CreositySpace

Connecting Kids to STEM Through Entrepreneurship

Collaborative Communities

Connecting Humans & Nature Through STEM

Instructional Guide

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Welcome to CreosititySpace

We're glad you're here.

We know our curriculum might look a little different from what you're used to, but it has been developed with the philosophy that participants learn better when what they are learning is put into a context relevant to them. This is true for everything we create—from comprehensive curriculum units to at-home science kits to workshops and camps.

CreosititySpace educational materials are designed with three goals in mind:

1. **Introduce young learners (and their teachers and family members) to various STEM topics.** Often, at any given point in time, only a few STEM topics make their way into the everyday discussion (e.g., coding and electronics), and as a young learner, one might think that if you're not interested in one of those few topics, there isn't a place for you in the STEM community.
2. **Give young learners practice with tools and processes common to science and engineering.** The use of actual science equipment (e.g., pre-poured Petri dishes and sterile cotton swabs) and technical terminology (e.g., design criteria, hypothesis) in an informal setting helps young learners feel comfortable, confident, and a sense of belonging to the spaces where these materials and vocabulary are used.
3. **Introduce young learners to a variety of STEM professionals and entrepreneurs.** It is essential that young learners "meet" STEM-involved individuals with whom they can relate. This connection can be made in a variety of ways, such as common interests or shared experiences, and helps participants see STEM as a part of their present and future.

We hope you and your young learners enjoy this CreosititySpace program and remember that STEM is NOT about knowing the "RIGHT" answer but about being BRAVE enough to ASK questions.

Do-Learn-Do-Invent Format

To support this educational philosophy, CreositySpace programs typically follow a *Do-Learn-Do-Invent* format. For a workshop or camp, this takes on the following general structure:

1. Do – Each session or topic begins with an introductory activity to engage participants, get the conversation going, and allow the facilitator to assess participants' interests and abilities.

2. Learn – After the introductory activity, the session leader guides participants through a more organized discussion and/or lesson about the relevant topic area. This "lesson" should connect participant experiences (from the introductory activity and everyday life) to the topic area and future investigations. This portion can be a mixture of direct instruction, videos, and group discussion.

3. Do – Depending on your specific program format, the second "Do" session can include a larger investigation or simply be a continuation of the introductory activity in a way that allows for deeper exploration. In addition to the hands-on portions of the investigation, participants are encouraged to discuss their initial hypothesis (or what they expect to see) before they begin the experiment and then reflect on the relevance and greater impact of what they have observed upon its conclusion.

4. Invent – The final step of the cycle encourages participants to combine what they have learned with their natural creativity to create an original invention or innovation. This section introduces a relatable real-world entrepreneur—their story, innovation, and business—to help provide the participants with inspiration and confidence. Participants then have an opportunity to work on an open-ended innovation prompt. This prompt is connected to the overarching topic of the session but is still flexible enough to give participants a chance to explore their ideas. After having some time to work on their inventions, participants are encouraged to share and discuss their ideas with the group. This can happen daily or during a dedicated session(s) at the end of the program.

Collaborative Communities Program Overview

The table below provides an overview of the *Collaborative Communities* program. With the theme of connecting communities to the natural world around them through science, technology, engineering and math (STEM), this program is divided into four topic areas:

- Your Natural Neighbors (three sessions)
- Harnessing Nature (three sessions)
- Sustainable Materials (two sessions)
- Design Challenge (two sessions)

Due to the session duration and cadence of the *Collaborative Communities* program, the Do-Learn-Do-Invent format has been slightly modified so that at times the second "Do" has been dropped, and many of the "Invent" sections focus on technology connections or relatable entrepreneur/innovator profiles.

Sessions are assumed to be ~ 45 min (60-min block with 5–10 min of welcome/cleanup time on either end).

Session	General Topic	Experiments	Technology/Science/Application
1	Your Natural Neighbors	Make your own bee hotel	Role of pollinators – the insect environment
2		Build your own living walls	Living walls/urban agriculture
3		Make your own suet feeder	Animals in your ecosystems
4	Harnessing Nature	Traits classification activity Design your own, bio-inspired, superhero	Traits and characteristics
5		Microbe match, Microbe battle royale (optional) Design your own composter	Microbes & composting
6		Bio-inspired matching game, Bio-inspired redesign	Biomimicry
7	Sustainable Materials	Paper clip polymers Create your own milk-based polymers	Biopolymers
8		Water drainage experiment	Concrete alternatives
9,10	Design/modify your own community space	Design challenge	Sustainable design

Before You Begin

Your Role

Your roles as facilitators are to provide encouragement and a general structure to support students (participants) throughout the program. This program aims to provide participants with an opportunity to explore STEM in ways they likely won't experience in a classroom setting. While the content of this program aligns with many elementary and middle school science, social studies, math, and ELA learning standards, **the primary objective is to help participants form a personal and lasting connection with STEM**. Completing an investigation the "right" way is not a focus. Instead, the focus is on the excitement of exploring, wondering, and asking questions. In fact, **most investigations don't have a right or wrong answer; as long as participants are engaged and exploring STEM, then they will be meeting the primary objectives**.

Note – Originally this program was designed to be facilitated by a team, a Classroom Specialist and a Scientist-Facilitator. While these roles might not be relevant to your situation, we've kept the preparation notes there as a reference. Feel free to adjust as is appropriate to your situation.

Classroom Specialist

You are the expert in time management, classroom management, supply management, and assessing the needs and capabilities of your participants. It is your job to adjust the daily flow of the instruction and investigations to meet the needs of your specific participant group. You and the Scientist-Facilitator should view yourselves as collaborators. Although they may be more versed in the technical language, it is your role to guide them on age-appropriate language and references. This can be especially challenging when talking about technical subject areas, so don't be hesitant to challenge them to find simpler words to explain scientific and technology subjects.

Scientist-Facilitator:

You are the expert in understanding and translating the technical content into everyday language. Even if a particular topic is new to you, your role is to digest technical information quickly and explain it in simple language. Collaborate with your Classroom Specialist, as they will help you engage the participants with age-appropriate vocabulary and relevant examples. It is your job to present the scientific content in relatable, real-world examples. This guide provides examples for this task, but don't be afraid to draw from your personal experiences.

Session Structure

In general, each session starts with a short discussion, either recapping the previous session's learning or setting the stage for the session's investigation. As quickly as possible, participants begin hands-on investigations. Direct, facilitator-led instruction is kept to a minimum, as participants tend to learn more when they are active participants in the instructional process. Thus, the "lesson" portion of each session typically starts with a question or discussion prompt, that participants discuss briefly before hearing about the science or technology specifics.

Instructional Layout

The instructional layout for each experiment or investigation includes:

Session 1: Insect Helpers

Key Learning Objectives	How do pollinators help you? How do insects help you? Why should we care about other living organisms?
Vocabulary	Living Organisms— Pollinator— Ecosystem— Sustainability—
Preparation	Review: • Before You Begin section in this guide • Instructional activities for session 1 • Lesson slides and how to videos • Pages 2 and 3 in the mentee notebook Prepare: • Your ***About Me*** slides and modify lesson slides as desired. • Find session 1 materials. Cut string into 25 pieces. Cut cotton swabs in half. • Make sure you are able to play the initial video.
To Be Handed Out	• Mentee notebooks • Pens/pencils (one per mentee) • Bee Hotel materials: o Per-mentee: ▪ ~ 10 bamboo stakes ▪ 1 toothpick ▪ ½ Cotton swab ▪ ~1 foot string ▪ 2 small rubber bands o Shared resources: ▪ Foil (for glue), ~ 1.5 x 1.5 inch squares ▪ White glue ▪ Scissors (to cut string and cardstock) ▪ Coloring supplies (optional) ▪ Tape (optional) ▪ White cardstock (optional)
Additional Required Supplies-Not in Kit	Scissors, Pens/Pencils, Coloring supplies (optional), tape (optional)

General Notes: The focus of this session is to welcome everyone, help mentees become comfortable, set behavior expectations, and generate a basic foundation of shared STEM and sustainability-connected experiences. Don't worry too much about staying on schedule, as today's session is about setting the tone.

Timing	Instructional Activities
5 min	**Welcome and Settle** • Welcome students. • Hand out or have students get the bags with their notebook and pen.
	Introduction During the introduction, the facilitator **not leading the introduction discussion** should be packaging up the Separation Strategies-Objects bags and laying out the Separation Strategies-Tools. Begin the discussion with a recap of the learnings from the previous day on waste and conservation. Ask the group, "Does anyone remember what we talked about last time?" (Answer – Reducing waste, doing more with what we have.) As a follow-up question ask, "Does anyone have an example of when they got more out of something they were working or buying?"

1. Investigation summary table
2. Additional facilitator notes
3. Detailed pacing for the session and instructional activities table

The **investigation summary table** provides a quick reference for the logistical components of that step—key learning objective, vocabulary, preparation activities, what is to be handed out, and additional supplies required.

The **additional facilitator notes** provide extra information on the background focus areas for the classroom specialist and the scientist-facilitator.

The **instructional activities table** provides the bulk of the instructional guidance for each session.

In the instructional activities table, you will find the details on lesson content, tips for facilitating and guiding your group, check-in instructions, etc. This guidance also provides notes on standard versus advanced instruction. In general, standard instructions are targeted at younger participants (grades 3–5), while advanced instruction is for older participants (grades 6–8). Overall, content for both instructional strands (standard and advanced) is similar. The main difference is that the advanced instruction flows slightly faster, allowing for deeper discussions/reflections and some additional activities toward the second half of each session.

Lesson scripting

Lesson scripting is provided in each section, either as detailed instruction or specific suggested language. It is included as a support but is not a requirement. If there is different language you would prefer to use or that you feel would work better for your participants, feel free to do that.

Vocabulary

Each section includes a few vocabulary words. Be sure to define these words the first time you use them. Age-appropriate definitions of these words are provided in the in the Summary Table and in the Glossary.

Text color guide

Throughout this guide different types of instructional information are presented in different colors.

- Black: general instruction
- Rust: preparation information or facilitator actions
- Purple: scripting
- Green: headings
- Bright Blue: emphasis

Participant Notebooks

A participant notebook is an important element in the scientific and engineering process. Not only is the process of recording ideas and observations critical to the scientific process, but it also instills a sense of ownership and pride in the participants. That being said, an overdesigned participant notebook can make participants feel like they are back in the classroom or working with a textbook. The participant notebook for *Collaborative Communities* has been designed to feel more like a scientific notebook/invention journal than a textbook. The front portion of the notebook contains space for participants to collect observations and thoughts associated with each session as well as some innovation prompts to help them think about how to connect scientific concepts to new technology development. **Participants should be encouraged to use the front portion of the notebook throughout the sessions. If they struggle with writing, they can express their thoughts on the prompt through drawing or sketches. If English isn't their first language, they should be encouraged to write in their preferred language.**

Extra Content

The back section of the participant notebook contains extra information that you're not expected to cover during the program. This includes additional reading, entrepreneur profiles, experimental extensions, etc. We have included this extra information as a way to encourage participants to explore STEM beyond the 10-session program. The readings and activities are an easy-to-implement way for participants to share their exploration with their parents, guardians, older siblings, etc.

It also provides you, the facilitator, with a few alternative activities that participants can work on at any given time. We realize that many young people have things beyond their control going on in their lives that might occasionally cause them to be unavailable for learning with the larger group. These extra activities provide a few low-key options so you can meet them where they are at and continue to provide a high-quality STEM experience.

Lesson Slides

Two sets of slides have been provided – Facilitator Slides and Lesson Slides.

- The Facilitator Slides contain all the content provided in the Lesson Slides plus some planning and preparation information for each session. This is a PDF file.
- The Lesson Slides are available to help guide each session (optional) and are designed to be used with the participants. This is an editable slide deck. We suggest you copy/download this to whichever digital location you are working from.

Since the Lesson Slide deck is editable, all slide number references in the Instructional Layout are for the Facilitator Slides and NOT the Lesson Slides.

Personal Experiences

Classroom Specialists and Scientist-Facilitators are encouraged to share their personal experiences, stories, and connections to any of the concepts or technologies discussed during this program. If applicable, you should feel comfortable replacing a technology or innovator/entrepreneur story provided with one of your own.

How To Videos

A series of How To videos have been created and can be found in the program google drive and on the CreositySpace YouTube channel. These are short videos for the Classroom Specialist and Scientist-Facilitator to preview each session's activities and investigations. They are a short run-through of each activity so that you have a visual reference to go with the written instructions. **These videos are NOT intended to be shared with the participants**. Please note, there is more than one way to run every activity, so if you'd like to make modifications that you think would better suit your group, please feel free to do so.

Session Materials

All the materials required for each session will be provided. Specialized materials are provided in the *Collaborative Communities* kit, while general items are provided by your organization. The table below outlines the materials that are needed for each session. When possible, the kit-provided materials are all grouped in a single session bag.

At the end of each session, all general items should be collected. The individual session instructions (next section) detail what should be done with kit materials (collected for a following session, sent home with participants, disposed of).

