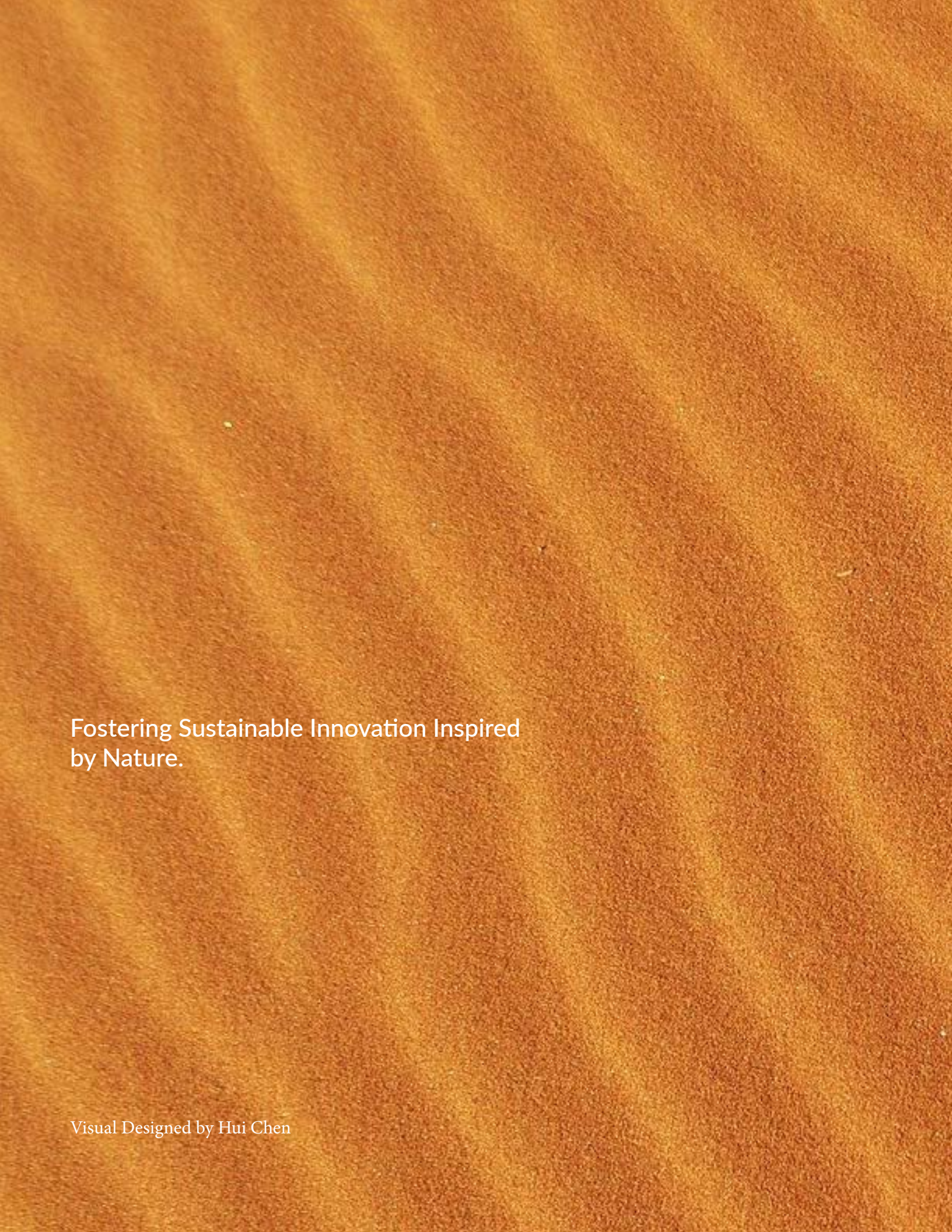
BIOCONNECT

Lesson Plans 08


Fostering Sustainable Innovation Inspired
by Nature.
Visual Designed by Hui Chen

Week Outline:

Day 1: What is Biomimicry?

