BIOMIMICRY
YOUTH DESIGN CHALLENGE

2022-2023

M MOTIVATE

I INVESTIGATE

M MATCH

I INNOVATE

C COMMUNICATE

BIOMIMICRY INSTITUTE

WHAT'S INSIDE:

For additional details, visit youthchallenge.biomimicry.org.

Dear Educators,

Welcome to the Biomimicry Youth Design Challenge (YDC), a STEM learning experience that empowers students in middle and high school to pursue project-based-learning skills needed to solve real-world problems. Learners have the opportunity to work with an adult coach to explore biomimicry and apply their new understanding to create nature-inspired, sustainable solutions to global and local design challenges. This digital resource provides a thorough introduction to teaching biomimicry and will equip you to bring the core concepts and methods into your classrooms, home-school environments, or afterschool programs so that students can successfully incorporate insights from nature into design.

Designing a nature-inspired solution to a global or local problem is a powerful learning experience that requires students to understand and connect:

- The causes and effects of a problem and the functional requirements to solve it;
- How living organisms have solved similar functional challenges;
- and The application of design practices to create and evaluate bio-inspired solutions

Please refer to the following pages for an overview of the YDC Storyline, the MIMIC framework on which it is built, and details about how this curriculum aligns with the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate), as well as Next Generation Science Standards, integrating Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts.

We hope this curriculum helps you deliver a curiosity-provoking, STEM-aligned educational experience that empowers your students to play an active role in furthering sustainable design and embracing an interconnected, socially responsible, and just society. If you have any questions as you explore this guide, please contact us at youthchallenge@biomimicry.org.

Sincerely,

The Biomimicry Institute

YOUTH DESIGN CHALLENGE STORYLINE

The sequence of lessons for the Biomimicry Youth Design Challenge (YDC) is built on the MIMIC Instructional Framework (see page 6) and focuses student innovators on helping humankind to reach the United Nations Sustainable Development Goals (SDGs).

Anchor Phenomenon: Nature solves problems with well-adapted designs, life-friendly chemistry, and smart material and energy use.

Driving Question: How can learning from nature help us solve local and global sustainability challenges?

Supporting the United Nations Sustainable Development Goals

Using nature as a model, mentor, and measurement tool for sustainability, we can create solutions to solve human design challenges that address the United Nations 17 Sustainable Development Goals (SDGs). Our mission for the Youth Design Challenge (YDC) is to mobilize the next generation of innovators to help address the global challenges we face—with a local approach. Applying nature's design blueprints to these challenges can help achieve the 2030 Agenda for Sustainable Development as agreed upon by leaders worldwide.

The encouraging alignment between the SDGs and the YDC is that all innovation points to climate action—from Goal 13, specifically calling out Climate Action, to all the goals interconnected within the climate crisis, such as Goal 3: Good Health and Wellbeing, Goal 12: Responsible Consumption and Production, and Goal 4: Quality Education. Each SDG in some shape or form can be attributed to furthering regenerative ecosystems for all species. To better understand how the YDC aligns with the SDGs and NGSS, visit this resource.

By implementing successful, locally-adapted, nature-inspired solutions, we can contribute to these collective sustainability goals for the planet.

Introducing and Defining Biomimicry

bio = life ***mimicry = learning from and emulating***

When we study and use nature as inspiration to design sustainable solutions, we are practicing biomimicry. Biomimicry offers hope in finding a way out of the complex challenges present in today's world and encourages humans to reconnect with the natural world. The thinking and application process incorporates learning from nature to create more regenerative, resilient, and biodiverse spaces. It helps students not only connect directly with the problems that affect their lives and communities, but also empowers them to be part of the solution.

Looking to nature to address human problems is not a new idea. Indigenous cultures have looked to fit in with and honor the natural environment for as long as humans have been around. When we're referring to biomimicry, we're approaching the process through the lens of scoping a problem, discovering nature's solutions, abstracting those biological strategies to be used in design, creating prototype concepts or real design applications that solve said design, and evaluating against sustainable benchmarks, i.e. how natural organisms solve these problems without destroying or poisoning their habitat in the process.

Through this approach, we also incorporate the three essential elements of a biomimetic design: Emulate, Ethos, and (Re)Connect, which will be explained in the Motivate section (see pg. 8). Iteration is important throughout the process in order to increase the likelihood of success and to help learners understand this is an iterative approach to design rather than a linear one, i.e. there is not a straight way to get there but rather a repeated process to come to the best solution as more information is discovered.

Ultimately, our hope is that by introducing students to these critical thinking skills and approaches to solving problems, while encouraging a fun reconnection to the natural world, they feel more empowered and passionate about science, technology, engineering, and mathematics.

The MIMIC Instructional Framework

While there are many different ways practicing biomimics look to nature to inform design, we have created the MIMIC Instructional Framework to introduce young learners to the core concepts of biomimicry and how to apply them within the context of a creative engineering-design challenge. Each 5E instructional segment within the YDC curriculum addresses one of the five MIMIC phases, which together encompass the introduction of biomimicry as a concept (Motivate), the core elements of a Biomimicry Design Process (Investigate, Match, Innovate), and the preparation of an entry to the challenge (Communicate).

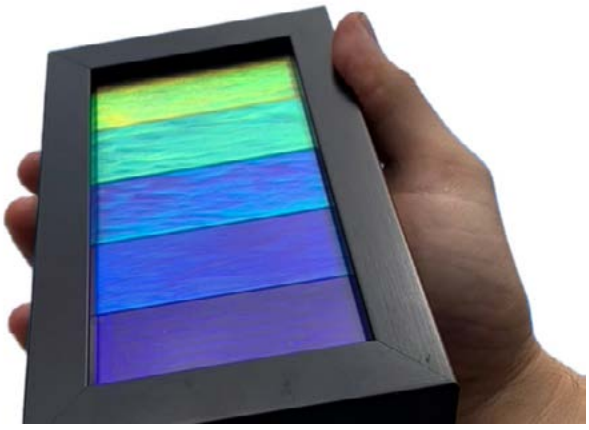
MOTIVATE Get inspired! Motivate your team by exploring a local or global problem and introducing the concept of biomimicry. Learn how the unique abilities of organisms help them to survive and thrive and how people have been inspired by them to design solutions to challenging problems.

INVESTIGATE Investigate the causes and effects of a problem learners are passionate about. Identify aspirational goals, constraints for the design, and the sustainable impact your solution will need to have to address the problem effectively.

MATCH Explore how nature has solved problems similar to yours by matching what you need your design to do with organisms that have similar abilities. Examine why those organisms have those abilities, how those adapted strategies function, and whether they could inspire your solution.

INNOVATE Create a biomimicry innovation that would help solve your selected problem. Refine your innovation after evaluating its strengths and weaknesses both in performance and how well it created conditions conducive to life.

COMMUNICATE Use the power of inspiration, storytelling, and scientific evidence to explain how your biomimicry design solves the selected problem and how nature has inspired it. Offer gratitude for the natural world for sharing wise strategies to better inform design.



Video: Cypris Materials

NEXT GENERATION SCIENCE STANDARDS

The foundational biomimicry, climate change, and design challenge alignments are shown in the table below. Alignment strength will depend on lesson choice, depth of instruction, and problem choice.

Additional specific physical, earth, and life science standards can be selected by choosing a particular Sustainable Development Goal as the focus for the design challenge.