Session	Kit Materials	General Materials
1	Participant notebook, toothpicks, bamboo stakes, glue, string, foil, rubber bands, white paper (optional)	Scissors (adult), participant writing materials (pen/pencil), tape (optional), coloring supplies (optional)
2	Participant notebook, soil, felt pocket, seeds, binder clip, coffee filter, acrylic frame, large scoop, foil	Scissors (adult), participant writing materials (pen/pencil), tap water
3	Participant notebook, bird seed, vegetable shortening, burlap, string, foil, large scoop, snack bags, plastic gloves	Scissors (adult), participant writing materials (pen/pencil), large spoon, paper towel
4	Participant notebook, traits cards, prototyping supplies	Scissors (adult & student), participant writing materials (pen/pencil), coloring supplies, tape, scratch paper
5	Participant notebook, containers, green and red puff balls, prototyping supplies, soil	Scissors (adult & student), participant writing materials (pen/pencil), coloring supplies, tape
6	Participant notebook, biomimicry handouts	Participant writing materials (pen/pencil), scratch paper, coloring supplies
7	Participant notebook, various paper clips, powdered milk, vinegar, craft sticks, paper cups, plastic gloves, cookie cutters, foil, snack bags	Participant writing materials (pen/pencil), large bowl (~ 1.5 gal, microwavable), paper towel
8	Participant notebook, filter holders, filter cups, 1 oz cups, foil, clay, rock, soil, tile, spoons	Pens/pencil, water, paper towel, timer
9,10	Participant notebook, Poster, Prototype supplies, any extra materials from previous investigations	Participant writing materials (pen/pencil), coloring supplies, scratch paper, tape and/or glue

Final Challenge

The final two sessions of this program are a sustainable design challenge. If possible, participants are encouraged to work in groups to share ideas and practice collaboration skills.

Prototypes

Building prototypes is quite an involved process—especially with younger participants—and typically requires many more sessions than are available in this program. That being said, participants really enjoy the prototyping experience, so some prototyping materials are provided in each kit in a communal ***Prototype Materials*** bag. This bag contains materials that can be used during sessions 4, 5, 9 & 10. Not all materials are recommended for sessions 4 and 5—suggested materials are identified in the session summary table. If there is a desire to augment this prototype supply, the list below includes some inexpensive, easy to get prototyping materials.

- String/twine/thin rope/thread
- Thread spools/wheels or similar for winding
- Paper clips, binder clips, pushpins
- Wire, pipe cleaners, craft sticks, small dowels, straws
- Boxes/baskets (all sizes), egg cartons, paper plates
- Cardboard, paper tubes (toilet paper, paper towel, wrapping paper)
- Glue, glue gun, tape (masking, duct, electrical)
- Construction paper, wax paper, plastic wrap, aluminum foil
- Markers, Sharpies

Preparation for Session 1

Review:

- Before You Begin section in this guide, instructional activities for session 1, and the background video (https://www.asla.org/sustainablelandscapes/Vid_Wildlife.html)
- Facilitator slides & how to videos
- Pages 2 and 3 in the participant notebook

Prepare:

- Your ***About Me*** slides and modify lesson slides as desired.
- Find session 1 materials. Cut string into 25 pieces. Cut cotton swabs in half.
- Make sure you are able to play the any videos

Session 1: Insect Helpers

<table>
<tr><td>Key Learning Objectives</td><td>How do pollinators help you? How do insects help you?
Why should we care about other living organisms?</td></tr>
<tr><td>Vocabulary</td><td>Living Organisms are all creatures that are alive big and small. Trees, animals, and humans are all examples of living organisms. Rocks and concrete are non-living.
Pollinator is a living organism – often a small animal or insect – that helps plants reproduce by spreading pollen from plant to plant.
Ecosystem is the interactions between the living things and nonliving things in an area.
Sustainability is to act or designing solutions to problems that don't hurt the environment, people, plants, or animals.</td></tr>
<tr><td>Preparation</td><td>Review:
Before You Begin section in this guide
Instructional activities for session 1
Lesson slides and How To video
Pages 2 and 3 in the participant notebook
Prepare:
Your About Me slides and modify lesson slides as desired.
Find session 1 materials. Cut string into 25 pieces.
Make sure you are able to play the initial video.</td></tr>
<tr><td>To Be Handed Out</td><td>Participant notebooks
Pens/pencils (one per participant)
Bee Hotel materials:
Per-participant:
~ 10 bamboo stakes
1 toothpick
½ Cotton swab
~1 foot string
2 small rubber bands
Shared resources:
Foil (for glue), ~ 1.5 x 1.5 inch squares
White glue
Scissors (to cut string and cardstock)
Coloring supplies (optional)
Tape (optional)
White cardstock (optional)</td></tr>
<tr><td>Additional Required Supplies-Not in Kit</td><td>Scissors, Pens/Pencils, Coloring supplies (optional), tape (optional)</td></tr>
</table>

***General Notes**: The focus of this session is to welcome everyone, help participants become comfortable, set behavior expectations, and generate a basic foundation of shared STEM and sustainability-connected experiences. Don't worry too much about staying on schedule, as today's session is about setting the tone.*

Please Watch the following video as general preparation for the program. This video might be a bit advanced for the younger students but provides a exceptional overview of the big picture objectives – to help participants be aware of the impact humans have on their natural neighbors and that there are many things that can be done to minimize that impact.

https://www.asla.org/sustainablelandscapes/Vid_Wildlife.html

Your kit includes a set of participant notebooks. The notebook stays with the Collaborative Communities kit – IT DOES NOT GO HOME WITH THE PARTICIPANTS UNTIL THE LAST SESSION – so that it is always available and does not get forgotten somewhere.

***Classroom Specialist**: Today's session is a good session for the Classroom Specialist to take the lead. Focus on setting expectations for the group (e.g., respectful communication), modeling best practices for the Scientist-Facilitator (e.g., engaging participants and encouraging discussions), and fostering a collaborative environment. Take this time to jointly establish some collaboration strategies that work best for you both.*

***Scientist-Facilitator**: Today's session is a good session for the Classroom Specialist to take the lead. Pay particular attention to how they engage participants, encourage discussion, and help foster an environment of collaboration and respect within the group. Take this time to jointly establish some collaboration strategies that work best for you both. Be sure to take some time during the introduction portion to discuss your area of expertise, your STEM pathway, and what motivates you to pursue a STEM career.*

***Science Background:** Today's session will focus mostly on changing participant perceptions about insects. Many people think insects are just pests, but today we'll be thinking about some of the cool things they can do and how they are helpful to communities. Today's activity involved building insect hotels. It is deliberately a relatively simple activity so that you'll have time available for introductions and getting to know your group.*

Timing	Instructional Activities
10 -15 min	**Welcome and Settle** • Introduce yourselves (*About Me* slides) – tell the participants a bit about your background, why you are interested in STEM and why you're excited to be working with them for this upcoming session. • Have the participants introduce themselves. • Hand out notebooks. Have the participants write their name on their notebook. These notebooks will stay with the kit for the entire program. At the end of the semester, participants will take their notebooks home. **Introduce Program Theme: Collaborative Communities:** Introduce the program theme with a quick discussion to help participants make a personal connection with STEM. Some discussion prompts include: • Raise your hand if you can tell me what STEM is/stands for. / Do you know what STEM is? • How would you describe STEM? How would you describe science and engineering? • When do you use STEM, science, or engineering during the session? • Can you think of how STEM, science, or engineering might help your community? After a short discussion (~ 5 min), let the participants know that the goal of this program is to think and learn about how we interact with the natural world around us and to think about how we can use this understanding to improve our communities. Also, let them know that you are expecting to learn from them just like they will learn from you.

	Initial Video and Discussion (Slides 7 – 8) This session begins with a short video about landscape architecture and specifically the benefits of green roofs. This is a simpler video from the 5-minute video we've asked facilitators to review, but it touches on some key concepts of working with the living environment and the benefits of adding green elements to urban centers. It is a good introductory video for participants. Before you start watching the video, as the participants to think about 2 questions: • What are some things animals need to survive? • What are some of the benefits plants and animals provide for us? After the video, have a short discussion about the above questions. Classroom specialists – please confirm you can play the video at your site ahead of the session. Video link: https://www.youtube.com/watch?v=RRta4aGJKfc As an alternative, the first two minutes of the following video can be shown—as you can download a copy of the video to your computer from Vimeo (you must create an account to do this). This video is a bit dense for younger students, so we suggest using the video discussion script that can be found on the google drive if using with younger participants https://www.asla.org/sustainablelandscapes/Vid_Wildlife.html (4:41 min)

10 min	Insect Discussion (Slides 9 – 16) Today's session will focus mostly on changing participant perceptions about insects. Many people think insects are just pests, but today we'll be thinking about some of the cool things they can do and how they are helpful to communities. Start this part of the discussion with a quick question asking, "Can anyone share with this group something they know or have observed about insects?" Allow about 2 – 3 minutes for some discussion and then proceed to talk specifically about bees, ants, and cockroaches. The slides contain discussion prompts for each insect: • What are some cool things about…? • How do… help humans? The notes part of each slide contains some interesting facts about each insect and some ways they help humans. Plan to take a bit of extra time with the first insect (bees) to discuss a bit more about pollination and how important pollination by bees is to food production throughout the US. Be sure to check to see if your group knows what pollination means. You can tell/remind them that plants—like humans—have male and female parts and need material from both to reproduce and produce food for us. Without pollination we wouldn't have any plants, trees, flowers, veggies, etc. There are also two versions of each slide, one with extra pictures to provide hints of ways each insect is helpful to humans. For younger groups we suggest skipping straight to the slide with the additional pictures. For older groups we suggest starting with the less populated slide and seeing what they can come up with.

15 min

Build Inset Hotels (Slides 17 – 19)

Gather the necessary materials for building 3D eye-masks.

What you need:

Bamboo stakes, small rubber bands, string (~1 ft/participant), glue, scissors, white cardstock (optional), tape (optional), coloring supplies (optional).

This initial design activity serves two purposes:

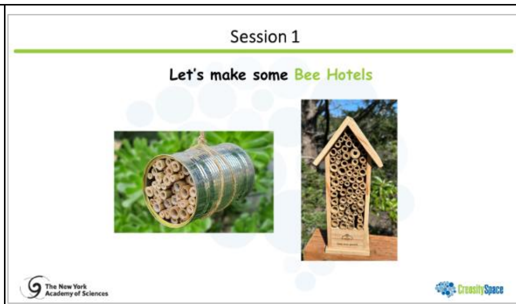
- Reinforces the concept that insects are important, and we should try to support them, and
- Introduces participants to the Engineering Design Process

This design project begins with a quick question:

> Can you think of something that would help the pollinators in your neighborhood?

Encourage participants to think back to the video and what living organisms need to survive (food, water, and shelter for young). After a very short discussion introduce the concept of insect hotels

- There are many different types of insect hotels.
- As habitat is being reduced, insect hotels provide a safe alternative for many pollinators.
- Different pollinators need a different structure.

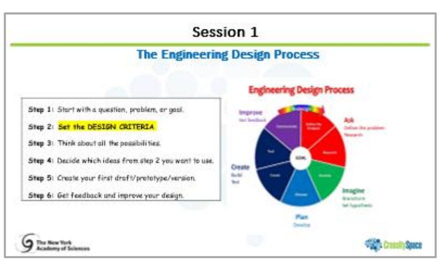


- Solitary bees – Carpenter, mason, leaf cutter – like tubes that are between 1 – 10 mm in diameter and 8 – 10 cm long. Today we're going to make insect hotels for solitary bees.

Engineering Design Process introduction (Slides 20 – 21)

As you are passing out materials introduce the group to the Engineering Design Process (EDP). This is a good opportunity for the Scientist-Facilitator to add their own perspective on the EDP. Please emphasize the concept of - **setting design criteria** – that will be a theme throughout the 10-session program.

For the bee hotel the design criteria are that:



- Bees like tubes
- Tubes should be 1 – 10 mm in diameter
- Tubes should be 8 – 10 cm long

Assembly Steps (Slides 22-25):

Note: Depending on the age and general manual dexterity of your group, it might be helpful for participants to work in pairs. This is recommended for groups with 2nd – 4th graders.

Step 1:

a) Make sure all bamboo stakes are hollowed out.


b) Some will be hollow to start while others will need to be hollowed out with a toothpick.

As groups are working on hollowing out their bamboo stakes, distribute glue and cotton swaps. Glue should be portioned out on small pieces of foil. Not much glue is needed—a portion the size of a dollar coin should be sufficient for every pair.

Step 2:

a) Using the cotton swab, place glue on the long edges of the stakes.

b) Group them up into a bundle and use the rubber bands to keep them in place.


Step 3:

a) Tie the string around your bundle to hold it together and also to make a hanger.


Optional – Decorate your bee hotel if you'd like.

	Support the participants as they assemble their bee hotels. **Younger participants** might need some help cutting and keeping their bundles together. **Collect any unused bamboo stakes, string, glue, rubber bands, and cardstock for future activities.** As participants are finishing up their bee hotels, discuss where a good place to put them might be. Generally, away from direct weather (i.e., somewhat protected) and near food and water (flowers or other plants they can pollinate) are good places for bee hotels.
5 min	Entrepreneur Spotlight (Slide 26) Entrepreneur Connection **A core tenet of CreositySpace STEM educational materials is that participants form a deeper connection with STEM, and science in general, when they see the concepts they are learning about being used to help their communities.** To this end, nearly every *Collaborative Communities* session contains a **technology connection piece** that features a relatable STEM innovator or entrepreneur who is using technology to help solve a community challenge. These technology connections not only serve to help make the STEM lesson more relevant but also give participants innovation examples to help provide some sparks or ideas for the final innovation challenge that happens during sessions 9 and 10. Mikaila Ulmer –Founder of Me and Bees Lemonade. This session's entrepreneurship connection is *Me and Bees Lemonade*. The company was founded by a young girl from Austin Texas who became interested in bees after being stung twice in one week when she was four years old. Immediately after being stung, she became scared of bees but

	decided to learn more about them anyway. She became fascinated with all bees are capable of and how they help us out. She also learned how threatened a lot of their habitat is. At a similar time, she was thinking about how to make a more interesting lemonade for a local competition when she came up with the idea of using honey to sweeten her grandmother's special flaxseed lemonade. The product was a hit and over a decade later you can find her Me and the Bees Lemonade in many grocery stores. Additionally, a portion of the proceeds from each sale go to help preserve bee populations. A summary about Mikaila is provided on slide 26.
Remaining time	**Cleanup and Reflection (Slide 27)** As participants are cleaning up, have them think about the following reflection prompt *Can you think of something else that would help the pollinators in your neighborhood*? This reflection prompt can be found in their participant notebook. Encourage participants to write or draw their ideas/reflections. Time permitting, have some participants share their ideas after the room has been cleaned up. ● Have participants hand in their notebooks. ● Collect extra paper, stakes, string, glue for future sessions. ● Participants can take home their bee hotels

Preparation for Session 2

Review

- Instructional activities in this guide
- The facilitator slides for session 2 & How To video, modify lesson slides as desired
- Pages 4 and 5 in the participant notebook.

