Biomimicry

A bite-sized introduction

Advance Copy, v.1

BIOMIMICRY INSTITUTE

Lesson 1

Introduction to Biomimicry

Duration: 2 class periods (~50 min each)	*Grades: 6-12*
What students do: Students are introduced to and learn about essential features of what biomimicry is through a slide deck, examples, and discussion. They embark on methods to explore the outdoors for what it can teach us, and begin keeping biomimicry journals which will help them develop as biomimics—practitioners of biomimicry—over the course of the unit.	
Learning objectives: 1. Students learn what biomimicry is. 2. Students gain experience doing secondary research. 3. Students gain experience presenting their work. 4. Students begin to document their ideas through the lens of a biomimetic engineer.	
Materials: • Slide deck for Lesson 1 • Student journals	

Getting Ready

- Review the provided slide deck, suggested discussion questions, and 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.
- Plan how and when you want to have students do the research activity and present their findings to their peers.

Procedure

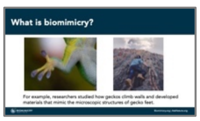
Presentation and Discussion

Begin by presenting/providing the slide deck to students and ***engage*** them by facilitating a discussion during this time. Use the discussion questions in the notes beneath the slides and below to help you facilitate discussion, either in-person or as discussion questions for students to think/write about together. If you would like to gain greater background about the topics covered in the slides, you can find additional information via the websites provided both in the slide notes and the Resources section.

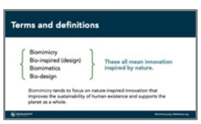
Discussion Guide:

Title Slide: Biomimicry: A bite-sized introduction. Lesson 1: Introduction to Biomimicry

Slide 2: What is biomimicry? Biomimicry is a method engineers and designers use for creating innovations, by looking to the natural world for ideas.



Slide 3: For example, researchers studied how geckos are able to climb walls and developed materials that mimic the microscopic structure of gecko feet. These gecko-inspired materials can be made into gloves that enable people to adhere to and climb surfaces, even sheer glass, without glue.



Slide 4: ***Terms and definitions***. There are many different terms that refer to innovation inspired by nature. They have different etymologies (word histories) and are used in slightly differing contexts, but they all mean essentially the same thing.

Biomimicry tends to focus on nature-inspired innovations that improve the sustainability of human existence and supports the planet as a whole. Why is it useful to know all these different terms? If you search the internet using one of these terms, will you get all the information you would get if you searched the internet using all of these different terms? You can have students test this out for themselves.

Slide 5: Simply looking like something in nature is not biomimicry (that's known as "**biomorphism**"). **Biomimicry** is learning from functional design in nature and applying it to human innovation. Innovations inspired by nature may or may not end up looking like the thing that inspired them.

What do we mean by "functional design"? Functional design is design that improves how something performs. This stadium is known as the "Bird's Nest Stadium," but it doesn't operate any better because it looks like a bird's nest. Does this car go any faster just because it has flames painted on it?

Slide 6: Simply using something from nature is not biomimicry (that's "**bioutilization**"). Biomimicry is learning from nature and applying the ideas this evokes to human innovation. Innovations inspired by nature may or may not end up using organic material in a design. Simply using feathers for insulation in a jacket is not biomimicry. What matters is that something in nature gives an inventor an idea for how to improve the design of what people make, such as studying downy feather structure to create better insulation materials.

Slide 7: Biomimics (people who use or practice biomimicry) can get ideas from anything in nature. Biomimics get ideas from biological structures (forms), processes, and systems.

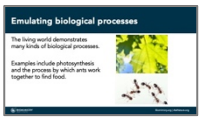
Slide 8: ***Emulating biological structures***. Biological structures are the easiest aspect of the natural world to recognize. Biological structures are everywhere, at both microscopic and macroscopic scales.

What do we mean by "structures"? What biological structures can you think of? What biological structures can you see right now? Shapes, textures, and mechanisms are all clearly structures. Here, we mean "structures" in its broadest sense. Can you think of any biological structures that are invisible (e.g., microscopic phenomena)? (What about biological behaviors, like bird calls? These are not physical structures, perhaps, but biomimics can also draw ideas from biological behaviors.)

Slide 9: Biological structures accomplish many things, so there is a lot to learn from these structures to inform human designs.

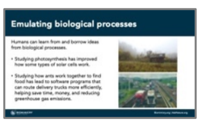
What creates biological structures? (Natural selection.) Why does natural selection tend to create things that perform well? How does this relate to why looking to nature for ideas might be a good idea for inventors? What do we mean when we say that nature is optimized? [If students ask about God, note that it would also make sense to look to nature to improve our technologies and designs if a supernatural entity created nature. However, the role of science is not to explore the supernatural.]