DISCIPLINARY CORE IDEAS (DCI)	SCIENCE & ENGINEERING PRACTICES (SEP)	CROSSCUTTING CONCEPTS (CCC)
BIOMIMICRY		
• MS, HS - LS1.A: Structure and Function • MS, HS - LS4.C: Adaptation	• Developing and Using Models • Engaging in Argument from Evidence • Constructing Explanations and Designing Solutions	• Structure & Function • Patterns • Systems & System Models
ENGINEERING DESIGN		
• MS, HS - ETS1.A: Defining and Delimiting Engineering Problems • MS, HS - ETS1.B: Developing Possible Solutions • MS, HS - ETS1.C: Optimizing the Design Solution	• Asking Questions and Defining Problems • Developing and Using Models • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions • Engaging in Argument from Evidence • Obtaining, Evaluating, and Communicating Information	• Systems & System Models • Influence of Science, Engineering, & Technology on Society and the Natural World • Structure and Function
CLIMATE CHANGE		
• MS, HS - ESS3.D: Global Climate Change • MS, HS - ESS3.C: Human Impacts on Earth Systems	• Asking Questions and Defining Problems Analyzing and Interpreting Data • Developing and Using Models	• Cause & Effect • Stability & Change
ADDITIONAL PHYSICAL, EARTH, AND LIFE SCIENCE STANDARDS		
Choose a Sustainable Development Goal that matches your class or program content as the focus for the design challenge. Refer to the document, UN Sustainable Development Goals Aligned to NGSS, for suggested alignments.		

MOTIVATE

The Youth Design Challenge (YDC) begins with students identifying a local or global challenge that they would like to explore and learn about biomimicry as a design process that could lead to sustainable solutions.

- Students can choose a problem that they have heard about in the news, in school, or ideally one they have experienced in their community (the goal is to choose problem they feel passionate or interested in learning more about).
- Students are then introduced to biomimicry as a sustainable design practice with the potential to help solve many of the challenges facing our world today.
- The final phases of the Motivate learning progression opens students' eyes to the amazing biological strategies that all organisms possess, that we can learn from as we design our world.

Goal: Introduce biomimicry and identify the problem.

Question Aligned to the Storyline: How could practicing biomimicry help us design solutions to challenges experienced worldwide?

5E Instructional Model—Engage: In Motivate, we focus on the Engage component, prompting students to identify a local problem and reflect on questions like "Why did this happen?", "What do I already know about this?", and "What can I find out about this?" We begin to explore the concept of biomimicry and learn how we can look to nature to solve the problem of interest.

Motivate Questions

Part 1: What are some current problems we are facing as a people?

Part 2: What is biomimicry, and how can it give us ideas to solve problems?

Part 3: Who are nature's design champions right outside our door?

Part 4: What are the essential components of biomimicry, and how do designers learn from nature?

Part 5: How are students like us practicing biomimicry to create nature-inspired solutions to sustainability problems?

Procedure Part 1

What are some current problems we are facing as a people?

1. Invite students to think about issues that we see on the news and hear are being discussed in their community and/or around the world. Give students about 2 minutes to think of an issue or problem that they would like to share. List the issues that students share and set aside for later.

    - **Optional Extension:** Have students take the list generated and sort according to categories or themes they decide upon and have them explain their choices.

2. Tell students that the issues that they feel are important are recognized in some shape or form as challenges we need to face globally. The United Nations developed a list of Sustainable Development Goals (SDGs) that group these issues for countries to align on making progress.

3. Watch the call to action video: **We the People for the Global Goals**. Afterwards, have students read the **SDG Fact Sheet** looking for connections to issues they have raised as important to us as a people.

    - Point out an example to help bridge understanding: If students included on their list, for example, that temperatures are increasing every year, causing droughts and fires, then SDG 13 is the one most relevant. Show students the **SDG 13 Sheet** on taking urgent action to mitigate climate change and its impacts, and scroll down to the Overview which has visuals of some of the problems listed.

4. Have students select a specific SDG that they feel aligns with one of the problems they feel passionate about for additional research. Ask students to log onto pre-approved sites to research the local problem more, and the students should confirm that the SDG and problem that they've chosen have accessible information.

    - Other forms of research might include physically exploring their community and talking with family members, community members, or problem stakeholders.
    - Ask students to be prepared to share answers to the following questions once they have selected the SDG (potentially during class, if time allows, or to be done for home study and returned the following day to discuss):

        - WHY have you chosen this SDG for further study?
        - WHAT do you know about issues that are part of the SDG?
        - HOW might these issues be impacting your community?

5. Tell students that the Biomimicry Institute holds an annual creative challenge (or contest) called the Youth Design Challenge (YDC) that encourages students to apply solutions found in nature to human innovations, to help reach and achieve the SDGs. Give students the **YDC Design Brief**, **Project Rubric**, and **Project Portfolio Checklist** to read and discuss in small groups.

    - Share how a design brief is a document used by professional designers and their clients to communicate the context, goals, and requirements of a creative project. They will get to become sustainability champions by taking on this project.
    - The Project Portfolio Checklist will help them keep track of their communication process, and the Project Rubric will be the grading and judging guide for their end solution. Terms on the rubric will be explored during this learning journey.

Additional Teacher Resource

- **Background on the UN SDG**

Procedure Part 2

What is biomimicry, and how can it give us ideas to solve problems?

1. Tell students that they are going to hear about a practice called biomimicry. Explain that *bio*=life and *mimicry*=imitate or copy. Introduce Janine Benyus, the author who popularized the term biomimcry, using the short film, **Biomimicry** (21:47). Then have students write down one thing they "Notice" and one thing they "Wonder" about biomimicry based on the video.

2. After the video, have students share their "Notice and Wonder" to the whole group. Create a list to keep for discussion later in the instructional segment.

- Consider asking a student to record the responses while they engage in the activity.

3. Tell students that biomimicry has been happening all around us. Show **Biomimicry Case Studies** one image at a time. For each example, ask students: "How would you describe this example of biomimicry?"

4. Tell students that each image shows a pair of photos: a bio-inspired technology and the organism that inspired it (biological model). Read (or request a volunteer) the notes on the **Biomimicry Case Studies** after each image has been shown and provide students with an opportunity to discuss the images.

5. Give students the **Biomimicry Definition and Key Terms Sheet**. Have students put a tally mark next to the words used during discussions so that they can begin to build familiarity with the biomimicry vocabulary words.

Additional Teacher Resources

- **What is Biomimcry?**
- **Biomimicry Toolbox Introduction**

Procedure Part 3 (Outdoor Option)

Who are nature's design champions right outside our door?

1. Have students watch the video "**What is Biomimicry?**" (2:03)

2. Review the **Exploring Function in Nature** worksheet and plan for a 45-minute activity outdoors (or indoors if there are natural objects available). In this activity, students learn to recognize function in biology by encountering, describing, and considering natural objects. Students will examine structures, behaviors, and processes of plants and animals through the lens of function, and connect this function to human challenges and technologies.

3. Head back inside and explain to students that biomimicry goes beyond observing nature: that we also learn *from* nature.

- Show the image **Two Viewpoints of a Tree** and explain that knowing about something might require instant recall (like a tree has leaves) but learning from that is a more complicated task (like *how* those leaves generate energy for the tree to grow), requiring deeper learning. That is our goal in biomimicry.
- As part of this experience, they will be looking for patterns that can be found across natural

ecosystems, essentially: what does nature do well and why do we want to mimic natural forms? Invite them to consider how we are striving to emulate patterns across the natural world, such as how organisms and ecosystems:

- Adapt locally attuned and responsive strategies
- Are resource efficient both in materials used and energy expended
- Cultivate cooperative relationships
- Breakdown products into safe nutrients
- Utilize multifunctional design
- Recycle all materials
- Build from the bottom up
- Fit in modular and nested components

Additional Teacher Resources

- For examples of ten patterns that can be found broadly across the majority of life on Earth, visit **Nature's Unifying Patterns** on the Biomimicry Institute's Biomimicry Toolbox.
- Another resource that contains additional design lessons based on nature is **Life's Principles**, from Biomimicry 3.8.

Procedure Part 4

What are the essential components of biomimcry, and how do designers learn from nature?

1. Tell students that biomimicry has three essential parts: Ethos, (Re)Connect, and Emulate and that they will need to strive for all three as they complete the YDC and work toward their design solution.

- **Ethos** refers to the aspirational goal of biomimicry. That is, understanding how life works and creating designs that continuously support and create conditions conducive to life (sustainability).
- **(Re)Connect** acknowledges that humans are part of nature. Biomimicry finds value in connecting to our place on Earth as part of life's interconnected systems, and encourages us to observe/spend time in nature to better understand how life works.
- **Emulate** refers to the scientific, research-based practice of learning from and then replicating nature's forms, processes, and ecosystems to create increasingly regenerative designs.