Day 2: Introduction to Desert Ecosystems

Day 3: Learning from Desert Organisms

Day 4: Biomimicry Design Challenge

Day 5: Design Challenge Group Presentations

Overview: *(Vocabulary in bold)*

The natural world is an incredible place filled with millions of different organisms that have inhabited our planet for much longer than humans. Many indigenous communities survived off the land for thousands of years by learning from other organisms in their habitat. The practice of looking to nature to survive and create new designs is ancient. Only in the last twenty years have we named this approach **"biomimicry"** and integrated looking to nature into formal design and academic spaces (although many tribal communities and indigenous cultures have never forgotten how to learn from nature). Biomimicry offers a new way to apply lessons from nature to the **invention** of healthier, more life-friendly technologies for people. We will be exploring this topic this week, and you will even have a chance to create your own design based on something we learn about from nature!

Biomimicry can be confused with some other terms that are used to describe different design approaches- and each of these practices is along what we call the "**Biomimicry Continuum"** (none are inherently "bad", but can be misinterpreted or not actually very **sustainable**). **Bio-morphic** refers to the practice of creating a design/structure that only looks like something in nature (i.e,. a leaf, a tree, etc.). **Bio-utilization** involves directly taking a natural or biological organism and using it in a design (i.e., bacteria, fungus, etc.). **Bio-assisted** means that a design did have the help of a biological organism, but it doesn't make up the entire design (i.e., water filtration using wetland plants/soil). **Biomimicry** is a deeper practice that requires that we learn about how natural organisms or systems function and translate these ideas into a final product-- but this approach does not take or use nature directly in the design. One of the tools that **biomimics** (people who practice biomimicry) use is the framework of **Life's Principles**: a set of 26 total principles that govern life on our planet (see Life's Principles page in kit). A group of scientists from around the world created this set of guiding principles that every living thing needs to do in order to survive. We can use these principles to guide our designs and evaluate how "life-friendly" they are. For example, does the design evolve to survive, adapt to changing conditions, or use low-energy

AZ State Standards:

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Next Generation Science Standards:

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Animals engage in characteristic behaviors that increase the odds of reproduction **(MS-LS1-4)**.
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Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function **(MS-LS1-2)**

Objectives:

The students will be able to…

- Understand how the concept of biomimicry, biomorphic, bio-assisted, and bio-utilized designs are different
- Explore the topic of learning from the natural world
- Understand how biomimicry can be used in human design
- Explore the topic of Life's Principles and how this tool is used in biomimicry

Materials:

- Biomimicry continuum slides/images
- Biomimicry Case Studies: rattlesnake skin
- Life's Principles Print Out
- Unlined paper (white and colored)
- Stapler
- Pens/Markers/stickers

Prior to Beginning Instruction:

Consider capturing student work and thoughts in their current science journals or prompt students to make a research journal. (15 min) Make Research Journal: have students create a booklet with 10 pieces of white unlined paper folded in half and stapled at the crease, with a color page folded for the cover/back. Students can write a title like "NAME's Nature Research Journal YEAR", and decorate with drawings/stickers/etc. This journal will be used for at-home thoughts and reflections throughout the week.

Procedure

1

(10 mins)

"What do you notice, what do you wonder?" Group Activity: Give the Life's Principles pdf to each student and ask them to spend 5 minutes observing the document and come up with one thing they notice and one thing they wonder. After giving students the student time to notice and wonder, have them each share one notice or one wonder as time permits. Post the wonder on one side of a T chart and the notice on the other side.

- Sentence Stem: "I notice..." and "I wonder...?"

2

(15 mins)

Biomimicry Intro: using the continuum (bio-morphic → bio-utilized → Bio-assisted → biomimicry). Discuss idea of biomimicry continuum, other fields that sound similar: biomorphism, etc. Mention that biomimicry is an ancient practice and new practice (as we encounter more problems and more life-friendly solutions).

- Use print-outs of picture examples for each term, have students guess which "bio" it is.

3

(15 mins)

Introduce Case Study/ Research review- Rattlesnake skin

- Present students with biomimicry research article. What do you notice? What questions does it inspire?
- Explain what the researchers observed. What do you think they did with this information?
- Explain the current research on it. What could you create from this?
- Link optional YouTube video of scientist talking about this research

4

(5 mins)

Optional Overview design discussion- Ask students if they can name a few designs that they use in their everyday lives. Is there a design that you think works really well, and one that perhaps is not as useful or well-designed? What makes a good design? (no right or wrong answer here)

- Talk through what we will be looking for in the end project for this week.

Resources:

Biomimicry Institute:
Sharing Biomimicry with Young People - This document provides an orientation to biomimicry for K-12 educators, describing the what and why of biomimicry with teaching suggestions for several core concepts. It is available to download from AskNature.