Prepare

- Find the session 2 materials.
- Cut felt pockets into individual pockets – adult scissors required.
- Determine if your site will allow for a small living wall to be stored and maintained on-site.

Session 2: Living Walls

Key Learning Objectives	The addition of plants can have a profound impact on urban and suburban spaces. Living walls and vertical gardens are effective in many low-footprint areas.
Vocabulary	**Living wall** is a wall with plants on it. **Vertical garden** is a garden that rises up vertically instead of horizontally.
Preparation	Review ● Instructional activities for session 2. ● The facilitator slides for session 2 & How To video, modify lesson slides as desired. ● Review pages 4 and 5 in the participant notebook. Prepare ● Find the session 2 bag. ● Cut felt pockets into individual pockets. ● Determine if your site will allow for a small living wall to be stored and maintained on-site.
	● Participant notebooks ● Pens/pencils (one per participant) ● Living wall materials: o Per Participant: ▪ Acrylic frame ▪ Felt pocket ▪ Coffee filter ▪ Binder clip After discussion ▪ Soil (1 scoop per participant) ▪ ½ cup scoop ▪ Foil (1 sheet per participant) ▪ Seeds (4 – 5 per participant)
Additional Required Supplies – Not in Kit	Participant writing materials (pens/pencils), adult scissors, tap water

General Notes

We don't recommend handing all the materials out at once. At the beginning of the session, distribute only the participant bag and the notebook. After the initial discussion on living walls, hand out the out the felt pockets, etc. Participants will need to try a couple of different configurations once they add the soil as the walls can be tippy at times. Make sure participants *figure out how to assemble their walls before adding the seeds. After the seed discussion, hand out the seeds.*

Activity differentiation *– Your kit contains flower seeds and microgreen seeds. Flowers are pretty, but they have limited usefulness from a food supply perspective. Microgreens and herbs can be used by participants in their homes but aren't as fun to watch grow. Depending on the age of your group, there might be more interest in one type of seed than the other.*

Soil Usage – The bag of soil provided also serves session 5 and session 8. Please make sure to only use about 2/3 of the soil for this session.

Classroom Specialist*: Today's session has a lot of different materials to hand out. Think about how to include the participants in this process to help it go faster and to avoid long periods of time where participants are sitting around. It is also your responsibility to determine if your host site has a location to store a small living wall and where that might be.*

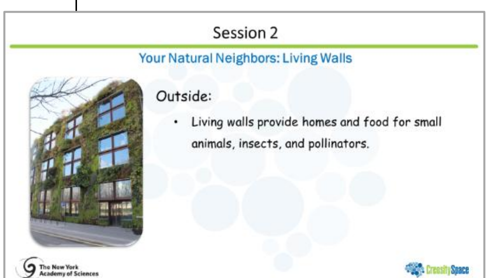
Scientist-Facilitator*: Living walls are becoming more common but are still more the exception than the rule in very urban environments. Think about if there are living walls you come in contact with regularly and what professional experiences you might have to connect with gardening or agriculture.*

Timing	Instructional Activities
10 min	**Welcome, Settle, and Initial Discussion Prompt** ● Welcome participants. ● Hand out notebooks. As participants are coming in and settling down, slide 30 up on the screen.  After participants have sat down, ask for volunteers to tell you where they can find plants in their neighborhood. After participants have had some time to state their opinions, switch to the next slide and ask if they've seen any examples of plants on walls?  Note: It is possible participants will have seen ivy growing on walls of some buildings. While ivy isn't the most helpful living wall material, it is still a type of living wall.
10 min	**Introduction to Living (or Green) Walls (Slides 31 – 34)** It is likely that this is a topic that participants aren't familiar with so it might be a good idea to start with some general questions such as: ● Have you ever heard of a living wall, green wall or vertical garden? ● If so, can you describe it? ● If not, what do those words make you think of?

After this short discussion, tell participants that living walls are merely walls with plants on them. There are many benefits of living walls (also known as green walls or vertical gardens).

Inside:

- The plants provide a source of fresh oxygen.
- The plants naturally absorb sound so people can work, talk, and think.
- Many people find the color green relaxing.



Outside:

- Living walls provide homes and food for small animals, insects, and pollinators.

Then ask participants what they think about using living walls to grow food? How might that be useful for them and their family? How might it be useful for people who live somewhere else?

25 min

Initial Living Wall Assembly (Slides 35 – 41)

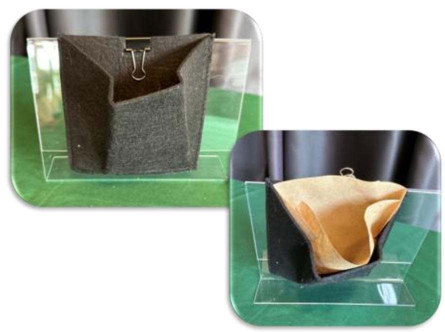
Let participants know they are going to assemble their own mini-living walls. Before they begin, have them think about their **design criteria** for the walls and have them write down their thoughts on page 4 of their notebook.

What you need: Student notebook, plastic stand, felt pocket, binder clip, coffee filter, seeds (flowers or microgreens), soil, tap water (not provided), foil for tray

Step 1:

a) Clip the felt pocket to the picture frame.

b) Put the coffee filter into the felt pocket.



Step 2:

a) Fill the pocket half full of soil.

At this point the participants may need to adjust their set-up so that the wall stands up properly.

After everyone's wall is stable it is time for the seed discussion. The kits contain both flower seeds and vegetable seeds. Time permitting, this is a great opportunity for a deeper discussion around the role of plants especially in urban settings.

	Ask the group to think about what factors, or criteria, they think they should consider as they determine what to put in their felt pockets. If they need some prompting, have them think about what plants need to grow:
	
	• **Sunlight and warmth** – Different plants thrive in different climates. Think about the light and the temperature where the living walls will be stored.
	• **Nutrients and support for their structure** – often this comes from roots and soil, but not always (for example, air plants are small and are self-supporting).
	• **Space** – Different plants need different amounts of space. The living wall pockets are small, so not suitable for large plants.
	• **Germination time** – Different plants take a different amount of time to grow. While this might not necessarily be a criterion for a suitable living wall plant, it is good to know when you can expect to see the first signs of plant growth.
	
	Discuss these different aspects with your participants as you think about seeds that should be used in the living wall pockets. Some examples are listed below:
	
	• **Sunlight and warmth** –
	    o Cirtus trees (orange, grapefruit) grow in warm southern states, while maple tree (and maple syrup) grown in northern states because they need the cold winter for the sap to run.
	    o Peppers need hot climates to grow, while potatoes do better in cooler climates.
	• **Space** –
	    o Corn grows 4 – 6 ft tall and needs ½ between plants. Lettuce grows in small bunches only a few inches high. Many herbs only need a ½ of spacing between plants.

Participants should decide which ones they want to use. Have them think about which one they will use and why and then share their thinking with the group.

Some reasons for each are:

- Flowers: Pretty, supports pollinators, fun to see what pops up.
- Microgreens: Useful for my family, I like the color green

Step 3:

a) Select the type of seeds you want to add.

b) Add seeds (2 – 3 evenly spaced) to the pocket and then cover with a thin layer of soil.

Step 4:

a) Use the foil as a tray to collect water.

b) Add ~ 1/8 – 1/4 cup of water to your plar

Optional

On-site Living Wall

If you're able to leave a living wall in a safe space onsite, there are some extra felt pockets.

This living wall will need to be affixed to a wall (there are some extra pushpins to do this) and the back and bottom of the felt pockets should be lined with foil to protect the wall from excess water. The coffee filters can go in the pockets directly and the extra binder clips should help hang the wall in the approved location.

Assign someone to do a light watering of the wall every 2nd or 3rd day.

Final 5 min	**Cleanup and Reflection (Slide 45)** As participants are cleaning up, have them think about the following reflection prompt from their notebook– If you could put a living wall somewhere, where would you put it and why? Encourage participants to write or draw their ideas in their notebooks. Time permitting, have some participants share their ideas after the room has been cleaned up. ● Have participants hand in their notebooks. ● Collect the ½ cup scoop for the next session. ● Participants can take their living walls home. ● Other materials that are in good shape should be collected to be used as prototyping materials in the final innovation challenge.

Preparation for Session 3

Review

- Review instructional activities in this guide
- Review the facilitator slides and How To video, modify lesson slides as desired
- Review pages 6 – 7 in the participant notebook.

Prepare

- Find the session 3 bag.
- Cut the burlap into 25 pieces. Cut string into ~ 1 ft pieces

Session 3: Suet Feeders

Learning Objectives	Animals need food, water, and shelter to survive. Even in urban environments there are little things we can do to help them survive.
Key Vocabulary	**Suet** – Suet is a fat and birdseed mixture that forms a cake and provides extra energy to the birds.
Preparation	Review ● Review instructional activities below. ● Review the facilitator slides and How To video, modify lesson slides as desired. ● Review pages 6 – 7 in the participant notebook. Prepare ● Find the session 3 bag. ● Cut the burlap into ~ 8 x 8-inch squares (25 squares), cut string into ~ 1 ft pieces
To Be Handed Out	● Participant notebook ● Suet feeder materials: ○ Per Participant: ▪ ~ 1 ft of string ▪ 1 square of burlap ▪ One set of plastic gloves ▪ Sandwich bag (hand out at end to take feeders home) ○ Shared Resources (participants will work in pairs to mix up their suet): ▪ Foil sheet ▪ Vegetable shortening ▪ Bird Seed ▪ ½ cup scoop
Additional Required Supplies – Not in Kit	● Participant writing supplies (pens/pencil) ● Adult scissors ● A large spoon ● Paper towels (optional)

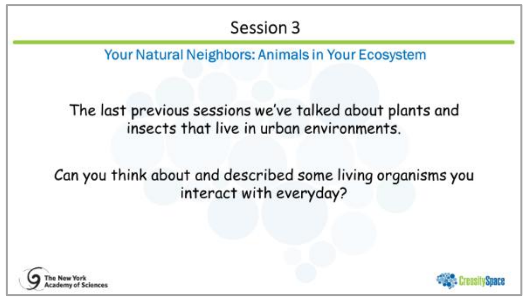
***General Notes**: Both the Classroom Specialist and Scientist-Facilitator should think about experiences they have had with birds. In urban environments we often focus on keeping pigeons off buildings and not about what birds actually do for us. Birds help with pest control and help with pollination and seed distribution.*

***Mess Warning**: This session can get pretty messy. Consider using paper towels under foil to cover the tables and avoid carpeted areas if possible.*

Classroom Specialist*: In addition to the learning objectives, today's session can be quite messy. Consider the best way to run the activity to help the building custodial staff ☺.*

Scientist-Facilitator*: Today's session is all about birds. Think about any personal or professional connections/experiences you can add to the existing lesson slides.*

Activity Considerations*: The participants should work in small groups to mix up their suet cakes. The general ratio for suet cakes is 2 parts seed (or dry materials) to 1 part shortening. We suggest starting with less shortening because it is easier to add a bit more. This activity can go pretty quickly, so it is useful to encourage participants to reflect on what they are doing and observing and how it relates to their design criteria.*

Timing	Instructional Activities
10 min	**Welcome, Settle, and Initial Discussion Prompt** ● Welcome participants. ● Hand out or have participants their notebooks. As participants are coming in and settling down, have slide 45 up on the screen.  After participants have sat down, ask for volunteers to tell you something they what to share about some living organisms they interact with every day. After a short discussion, reshow the video from session 1 (whichever one you used) and ask participants to think about how it fits with some of the topics you have already discussed. What is new?
10 min	**Neighborhood Birds (Slides 47 – 49)** Let participants know that during this session we're going to focus on the birds in our neighborhoods.  Work through the three questions on the slide with your group. There are very few wrong answers, but a couple of things you are likely to hear include:

What are some ways birds help us?

- Pollinators
- Eat insects
- Spread seeds
- Can be fun to watch

What are the things they need to thrive?

- Place to live
- Food and water
- A safe place to raise their young

What could we do for them?

- Plant trees and shrubs for them to live in
- Fountains and water sources
- Native plants
- Bird feeders

Ask participants if they can name some birds that can be found in NYC. If the room has a whiteboard, list out some of their answers. The slide deck also includes a list and pictures of some common NYC birds.

Types of Bird Feeders (Slides 51 – 52)

Obviously, different types of birds need different types of feeders. And, of course, some birds can't feed at any common household feeder (e.g., ducks, geese, falcons). Pull up slide 54 and discuss with the group the features, pros and cons of different bird feeders and the birds they support.