2. Explain that biomimicry designers abstract terminology from biology to be used in design. During the design process of emulating an object's form, process, or system, a biomimicry designer might need to translate what an organism can do into what an engineer might understand. More will be explained on this process in the lessons to come.

3. Have students complete **The Language of Biomimicry** activity. Students can do this activity on their own, in small groups, or led by a teacher. Tell students that:

- Biomimicry innovations are based on the biological strategies of organisms.
- **AskNature.org** is a website that organizes biological strategies by function to help biomimicry designers find inspiration for new organisms.
- **Optional Extension:** Have students do an **AskNature Scavenger Hunt** as an independent activity.

Optional bonus activities to further understanding and engagement:

- **Media:** Have students watch **CBS Sunday Morning: The Fascinating World of Biomimicry** (6:00) that introduces biomimicry designers and how they are solving problems by learning from nature.
- **Outdoor Activity:** Take students outside for **Exploring Function in Nature** using the Function Junction Cards Activity. The **Function Junction Activity Cards** allow students to work in partners using their senses to describe organisms to one another and select a function to find an organism outside that performs that function. These activities have modifications that allow for them to be done indoors.
- **Guest Speaker:** Invite a local naturalist, zoo/aquarium staff, park/garden staff, etc. (anyone who works closely with plants or animals) to speak to your class about the unique adaptations and abilities of the organisms they've encountered.

Procedure Part 5

How are students like us practicing biomimicry to create nature-inspired solutions to sustainability problems?

1. If time during class or home activity: Tell the students that young people across the world have been using biomimicry to propose innovative sustainable designs. Pick either the first place winner for your grade from a previous program year or a project of general interest to the class.

    - You can review previous submissions that include project videos in the **Youth Design Challenge (YDC) Winners Collection** on AskNature.

2. Place students in small groups to view the previous YDC winners you have selected.

3. Ask the students to think about how the teams learned FROM (not just about) the organisms that inspired their projects. What do they find inspiring about these solutions?

4. Ask students to pick two teams to review and share what excited them about the problem, the steps they took to learn from nature, or the final solution.

5. Return to the **Design Brief** and brainstorm with the students what they will need to know and be able to do to be successful in this design project.

6. Have students begin a Biomimicry Notebook that has **a template of the submission documents** with a document organizer. Review each part of the submission process and briefly discuss so they understand what their final project will need to include.

7. Have each student either write a 1-3 paragraph summary of what biomimicry is or fill out the **Frayer Model** as an assessment to check their understanding.

    - **Optional Extension:** As an essay prompt, have students write a short 1-3 paragraph essay explaining what biomimicry is and how others have used biomimicry to solve design challenges.

Motivate: Vocabulary

Biology
Biological Model
Biomimicry
(Design) Brief
Climate Change
Design
Designer
Emulate
Engineer
Ethos
Form
Function
Innovation
Organism
Process
(Re)Connect
Regenerative
Sustainability
Sustainable Development Goals (SDGs)
System
United Nations

Additional Teacher Resources

- 30 Animals that Made us Smarter Podcasts (15-20 minutes)
- How Does the Star Nosed Mole Sense AskNature Video (3 minutes)
- BEETLES I Notice I Wonder Activity Guide (45-65 minutes)

INVESTIGATE

The Investigate section of the Biomimicry Institute's Youth Design Challenge (YDC) begins with students understanding human impact and further investigating the causes and effects of the problem they would like to solve using biomimicry.

- Students continue to narrow broad issues and goals presented in the **UN Sustainable Design Goals (SDGs)**. The educator/coach has the option of selecting one or more SDGs (aligned with the Next Generation Science Standards) for students to work with, or letting students choose their own SDG.
    - *The modeled activity uses climate change, however, educators are encouraged to select a goal that resonates with students and is aligned with instructional goals.*
- Teachers guide students in a deeper investigation of their chosen problem, in preparation for asking how nature solves similar problems in the upcoming Match section.
- Investigate wraps up with learners considering what their designs would need to do to solve the problem and describing the design project's criteria and contraints.

Goal: Investigate, identify, and define the problem to be solved sustainably using nature as a mentor.

Question Aligned to the Storyline: To solve our selected problem, what does our design need to be able to do, and what are the criteria and constraints for success?

5E Instructional Model—Explore: In Investigate, we focus on the Explore component, and the activities are designed to introduce students with an experience that helps prepare them for later introductions to scientific and technological explanations of how biological strategies function to better inform design. They will have time to investigate the problem chosen in alignment with the Sustainable Development Goals (SDGs). Teachers are encouraged to ask probing questions and promote student-to-student interaction.

Investigate Questions

Part 1: How might we use SDGs to identify design opportunities related to human impact?

Part 2: How will we decide which specific problem will be the focus of our design challenge, and who might be impacted by our designs?

Part 3: Which SDG will we focus on, and why is it important?

Part 4: What does our design need to be able to do to solve the specific problem, and what are its limitations?

Procedure Part 1

How might we use SDGs to identify design opportunities related to human impact?

1. Share with students that humans can make impacts to the environment with design in many different ways, including water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land). These impacts can be linked to several **SDGs**. Invite them to think of some ways that human impact is made worse when we don't think about the consequences of our choices of the products we design.

2. Reminds students that the **SDGs** have the word "sustainable" in them, because sustainability is critical to lessen negative human impacts and move toward positive ones. Tell students that sustainability means meeting our own needs without compromising the ability of future generations to meet their own needs.

- Also tell students that environmental sciences and environmental engineering focus on the quality of not being harmful to the environment or depleting natural resources, and thereby supporting long-term ecological balance.

3. Revisit the **Design Brief**, and ask students to explore what they will need to know before designing ("What do you need to know before designing?"). Make a list of their questions that can be referred back to as the class works their way through MIMIC.

- Consider the context (climate, temperature constraints, location, and other factors affecting how and where the design is used, and by whom), as well as other limitations and constraints to be mindful of in deciding what needs to be known before designing.

4. Tell students that researching how to design, and investigating who might be impacted by our designs, is part of the process. Then we will look to nature to learn how there are strategies to solve these problems all around us.

Teacher Resources:

- Review ESS3.C Human Impacts on Earth Systems in **A Framework for K-12 Science Education: Practice, Crosscutting Concepts, and Core Ideas**.
- **Chapter 7: Dimensions 3: DCI-Earth and Space Sciences** (p. 194) to understand the goals of sustainability.

Procedure Part 2

How will we decide which specific problem will be the focus of our design challenge, and who might be impacted by our designs?

1. Do the modeled activity below with your whole class (as needed) for students to understand the process of identifying a specific SDG to be addressed, the context, criteria, and constraints, and proceed to the parts that follow in this procedure.

Modeled SDG Activity—on #13 Climate Change

- **SDG #13** focuses on action to mitigate climate change. Show the overview section to the whole group. Use this infographic to discuss the information on the page with focused attention on the bottom portion that states: *Rising global temperatures continue unabated, leading to more extreme weather.*

- Ask students to investigate some of the existing solutions that have been designed to mitigate the acceleration of climate change that have caused global rising temperatures, such as using renewable energy through solar and wind or changing diet to eat less carbon-intensive foods. After they have had the chance to search and share, have them discuss some ideas with the group. ***Optional Resource:*** **Project Drawdown Solutions**
- Explain how these solutions have made positive impacts toward climate action, and how even existing solutions can be improved with biomimicry, because nature is full of sustainable designs.
    - **Example:** **This YDC Team** looked to nature to improve wind turbines by decreasing frost build-up on turbine blades, which can negatively impact performance. Inspired by mint and lotus leaves, the team came up with a solution that could prevent drag-inducing frost from building up on wind turbine blades, thereby improving their efficiency and reliability in cold climates, without the use of chemical deicing agents. It is designed as an add-on to exisiting turbines to improve the overall performance and decrease risk of damage.
        - Takeaway: The turbine blade needs to keep ice from building up on the surface. The mint plant prevents frost from forming due to ridges, and lotus plants have a bumpy surface with wax crystals making it super hydrophobic. These biological strategies inspired the design.