AskNature:
Resources - A diverse library of resources for teaching and learning about biomimicry. The collection can be filtered by resource type and audience.

Overview: *(Vocabulary in bold)*

Deserts are defined as areas in the world that receive very little **precipitation** (water that falls from sky: rain, snow, ice, etc.). They also experience extreme variation in temperature- ranging from freezing at night to well over 110 degrees fahrenheit during the day. These environmental factors of the desert impact what organisms (plants and animals) can survive there.

One of the main **mechanisms** for cooling in animals (and many birds) in the desert is called **evaporative cooling**. **Evaporation** is the process of liquid water transforming into a gas in the air -- triggered by a temperature increase. For mammals, like the camel, coyote, and Mexican Gray Wolf, their thick coat of fur provides an **insulative layer** of protection (cover layer that protects from heat and moisture loss), so when the sweat evaporates from the surface of their skin, no excess moisture is lost to the air. Many of these animals also "pant", which is also evaporative cooling through the mouth, with many blood vessels in the skin of lips that then cool the rest of the body down through **circulation**. These mechanisms for cooling are examples of **adaptation** to the desert environment: a **trait** that improves their chances of survival and can be passed down through generations (heritable reproduction). Humans can also adapt to live and survive in the desert. We also must protect our bodies from the intense sun, and learn how to cool ourselves in the extreme heat. We will explore how animals have accomplished this and how we might learn from them today.

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Structure and Function
Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function **(MS-LS1-2)**

Objectives:

Students will…

- Discover the environmental factors that make the desert unique
- Gain an understanding of the challenges of living in the desert
- Explore organisms that have survived in the desert, and learn what strategies make their survival possible
- State at least two physical and two behavioral adaptations of a desert organism
- Start to explore and understand evaporative cooling mechanisms

Materials:

- BioConnect videos from the Phoenix Zoo of the following organisms- camel, elephant, fennec fox
- Paper
- Pencils
- Nature Research Journal
- Desert organism image cards

Procedure

1 (10 mins)

Group Conversation: How do animals stay cool in the desert? Ask: What are some things that you like to do when it's warm outside? List the activities then ask what they typically wear when they do the listed activities. Add to the list that was created for clothing/outer layer/outfit.

2 (20 mins)

Adaptation Activity- *Optional Outdoor Activity*

- Team or partners have 5 minutes to create a list of all the desert animals and plants that they can identify. Examples: look in the air, close to the ground, in bushes, water sources, etc.
- Come back together to discuss different organism's traits that allow them to survive -- example of evaporation cooling. How do you think a coyote stays cool with a fur coat, or raven with black feathers?
    - Examples might include: only being out at night, digging burrows, seeking shelter in the shade, panting
- Explain some common features of a desert, focusing on lack of water and extreme heat; and how different organisms need to evolve in order to survive.
    - Difference between physical and behavioral adaptations
    - Physical: insulation, large ears, etc.
    - Behavioral: nocturnal, underground dens, panting, finding shade

3 (15 mins)

Return to the classroom and show Zoo videos about champion organisms for the desert: camel, elephant, and mexican gray wolf.

- Discuss some traits of these organisms, what allows them to survive? Think about this question for tomorrow.

At-Home Activity (Extension Activity):

Have students sit quietly outside near their house and observe for 10-15 minutes. They should write down what they see, smell, and feel - what is the weather like? What plants or animals do they see? What traits or adaptations can you observe? Do they notice anything weird or cool? Option to include a drawing of one organism as well. This activity is just to begin the process of learning to observe the natural world.

Assessment:

Can use as an exit ticket for in-person or virtual poll (insert virtual tool here).

- What is the definition of a desert? What environmental factors does the Sonoran Desert have?
- What are 3 factors that make living in a desert environment so difficult for animals?
- Imagine you are a camel, elephant, or Mexican Gray Wolf. Write a short story describing how you would survive a hot summer's day. Hint: make sure to describe both physical and behavioral adaptations!