Slide 10: For example, biomimics have emulated the microscopic structures on leaves to create more sustainable hydrophobic (water-repellent) surfaces, e.g. on fabric. Before this, the primary way hydrophobic surfaces were created was through using highly toxic chemicals.



Slide 11: ***Emulating biological processes.*** The living world demonstrates many kinds of biological processes, where characteristic sequences of interacting parts occur. Examples include photosynthesis (in which plants combine CO_2 and water using sunlight to create sugars, cellulose, etc.) and the process by which ants work together to find food.

How is a biological process different than a biological structure? (Processes involve sequences of events, involving the element of time.)



Slide 12: Humans can learn from and borrow ideas from biological processes. For instance, by studying photosynthesis people have improved how some types of solar cells work. And by studying how ants work together to find food, computer scientists have written software programs that can route delivery trucks more efficiently, helping save time and money, and reducing greenhouse gas emissions.

Can you think of other biological processes? (The physical development of an organism, ecological succession, nitrogen fixation in soil, water purification, etc.)

Slide 13: ***Emulating ecological systems.*** Most manufacturing systems designed by people create a lot of waste in the process of production. These systems are "linear" in the sense that raw materials go into production and waste comes out. (A system is a set of things working together as parts of a mechanism or an interconnecting network. Systems can be defined at different scales, e.g. a local manufacturing plant is a system nested within the largest system of global manufacturing.)

Can you think of any "linear" production systems? Look around and think about how something you can see is produced. What raw materials are used? What waste is created? (There can be solid, liquid, or gaseous waste.) What's wrong with having "linear" production systems? What problems result? Are linear production systems sustainable? Why or why not?

Slide 14: An ecological system, or ecosystem, is a system consisting of biotic and abiotic components functioning together as a unit. Ecological systems are characterized by having high and sustained diversity and production, despite having low amounts of nutrients flowing through them. They achieve this by efficiently transferring nutrients through food chains, i.e., there is no waste (waste = food).

It's important to remember that all human-designed systems reside within the context of ecological systems. Our systems are not separate from natural systems.

What ecological systems are you aware of? What are the various parts of this system and how do the parts interact? Do all ecological systems have things in common? What do they have in common? (e.g., decomposers, no waste, high productivity, diversity, resilience)

Slide 15: One way humans can emulate ecological systems is by doing things like recycling high-value materials, designing things to be easily recyclable, and designing things to be easily disassembled and biodegradable.

What aspect of nature does recycling mimic? Can you imagine a human-built world where everything gets recycled or composted? What prevents this? What could encourage this? If recycling mimics part of ecological system functioning, why won't recycling work for all materials?

Slide 16: Humans can also emulate ecological systems by using the waste from one manufacturing process as the input for another manufacturing process. For example, in a Costa Rican dairy farm, the manure from the cows is fed to bacteria in a device called a "biodigester." There, bacteria biodegrade the manure and give off methane gas. The methane is burned to produce electricity that is used to run the machinery for milking the cows. Meanwhile, the profits from the milk are used to pay off the biodigester.

Activities

Use the following activities to help students further ***explore*** the concepts introduced and ***extend*** their learning.

Outdoor observation

Have students explore nature first hand by going outside for 5 minutes…in the schoolyard, in their backyard, anywhere they can see a little nature—a weed growing through a crack in the pavement is enough.

- Ask students to find a place where they can observe something in the natural world, and to sit there for a few minutes, just observing whatever aspect of nature they can see.
- Ask them to think about one question while they're outside: "What is this organism good at?"
- After 5 minutes, have students share their observations and thoughts with the rest of the group.

Research biomimicry examples

Have students research 1-3 examples of biomimicry and explain their examples to the class through a presentation. They can begin the research immediately after the last activity and present their examples either towards the end of that same class period, or at the next class period (doing the assignment as homework). This activity lends itself to students learning how to review, examine, and evaluate scientific information, if this learning objective is of interest.

- Challenge students to find biomimicry examples that emulate biological structure, processes, and systems. Each presentation should identify the biological model(s) that inspired the innovation, how the biological model(s) inspired the innovation (e.g., how the biological model(s) work, how the inventor came up with the idea), and how the innovation is an improvement over other designs. Encourage the use of images, video, diagrams, etc. to help explain aspects of the presentation. Provide students with a time limit for their presentations.

- Remind students to search the internet using all terms related to biomimicry (bio-inspired, etc.). Also, encourage students to try using Google Scholar, a searchable database of scientific literature (accessible by typing "Google Scholar" into an internet search engine or at scholar.google.com), to review original research. You can also consider introducing them to the website AskNature. (Students will also be using AskNature in Lesson 4 and 5.)