2. Once you have completed the activity on climate change, decide whether the class will all be addressing SDG #13 or another one. Explore with students how to make the chosen goal more personal and tangible, aligning back to a specific problem they can solve that helps reach the goal.

- Use the modeled activity above to unpack the other SDGs in a similar way as needed, then use the **Reframing Problems Activity** to redescribe the challenge into possible areas of action.
    - The emphasis here is on what the solution does, not the exact details of what the solution is or how it might work. It's important not to get too far down the road of designing a solution, because that is where nature's creative lessons will offer a new lens for us to peer through.
- You may find the need to focus on a limited number of the SDGs for classroom YDC participation, or might also choose to do each of the 17 SDGs in this modeled format to support students with reframed statements.
- The following document can be used to further align science instruction around specific SDGs: **Aligning NGSS to SDGs**.
    - Students might also benefit from exploring the **"Why it Matters"** sheets for each SDG for the purpose of defining problems to solve.

3. Continue deeper into this process with your students, telling them that biomimicry designers define the challenge prior to taking action. They will not be able to create an effective solution to a problem that they have not properly defined. This is an opportunity to refine clarity.

- Use the worksheet **Define the Challenge** to take student SDG information through the process and to reframe the challenge into a design question.
    - Tell students that identifying the functions of these designs is important for the next step in the process during Match, where they will begin looking for biological models in nature that have these same functions.

4. Tell students that one way that designers attempt to make sure they are designing with sustainability in mind is to perform an empathy interview. Empathy interviews are a type of research done in an interview format with people who are affected by the problem we want to solve and might be impacted by our designs. For SDG #13 on climate change in our modeled example, if our goal were to mitigate impacts of

extreme weather, we might perform an interview with people in areas that are prone to wildfires, drought, hurricanes, or floods.

5. Consider working with local social organizations, businesses, colleagues on campus, administration, or parent groups to assess who might be available for a 30-minute empathy interview.

- Please note that district policy on adult guest speakers might need to be reviewed. Researching online first person accounts is an alternative approach.

6. Teach students about conducting interviews with people who might be impacted by what they design. Use the **Empathy Interview Tool** to become familiar with the process and goals of empathy interviews. This tool has been used by high school teachers to improve the student online learning experience. If the linked tool is inaccessible to your students (due to age or other considerations), consider having a student use the following format:

- Thank the person for their time.
- Introduce yourself.
- Introduce the SDG that was selected as the reason for the discussion.
- Ask the following questions:
  - How might these issues be impacting your/our community?
  - Who else might be negatively impacted by this issue?
  - What do you feel is most important for others to know about how this SDG works?
- Thank the person again for their time.

Procedure Part 3

Which SDG will we focus on, and why it is important?

1. Tell students that they will now select a specific SDG and problem to explore for the purpose of creating a design that has considered criteria and constraints. The process will be the same as with the modeled process of using SDG #13 (in Part 2 of this lesson).

- The SDG that students explore might be the same one that was identified in the Motivate section, or it might be another SDG that feels relevant to their lives.
- Encourage students to work together in pairs or small groups if they have selected/are unpacking the same SDG.
- Ask students to explore the "Targets and Indicators" and "Progress and Info" tab sections of their **SDG** to ensure that they understand the goals.

2. Explain to students that science and design (and engineering) are closely connected. Scientific observations can help to inform their designs.

3. Share that they will be creating a poster (or Google Slide/digital interface) of their selected SDG for sharing. The SDG that is selected to share in class may be the SDG that is submitted to the YDC, or students may decide to select another SDG based on feedback. The following should be on each poster:

- SDG number and title on the top, along with group member names
- What are the causes of this SDG? (causes)
- How is the earth impacted by not accomplishing or achieving the SDG? (What's the science?)
- Why are the people concerned about meeting the SDG? (effects)

- What are people doing to slow the negative effects identified in the SDG? (mitigation solutions)
- What are people doing to lessen the harm identified in the SDG? (current solutions)
- A summary sentence on the information gathered.

4. Tell students to continue recording all information from the poster into their Biomimicry Notebooks. A picture taken of the poster might also be logged in a digitial format.

5. Host a classroom gallery walk. Have students practice scanning each other's posters for the purpose of providing feedback on what they have selected to display. Conduct a student gallery walk of the posters with feedback sessions as appropriate to the classroom goals.

6. Tell students that in the next phase of MIMIC, they will have an opportunity to use the information that was gathered while outside and/or information gathered from **AskNature.org** (the world's largest database of biological strategies for sustainable innovation) to begin identifying biological strategies that could inform their biomimetic design.

7. Use student posters (assigning points for each bullet point of poster content) to evaluate student learning.

Procedure Part 4

What does our design need to be able to do to solve the specific problem, and what are its limitations?

1. Tell students that you are going to revisit the answers to "What do you need to know before designing?" (in Part 1 of this section). Separate the list into possible criteria, or what the design has to do, context considerations, and possible constraints or limitations of resources.

- Remind students that design problems have their own unique criteria and constraints.
    - If the whole class is working on one problem, they will be able to identify criteria and constraints together.
    - If there are groups in class working on a variety of problems, then each group will have to identify the criteria and constraints specific to their problem.

2. Explain that criteria, which typically reflect the context of the how and where the design will be used, and needs of the expected end-user of a technology or process, address such things as how the product or system will function (what job it will perform and how), its durability, and its cost. Sustainability criteria should also be included. Criteria should be quantifiable, whenever possible, and stated so that one can tell if a given design meets them, with focused attention give to sustainability.

- Context can include many factors, but it's essential to identify the needs of stakeholders (those who will be impacted) and the location or setting in which the design will be used. Without this context, a design challenge is often too broad to be addressed successfully. On the other hand, remind students to be careful not to define the context too narrowly.

3. Let students know that constraints, which frame the most important conditions under which the problem must be solved, may be physical, economic, legal, political, social, ethical, aesthetic, or temporal (related to time and place). In terms of quantitative measurements, constraints may include limits on cost, size, weight, or performance, for example. This also includes sustainably-minded constraints, such as not wasting fresh water or emitting pollution.

- Explain that applying too many constraints before beginning the design process can limit the number and variety of potential solutions. Asking the right question at the beginning of the project will guide them in their research and offer a better chance of arriving at an innovative and impactful solution.

4. Invite students to explore the patterns they have witnessed so far in learning what nature does well, such as using locally available materials, minimizing energy use, and using life-friendly chemistry. These are valuable considerations that can be introduced as aspirational ideals that we can return to in the final evaluation of how well the design functions. This is also a key component of the Ethos component of biomimicry.

- Remember that these resources are available for deeper exploration of patterns found in nature: **Nature's Unifying Patterns** and **Biomimicry Life's Principles**.

5. Revisit the list of questions and categorize them as criteria, constraints, or unknown.

6. Once the list has been categorized and reviewed together by the group, invite students to phrase their selected challenge as a question that begins with, "How might we...?"

- Their question should give a sense for the criteria and context in which they are designing, as well as the impact they want to have and what/whom it benefits. If it doesn't, it may be too broad.
- Their question should also be somewhat open-ended to ensure they haven't jumped to conclusions about what they are designing. If the question is very specific, it may be too narrow.
- Try a few variations. Then circle the one that is not too broad or too narrow, but just right for the chosen design challenge.