Links/Resources:

Desert description:
https://www.nationalgeographic.org/encyclopedia/desert/

Adaptation definition:
https://www.nationalgeographic.org/encyclopedia/adaptation/

Adaptation and Trait overview:
https://www.britannica.com/science/adaptation-biology-and-physiology#:~:text=Examples%20include%20the%20long%20necks,daggerlike%20canine%20teeth%20of%20carnivores.

https://www.desertmuseum.org/desert/sonora.php
https://thinktv.pbslearningmedia.org/resource/tdc02.sci.life.eco.desert/desert-biome/

Overview: *(Vocabulary in bold)*

Animals and plants that live in the desert have developed adaptations that allow them to survive in the harshest environment- including very limited water supply and extreme temperature variation. Natural selection leads to these adaptations, by "selecting" traits that allow the organism to survive and reproduce.In today's lesson, we will explore some of these adaptations, and begin to understand how we can learn from organisms for our own desert survival.

Homeostasis is the way animals maintain a stable internal balance in their body. It allows animals to function in the changing external conditions surrounding their body. Animal organs and organ systems constantly adjust to internal and external changes through a process called homeostasis ("steady state"). Homeostasis means to maintain dynamic equilibrium in the body. It is dynamic because it is constantly adjusting to the changes that the body's systems encounter. It is an equilibrium because body functions are kept within specific ranges. Even an animal that is apparently inactive is maintaining this homeostatic equilibrium (Source: Organismal Biology). One of the main mechanisms for maintaining homeostasis is through evaporative cooling, either sweating or panting. We will explore these strategies more in depth in today's class.

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Structure and Function
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Objectives:

Students will…

- Learn about how specific desert animals and plants have adapted to the desert conditions
- Describe the strategies and mechanisms used by plants and animals to tolerate extreme conditions in the desert
- Start to explore and understand evaporative cooling mechanisms

Materials:

- BioConnect 3D model: Camel Fur
- Natural artifact: coyote Fur
- Inquiry Cards: coyote fur
- Spray bottle with water
- 2 heat lamps
- 2 thermometers
- Poster paper
- Pens/markers

Procedure

1 (30 mins)

Biomimicry Kit Stations Activity. Have students break into three groups and rotate through the biomimicry kit stations (10 minutes per station). During their time at a station, the group should explore the model- how does it work? Is this a strategy for water or heat management? What is the organism strategy and mechanism for water capture or heat management?

- **(10 min) Station activity #1:** take the temperature of your arm without spraying water, and spray water, wait a while, and take temperature during evaporative cooling. Discussion questions: What does the hand with water sprayed feel like, is it cooler than the other non-sprayed hand? Why would spraying water help you feel cooler?
- **(10 min) Station activity #2**- Coyote fur artifact: Place coyote fur box under heat lamp. After 5 minutes, with your hand and the thermometer, test to see how hot it has become. Explore the fur with the jeweler's loupe to see how dense the fur is. Would you think that this fur helps the organism keep cool? Why or why not?
- Once students have explored the artifact, read the Inquiry Card together to understand more about how their fur helps to regulate the temperature of the organism. Discussion questions: Can you name other desert animals that have this fur color? Do you think dark color fur or light color fur would be better in the desert? What might this coat color or density tell us about abiotic or biotic factors the coyote deals with in the desert?
- **(10 min) Station activity #3**- Camel fur 3D model: Place camel model with cover under heat lamp. After 1 minute, observe how the inside has changed color, and record the temperature. Then, take off the cover and place it back under the heat lamp. Record the temperature at 30 seconds and 1 minute, and observe how the inside changes color quicker.
  - Discussion questions: *Which version became hotter quicker? Does the fur (cover) help to manage the temperature? Why do you think that a thick layer of fur would be useful in the desert? What might this fur density tell us about abiotic or biotic factors the camel deals with in the desert?*

Links/Resources:

Optional Video of sweating (1:04)
https://medlineplus.gov/ency/anatomyvideos/000127.htm#:~:text=A%20body%20has%20between%20two,and%201%25%20salt%20and%20fat

2 (20 mins)

Champion Organism Poster (Group Activity)

