussion during this time. Use the discussion questions in the notes beneath the slides to help you facilitate the discussion, either in-person or as discussion questions for students to think/write/converse about together. Pause the presentation in order to do the activities described.

Discussion Guide:

Title Slide 1: Biomimicry: A bite-sized introduction. Lesson 3: Learning to Connect Function with Design.

Slide 2: What is functional design? Functional design is design that accomplishes something of value. Do the flames on this car make the car go faster? The flames are a design, but they are not what we mean by functional design.

Slide 3: Studying what makes organisms aerodynamic, so that we can apply ideas from what we learn from nature to the design of a vehicle, is an example of what we mean by functional design. Functional design is important because that's what biomimics draw inspiration from. Nature's abilities inspire biomimics to innovate new technologies and designs.



Slide 4: How do we identify functional design? Often, we may not recognize the functions that the designs we see achieve.

For instance, for many years, people did not think the human appendix served any current purpose. Many believe today that it is a very important organ and serves to help our digestive system.

How can we better recognize functional design, so that we can draw technological inspiration from it?

Slide 5: One effective approach is to ask ourselves and others questions about the designs we see. Why are they there? Why are they that way? What might these designs achieve?

For instance, you may be at the grocery store and see these cantaloupes, and think, why do cantaloupes have those intriguing patterns of lines on their surface? Or you may be outside and think, why do grass blades end in a point? Or you might look at your own body and think, why do people have toes? How do toes help us?

<u>Activity</u> (pause presentation)

Observe Nature
Engage students by having them go outside, identify some designs in nature, write down in their journals some functional questions about the designs they see, and then share their observations and questions with the rest of the class. Then continue with the slide deck.

Observe a Soda Can
Using the slide deck and a soda can (real or pictured), have students spend five minutes ***exploring*** the idea of function, by observing and thinking about the functional design of a soda can. ("Make a list of the design features you notice and reasons why you think each design feature is the way it is.") Students should make a list of all the functional design aspects of the soda can they observe. After a couple minutes, you can ask your students to share a few of these with the rest of the class. Then continue with the slides.

<u>Continue Discussion</u>

Slide 6: What functional design elements can you identify in a soda can? It might help to remember that a soda can begins as a sheet of aluminum, before it becomes shaped the way it is.

Slide 7: We can think of these factors influencing the design of something as its **operating environment**; the environment in which the physical object must operate successfully. So, what's the operating environment of a can of soda?

Slide 8: Well, its purpose is to serve as a container for a beverage, so it has to fit into a person's hand. No point in making a can of soda you have to pick up with a full-body hug, or a pair of tweezers! And so, the can has a curvature and circumference that fits comfortably into the average adult hand.

Slide 9: But there's more. It shouldn't spill in storage, but needs to open easily for drinking, and that's tricky. If its seal is too weak, it will puncture when handled or being transported; if it's too strong, customers won't be able to open it.

Slide 10: So, soda cans have a weakened area on the top that opens with an amount of pressure greater than what you can generate by pushing with your finger, but you can still open it if you do it the right way. The can comes with a built-in tool, made of metal, that you activate, which concentrates force on a smaller area than your finger can. To avoid littering the metal tab, it's designed to stay attached on one side. The top also has two sets of grooves around the top, to catch liquid so it doesn't spill and land on the drinker.

Slide 11: The bottom has a ridge which functions in at least two ways: it strengthens the bottom to avoid accidental crushing, and the ridge also neatly fits into the groove around the top, so cans can be easily stacked.

Slide 12: Thinking about the operational environment of something and the likely functional aspects of its design can change how you understand and appreciate something.
Do you see this can the same way as you did a few minutes ago?

Slide 13: How can we apply this way of seeing design to the natural world?

Slide 14: We can apply the same thinking process to things in nature, too. Let's try to understand the design of coconut trees by looking at their operating environment.

Pause for activity. Have students take a moment to write down the features of coconut trees that they notice, and aspects of their operating environment that they think account for these designs. Have them explain their ideas with the class, then continue with the slide deck.

Continue discussion. Biologists call the operating environment of an organism its ecological context. What is a coconut tree's ecological context or operating environment? What factors seem likely to influence its design? Why does it look the way it does, and behave the way it does? Well, what do we know about coconut trees? Where do they grow? That's right: in the tropics, along the shore. Coconuts float, after all, and coconut trees rely on oceans to help their seeds travel across enormous ocean expanses.

Slide 15: So, what's the wind like on the coasts? That's right: it's strong. Growing on coasts, coconut trees regularly receive a lot of wind, unimpeded by mountains or buildings, or even other trees. Wind is a part of a coconut's ecological context, a prevalent part, part of the condition within which coconut trees must operate successfully.

Slide 16: How might the design of these leaves be a response to the coconut trees' operating environment? We can pretty quickly detect a number of features of coconut trees that seem well-designed for functioning successfully under windy conditions. Their leaves are designed to allow wind to pass through them; they're "pre-torn" you might say.