Investigate: New Vocabulary

Climate
Constraints
Criteria
Ecological
Empathy Interviews
Human impact
Scientific observations

Additional Teacher Resources

- **Our Climate, Our Future Videos** (2-5 minutes)
- **The Emergent Pattern of Climate Change** (12 minutes)
- **Before the Flood** (Documentary; 96 minutes)
- **Climate Change Resources from Previous YDC Program Cycles**
- **Global Climate Change: Vital Signs of a Planet**, NASA
- **Climate Literacy and Energy Awareness Network**, CLEAN
- **A Student's Guide to Global Climate Change**, EPA

MATCH

The Match section of the Biomimcry Institute's Youth Design Challenge (YDC) begins with students refining their understand of what is and what is not considered biomimicry. They receive an overview of the Biomimicry Design Process, which they will learn already started when they defined their problem in the previous Investigate section. They will then biologize their design problems (translating the functions and context into biological terms so that they can be searched on AskNature.org).

They have learned about what they want their design to DO, and that there are lessons to be learned from nature. Now they will perform the steps to discover biological models and arrive at an understanding of which strategies can be emulated in the upcoming Innovate section to create a design solution.

- The goal of 'biologizing' the design problem's key function is to arrive at one or more "How does nature...?" questions that can guide students in their research as they look for biological models.
- Students will research multiple biological models (organisms) and identify which of them have strategies that could help them solve their design problem.
- They will then translate those promising strategies into design terms by removing the biological terminology and distilling the essential functional elements into a design strategy.
- Learners are encouraged to conduct research in nature (if possible) and may also use the AskNature online database as a valuable resource.
- To conclude, students assess how well their design translations summarize the biological strategies on which they focused. Students are encouraged to take photos and make sketches to capture and document their design process.

Goal: Identify biological strategies aligned to the function of their design.

Question Aligned to the Storyline: How can we use biological strategies found in nature to inspire a solution to the identified problem?

5E Instructional Model—Explain: In Match, we focus on the Explain component. You will be equipped with resources and information to support the learning and implementation of the scientific concepts embedded in the practice of biomimicry. Students will begin to understand the evidence-based models and explanations found in nature that will help them design a solution to the problem based on the established criteria.

Match Questions

Part 1: What is and is not biomimicry?

Part 2: How does the practice of biomimicry emulate biological strategies to influence design?

Part 3: How do we translate a problem into a research question to ask nature (biologize)?

Part 4: Which organisms have strategies for solving problems that are similar to the problem we want to solve?

Part 5: How do we translate biological strategies into design?

Part 6: Which of the abstracted design strategies are best suited to solve the problem?

Procedure Part 1

What is and is not biomimicry?

1. Have students answer the following statements with a "yes" or "no" for what biomimicry is based on their learning so far:

A. A person dissects a frog or grasshopper to see how it works? **No**
B. A telephone pole that has branches so it looks like a tree? **No**
C. A paint that imitates the surface of lotus leaves to rinse off quickly? **Yes**
D. A person raises fish or butterflies in their classroom to observe life cycles? **No**
E. A solar panel that collects more sunlight by following the sun like a flower? **Yes**
F. A mushroom that has been turned into insulation? **No**
G. A helmet that uses synthetic hollow spines to create padding? **Yes**

2. Explain that questions C, E, and G have emulated the function of a biological organism to inform the design. The surface of the lotus leaves make it hydrophobic, the solar panels mimic the process a flower uses to optimize sunlight intake, and the helmet mimics how hedgehogs absorb and distribute the shock of impact with their quills. None of these options use the organism to perform the function.

3. Tell students that this is different from option F, which can be considered bioutilization, because it is directly using the mushroom to perform the function of the insulation. Bioutilization and biomimicry can (and often must) work together, because there is no sense in reinventing a solution nature already does best. Biomimetic designs that include bioutilization should do in a way that is not harmful to the environment.

4. Option B is an example of biomorphism, where the design resembles a living organism for aesthetic, not functional, purposes.

5. Option D could be a way to (re)connect with the natural world, but it does not contain the other two parts of biomimicry. And lastly, option A is an approach used by researchers studying biology, and could lead to us better understanding how the frog/grasshopper has adapted certain strategies for living, but it is not a direct approach to practicing biomimicry.

Extension Activity: Extend this assessment of biomimicry by instructing students to look for and think of more examples and non-examples, quizzing one another in small groups.

Procedure Part 2

How does the practice of biomimicry emulate biological strategies to influence design?

1. Have students revisit the information gathered in the **Exploring Function in Nature** activity from the Motivate section.

- Remind them that biomimicry relies on deep observation of nature, specifically, to discover a trait that an organism has, the function or purpose of the trait, and how they have adapted strategies to perform that function.
- Encourage students to (re)connect with nature by going outside to observe organisms and their habitats or closing their eyes and sitting outside to be part of the natural world. This is an activity that can be revisited time and time again to help internalize the sense that they are part of the natural world.

2. Tell students that there are several ways to approach a design problem using biomimicry, and that today they're going to learn about the **Biomimicry Design Process**. Explain the steps laid out below as an overview, and in the upcoming sections students will be able to perform each one as they continue to work toward a design solution. The steps in the process are: **Define, Biologize, Discover, Abstract, Emulate, Evaluate**.

3. **Define:** Share that the students performed this step in the previous Investigate section where they defined the problem they are working with and how it aligns with a particular Sustainable Development Goal (SDG).

4. **Biologize:** "Biologize" is a fun name for the process of translating a design problem into biological terms/language. To formulate good research questions, students will need to take the needs or functions identified in the design question from Investigate (How might we...") and rephrase the question so they can more easily find answers in biology.

5. **Discover:** During this stage, students will look for biological models (from organisms and the ecosystems they live in) that need to address the same functions laid out from defining the problem and criteria needed for their designed solution. Spending time outside will help students identify the strategies used from organisms that support their survival and success.

6. **Abstract Design Strategies:** To abstract something means to make a conceptual model of it. We will first translate our design problem into language that we can ask nature, and then we will translate that biological concept back into design language.

7. The remaining steps of the Biomimicry Design Process (**Emulate** and **Evaluate**) are where we create a solution inspired by nature and analyze how well we met the design criteria. This will be more deeply explored during the next section of the YDC (Innovate).

Procedure Part 3

How do we translate a problem into a research question to ask nature (biologize)?

1. Tell students that in order to begin looking for design inspiration in the world, biomimicry designers need to ask the right kinds of questions. The goal is to reframe the functions of what their design needs to do using biological terms, and then "ask nature" for advice.

2. Ask students to analyze the essential function and criteria their design solution must address. Have them reframe them in biological terms, so that they can "ask nature" for advice.

- Use the "How might we...?" information from the **Define the Challenge** worksheet to begin the **Biologize Function and Context** worksheet.
  - **Teacher Resource: Sample Answers for Biologize Function and Context** worksheet.
- Tell students that they may use the **Biomimicry Taxonomy** sheet to help them ask the design questions in a biological context. Students may move from the center outward or from the edges to the center in order to help them understand how functions are grouped. Encourage students to examine the entire sheet.

3. A good test of a biomimicry research question is whether it can logically complete the phrase, "How does nature...?" Explain to students that if they simply used their original design question to complete the sentence, it probably wouldn't make any sense.

- For example, asking "How does nature make their city stop flooding?" sounds pretty silly. And it wouldn't help them begin searching for biological models. But once they biologize it into "How does nature manage disturbance in a community?" or "How does nature protect from excess liquids?" a research path becomes clearer. This simplified question expresses the essence of what the design challenge is all about.

4. After students have gone through iterations of biologizing the function, they will be ready to move into the next phase where they will discover biological organisms that have solved similar problems.

Procedure Part 4

Which organisms have strategies for solving problems that are similar to the problem we want to solve?

1. There are many tools available to use during this process as we begin to research effective strategies from the biological world. With **AskNature Biological Strategy** pages, students will be able to select the function phrases from the taxonomy into the search bar on the website.

- Students in upper grades may find it helpful to navigate through AskNature themselves, if they have access to an internet-connected device.
- For younger students, coaches may want to find relevant materials on AskNature and present select materials to their students.
    - **Collections** contain examples of Biological Strategies related to a theme, such as water, waste, or transportation. This may be a helpful resource for you to introduce to younger students.
- Students are also encouraged to go outside, (re)connect with the natural world and observe which organisms they see—continuing to ask the question: what is nature doing here?