	Hummingbird feeders – sugar water, good only for hummingbirds, need to be careful that it doesn't mold in summer or freeze in winter. Hummingbirds need about half their body weight in bugs and nectar, feeding every 10-15 minutes and visiting 1,000-2,000 flowers throughout the day. When it is cold, they are often awake before other birds and go to sleep later than the other birds. Seed feeders – Good for smaller birds. Can attract a variety of birds as long as they can perch on the feeder. Suet Feeder - Suet is particularly attractive to woodpeckers, nuthatches, chickadees, jays, and starlings. Wrens, creepers, kinglets, and even cardinals and some warblers occasionally visit suet feeders. They can be better for bigger birds that have trouble landing on seed feeders. We are going to focus on suet feeders. Looking at the list of NYC birds, which ones do you think might take advantage of a suet feeder? 1. House Sparrow 2. American Robin 3. European Starling 4. Rock Pigeon (unlikely – more often ground feeder) 5. Blue Jay 6. Northern Cardinal 7. White-Throated Sparrow 8. Mourning Dove (unlikely – more often ground feeder) 9. Common Grackle 10. Red-bellied Woodpecker 11. Gray Catbird 12. Downy Woodpecker 13. Song Sparrow 14. Northen Flicker 15. Tufted Titmouse 16. Red-Winged Blackbird 17. Common Yellowthroat 18. House Finch

	19. Ovenbird 20. White-breasted Nuthatch 21. Northern Mockingbird 22. Black-capped Chickadee 23. American Goldfinch 24. Dark-eyed Junco 25. American Crow (unlikely – too big) 26. Mallard (unlikely – too big, ground feeder) 27. Monk Parakeet (unlikely – too big) 28. Peregrine Falcons (unlikely – too big)
15 – 20 min	**Building a Suet Feeder (Slide 53 – 56)** (Note: In this session participants will be making smaller suet feeders without an external structure, so, unless they place it somewhere the larger birds can stand, likely only smaller birds will be able to feed at it.)  **Step 1:** Participants should begin this activity by thinking about their suet feeder design criteria. This brainstorming can be done as a group or else participants can work in pairs. Design criteria • Suet cake must be a solid, cohesive mixture of seed and shortening. • It must be able to hang from a tree. • There must be a structure to support the suet while still enabling the birds to get at it. • If you want larger birds to be able to feed at it, they must have someplace to stand. After participants have had some time to think about their design criteria it is time to start preparing the cake. For each pair give them a scoop of birdseed and a heaping spoonful of shortening (in separate piles). **Note: More**

shortening than is needed is provided. The ideal volume ratio of shortening to seed is 1:2 – so make sure not to start off with too much shortening.

Step 2: Making the cake.

Participant pairs should experiment a bit with different amounts. Encourage them to figure out the best ratio of shortening to seed.

a) Put on a pair of plastic gloves.

b) Take a small portion of shortening and mix it with some birdseed. **Track the relative volume of shortening to seed that you use. It is better to start with less shortening – you may need to experiment a bit with this.**

c) Form seed and shortening into a cake or ball.

Step 3: Assembly.

a) Using the string and burlap, form the mixture into your desired shape.

b) Be sure the cake is easily accessible to the birds – you may need to cut small holes in the burlap.

Step 4: Deploy.

a) Test the structural integrity of your suet feeder. If necessary, make adjustments to your design.

10 min	**Entrepreneur Connection (Slide 57)** Entrepreneur Profile: June Grant, Principal and founder of blink!LAB Architecture The Challenge June knew she wanted to be an architect since she was five years old growing up in Jamaica. She loved driving around the island seeing new homes and buildings under construction. Growing up in Jamaica, June knew what it was like not to have enough water, electricity, or air conditioning, so when she finished school, she wanted to make sure the buildings she created didn't waste energy or resources. The Solution: June uses her understanding of the environment and renewable energy (like solar) to design buildings that are better for the environment. June was profiled by the Sierra Club as one of the Faces of Clean Energy. You can see the video on YouTube at www.youtube.com/watch?v=_LOvAKw-m5U
10 min	**Cleanup and Reflection (Slide 58)** As participants are cleaning up, have them think about the following reflection prompt – Where are you going to hang your suet feeder? Time permitting, have some participants share their ideas after the room has been cleaned up. ● Have participants hand in their notebooks. ● Participants can take home their suet feeders in the snack bags. ● Save any extra materials for the final design challenge (burlap, string, seed). ● Dispose of extra shortening.

Preparation for Session 4

Review and prepare:

- Review instructional activities in this guide
- Review the facilitator slides, modify lesson slides as desired
- Review pages 8 – 9 in the participant notebook
- Review and cut up traits and characteristics cards

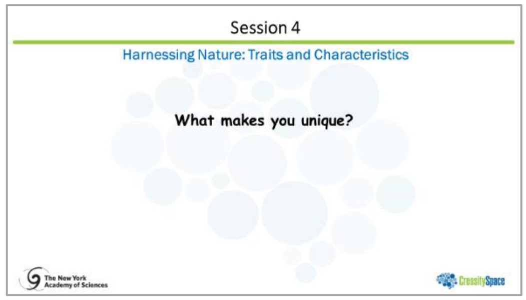
Session 4: Traits and Characteristics

Key Learning Objectives	Participants will learn about traits and characteristics – what they are and how they help us organize the world around us. Participants will also learn that by understanding the traits and characteristics of living organisms around us we can learn how to work with nature as we develop new technologies.
Key Vocabulary	**Trait** is a variant of a given character, in other words, the versions or examples that would show up in the category. **Characteristic** is a feature, inherited by offspring from their parents, that varies among individuals. It may help to think of a character as describing the "category of features." **Unique** is something about that is special or different from others.
Preparation	Review ● Review instructional activities in this guide. ● Review the facilitator slides, modify lesson slides as desired. ● Review pages 8 – 9 in the participant notebook. Prepare: ● Cut up and review traits and characteristics cards.
To Be Handed Out	● Participant notebook ● Traits and characteristics sorting activity (groups of 4) o The kit contains six sets of cards. ● Superhero building supplies: o Participants can design their superhero in their notebooks, or they can dive into the bag of prototyping supplies to mockup their superhero (craft sticks, pipe cleaners, feathers, paper, tape, etc.).
Additional Required Supplies	● Participant writing supplies (pens/pencil) ● Adult scissors or paper cutter ● Student scissors, tape, coloring supplies, scratch paper

***General Notes**: This session topic – traits and characteristics – forms a key connection between the specific facts discussed during the first few sessions and how one can build on those facts to create new connections. It takes participants beyond the idea of just "learning about things" to a place of "how can I use what I know about things to do something totally new/solve a problem/invent a new technology?" Keep this bigger picture goal in mind as working through the session lessons and the main design challenge.*

***Classroom Specialist**: This session challenges participants to tap into their inner creativity and ideas. For many young learners this can be a bit challenging to do in a larger group setting for* *fear of getting laughed at or for fear of people thinking your ideas or skills are scary. Your skills in creating a warm and accepting environment will be important during this session. Be on the lookout for participants who are being extra quiet or who might be nervous to share their ideas.*

Scientist-Facilitator*: As mentioned in the general notes, this session is the bridge between learning specific information and thinking about how to apply that knowledge to solve a problem. This is a powerful concept for young learners to be exposed to and really forms the foundation of what it means to be a scientist/engineer. As you go into this session, think about your personal experiences with applying knowledge from one area to solve a problem in another area.*

Timing	Instructional Activities
10 min	**Welcome, Settle, and Initial Discussion Prompt** ● Welcome participants. ● Hand out or have participants collect their notebooks. As participants are coming in and settling down, have slide 64 up on the screen.  After participants have sat down, ask for volunteers to tell you something that makes them unique—or different than anyone else (or than some people). Note: Make sure participants only talk about themselves (and not others) and if no one is interested in sharing, do not force the issue. **Characteristics, Traits and Organization (Slide 62)** Begin the session with a general discussion on organization and why we put things in certain places. You can use a relevant example such as the classroom, the library, or the grocery store to help illustrate the point and then ask the participants if they can think of their own examples. After discussing the *what*, move on to chat about the *why*. Why do we organize things and how do we choose to organize them? There are many possible answers, but make sure the discussion also includes the concept of similarities and patterns (both of how things look and how we use them) between different objects as a reason why things are often grouped together. From this discussion you can introduce the concepts of

	characteristics and traits as a way to organize things. An example introduction is outlined below. Look in the cupboards in your kitchen—how are things organized? Probably the plates and bowls are in one place; cups in another; and knives, forks, and spoons in a drawer. People often like to organize their "stuff" based on its shape, size, and function. This helps us remember what we have and where to look when we need something. A similar thing can be said about how scientists keep track of living creatures. They like to group them together based on their similarities: how they look, what they are made of (their DNA), and how they behave. This activity of classification is called taxonomy. **Taxonomy** helps us keep track of all the organisms in the world and also helps us to understand where they came from, what they need to survive, and how they can be helpful (or harmful) to humans. Sometimes the words **character (or characteristic)** and **trait** are used interchangeably. To avoid any confusion simple definitions are provided below. **A characteristic**, or character, is a feature, inherited by offspring from their parents, that varies among individuals. It may help to think of a character as describing the "**category of features**." Some examples include hair color, flower color, and having fingers or toes. **A trait** is a variant of a given character, in other words, the **versions or examples that would show up in the category**. Example traits for hair color would be brown, blond, and black. Example traits for flower color might be red, purple, and white.

10 min	**Characteristics and Traits Sorting Game (Slide 63)** This is a group activity. Assign or have your participants organize themselves into groups of ~ 4 (there are enough supplies for 6 groups max). For the following investigation you'll be organizing the cards in a number of different ways. Each time we organize them we'll spend some time discussing WHY you decided to organize the cards that way. Have the groups each take a set of cards and organize them based on whichever reason they think is most interesting or relevant. Then have them use just the animals and pick a category by which to organize them. Some possibilities include: • How do they move (e.g., swim, fly, walk)? • How many legs do they have (0, 2, 4, 6, 8)? • What covers their body (hair, fur, feathers, scales, other)? • How are their young produced (live, eggs, eggs in water)? Have the participants take turns describing to the group the criteria they used to sort the animals.
10 min	**Cool Plant and Animal Traits (Slides 64 – 67)** Ask participants if they remember some of the cool traits of the insects we discussed in the first session? ● Ants can lift 10-50x their body weight. ● Bees have 5 eyes and can fly at speeds of 20 mph. ● Cockroaches can live almost a month without food, two weeks without water, and hold their breath for 40 minutes.

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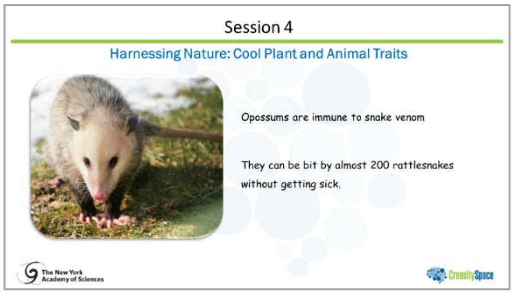
Share some of the cool plant and animal traits on the following slides and then invite participants to share some cool plant or animal traits they know about.



Slide 68 contains a list of cool animal and plant traits if your group is slow to offer up other ideas. No need to read through the list but just keep it up on the screen as groups work through their superhero or super villain design.
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<td>Remaining time until clean up min</td>
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Superhero/Super Villain design (Slide 69)

For the remaining time (minus cleanup) participants will work on their superhero/super villain design.

Working alone or in small groups, participants are to design their own superhero (or super villain), with as many cool traits as you want. Be sure to determine the backstory of your superhero (or super villain) that describes where and how they got their super-powers.

There is space in their student notebook to sketch out their design. If they are uncomfortable drawing they can write about their superhero/super villain or use some of the prototyping materials (craft sticks, pipe cleaners, paper, feathers, etc.) to make a mock-up of their design.
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5 - 10 min	Cleanup and Share ● Have participants hand in their notebooks. ● Participants can take their superhero/super villain mock-ups home. After participants have cleaned up, encourage them to share the story and description of their superhero/super villain.

Preparation for Session 5

Review

- Review instructional activities in this guide.
- Review facilitator slides & How To video, modify lesson slides as desired.
- Review pages 10 – 11 in the participant notebook.
- Decide if you will do the Microbe Battle Royal, and, if so, the space that you will use for it.
- Review the Microbial Fuel Cell videos and decide if they are appropriate for your group.
    - Microbial Fuel Cell explanation (2 minute)- https://www.youtube.com/watch?v=ZotwUJAb8R4
    - Video of Orianna explaining their microbial fuel cell product (1-minute) https://youtu.be/-3GHugRvx9w

Session 5: Microbes

Key Learning Objectives	Participants are introduced to the exciting world of microbes and how we interact with them in everyday life. They also learn about the value of composting.
Key Vocabulary	**Microorganisms** are very small living creatures that you need special equipment to be able to see. Bacteria are an example of microorganisms. **Microbes** is a short form, sort of a nickname, for microorganisms. **Composting** is the activity of turning old food waste or scraps into soil for plants. **Nutrients** are part of food that helps a living organism grow. For plants nutrients are found in the soil (or sometimes added to the water). **Microbial fuel cells** are a special type of "battery" in which microbes generate electricity instead of chemicals. (Note: Fuel cells are technically not batteries, but for young learners this comparison is helpful for overall understanding).
Preparation	Review ● Review instructional activities in this guide. ● Review facilitator slides & How To video, modify lesson slides as desired. ● Review pages 10 – 11 in the participant notebook. ● Decide if you will do the Microbe Battle Royal, and, if so, the space that you will use for it. ● Review the Microbial Fuel Cell videos and decide if they are appropriate for your group.