Introduce the biomimicry journal
After students have presented their examples of biomimicry to the class, discuss with them the importance of two things in practicing biomimicry: noticing what nature is good at (because this serves as an inspiration to biomimics) and identifying challenges/opportunities to make the world a better place (what engineers call developing a "problem consciousness"). Refer to examples of biomimicry the students researched to emphasize the importance of these skills in the practice of biomimicry.

Because these skills are so important, tell students that during this unit they will be practicing them by keeping a biomimicry journal and occasionally sharing its content with the rest of the class. Ask students to create two sections in their journal and label them: "Nature's Abilities" and "What's Worth Doing?".

- In the "Nature's Abilities" section students should write down personal thoughts/observations they have about what nature is good at doing (e.g., how birds are good at flying).
- In the "What's Worth Doing?" section, students should write down personal thoughts/observations they have about what needs to be changed or improved in the world (i.e., challenges or opportunities that a new design could address).
- Tell students they should aim for at 1-3 entries per journal section each day and be prepared to discuss their thoughts and observations in class. You might suggest that they try to repeat the outdoor observation activity every day (visiting the same or a new place) and reflect on how their awareness changes.

Extensions

This lesson can be enriched and lengthened by having students spend more time observing nature outdoors. Additional sources for nature observation activities can be found in the Resources.

Modifications

First-hand experiences in nature (even urban nature) are very important to the learning and practice of biomimicry. 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 showing students some video clips of organisms in their natural habitat. Animal webcams are one option (see the Resources for examples). You could also use clips from nature films. If the video has voiceover that describes or explains what the organism is doing, mute the audio so that students will use their own powers of observation to interpret what they are seeing.

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/EU5uv2TgZADxxnF96

Resources

- Janine Benyus: "Biomimicry's surprising lessons from nature's engineers." TED2005. <https://www.ted.com/talks/janine_benyus_biomimicry_s_surprising_lessons_from_nature_s_engineers>
- Janine Benyus, *Biomimicry: Innovation Inspired by Nature*. 1997. <https://www.amazon.com/Biomimicry-Innovation-Inspired-Janine-Benyus/dp/0060533226>
- Stanford Report, November 21, 2014. "Stanford engineers climb walls using gecko-inspired climbing device." <https://news.stanford.edu/news/2014/november/gecko-inspired-device-112114.html>
- Breaking Down Toxic PFAS: <https://earthjustice.org/features/breaking-down-toxic-pfas>
- How Big Oil Misled the Public into Believing Plastic Would be Recycled: <https://www.npr.org/2020/09/11/897692090/how-big-oil-misled-the-public-into-believing-plastic-would-be-recycled>
- The Story of Microfibers (video): <https://www.storyofstuff.org/movies/story-of-microfibers/>
- Michael Pawlyn: "Using nature's genius in architecture." TEDSalon London 2010. <https://www.ted.com/talks/michael_pawlyn_using_nature_s_genius_in_architecture?language=en>
- Costa Rica Diary Farm case study: <https://jyx.jyu.fi/bitstream/handle/123456789/18308/1/9513921549.pdf>
- Google Scholar <scholar.google.com>
- AskNature <asknature.org>
- Nature Observation Exercises, Biomimicry Toolbox, Biomimicry Institute. 2015. <https://toolbox.biomimicry.org/wp-content/uploads/2015/01/Nature_Observ_Exercises.pdf>
- Animal webcams <https://www.adventure-journal.com/2020/03/if-youre-stuck-inside-might-as-well-enjoy-this-list-of-animal-cams>

Standards Alignment

Next Generation Science Standards (NGSS)

Science and Engineering Practices

- Engaging in Argument from Evidence.
- Obtaining, Evaluating, and Communicating Information.
- Asking Questions and Defining Problems.
- Constructing Explanations and Designing Solutions.
- Connections to Nature of Science: Scientific Investigations Use a Variety of Methods.

Crosscutting Concepts

- Structure and Function.
- Connections to Engineering, Technology, and Applications of Science: Interdependence of Science, Engineering, and Technology.
- Connections to Nature of Science: Science is a Human Endeavor.

Common Core State Standards (CCSS)

- ELA-LITERACY.RI (Reading: Informational Text).6/7/8/9-10.1/2/3/4/8/10
- ELA-LITERACY.RI (Reading: Informational Text).11-12.1/2/3/4/10
- ELA-LITERACY.SL (Speaking & Listening).6/7.1(A/B/C/D)/2/3/4/5/6
- ELA-LITERACY.SL (Speaking & Listening).8.1(A/B/C/D)/3/4/5/6
- ELA-LITERACY.SL (Speaking & Listening).9-10/11-12.1(A/D)/2/4/5/6
- 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