2. Using these tools, students should research 2-5 biological strategies that all exhibit functions that are needed to solve their identified problem (more is always better, but they can also return to this step later if they need more strategies to work with). Encourage students to document all of the strategies they researched. This is a good place for citation skills practice.

- Explain to them that these strategies should not simply be "an attachment" to their design, but should be the main component. A good way to assess this is by asking, "If I take the biological strategy away, is the organism still able to achieve this function?" The goal is that it would not function without the biological strategy.

3. Review the vocabulary term "function" and explain "biological strategy" and "mechanism" with students. A biological strategy is the way an organism performs a function. It's an adaptation that the organism has evolved in order to survive, and essentially "how" a function is accomplished. Mechanism goes a bit deeper into understanding the specific way an organism performs the strategy.

- Biological strategy and mechanism are nuanced terms and are sometimes used interchangeably. Basically we're seeking enough details to show specifically how a function is achieved.
    - Consider a strategy to be "cactus ribs keep them cool," and a mechanism would explain how corrugated shapes create pockets of shaded, cooler air that help them shed body heat (and further detail would show the specific measurements of how much distance is between each rib, how deep the pocket is, what angle it faces, etc. in order the fully satisfy the function of cooling).

- A way to explain these nuances is to emphasize that function refers to WHAT the organism's traits or behaviors do for the organism to support their survival; strategy is a general overview of THE WAY a function is achieved; and mechanism focuses more specifically on HOW the strategy works.
- This will take practice. We want to make sure the biological strategy is understood deeply enough to be able to clearly communicate what the strategy does (its function) and how it is accomplished (strategy/mechanism).

4. Have students draw sketches of the biological strategy and mechanism with as much clarity as possible. Words can be shared in tandem with the sketches to explain what is happening in the diagram.

- Note that some biological strategies or behaviors can be more helpful than others when solving specific problems. To derive the best solution to a problem, the forms, processes, and systems of many natural ecosystems should be investigated and the most beneficial ones should be incorporated into the design of the solution in the next Innovate section.
- In the drawings, label how each organism's traits work to accomplish the needed function given the specific conditions and context (i.e. variables) in which the organism lives.
- Explain that the conditions and context pertain to the environment in which the organism is found (i.e. Does the organism live in water? Does the organism travel through air? Does the ecosystem have a tropical climate or a desert climate, and how does their biological adaptation function in this environment's conditions?).
    - Remind them of the context and constraint variables explored in defining the problem and how similar variables can be similarly considered for the organism's strategy.
- Tell students their drawings don't need to be perfect or even look good. It is the process of drawing that helps students understand how the mechanism works.
    - A variation on this theme is to have students teach/explain their organism's mechanism to a partner and ask the partner to sketch out what they think is happening based on the description they hear.

5. Explain that from here students will be translating the strategies into design language, and they can always go back to access more research if needed for learning how the organism achieves these strategies.

Procedure Part 5

How do we translate biological strategies into design?

1. Now that students have found some biological strategies, the next step is to identify the underlying working principles that can be applied in a design solution. Biomimicry designers do this by using the mechanisms that make the biological strategy work and re-stating them without using biology-specific terminology. The result is an abstracted design strategy. Think of it as the reverse of "biologizing" the design question. Now, you are "design-ifying" the biological strategies.

2. Have students go back to their sentence that describe the biological strategy and highlight or underline keywords or phrases that address the function (purpose/WHAT it does) and mechanism (HOW it's done).

- For each biological strategy, have students write a complete sentence using this sentence structure to summarize the biological strategy:
    - Include the organism, the function (WHAT it does), the mechanism (HOW it's done).
    - Example: The antennae of the honeybee enable smooth landings by sensing the landing distance and angle, signaling the body to orient appropriately.

3. Explain how to replace the working principles of the strategy with terms from engineering and design. Biological words with neutral synonyms are replaced, i.e. take the biological context away. (Example: "fur" is replaced with "fibers"; "skin" is replaced with "membrane"; "bone" is replaced with "porous structural support").

- Tell students that several interpretations of a biological strategy might all be correct if they are representing their ideas through the evidence of what the organism does. This approach is connected to the Next Generation Science Standards, Science and Engineering Practice #7 - Engaging in Argument from Evidence.
- **Additional Teacher Resource:** While likely too advanced to share with students, the **Biology to Engineering Thesaurus** resource worksheet can be helpful in guiding them in this process.

4. Finally, students rewrite the biological strategy using the engineering/design words that were substituted for biological words.

- For example, here's a simply stated biological strategy: The polar bear's fur has an external layer of hollow, translucent (not white) guard hairs that transmit heat from sunlight to warm the bear's skin, while a dense underfur prevents the warmth from radiating back out.
- A designer might be able to brainstorm design solutions using just that. But more often, in order to actually create a design based on what we can learn from biology, it helps to remove the biological terms and restate it in design language.
- Here's a design strategy based on the same biological strategy: A covering keeps heat inside by having many translucent tubes that transmit heat from sunlight to warm the inner surface, while next to the inner surface, a dense covering of smaller diameter fibers prevents warmth from radiating back out.
    - An even more detailed design strategy might talk about the length of the fibers or the number of fibers per square centimeter, i.e. if that information is important and its analog can be found in the biological literature.
- Additional sketches and diagrams are helpful to use here as well in ensuring that the new design statement is able to be understood and contains the key components of the biological strategy and mechanism.

Procedure Part 6

Which of the abstracted design strategies are best suited to solve the problem?

1. Tell students they will have an opportunity to explain from evidence (this is a Next Generation Science Standard practice) as to why their discovered strategies are the best model for solving the problem they selected.

2. Determine whether small groups or the whole group together would meet your students' needs better, then ask them to share:

- Sketches and summaries of the biological strategies;
- The abstracted design strategy sentences they wrote;
- The problem they are trying to solve and how these strategies could help.

3. Tell students that they will be able to make iterations, or improvements, to their design principles based on how well their peers understood the ideas presented. If necessary, allow students to review the Design Brief and Biomimicry Design Process (found in Part 2 of this section) for clarity on how to iterate on their design ideas.

Match: New Vocabulary

Abstract (Design Strategy)
Biologize
Biomorphism
Biomimicry Design Process
Bioutilization
Biological Strategy
Biomimicry Taxonomy
Iterate
Mechanism
Trait

Additional Teacher Resources

- **Ask a Biologist**, Arizona State University
- **AskNature Collections**, Biomimicry Institute
- **Pathful Connect** (platform for connecting industry experts to classrooms)
- **References for Biology Research (Biomimicry Toolbox)**, Biomimicry Institute

INNOVATE

The Innovate section of the Biomimicry Institute's Youth Design Challenge (YDC) begins with students brainstorming potential applications using their abstracted design strategies, and then they will create and construct a prototype design. They will refine that design through several emulation and evaluation phases to reach their final solution.

- During this iterative process, students will create a visual representation that communicates how their biomimicry design solution addresses the selected problem and assists in reaching the chosen SDG.
- As the Innovate section wraps up, students evaluate the design's ability to provide a solution to the local problem. This is an important step in the design process as students will need multiple opportunities to improve their designs.
- Students should continue taking photos and documenting their design process to show the improvements and explain why those changes were made.

Goal: Create and refine a nature-inspired solution to effectively address an identified problem and evaluate how well the solution will function.

Question Aligned to the Storyline: How can we, as biomimicry designers, apply our translated strategies to create a design that addresses our identified problem?

5E Instructional Model—Elaborate: In Innovate, we focus on the Elaborate component. Now that students have constructed explanations of how nature solves certain functional problems, and students have abstracted design strategies using these phenomena, they will have the opportunity to further their experience to apply these strategies in creating a design solution for their chosen problem.

Innovate Questions

Part 1: How do we apply abstracted design strategies to create a sustainable design?

Part 2: What might be some patterns or relationships that arise from the abstracted design strategies, and how could they be used to create an innovation?

Part 3: How will we refine our biomimetic design concept to improve its effectiveness in solving the identified problem?