To Be Handed Out	● Participant notebooks
	● For Microbe Battle Royale
	    o Flag football belts and flags
	    o Space for the game
	● For Composter:
	    o Per Participant:
	        ▪ 1 container
	    o Shared Prototyping Resources (participants can pull from them to make their composter)
	        ▪ ~7 beads test compost mixing (4 – 7 each)
	        ▪ Prototyping supplies (fabric, pipe cleaners, wire, paper straws, craft sticks)
	        ▪ ½ cup scoop (to hand out soil at the end)
	    o To be handed out at the end:
	        ▪ ½ scoop soil
	        ▪ Pinch of microbe starter

Additional Required Supplies	● Participant writing supplies (pens/pencils) ● Scissors (student) ● Tape, glue ● Coloring supplies (optional)

General Notes

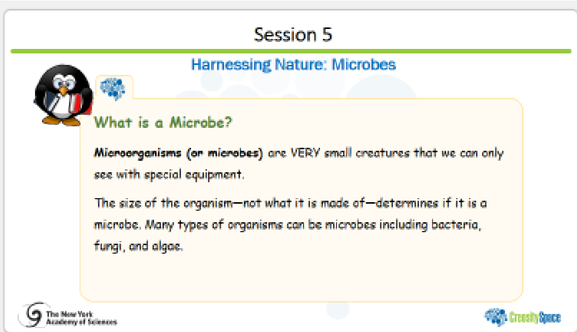
*There is a lot going on in this session. We suggest that the **Classroom Specialist & Scientist-Facilitator** spend some time during the end of session 4, discussing how much of this session will work for you. Also, the Microbe Battle Royale is an activity that can be inserted anywhere in the program after this lesson on microbes. It is a good activity if you find your group having a day where they can't really concentrate and need to get up and move around.*

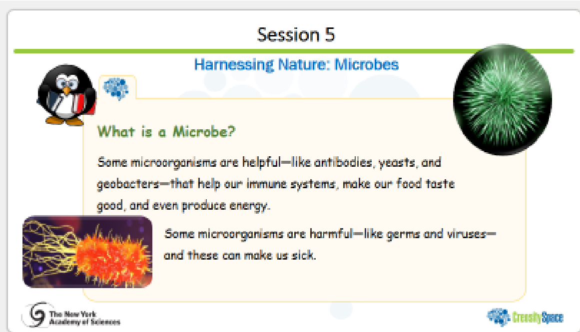
Classroom Specialist: *There are two versions of the introductory question (slide 75). Please determine which one (or both) will be more appropriate for your group.*

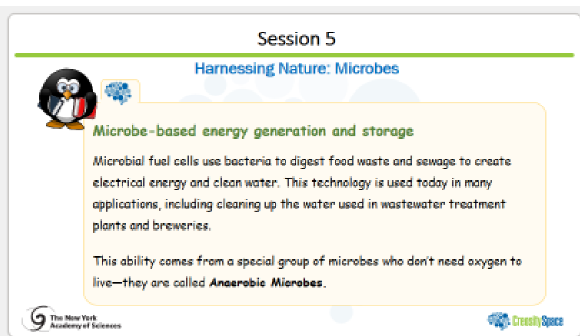
Scientist-Facilitator: *Microbial Fuel Cells are a great example of traits designed for one purpose (microbe function) can be used to serve a different purpose (energy generation). Continue to think about relatable experiences you can highlight to help the group get into the innovation mindset. The next session focuses on biomimicry specifically.*

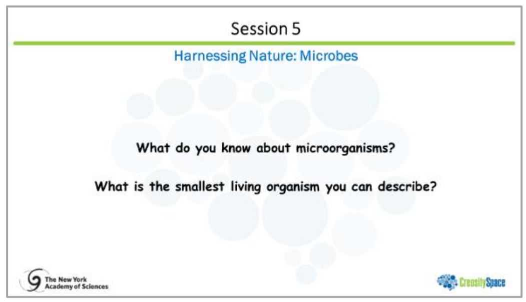
Background

Microorganisms (or microbes) is an interesting class of organisms. They are a grouping based entirely on size and not on genetics. That is, the category of microorganisms (or microbes) includes members from different biological "kingdoms" including from the Bacteria, Fungi, Archaea, and Protista groups.







Timing	Instructional Activities
10 min	**Welcome and Settle** ● Welcome participants. ● Hand out or have participants collect their notebook. As participants are coming in and settling down have slide 72 up on the screen. *Note: You may choose to only have the second questions up on the screen as not to intimidate the group.*  After participants have sat down ask for volunteers to tell you what they might know about microorganisms. (Alt version – What is the smallest living organism you can describe?) It is possible participants won't know much about this topic. If that is the case, proceed to the next slides without much discussion. **What is a Microbe? (Slides 73 – 75)** Microorganisms (or microbes) are VERY small creatures that we can only see with special equipment. The size of the organism—not what it is made of—determines if it is a microbe. Many types of organisms can be microbes including bacteria, fungi, and algae. Some microorganisms are helpful—like antibodies, yeasts, and geobacters—that help our immune systems, make our food taste good, and even produce energy.

Some microorganisms are harmful—like germs and viruses—and these can make us sick.

Microbes in our food

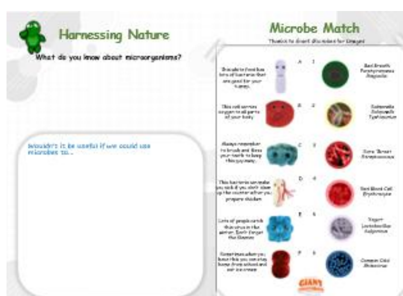
Do you like yogurt? How about sauerkraut, kimchi, or bread?

Originally, using microbes for fermentation was used as a method to preserve food. Today scientists, chefs, and entrepreneurs are taking it a step further and turning the practical into a delicious treat.

- Bread – fungus (yeast) (Saccharomyces cerevisiae)
- Yogurt – bacteria (Lactobacillus bulgaricus and Streptococcus thermophilus)
- Kimchi – bacteria (Leuconostoc, Weissella, and Lactobacillus)

Microbe Match (Slide 76)

Hopefully by this point the participants are starting to think of examples of where they interact with microbes in everyday life. Have them turn to page 11 in their notebooks and work in pairs on the Microbe Match activity.



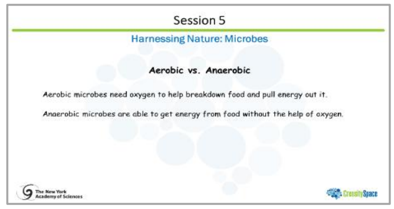
They might not be familiar with the Latin names for the microbes, but they should be able to use all the clues available to connect the plush microbe to their microscope slide picture. Remind participants that they don't have to work in any specific order and that they can use all the tools available to them to make a match (color, microbe shape, etc.).

Answers: A-5, B-4, C-1, D-2, E-6, F-3

5 - 15 min

Aerobic vs. Anaerobic (Slides 77 – 78)

One cool trait about microbes is that some of them don’t need oxygen to survive! These are called anaerobic microbes.



Have participants think about where they would explore if they didn’t need oxygen to survive.

Microbe Battle Royale (optional) (Slide 79, 80)

This is an optional game that you can play with your group if you think they would benefit from a bit of moving around. It is a microbial take on a classic prey/predator population game.

1. Divide the group into three teams. Teams will rotate through being the anaerobes, aerobes and “food” (“food” is both food and oxygen). Every player receives a flag football belt but only the “food” team wears flags. It is suggested that each member of the food team wear four flags. The flags do not need to be all the same color.
2. The anaerobe and aerobe teams line up on either end of the field of play. The “food” team places flags on their belts – blue for oxygen, red for food – and stands spread out in the field of play. Once positioned on the field of play, “food” team members do not move.
3. Participants are reminded that some microbes need food and oxygen (Aerobes) to function while others just need food (Anaerobes).

   Anaerobes don’t need oxygen to breathe, but don’t get as much energy per unit food, so they must gather two units of food each time (but no oxygen) in order to tag the next person in.

   Aerobes need oxygen, but not as much food – so they need one unit of oxygen and one unit of food each time.
4. The line leader on either side starts at the go signal by entering the arena and gathering food and/or oxygen. After returning with the food/oxygen, he/she will tag in the next individual and both will go out and get more food/oxygen and both tag in the next two people, and so on. The game stops when there is no food left.

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Different rounds can simulate different environments. For example, a low oxygen environment like a stagnant pond will have more food than oxygen. As a result, in a low oxygen environment (where aerobes will take longer to find the O2 they need) anaerobes will generally win, and vice versa in a high oxygen environment. The slide deck lists various examples.
Safety note – Participants should be reminded not to crash into the food players when grabbing the flags.
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Microbes and Waste (Slides 81 – 84)
Humans generate a lot of waste. That waste ends up in our landfills and in our waterways—taking up space and putting stress on the environment. There are a bunch of ways that microbes can help us address our waste problem.
Note: A slide on soil is included in your slide deck. It may not fit with your lesson flow or time available, but we wanted to include it as useful background and so you had some details available if asked.
Composting
Ask participants if any of them know about composting.
Composting is a way to turn some food scraps (mostly only veggies) and yead waste (leaves, grass, etc.) into nutrient-rich soil. This process helps return the extra nutrition from our waste food into food for plants.


A successful composter requires 4 ingredients:

Browns - This includes materials such as dead leaves, branches, and twigs. These provide the carbon for your compost.

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- Greens - This includes materials such as grass clippings, vegetable waste, fruit scraps, and coffee grounds. These provide nitrogen for your compost.
- Water - Having the right amount of water, greens, and browns is important for compost development. The moisture helps the browns and greens to decompose.
- Microbes – Many people add microbes to their compost to help speed up the process.

Composters also often benefit from spinning or rotating so that the materials inside can be mixed up. Typically, composters are big and bulky and not easy to use if you're in an urban environment.

Today we're going to make (and learn about) some smaller composters.

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<td>10 - 15 min</td>
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Build Your Own Composter (Slides 85 – 87)

At this point each participant should be handed their own container to form the base of their composter. Remaining construction materials (wire, string, straws, craft sticks, tape, fabric, scissors) should be placed in a common area. Participants should be given ~ 7 puffballs to use as simulated soil in their composter so they can test out the mixing.

Together, set the design criteria for the composter:

- Must be sealed,
- Must allow for some air flow,
- Must be able to add water,
- Must be able to have some mixing.

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	Participants should be allowed time to explore different ideas. They should be encouraged to work in pairs or small groups. There is no right or wrong answer. The slide deck provides one solution should your participants get stuck, but don't be afraid to let them work at things a bit. At the end of the construction time, participants can swap out the puffballs for ½ scoop of soil and a pinch of microbe starter. When they take their composters home they can add veggie scraps. **Lomi video – Time permitting** Should you have enough time, the following 1-minute video might be fun to share with your group. In addition to describing some of the most recent innovations in counter-top composting, it provides a quick recap on the challenges around global waste and the benefits of composting. https://youtu.be/HYv6d6U0E2s
Time permitting	**Microbial Fuel Cell Video** Time permitting but there are a couple of cool Microbial Fuel Cell videos you can share with your groups to emphasize the cool things microbes can do for us. • Microbial Fuel Cell explanation (2 min)- https://www.youtube.com/watch?v=ZotwUJAb8R4 • Video of Orianna explaining their microbial fuel cell product (1-min) https://youtu.be/-3GHugRvx9w There are also some entrepreneur vignettes to discuss with the group if there is extra time.
Final 10 min	**Cleanup and Reflection** As participants are cleaning up, have them think about what they would use microbes for if they could train them to do anything they wanted. • Collect participant notebooks. • Collect any extra materials for the final design challenge. • Participants may take home their composters.

Preparation for Session 6

Review

- Review instructional activities in this guide.
- Review facilitator slides, modify lesson slides as desired.
- Review pages 12 – 15 in the participant notebook.

Prepare

- Discuss and consider the amount of support your participants will need for their bio-inspired redesign activity.

Session 6: Biomimicry

Key Learning Objectives	Participants will be introduced to the concept of biomimicry and will have the opportunity to explore how using biomimicry can help us develop technologies that are more sustainable and environmentally friendly.
Key Vocabulary	Biomimicry is the design of products, technology or solutions that are modeled on the living world (plants, animals, etc.).
Preparation	Review ● Review instructional activities in this guide. ● Review facilitator slides, modify lesson slides as desired. ● Review pages 12 – 15 in the participant notebook. Prepare ● Discuss and consider the amount of support your participants will need for their bio-inspired redesign activity.
To Be Handed Out	● Participant notebooks ● Biomimicry handouts ● Scrap paper
Additional Required Supplies	● Pens/pencils ● Coloring supplies ● Scrap paper

General Notes:

Biomimicry is the cornerstone of sustainable design. The previous sessions have been laying the foundation for participants to appreciate the natural environment around them – sometimes hard to do in a highly urban environment – and look to work WITH nature instead of in spite of it or against it.

This session is less about building or hands-on experimentation and more focused on learning about the breadth of biomimicry and bio-inspiration in sustainable design.

The amount of support and guidance groups will need for this activity will likely vary significantly with age and reading ability and is something the ***Classroom Specialist and Scientist-Facilitator*** *should think about ahead of time.*

Classroom Specialist and Scientist-Facilitator*: There are a number of common biomimicry examples discussed in this lesson. If you have personal experience with biomimicry or bio-inspired design, please add that to the discussion.*

Background

Session 6

Harnessing Nature: Biomimicry

Copying from other organisms is called BIOMIMICRY

Bio means "from nature" and mimic means "to copy" so biomimicry means "to copy nature".

People normally group types of biomimicry into three categories:

- Form → copying shape
- Process → copying how something is done
- Ecosystem → Copying how different living things interact

Session 6

Harnessing Nature: Biomimicry

Bio-Inspired Redesign

Heat Island Reduction Concrete builds, reflective windows, and asphalt streets make urban environments hotter. Pick a design element or two you could incorporate in your neighborhood to make it cooler in the summer.	**Smart Water Usage** All the rain in NYC goes down the storm drains and into the water treatment plant. Pick up park or a building in your neighborhood, and design A bio inspired way to use some of that rainwater.
Building Energy Buildings take a lot of energy to heat, cool, and to power things like light and computers. Pick a bio inspired way to make your school, home, or corner grocery store more energy efficient.	**Ground stabilization** New York City has a lot of coastal lines and beaches, that can be damaged in storms both from waves and from rain. Upgrade your favorite waterfront park or beach with some bio inspired features to protect the coastline and the people using it.