Slide 17: Their trunks are ribbed. This design is one we use ourselves, when we desire both flexibility and strength, such as in certain kinds of tubing.

Slide 18: Growing in easily eroded sand, they can't rely on just a few large roots; instead coconut trees have dozens of roots emanating in all directions.

Slide 19: And if eventually the eroding sand overwhelms their anchoring system, coconut trees begin to lean. Because of the tree's attraction towards light, and patterns of sand erosion, these trees naturally begin to lean towards the sea, bringing their canopies over the highwater mark of tides and waves. This positions them perfectly to drop their coconuts into the ocean… which float away to other beaches, and so produce the next generation of coconut trees, continuing the successful design of coconut trees in the world.

Slide 20: What does it mean to say, "good design begets good design"? Remember, design in nature helps organisms survive and thrive.

Slide 21: Why is functional design important? It can be fascinating to learn all the many ways design in nature accomplishes something important in often clever and elegant ways. It's also the basis of biomimicry. Biomimics draw on functional design to inspire technological innovations. For example, recall the microscopic texture of some leaves, and how they enable a plant to have self-cleaning surfaces.

Extension & Assessment Opportunities:

The following activities can be used to ***extend*** and/or ***evaluate*** student learning.

Observe functions in nature

Have students go outside and try to find examples in nature of general functional abilities. See the activity, "Hunting and Gathering for Ideas," in the Resources list.

Read about biological functions

Have students read a science paper on biological function and answer the questions below. Invite students who found their research really interesting to share it with the rest of the class.

a) What is the organism or biological entity (biochemical, organ, etc.) discussed in the paper?
b) What feature of the organism/entity is discussed?
c) What function does this feature perform? (What does it do?)
d) What's the story behind the research? How did the researchers come to hypothesize about the feature's function?
e) How did the researchers arrive at their conclusions? What was their experimental approach?

Note: You can select the paper(s) or let them search for one (preferred). To find a paper, students could go to Google Scholar and search for "biological function" or "adaptation" + [organism of interest, e.g., "ants"]. For an example, see the paper "Mechanisms of Adhesion in Geckos," in the Resources list.

To answer (d), students may also need to search for other (non-primary research) articles that provide more biographical/human interest kinds of information related to the research. National Geographic, Scientific American, natural history magazines and websites, etc. are all good sources.

Describe how a biological function works

Have students (a) research a biological function and how it works, (b) make a drawing or model that illustrates how it works, and (c) present their work to the rest of the class.

Modifications

While there is no substitute for experiencing nature in person, if it is truly not possible or safe for your students to go outside, the nature observation activity can be modified by having students observe/examine natural artifacts or images of organisms.

Lesson Feedback

This lesson is part of an advance release of five lessons within a ten-lesson unit of study that is currently in development. If you teach this lesson, we would love to hear how it went and any thoughts you may have for improving it. Please share your feedback via the following survey link: https://forms.gle/qLG2e7JbUWYEseZp7

Resources

- Activity: "Hunting and Gathering for Ideas" <https://asknature.org/resource/hunting-gathering-for-ideas/>
- Google Scholar <scholar.google.com>
- Kellar Autumn and Anne Peattie. "Mechanisms of Adhesion in Geckos." Integrative and Comparative Biology (2002) <http://biomimetic.pbworks.com/f/Mechanisms+of+Adhesion+in+GeckosAutumn.pdf>
- *National Geographic* <https://www.nationalgeographic.com/>
- *Scientific American* <https://www.scientificamerican.com/>

Standards Alignment

Next Generation Science Standards (NGSS)

Science and Engineering Practices

- Developing and Using Models.
- Engaging in Argument from Evidence.
- Obtaining, Evaluating, and Communicating Information.
- Developing and Using Models.
- Constructing Explanations and Designing Solutions.
- Connections to Nature of Science: Scientific Knowledge is Based on Empirical Evidence.
- Connections to Nature of Science: Scientific Investigations Use a Variety of Methods.
- Connections to Nature of Science: Scientific Knowledge is Open to Revision in Light of New Evidence.

Crosscutting Concepts

- Structure and Function.
- Systems and System Models.
- Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology.
- Connections to Nature of Science: Science is a Human Endeavor.
- Connections to Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems.

Common Core State Standards (CCSS)

- ELA-LITERACY.W (Writing). 6-12.1/2/4/5/7/8/9
- ELA-LITERACY.SL (Speaking & Listening).6-12.2/3/4/5/6
- ELA-LITERACY.RI (Reading Informational Texts).6-12.1/2/3/4/5/6/7/8
- ELA-LITERACY.RST (Science & Technical Subject).6-8/9-10/11-12.1/2/4/7/8/9/10
- ELA-LITERACY.W (Research to Build and Present Knowledge).6-12/7/8/9