Part 4: How will we ensure that our biomimetic design appropriately addressed the identified problem?

Part 5: How did this process help us better understand and connect to nature?

Procedure Part 1

How do we apply abstracted design strategies to create a sustainable design?

1. Remind students that they've now discovered and translated several design strategies from nature. They will now begin to capture the essence of the various strategies and mechanisms, through the **Emulate** phase, to determine whether using one or more strategies could help fulfill the **Design Brief**.

2. Tell students that they will now continue on their work of creating biomimetic designs using the Biomimicry Design Process with a focus on **Emulate** and **Evaluate**.

3. Elaborate on how during the **Emulate** phase of the design process, they will look for patterns and relationships among the strategies that were abstracted from biological models. They will also brainstorm application ideas for how one or more of their design strategies can be used to create a sustainable product, process, or system. And finally, they will create a solution!

4. During the **Evaluate** phase of the Biomimicry Design Process, the goal will be to assess how well the design concept meets the **Design Brief**, while adhering to the criteria and constraints of the selected challenge. Another very important evaluation will be on whether the design is furthering sustainable goals, observing some of the patterns found in nature (like using only abundant resources, using low energy, conserving water, etc.), and considering any unintended consequences their designs might have on the environment. Considering how the solution also meets the goals of (Re)Connect and Ethos will be important as well.

Procedure Part 2

What might be some patterns or relationships that arise from the abstracted design strategies, and how could they be used to create an innovation?

1. Invite students to explore some of the patterns seen between the abstracted design strategies they have focused on.

- Use the **Uncover Patterns** resource from the Biomimicry Toolbox to help with this process.
- Ask students to compare their abstracted design strategies side-by-side, looking for central ideas or unifying concepts that could summarize the strategy and be used for design.
- It may be helpful to have students work in pairs or small groups on each of their strategies.

2. Once the patterns or relationships have been identified from the various statements, have students brainstorm potential application ideas:

- One abstracted design strategy may provide the strategy needed to solve the design problem, but students can also combine multiple abstracted strategies to solve the problem.
  - **Note:** during the YDC judging process, some teams have received higher scores in years' past, because of their creative implementation of more than one biological model—however, that does not mean a very well-delivered design based on learning from a single organism would be overlooked.
- Have students elaborate on how this new strategy might be used to solve their selected problem. Tell them to consider each of their abstracted design strategies in relation to the original design question or problem they identified in the **Define** step.
  - "How can this strategy inform our design solution?"
  - Have students write down all of their ideas and then analyze them.
  - The **Biomimicry Brainstorming Activity** provides one way of doing this.

- Assist teams as they work. After about 20 minutes, or when students have explored all of the potential application ideas in the brainstorm, instruct students to study the collection of ideas they captured. Ask students: "Do any of the ideas seem to fit together?" and "Can you recombine or mix them to arrive at new ideas?"
- Have students draw lines, arrows, and add notes as needed to capture their observations and additional ideas. Give students approximately 15 minutes for this part of the activity.
- Check in with teams as they work to monitor their progress and answer questions.

3. Remind students of the path that they have taken:

- Students were given a Design Brief that asked them to identify and solve a problem connected to a local and/or global issue. **(Define)**
- Students were introduced to biomimicry as a way to create sustainable designs.
- Students were shown how organisms have lessons to teach us about solving problems.
- Students were asked to match their design needs with several organisms' strategies. **(Biologize** and **Discover)**
- Students were shown how to translate these strategies for use in design and brainstorm application ideas. **(Abstract Design Strategies)**
- Students are now asked to design and create their innovation based on their research **(Emulate)** and after that they will **Evaluate** how well the solution meets the defined problem.

4. Have students make concept models of their design ideas. Note the difference between a biological model and a concept model explored here. These models might be drawings, diagrams, or physical replicas/prototypes of the design concept. The important point to remember is that the model is clearly understandable to others and communicates the key features and purposes of their design.

- Encourage students to think about and incorporate details into their designs. Here are some questions you might ask:
  - What are the dimensions? How much space does it need?
  - What is my design made of? Are the materials sustainable or sustainably-sourced?
  - How does my design fit into the environment in which it is designed for?

Procedure Part 3

How will we refine our biomimetic design concept to improve its effectiveness in solving the identified problem?

1. Tell students that design requires multiple concepts and ideas to be analyzed and explored through various iterations before settling on a design solution in the **Emulate** phase of the Biomimicry Design Process.

- If possible, talk with the stakeholders affected by the problem or experts from students' empathy interviews. They can ask for feedback on the strongest idea(s) they think are worthy of pursuing.
- Solutions have strengths and weaknesses. It is important to consider how the solutions will work not only for performance capabilities and for solving the problem being addressed, but also for whether they are offering true sustainable solutions and not unintentionally doing more harm.

2. Refine the list of brainstormed application ideas to pursue the strongest potential solution that they will want to develop for their biomimetic design.

3. Encourage students to create two- and three-dimensional models that highlight the abstracted design strategy for their design concept.

- Consider having students use homemade sculpting clay or scrap materials from a junk drawer as a way to increase their awareness of the design features.
- Free, online websites and resources like TinkerCAD or 3D Slash can be easy introductions to 3D modeling and design, as well.
- If resources are limited, sketching, illustrations, and written explanations will suffice.

4. Tell students that the model that is created and based on their abstracted design strategies might require several versions before it is complete. Use class time for students to continue working on their biomimetic designs for however long seems reasonable.

- **Note:** Ideally, students would iterate 2-3 times before arriving at their final submitted work—each time refining their design based on data/evidence and justifying their design decisions in the light of their identified problem.

Procedure Part 4

How will we ensure that our biomimetic design appropriately addresses the identified problem?

1. Have students review the strategies and mechanisms that informed their final design. Ask them to think about how the strategies and design concepts they are working with relate to patterns also seen in nature that were explored in the previous lesson (i.e. using multifunctional design, building with modular and nested components, etc.).

- Remind students that biological strategies should not have simply been "an attachment" to their design, but should have been the main component, so that should be the same for their abstracted design strategy.
- For example: jackrabbit ears cool through their large surface area that dissipates heat. A design solution for a cooling tower should not then be to add "rabbit ears" to a standard cooling tower model.

2. Have students **Evaluate** the design concept(s) for how well they meet the criteria and constraints of the design challenge. Refine and revisit previous steps as needed to produce a viable solution.

- These next few steps are all about assessment. Students will examine the design concepts they have developed for how well they solve the selected design challenge in a life-friendly way and for how feasible the designs could be in real-world application.
- Although **Evaluate** is shown as the "last" step in the Biomimicry Design Process, evaluation should occur multiple times throughout the design process and with increasing rigor.

3. Ask students to consider potential barriers or limitations that their design concept might face (i.e. technology, cost, matierals, regulations, culture) and how the solution could be deployed in the real world. Is implementation/adoption of their idea feasible? What are the next steps it would take to achieve their goals?

4. Help students assess and explain how their final design helps solve their problems by reviewing the **Design Brief**. If the design did not clearly solve the problem, have students describe why and propose changes to the design to make the design a more effective solution to the problem.

5. Elaborate on the Ethos component of biomimicry and how the **Evaluate** phase includes reflection on the aspirational ideals we have set for how well the design supports life (i.e. is sustainable). Others goals could be aiming for zero waste, modular design, life-friendly materials, multifunctionality, and cooperative relationship opportunities. Solutions should also evaluate the (Re)Connect component: how have the students' design solution help humans better reconnect with nature?

- Communicating the value of the design, considering its ability to solve the problem, and explaining how the design matches nature's sustainability is an essential part of the evaluation process for biomimicry.
- Communicating scientific and engineering discoveries is also essential to help stakeholders understand the importance of the project.

6. In small groups, have students create a visual representation of how their bio-inspired design solution for the local problem contributes to reaching their chosen SDG.

Procedure 5

How did this process help us better understand and connect with nature?