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Session 6

Harnessing Nature: Biomimicry In Architecture

Construction and Materials

Mushrooms-Mycelium The root structure of mushrooms (called mycelium) is an extensive network that binds soil in the wild. Developers can use just the roots (not the fruit) to bind lightweight insulating material (like straw) and make a biodegradable material that can be used for packaging or insulation.	**Leave, rivers, flower petals** Curves surfaces are found throughout nature and are both pleasing to the eye and low energy ways for air and water flow. Curved buildings are not only pleasant to look at but also support better airflow inside.
Spider Webs Spiders don't want birds crashing through their webs so they have a special UV reflective materials in their silk to deter birds. Some glass manufactures are trying to replicate this with their window glass.	**Beehive Honeycomb** The honeycomb structure used in beehives is very strong but uses the minimum amount of material for the volume. Lightweight building can use this technique to build a strong structure with the least amount of material.

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Session 6

Harnessing Nature: Biomimicry In Architecture

Energy Efficiency

Sunflowers Sunflowers naturally track the sun to maximize exposure. Solar cell manufactures have mimic this behavior to help design systems that capture the most sunlight.	**Sedona Cactus** These giant cacti have ridges in their truck. These ridges provide built in shade to help keep the cactus cool in the hot sun. Some construction companies have employed similar strategies to help keep buildings cool.
Slime Molds Are a fugus that is very good at mapping the most efficient route to get to its food. City planners are using it to plan the fastest ways to move around, and between, complex and highly populated cities.	**Termite Mound** The small holes and tunnel network force air circulation in termite mounds. Similar

Session 6

Harnessing Nature: Biomimicry In Architecture

Water Usage & Ground Stabilization

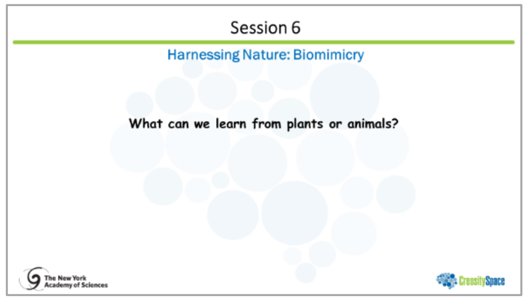
Plant Respiration One-way plants help keep neighborhoods cool is because of water evaporation from the surface of their leaves. Building off this concept, some buildings and public spaces have created artificial mini waterfalls that use recirculated collected rain-water to keep the area cooler through evaporation.	**Tall Vetiver Grass** This grass is known for its very long root system that helps stabilized sandy shores against erosion. Using a similar design, engineers often insert 8 ft long steel poles into unstable ground to stabilize it prior to construction.
Forest Ecosystems, Tree Trunks Plants and tree root systems naturally filter water and slow run-off. By plants small greenspaces in sidewalks and parkettes, the amount of rain that enters the sewers and water treatment systems can be decreased. Additionally, the quality of that water improves and puts less strain on the water treatment plants.	**Oyster Reefs** Oysters extract minerals from the water to make their shells. They also filter toxins out of the water naturally. Many costal towns (including around NYC) are creating breakwaters from oyster shells that help protect the coast and clean the water.

<table>
<tr><th>Timing</th><th>Instructional Activities</th></tr>
<tr><td>10 min</td><td>

Welcome, Settle, and Initial Discussion Prompt

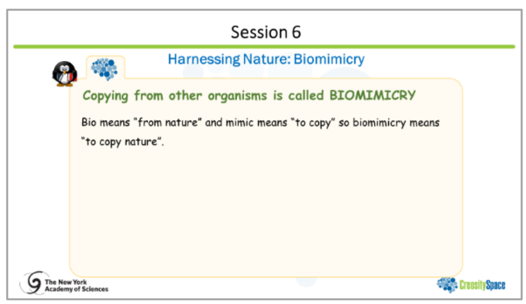
- Welcome participants.
- Hand out or have participants collect their notebooks.

As participants are coming in and settling down have slide 93 up on the screen.



After participants have sat down ask for volunteers to tell you if anyone has any suggestions on things we can learn from plants or animals?

Introduce the concept of biomimicry (Slide 94)



While copying from another student on a test is not a good thing, copying from nature to solve challenges is always welcomed. The Earth is over 3.8 billion years old, so plants and animals have had a long time to learn what works and what doesn't work. **The field of STEM that focuses on learning from nature is called biomimicry. Bio means "from nature" and mimic means "to copy" so biomimicry means "to copy nature".**

Who remembers what the definitions of characteristics and traits are?

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A characteristic, or character, is a feature, inherited by offspring from their parents, that varies among individuals. It may help to think of a character as describing the "**category of features**." Some examples include hair color, flower color, and having fingers or toes.

A trait is a variant of a given character, in other words, the **versions or examples that would show up in the category**. Example traits for hair color would be brown, blond, and black. Example traits for flower color might be red, purple, and white.

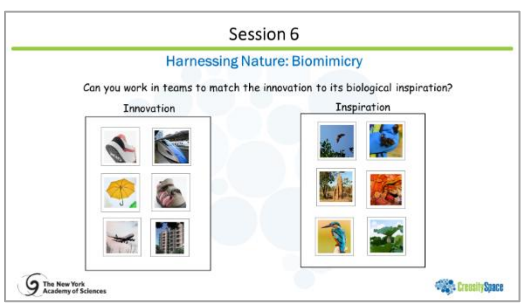
Let's take some time to explore some inventions that were inspired by nature.

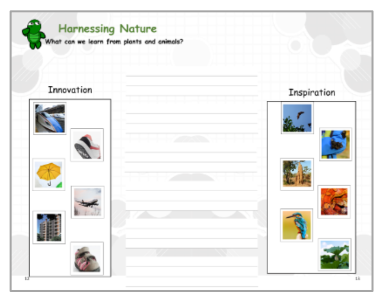
---

15 min

Biomimicry Matching (Slides 95 – 113)

Participants should work in teams of 2 or 3 to match the innovation with the inspiration (pages 12 – 13 in their notebooks). Give participants 5 – 7 minutes to work through the matches. Groups should propose the trait that was copied for the innovation. Some are easier than others.





After participants have had a few minutes to try to match examples, work through the series as a group. We suggest the following sequential approach:

1. Start with the biological inspiration, seeing if participants can identify the copied trait and the innovation. (Likely this will only be possible for older groups).

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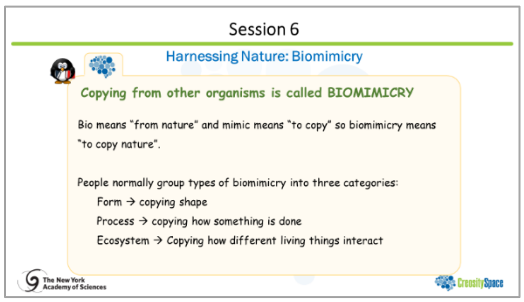
2. Next move to the second slide that identifies the key trait that is copies.
3. If no one is able to identify the innovation, move to the third slide that connects the innovations to their inspiration.

End the activity with a discussion of the different categories of biomimicry: Form, Process, and Ecosystem.

Note: There are longer definitions of each type of process in the back end of the participant notebook.



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<td>25 min</td>
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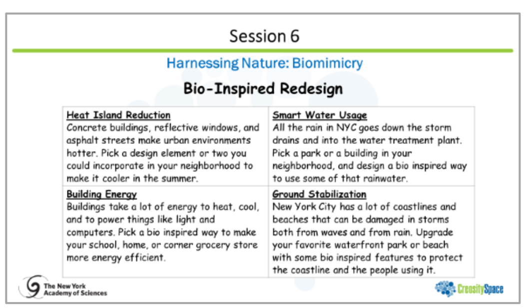
Biomimicry Redesign (Slides 115 – 119)
The remaining time in today's session is for a biomimicry redesign challenge. This session serves to give participants practice applying what they are learning about building collaborative communities. The amount of support and guidance groups will need for this activity will likely vary significantly with age and reading ability and is something the Classroom Specialist and Scientist-Facilitator should think about ahead of time.



For the Bio-Inspired Redesign participants can work in groups of up to three people to choose one place or building for which they can do a mini-bio-
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	inspired redesign. They don't need to completely redesign the space, but more suggest and describe an upgrade. They can pick from the list on the slide or else suggest their own location. Heat Island Reduction Concrete buildings, reflective windows, and asphalt streets make urban environments hotter. Pick a design element or two you could incorporate in your neighborhood to make it cooler in the summer. Smart Water Usage All the rain in NYC goes down the storm drains and into the water treatment plant. Pick a park or a building in your neighborhood, and design a bio inspired way to use some of that rainwater. Building Energy Buildings take a lot of energy to heat, cool, and to power things like light and computers. Pick a bio inspired way to make your school, home, or corner grocery store more energy efficient. Ground Stabilization New York City has a lot of coastlines and beaches that can be damaged in storms both from waves and from rain. Upgrade your favorite waterfront park or beach with some bio inspired features to protect the coastline and the people using it. Slides 115 – 118 will be provided to groups as a reference handout they can use for their redesign.
10 min	Cleanup and Design Share Today's session requires less cleanup than typical, so use this last 10 minutes to give groups a chance to share and describe their designs. Cleanup ● Have participants hand in their notebooks.

Preparation for Session 7

Review

- Review instructional activities in this guide, facilitator slides, and How To video
- Review pages 16 – 17 in the participant notebook.
- Modify lesson slides as desired.

Prepare

- Determine strategy for heating milk (including bringing a container that can be used to heat up the milk)

Session 7: Biopolymers

Key Learning Objectives	Participants will learn about polymers, what they are and why they have become so popular. Participants will also learn about challenges associated with polymers and how nature can help us benefit from the advantages while controlling or mitigating the disadvantages.
Key Vocabulary	**Atoms** are the small building blocks that make up everything around us. Sort of like a 1 x 1 Lego® piece. **Carbon** is a specific atom that is found in living organisms. **Molecules** are a group of atoms that join together to make a bigger particle. Sort of like a couple of Lego® pieces put together. **Insulators** are materials that DON'T allow heat or electricity to pass through them. **Conductors** are materials that DO allow heat or electricity to pass through them. **Semiconductors** are materials that DO allow electricity to pass through them under certain conditions (so not always) **Polymer** is a particle (or molecule) that is made of up repeating smaller particles. **Biopolymer** is a polymer made by a living organism. **Enzyme** is a special molecule (or particle) that living organisms use to decompose or deconstruct other molecules (or particles).
Preparation	Review ● Review instructional activities in this guide, facilitator slides, and How To video. ● Review pages 16 – 17 in the participant notebook. ● Modify lesson slides as desired. Prepare ● Determine strategy for heating milk (including bringing a container that can be used to heat up the milk)

To Be Handed Out	● Participant notebook
	● Paper clip polymers (participants should work in teams of 4). Each group receives:
	    o ~30 regular paper clips
	    o 5 odd-shaped paper clips
	    o 2 – 3 colored paper clips
	● Milk polymers (participants should work in pairs). Each group receives:
	    o 2 sets of plastic gloves
	    o Paper cup
	    o Craft stick
	    o 3 packs of vinegar
	    o Sheet of foil
	    o ~3/4 cup of warm milk (100 – 140°F)

	○ 2 snack bags (to take their polymer creations home) Shared Resources ○ Mini cookie cutters
Additional Required Supplies – Not provided in kit	● Pens/pencil ● Paper towel ● Large mixing and microwavable container for milk (can use cups in a pinch) ● Meat or candy thermometer (optional)

General Notes:

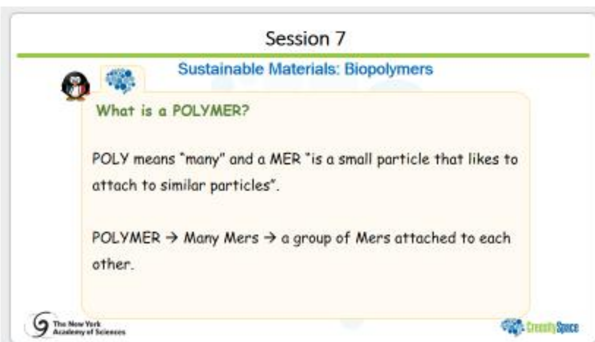
It is likely that participants will not be familiar with atoms or molecules as these concepts typically aren't taught until 8th grade. We suggest you start with the word "particle" to describe both atoms and molecules and only expand into more detail as a differentiation strategy for groups that are moving through the material quickly.

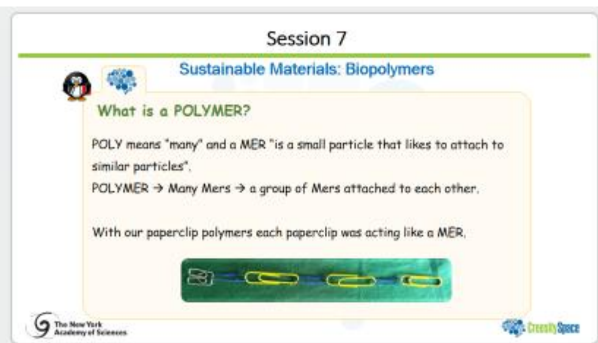
The milk polymer has the potential to be a smelly and messy activity. Make sure you have plenty of paper towels and be careful to stay off any carpet if possible.