- Review the vocabulary terms: strategy and mechanism. Emphasize that strategy focuses on WHAT and mechanism focuses on HOW.
- Break students into small groups (no more than 4 students) and have them choose a champion organism from the ones we have just explored.
- Give students a large piece of poster board or butcher paper. Have them divide the poster into 4 equal sections, with a circle in the middle (connecting to all sections) for general biology/drawing. Explain that they will be adding to this poster each day of the project. Today, they will be filling in the middle and first two boxes.
- Middle section-- Student teams should add the organism name, their own drawing, and summarized biology (sentence or two) to the middle section of their poster.
- For the first box, have students write out the Strategy: WHAT the organism is doing.
  - Use this sentence frame: "The ____ (Organism) _____ (Strategy - ex: stays cool, manages heat)"
  - TIP- The strategy should be a few words (i.e. cools or decreases its body temperature)
- For the second box, have students write out the Mechanism: HOW does the organism accomplish the strategy (with specific body part).
  - Use this sentence frame: "The ___'s (Organism; ex- fennec fox) ___ (Body part; ex- large ears) ____ (function; ex-disperse heat) ___ because of/and or through (structure of body part; ex-have large surface area with thin skin that exposes blood vessels) _____ (add any other details).
  - Add a sketch to this box too- can be a quick and simple drawing or diagram. Drawing at the same time you write a biological strategy will help you visualize and then verbalize the strategy.
  - TIP- Mechanism should be a sentence or two, explaining in detail how the strategy works.

At-Home Activity (Extension Activity):

Students will find another spot to journal, can be the same as yesterday. They should spend some time observing, then write down one animal that they see (can be a bird, insect, etc). What is the organism doing? How are they doing it? Are you observing them performing a behavior?

Assessment:

Rubric for Poster, review of Nature Research Journal from previous day

Overview: *(Vocabulary in bold)*

Biomimicry is the practice of applying lessons from nature to the **invention** of healthier, more sustainable technologies for people. Biomimetic designers ("biomimics") focus on understanding, learning from, and **emulating** the strategies used by living things, with the intention of creating designs and technologies that are sustainable. The products of **design** are all around us. Every human-made thing you use and service or system you interact with was designed by someone (Source: Biomimicry Toolbox).

Today we will all be "biomimics" and "designers", and will work in teams to create something inspired by one of our **champion organisms** that students have explored the past few days. In each group, we will walk through the biomimicry design process: starting with a challenge, and finding inspiration for solutions in nature. One of the key parts of translating biological information to a design idea is a term called the **"Abstracted Design Principle" (ADP).** For this, we will go through a process together to re-write the biological mechanism and strategy into a new statement that does not include biology and can be used in a variety of spaces (engineering, architecture, design, medical, etc.). This ADP is a crucial component to practicing biomimicry: it is the bridge between biology and design. As biomimics, we must understand the biology well enough to create an accurate statement that can be applied to a more general audience. It can be really tricky getting this part right, which is why we will practice today step-by-step together. The more practice you have creating ADP's the better biomimic you will be!

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Objectives:

Students will…

- Explore what it means to be a designer and biomimic
- Learn about how to craft an abstracted design principle
- Practice brainstorming and group decision-making
- Begin to develop their own design based on a desert organisms strategy and mechanism

Materials:

- Paper
- Pens
- Poster board (1 for each group)

Procedure

1 (5 mins)

Present biomimicry challenge and process for group work. Break students into the same groups that they were in yesterday (for strategy/mechanism activity--cluster tables to make this more intuitive).
Challenge: New invention to help people survive in the desert; either focused on heat management or water conservation.

2 (30 mins)

Create "Abstracted Design Principle": *Give only the instructions for one section one bullet at a time, then wait for students to complete that task before giving the next instruction (not all at once). Review strategy and mechanism with groups as needed based on their posters.*

- Give example of well-written ADP (included in ADP Cheat Sheet)
- STEP 1- Once strategy and mechanism is written students should go through and underline each word that is related to biology (i.e. "water", "cell", "leaf").
- STEP 2- Replace all the biology words from the above step with words that are similar, yet do not include biological context. Students can use a thesaurus to find alternative words (i.e. water= fluid, hair=small tubes, etc).
- STEP 3- Finalize by re-writing strategy and mechanism, but without any biology words (using replaced words from above step). Write this in Box 3 of their poster. This is your "Abstracted Design Principle".

3 (15 mins)

Brainstorm: Groups should brainstorm about 5-10 ideas for what they could design based on their written Abstracted Design Principle.