1. Begin by asking students to reflect on their own whether they feel more connected to the natural world after this experience. Ask questions like, "How has your relationship to being outside changed?" and "How has your perspective about organisms, ecosystems, human impact, or design changed since beginning this project?" Invite them to also consider how the community in which they are solving their challenge might change for the better if more people were more deeply connected to nature in this way.

2. Have students get into groups to share their reflections and come up with a list of ways this process surprised them both in learning from the natural world and how we can create better designs that are helpful to the environment and to us as a society.

3. Come back together as a group and share ideas.

4. Invite students to consider the practice of gratitude. Thanking nature for the guidance to solve these problems helps strengthen the Ethos element of biomimicry.

Innovate: New Vocabulary

Evaluate Model Protype

Additional Teacher Resources

- Next Generation Science Standard: Appendix G - Crosscutting Concepts
- Bozeman Science Patterns Video (7 minutes)
- Rapid Prototyping, IDEO
- Homemade Sculpting Clay (6 minutes)
- 3 Ways to Practice Gratitude, Nemours TeenHealth

COMMUNICATE

The Communicate section of the Biomimicry Institute's Youth Design Challenge (YDC) has students present their designs with clear language around the problem that was solved, the inspiration for their design solution, what their design accomplishes, and how well it meets sustainability goals.

- Students will gather the information from their biomimetic design project and create a **Project Portfolio**.
- After a classroom review, the top three designs will be considered for submission to the YDC. A limit of three project submissions per coach/educator will be accepted. Please use the steps in this section to select the strongest three projects to submit to the YDC.
- Educators can choose to follow the instructions given in the Communicate section of this curriculum or they may choose to go directly to the **site** to submit student projects.

Goal: Explain how your design solves the selected problem, how it was inspired by nature, and how you created a design in real life.

Question Aligned to the Storyline: What did you learn about biomimicry, and how can you communicate the process of designing with nature in mind?

5E Instructional Model—Evaluate: In Communicate, we focus on the Evaluate component, which provides opportunities for learners to assess their own progress, and educators empower students to assess their understanding of the knowledge and skills gained throughout this experience. Educators are also given the opportunity to evaluate student progress toward achieving learning outcomes.

Communicate Questions

Part 1: How is the biomimicry solution going to be communicated in it in its effectiveness to help solve the identified problem?

Part 2: How do we decide which of our design projects to submit to the Biomimicry Institute's YDC?

Part 3: How can you share what you learned and experienced so others recognize biomimcry as a sustainable design process?

Procedure Part 1

How is the biomimicry solution going to be communicated in its effectiveness to help solve the identified problem?

1. Have students revisit the **Design Brief**. The strongest projects are those that are most aligned to the Design Brief and the **YDC Project Rubric**. Let them know in this section they will be working on the final project needs, including creating a Project Overview, Video Pitch, Project Portfolio, Project Image, and Team Photo.

- Complete all of these steps for all student projects for grading. The next phase will help you determine which of the projects to submit.
  - **Note:** The YDC submission portal is **here**.
- Revisit the **Project Portfolio Checklist** with students.

2. Using the **Project Portfolio Checklist**, begin working on the following sections, beginning with the Project Overview.

Project Overview:

Save these responses for the YDC Submission Portal and/or for grading.

Have students write an answer to each of the three questions below. **Each response is limited to 100 words.** The answers will be the first thing judges will read about the project, so make sure they are succinct, complete, and well-written.

What is the problem your team solved for this challenge?

- What is the problem addressed?
- How is the problem connected to the selected SDG?

How is your solution inspired by nature?

- What organisms did you learn from?
- How effectively did you translate the biological strategies for use in the final design?

What does your design solution do?

- How does it address or solve the problem you selected?
- How did what you learned from nature inform your design?

Two-Minute Video Pitch:

This connection to Visual and Performing Arts may take place during art/drama/after-school programming, asynchronously, etc.

A video pitch is the second requirement for submission to the YDC. The video pitch is an engaging overview of the design project and convinces viewers that the idea has merit. For additional suggestions and resources, here are some **Video Pitch Ideas**.

Be sure to include the following in the Two-Minute Video Pitch:

- How the empathy interview or research was carried out with the results about what was learned;
- Clearly explain the project that will be seen and how it relates to the selected SDG;
- How the design is inspired by nature;
- And communicate key discoveries or insights from the design process.

Project Portfolio:

A Project Portfolio is a document or presentation that combines narrative and images to tell the story of your team's biomimicry design and process for developing it. The portfolio should illustrate how the team approached selecting a specific problem, how they researched biological models, and how they developed the bio-inspired design solution, including refining ideas and getting back feedback from others.

This must be uploaded as a PDF for submission to YDC.

- **Slide 1: Title Page:** Project Name, Coach Name, Team Members, School or Organization, Grade Level, and Project Photo (Can be a sketch)
- **Slide 2: Meet the Team:** Team Photo (with coach if possible), Names, Ages and General Info
- **Slide 3: Project Abstract:** Problem and SDG Addressed, Biological Models used as Mentors, Criteria and Constraints listed (summary of the project in 75 words or less)
- **Slide 4: Innovate:** Problem is defined with a proposed solution that defines who needs the design, what is needed in the design, and why the design is needed
- **Slide 5: Inspiration/Match:** The biological models that were used for the design, including the abstracted design strategy
- **Slides 6 & 7: Iterations/Process:** The process of developing the designs along the way. Show all of the "design failures" that have occured. Annotate the models to show the strengths and limitations of the designs.
- **Slide 8: Final Project Image:** Image with labels of design features, include how the 3 essential elements of biomimicry were used in the design
- **Slides 9 & 10: References and Works Cited:** For all sources, image credits and experts consulted. Include any AskNature pages used (If image credits are provided with captions, there is no need to provide additional citations in the references list).

Project Image

The project image is a drawing, diagram, or photograph that clearly portrays your team's design solution. Include top and side views of the project and upload as JPG format. The image cannot be smaller than 1500px by 1000px.

Include an image caption that explains the key features that are being presented (entered separately in the submission form).

Team Photo

This may be the same photo from the Project Portfolio (entered separately in the submission form). JPG file format for the image and larger than 600px by 400px. Consider horizontal and vertical versions, if possible.

Procedure Part 2

How do we decide which of our design projects to submit to the Biomimicry Institute's YDC?

1. Tell students that a lot of great work has taken place and they must now work as a community to submit (up to three of the strongest) design projects to the YDC (the ones most aligned to the sustainability criteria, **Design Brief**, and three essential parts of biomimicry).

2. Explore the options below for selecting the top three projects (after comparing them to the **Design Brief** and the **YDC Project Rubric**).

- Display projects during STEM Fairs, science fairs, Open House, parent-teacher conferences, etc. and use surveys for judging (or ask a formal judging panel of teachers, local community members, guest experts, etc. to review)
- Hold a biomimicry design fair in your classroom, requiring students to give their video pitches in person to small groups. Allow students to use the rubrics to judge the top three.
- Hold a biomimicry design fair in your classroom, and allow staff and parents to use the rubric to judge the top three. This will require an introduction to biomimicry (to discuss biomimicry components, above and beyond a science fair), and can be used to spark community discussion and continue the conversation beyond the YDC deadline.
- Have students vote on two of the projects that will move forward, and you make the final decision. The YDC Project Rubric can also be used to assess mastery and convert student work into a score/letter. You could use this scoring to pick the top three teams (or if students are voting, use the team with the highest score that was not selected by their peers).
- Invite a guest panel of science professionals to judge the projects virtually or in person.

3. Submit the three selected projects to the **YDC**.

Procedure Part 3

How can you share what you learned and experienced so others recognize biomimicry as a sustainable design practice?

1. Invite the selected teams (and any other teams who you like) to share how their biomimicry journey has impacted their understanding of local and global issues.

2. Have students think about how they can take their designs further. Are there other organisms that students might have missed that could have helped in their design?

3. Celebrate! Give students a high five that they completed this inspiring project and that they are taking steps in learning about how biomimicry is helping to solve global issues!

Communicate: New Vocabulary

Portal
Portfolio
References
Rubric
Submission
Video Pitch
Work Cited