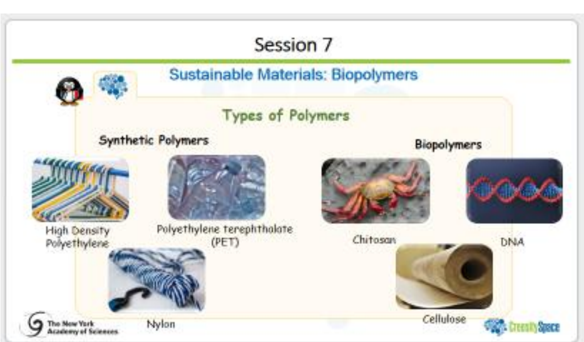
Classroom Specialist/Scientist-Facilitator

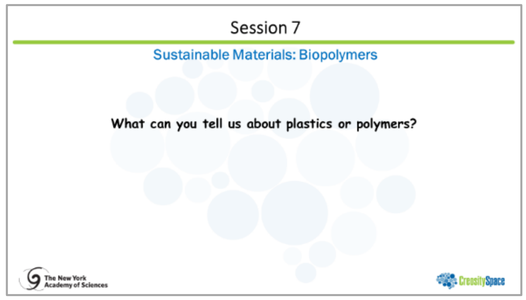
The paperclip polymer activity can get a bit chaotic as the groups merge their resources to build more complicated paperclip polymers. This is an opportunity for the Classroom Specialist to help keep everyone focused and on-task while allowing for creativity.

Background





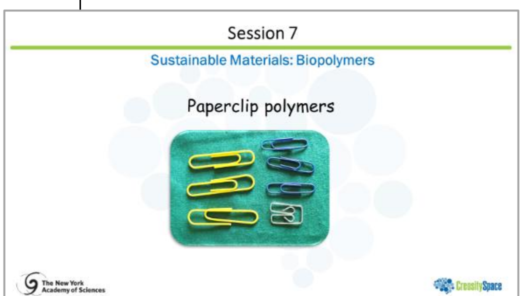


Timing	Instructional Activities
5 min	**Welcome and Settle** ● Welcome participants. ● Hand out or have participants collect their notebooks. As participants are coming in and settling down have slide 122 up on the screen.  After participants have sat down ask for volunteers to tell you something they what to share about plastics or polymers. Note: This is not a time to correct any misconceptions but more a chance to give you a sense of what they know, what they don't know, and what they are interested in finding out.
15 min	**Paper Clip Polymers (Slides 123 – 124)** *Facilitator Note: Since it is unlikely that many participants are familiar with polymers and/or any chemistry fundamentals, the paper clip polymer activity serves as a great visualization of the two key characteristics of polymers:* ● *Polymers are made up of repeating units (or pieces). Often (but not always) these units are similar but not identical.* ● *Polymer units (or pieces) can be attached or assembled in very different ways. With paper clip polymers this results in shapes that can look very different. With real polymers, this results in physical and chemical properties that can be very different*.

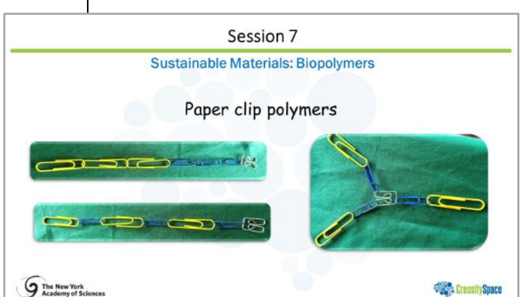
Slides provided are intended to be illustrative only as participant groups will have more and different paper clip options.

Participants will work in groups of 4 to build paper clip polymers. They'll start with ~30 paper clips and the challenge to build as many different polymer chains as they can think of.

Note: It might be better to start younger groups off with a smaller number of paper clips. Also, depending on the collaboration skills of your group, you might want to have participants work in pairs versus groups of 4.



Ask participants to come up with different configurations, have them share what they are making with the group.



After participants have had a few minutes to work in pairs, have them form groups of 4 or 8 and combine their resources. Can they come up with any new structures?

After 2 – 3 minutes, have the participants combine into larger groups. Again, have them pool their resources and determine what new paperclip polymers are possible.

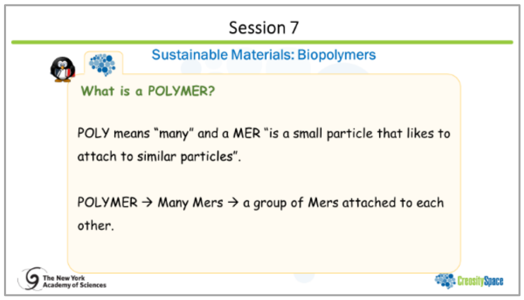
Finally, if it seems reasonable, have the entire group combine all the paper clips into a single pile and see what is possible.

10 min

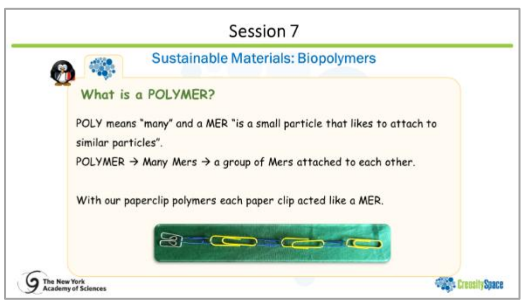
What is a Polymer? (Slides 125 – 127)

POLY means "many" and a MER "is a small particle that likes to attach to similar particles".

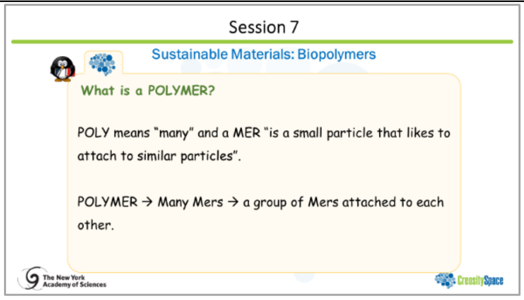
POLYMER ⍰ Many Mers ⍰ a group of Mers attached to each other.



With our paperclip polymers each paperclip acted like a MER.



Polymers are generally flexible materials that are comprised mostly of carbon – which is a type of particle that makes up most living organisms (like you, me, plants, animals). The big thing about carbon is that is not a metal. Having said that, the possibilities for chemical composition are almost infinite as the polymer molecule is generally created by combining small groups of two to six atoms. Novel polymers can span the range of insulators, semiconductors, and conductors, and researchers and engineers are finding many new materials and applications each day. (Note: Most participants should have learned about insulators and conductors in grade 2 but it may be good to define them here. Also, only discuss semiconductors with older students)

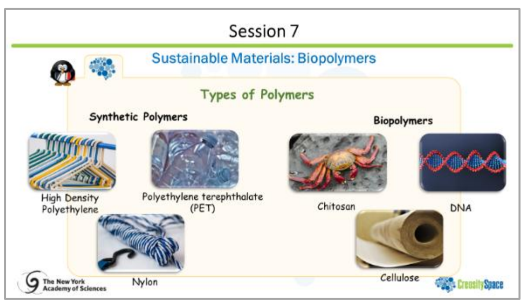


There are many types of polymers –

Synthetic polymers are made from oil and fossil fuels.

Biopolymers are made by living organisms or in a similar way (process biomimicry) as a living organism would.

Biopolymers are typically biodegradable whereas synthetic polymers are generally not biodegradable.



15 – 20 min

Milk Polymers (Slides 128– 132)

What you need: Gloves, paper cups (one per participant pair), vinegar pouches (3 – 4 per participant pair), molds, craft sticks, foil, paper towel.

Premix the powdered milk in a large microwavable bowl. **Add ~8 cups of water to the provided powdered milk.**

Have participants work in pairs to prepare their milk polymer. Each participant pair should get about ¾ cup of warm milk. You can re-use the scoop from sessions 2 and 3 to dish out the milk (it is ~ ½ cup). The cups

	provided are microwavable, so if necessary, milk can be heated up in small cups. Step 1: a) Mix powdered milk with water to create liquid milk. b) Heat milk in the microwave until it is warm. i. You can experiment with temperature if you want but be careful not to make it too hot that it becomes a hazard. Milk should be no warmer than hot coco that would be enjoyable to drink (i.e., not hot coco that would burn your mouth!). Target temperature is between 110 – 140°F. Step 2: a) Add vinegar to milk while stirring. i. Have one of the participant pairs in your group record the observations after each packet of vinegar is added. ii. Make sure to keep track of the number of packets added. (Note: The cooler the milk the more vinegar that is needed) Step 3: a) After a few packets of vinegar, the molecules in the milk (the protein) will start to link up and you will have created a semi-solid mass that feels like Play-Doh or Silly Putty. Wearing the gloves, take this polymer out and divide it evenly. b) Using the craft sticks, or your hands, press the polymer out into a flat mass like you would roll or press out cookie dough. Use cookie cutters to cut out a few shapes. (Participants may want to create some shapes free form, that is OK too.) Encourage participants to poke a hole in the top of their shape in case they want to put a string through it after it dries.

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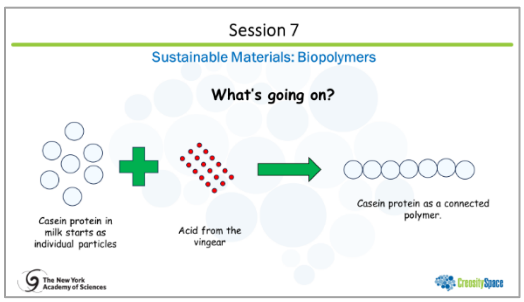
When participants are finished making their milk polymer forms, hand out the snack bags. It will take the milk polymers a few days to dry, so they will still be a bit wet (and smelly) when they take them home.

What's Happening?

When milk is heated and combined with an acid, such as vinegar, the casein molecules unfold and reorganize into a long chain. Each casein molecule is a monomer and the chain of casein monomers is a polymer. The polymer can be scooped up and molded, which is why plastic made from milk is called casein plastic.



Casein was once used to manufacture buttons, as it was a hard, strong substance and did not dissolve in water. However, polymers from casein can be expensive, and as the demand for plastics increased, a cheaper, oil-based version was discovered. Casein plastic is still used in manufacturing today to aid glue in book binding as well as serving as a glaze for paper.
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Biopolymer Innovations (Slide 133 – 134)

Both innovations featured in this session are examples of PROCESS biomimicry.

The first is from a company called Mussel Polymers Inc. The key inventor, Jon Wilker is a professor at Purdue University who studies underwater animals like oysters, mussels, and clams. He noticed how strongly muscles can attach themselves to rocks and figured out a way to make the "mussel glue" in the
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	lab. This glue is environmentally friendly and works 300 times better than products currently in use. The second is from a company called Intropic Materials. They are studying how nature decomposes biopolymers and trying to enable that same process in synthetic polymers. By adding specific particles (enzymes) to the synthetic polymer, they allow nature to decompose synthetic polymers as they would biopolymers. There is an interesting video that describes the process. https://www.youtube.com/watch?v=zzxuiJFXWkY
Final 5 min	**Cleanup and Reflection** As participants are cleaning up, have them think about *If they could design a polymer, what would you want it to do?* ● Have participants hand in their notebooks. ● Participants may take home their milk polymers. ● Keep scoop and unused paper cups. Collect paper clips for design challenge. ● Everything else used can be discarded.

Preparation for Session 8

Review

- Review instructional activities in this guide, facilitator slides, and How To video.
- Review pages 18 – 19 in the participant notebook.
- Modify lesson slides as desired.

Prepare

- Locate the session 8 materials.
- This investigation has a fair amount of material distribution to start with. Consider how you want to distribute the materials to the groups in a timely manner.

Session 8: Concrete Alternatives

Key Learning Objectives	Participants will learn that the ground beneath them serves many purposes. In addition to supporting buildings and creating homes for wildlife, the ground helps control water levels. Smart ground choices can help prevent flooding, erosion, and drought.
Key Vocabulary	**Concrete** is a hard building material that is made from cement, sand, and rocks. It is very durable but also heavy. **Alternative** is a replacement or different material that can be used to perform a task. **Run-off** is the name given to water that comes from rain but isn't absorbed into the ground. **Erosion** is the removal of the surface layer or dirt or ground by wind or water motion. **Drought** is the condition when there is much less rain/snow than typical or than is needed by a community.
Preparation	Review ● Review instructional activities in this guide, facilitator slides, and How To video. ● Review pages 18 – 19 in the participant notebook. ● Modify lesson slides as desired. Prepare ● Locate the session 8 materials bag. ● This investigation has a fair amount of material distribution to start with. Consider how you want to distribute the materials to the groups in a timely manner.

To Be Handed Out	● Participant notebook
	● Ground water investigation – participants will work in groups of 3 or 4
	  ○ Each group receives:
	    ▪ Bottomless condiment container
	    ▪ 5 – 7 coffee filter paper cups
	    ▪ 4 x 1 oz cups
	    ▪ Foils sheet
	    ▪ teaspoon
	  ○ Shared resources
	    ▪ Soil, clay, rocks, water, tiles

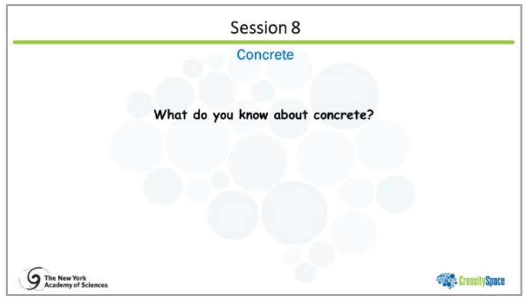
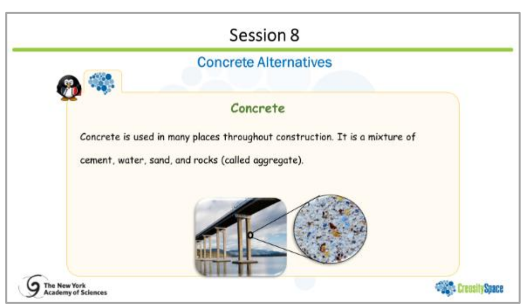
Additional Required Supplies - Not Provided in Kit	● Participant writing materials ● Paper towels ● Tap water ● Timer

General Notes:

Mess Warning: While not as messy as the milk polymers or suet feeders, this investigation involves water so has the potential to make a mess.