- Explain Brainstorming Framework: Don't worry about feasibility right now - anything is possible and think outside the box. Do not put down another's ideas. Have fun!
- Students should make a list of about 5-10 potential ideas/ innovations of where this design principle could be used in our built environment (agriculture, building, transportation, textiles, etc.)
- Assess the ideas you brainstormed by discussing them openly and ranking them as a group (or voting for favorites). Explain that just because the group doesn't pick the one you came up with doesn't mean your idea is "bad". Be open to others' ideas/feedback and what will be best for the group during this project.
  - Discuss: Which one is most feasible/practical for your group? Which one is most effective for helping people stay cool in extreme environments? Which one are you most interested in creating?
  - If your group hasn't picked one based on discussion, have each person choose their top 3 ideas for this project and put a star next to those 3 ideas. This can be done anonymously if needed. The idea with the most stars wins.

Assessment:

Rubric for Final Group Poster
Check for understanding for ADP on Poster: does it correctly translate the biology to a design concept? Are there components missing or mis-interpreted?

At-Home Activity (Extension Activity):

Students will find another spot to journal for 10-15 minutes. It can be the same throughout the week.
Select one or both prompts;

- They should spend some time observing, then write down one organism that they see (can be a bird, insect, plant etc). What is the organism doing (strategy)? How do you think it is doing that (mechanism)? Change the strategy and mechanism you just identified to an ADP by replacing the biotic words with abiotic ones.
- Reflect and think about the last 4 days; what have you learned about desert organisms and strategies for survival? What are you excited about sharing with your classmates

Links/Resources:

Tips for writing an ADP:
https://toolbox.biomimicry.org/methods/abstract/

https://toolbox.biomimicry.org/

Overview: *(Vocabulary in bold)*

Today, students will finalize their projects and present to each other. This will be the culminating day for the past week, and an opportunity for students to showcase their learnings with each other. An important component of biomimicry is the ability to **translate** and communicate biology information and design ideas. For their final day, each student team will finish creating their idea, illustrate and describe the **invention**, and present a poster with all relevant information. They will then do a "gallery" walk, and view other's posters, provide feedback, and reflect on their experiences.

Students will be asked to reflect on other project's use of **Life's Principles (LP)**. If there was a design that addressed a LP really well, or if a LP could have been addressed more. This offers some connection to our first day exploring the LP's and their connection to every biomimicry design. Now we get to see it in action! How may LP's are addressed in each design? Or how could designs work to include more LPs?

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8.L4U1.12 - Gather and communicate evidence on how the process of natural selection provides an explanation of how new species can evolve.	**8. SL.1**- Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

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Objectives:

The students will be able to…

- Synthesize learnings from entire week
- Create presentation about these learnings to present to their classmates
- Be able to explain the biology, strategy, and mechanism of their chosen champion organism
- Discuss their unique design idea
- Provide feedback for classmates given their understanding of biomimicry

Materials:

- Poster (from previous two days)
- Markers/pens/pencils
- Nature Research Journal (to turn in)

Procedure

1 (15 mins)

Finalize Group Work: Each group will finish up their design idea and draw it out in the last box of the poster board. Teams should give their design a name, short description, label sketch, and decide where it would be best used.

- Poster now includes: strategy, mechanism, ADP, ADP Drawing, and new invention idea with drawing/diagram

2 (20 mins)

Gallery walk for all inventions
Set up a "Gallery Walk" where students silently move around the room, reviewing each group's poster with emphasis on assessing each new invention.
Students should provide written feedback to at least one other group. Provide each student with post-it notes where they can write their reflections and post near each poster. Provide feedback sentence stems for students such as:

- One question I have about your project is...
- One suggestion I have for your project is...
- One thing I like about your project is...

3 (15 mins)

Reflections and comments: Groups should provide verbal feedback to one another and record thoughts on paper for the following questions-

- What is the most exciting thing you learned from this project?
- What was your favorite part of this project?
- What Life's Principles does this project or design address clearly?
- What Life's Principles could this project or design include?

Assessment:

Rubric for Poster, review Research Journals from the week
OPTIONAL: Biomimicry Design Challenge

Resources:

Life's Principles Page

The lessons in BioConnect will support your students in the Biomimicry Youth Design Challenge (YDC). The YDC introduces middle and high school students to the rapidly growing field of bioinspired design while acting as a bridge from core concepts to advanced project-focused STEM. YDC empowers students to access the teachings of nature while learning 21st century skills.

Sign up to access the YDC curriculum at https://youthchallenge.biomimicry.org.

Fostering Sustainable Innovation Inspired by Nature.

View and download digital files
(lesson plans, rubric, associated materials, and 3D model file):

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