***Classroom Specialist**: Today's session has a lot of different materials to hand out. Think about how to include the participants in this process to help it go faster and to avoid long periods of time where participants are sitting around. Spoons and some extra cups are provided but you might want to bring in a few extra containers if possible.*

***Scientist-Facilitator**: While concrete and groundwater management are not the most thrilling science and engineering concepts, they are very topical. This year alone, almost every state in the United States has faced some sort of flooding event. As you prepare for this session, please consider how to bring a personal perspective to this topic—such connections have been shown to increase student engagement. Additionally, encourage the participants to really think about their neighborhoods and where concrete is necessary and where it could be replaced with something a bit more helpful from a water management perspective.*

Timing	Instructional Activities
10 min	**Welcome and Settle** ● Welcome participants. ● Hand out or have participants collect their notebooks. As participants are coming in and settling down have slide 137 up on the screen.  After participants have sat down ask for volunteers to tell you something they what to share about what they know about concrete. Note: This is not a time to correct any misconceptions but more a chance to give you a sense of what they know, what they don't know, and what they are interested in finding out. **What is concrete? (Slides 138 – 141)** Concrete is used in many places throughout construction. It is a mixture of cement, water, sand, and rocks (called aggregate). 

	Allow participants to brainstorm a bit about all the ways that we use concrete. After they've had some time to discuss and share, spend a little time filling out the table on slide 140 about the Pros and Cons of concrete. Concrete is used in many places throughout construction. Some examples are driveways, walkways, and foundations. It is very strong and durable but requires a lot of energy to make. As well, regular concrete does not provide many benefits for plants and animals.
15 min	**Ground Water Experiments (Slides 143 – 147)** One of the challenges we face in urban environments are issues related to excess water during heavy rains or strong ocean storms. Let's examine four different types of ground material and model what happens to them in the rain. Before we begin - What do you think some design criteria are for ground covering? Participants should work in groups of 4. **What you need:** 4 x 1 oz cups, soil, clay, tiles (to simulate concrete), small rocks, a teaspoon, water, condiment container, paper filter cups.  **Step 1:** a) Set out four paper filter cups and fill one each with tiles, soil, gravel, and clay respectively. All should be about the same height (~ 1 inch or 4 tiles). b) Gather two 1-ounce cups of water

Step 2:

a) Starting with the tiles, place the paper filter cup into the condiment container. Place or hold a 1-ounce cup under it to catch the water that comes through on the next step.

b) Pour 1-ounce of water on top of the tiles. Wait 1 minute to see how much of the 1-ounce of water makes it through. Describe how fast or the water moved through the system.

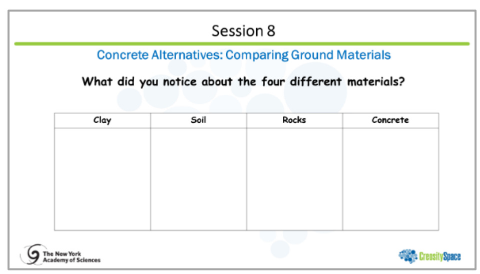
c) Pour a second 1-ounce cup of water over the tiles. Repeat the observations from step 2b. Gently touch the top of the surface of the tiles and describe what you feel.

d) Repeat Steps 2a-2c for the soil, clay and rocks.

Have participants record their observations in their notebook (page 18).

Discussion

As a group discuss your observations. Ask the participants what these observations might mean for how a given type of ground cover responds to heavy rains or storm surge.



Key observations:

- *Clay absorbs a lot of water but has no strength or ability to keep its shape.*
- *Soil is similar to clay, perhaps a bit stronger but absorbs a bit less water,*
- *Rocks absorb some water (more surface area), but not a lot.*
- *Concrete doesn't absorb any water & the water runs through it quickly.*

Key observations - Concrete has a lot of advantages in the strength department, but it can't hold any water, which can be an issue when severe rains or coastal storms come. It also doesn't allow for growth of plant or animal habitat.

10-15 min	Concrete Alternatives and Innovations (Slides 148 – 151) A number of innovators and entrepreneurs are working to develop concrete alternatives that provide the same strength and chemical resilience as regular concrete but are more supportive to the natural environment. Timbercrete Normal concrete is made by mixing rocks into cement. The final product is very strong but very heavy. With timbercrete sawdust or wood chips are added to the cement mixture instead of rocks. This makes a lighter concrete-product. The lighter weight decrease transportation costs and the material uses parts of wood that would otherwise go to waste. Grasscrete Grasscrete does not form blocks for building but reduces the amount of concrete required in a walkway or driveway. A cutout pattern is made so grass or plants can grow between pieces while still maintaining a hard surface. Grasscrete increases the ground's ability to absorb water compared to a space paved over completely. It also allows places for plant life to grow. Biocompatible Concrete A new field of concrete alternatives includes the group of ***biocompatible concretes***. With these materials, a fifth material is added to the concrete blend—in addition to the cement, water, sand, and aggregate—to enable the concrete to actively support living organisms. Entrepreneur Profile - Evelyn Tickle Evelyn went to school to study Architecture and has always had an interest in biomimicry and sustainable design. By adding specific chemicals to match the oyster shell composition, and producing concrete forms that allow for the integration of living organisms, Evelyn was able to develop a product with the strength of concrete but that also supports marine ecosystems. This is a great

	example of form, process, and ecosystem biomimicry and has established Evellyn's company GROW as an internationally recognized leader in the field of coastal resilience.
Time permitting	**Ground Water Experiments Round 2** Repeat your previous experiment but now try combinations of materials. Is there a combination that might work better for different applications?
Final 5 min	**Cleanup and Reflection (Slide 153)** As participants are cleaning up, have them *Think about a place in your neighborhood that uses concrete.* *Is there something you could replace that concrete with that would still perform the same task but also work with the plants and animals in the neighborhood?* ● Have participants hand in their notebooks. ● Collect tiles for use in the final challenge, dispose of all other materials.

Session 9, 10 preparations

Review

- Review instructional activities in this guide and facilitator slides
- Review pages 20 – 26 in the participant notebook.
- Familiarize yourself with the NYC pocket parks.
  - https://away.mta.info/articles/guide-to-pocket-parks-in-midtown-manhattan/
  - https://gothamist.com/arts-entertainment/the-8-best-pocket-parks-in-manhattan
  - Google maps is also a great resource for participants wanting to look at pictures of the parks.
  - If you have limited digital resources and/or a young group, you might want to limit the choice to 2 or 3 possible pocket parks and print out some pictures for participants to work from.

Prepare

- Modify the lesson slides as desired.
- Gather all remaining kit materials (including the bag labeled prototyping materials) for students to use to build their prototypes.
- Review the list of additional prototyping materials (p. 13) and decide if you or your participants want to bring any of these materials in to use for building prototypes.

Sessions 9 & 10: Innovation Challenge

Key Learning Objectives	In addition to seeing themselves as inventors, participants will become more familiar with the engineering design process. Additionally, they will work on developing their collaboration skills.
Key Vocabulary	**Prototype** is a model or mockup that helps inventors visualize or test out an idea or concept. **Brainstorming** is the activity of generating as manage ideas related to a given topic as possible.
Preparation	Review ● Review instructional activities this guide and facilitator slides ● Review pages 20-26 in the participant notebook. Prepare ● Modify the lesson slides as desired. ● Gather all remaining kit materials (including the bag labeled prototyping materials) for students to use to build their prototypes. ● Review the list of additional prototyping materials (p. 13) and decide if you or your participants want to bring any of these materials in to use for building prototypes.
To Be Handed Out	● Scrap paper ● Prototyping materials ● Posters
Additional Required Supplies	● Coloring supplies ● Additional prototyping materials (optional)

***General Notes**:* Over the last **two sessions of the program** participants will have an opportunity for their ideas to take center stage.

Your roles, as Scientist-Facilitator and Classroom Specialist, are to provide encouragement and a general structure to support participants through their idea exploration. You are not responsible for the quality of an idea or for whether a solution "works" or "doesn't work." This experience aims to harness participants' natural curiosity and innovative spirit while inspiring and nurturing a community of innovative minds. Market-ready products are not expected.

First session (session 9) will involve the following tasks:

- Selecting their design challenge.
- Forming groups (maximum of three people). Participants can also work as individuals.
- Completing the initial brainstorming and idea selection (pages 22–23 in the participant notebook).
- Time permitting: Participants/groups might begin sketching their innovations (page 24).

The second session will focus on:

- Sketching out and describing their innovation on page 24 of their notebook.
- Time and resource permitting—building a prototype/drawing on the poster
- Time permitting—presenting their innovation to the group.

Classroom Specialist, Scientist-Facilitator: This innovation challenge has a tight schedule. Participants, especially those working in groups, will need a lot of support to stay on track. Be empathetic but firm in keeping to the allotted time for each step.

Session 9

Timing	Instructional Activities
5 min	**Welcome and Settle** ● Welcome participants in and distribute notebooks.
10 min	**Challenge Introduction (Slides 156 – 159)** Participants have been thinking about light and how we use properties of light to develop new technologies. Also, participants have been learning about inventors, entrepreneurs while working on their brainstorming and collaboration skills, and now it's time for them to take those skills to the next level. General introduction Introduce the challenge to the participants by saying, "Over the past weeks we've learned about all sorts of things related to living with our natural neighbors. We've also had a chance to hear about cool inventors and entrepreneurs like Mikaila, Orianna, Aaron, and more. Now it's time for your ideas, and your solutions, to take center stage!" Challenge question selection and group formation Tell participants, "Now it is time for you to put together all of the individual things you have learned over the program and design a community space that is functional and works with the living ecosystem in the area. You can either create community space from scratch or modify an existing NYC pocket park to include some of the innovations and concepts you have explored during this program (e.g., https://away.mta.info/articles/guide-to-pocket-parks-in-midtown-manhattan/)

	Have participants identify which prompt would rather do (modify an existing space or create something totally new). Give participants <u>**5 minutes MAX**</u> to decide if they want to work in a group of people who are interested in doing the same thing or if they want to work alone. Due to time constraints, the maximum group size should be three people. Once participants have decided which challenge they will be working on and their group (if applicable), have them write their challenge prompt in the space on the top of page 22. Facilitators should circle the room to help anyone who needs it.
15 min	Brainstorming (Slide 160) After participants are settled in their groups and/or have decided on the challenge question, it is time to get them started on brainstorming. Explain to the participants, "The next step in the process is to come up with ideas. This is called **brainstorming**. During brainstorming, you must do the following things. • Come up with as many ideas as possible related to your challenge question. Don't worry about deciding if an idea is good or bad right now. • Think about how you want to address the challenge question. Is your innovation a device? Is it a service? Is it something totally new or an improvement on an existing product? • Figure out what exactly you want your innovation to do. Keep track of your ideas in the All the Ideas section on page 22." During this part of the ideation step, participants will generate as many ideas as possible. Emphasize the importance of diversity in coming up with solutions.

	If teams are struggling to get started or if some team members are dominating the conversation, here are a few good prompts to get them back on track: ● Suggest participants draw out their ideas first. ● Tell participants that all team members must contribute at least two ideas. **Give participants the halfway point time-check in this session.**
15 min	Idea Selection For the last 15 minutes of the session, participants should work on selecting the ideas they want to use in their innovation. Explain to participants that, "During the second half of this step, you will talk about the ideas you generated during brainstorming and choose your favorite ones. These are the ones that will go into your innovation. It can be hard to agree on which ideas you want to use in your innovation. If there is an idea you really like but it doesn't get selected to move on, you can put it in the Backup Ideas area." If participants are having trouble deciding which ideas to select here are two methods to try: ● Voting—Each team member gets three votes and marks three ideas that they like. Independent voting allows all team members to have a voice. ● Everyone picks an idea—Each team member gets to pick one or two ideas to be incorporated into the innovation. During this session, participants can start sketching out their designs (page 24) if that helps them think and discuss
Final 5 min	Cleanup Have participants put their notebooks and any prototypes in the extra bags provided.

Session 10

Timing	Instructional Activities
5 min	**Welcome and Settle** ● Welcome participants in and hand out notebooks. ● Hand out prototyping supplies.
10 min	**Initial Design (slide 161)** Participants should have completed their idea generation and selection last session and should now start sketching out their design. Participants should spend about 10 minutes sketching out their design in one of the spaces on page 24-25. Even if someone else on the team is the official "drawing person," all participants should sketch something in their notebooks. Give participants a halfway point time-check at around 5 minutes.
20 min	**Prototype (Slide 162)** After about 10 minutes participants should shift their focus from the initial design phase to working on their prototype or larger poster. If you are thinking about having participants present their design, suggest they consider the following questions: ● Where did you put it? ● Who will use it and how? ● What are some key features that will work with your natural neighbors?

1–2 min per group **Optional**	Presentations (Slide 163) Having an opportunity to present is a great learning experience, even if participants only say one sentence (or even, for some, just standing up there is a great experience). Even if groups are only speaking for 30–45 sec plan for 1–2 min per group for nerves.
5 min	Final Reflection As a final reflection discussion ask the participants to tell you one thing they learned during the program that surprised them or a new personal connection they made to STEM. Take this time to give participants your personal reflection on the program and some words of wisdom and/or encouragement.

Vocabulary

Alternative is a replacement or different material that can be used to perform a task.

Atoms are the small building blocks that make up everything around us. Sort of like a 1 x 1 Lego® piece.

Biopolymer is a polymer made by a living organism.

Brainstorming is the activity of generating as manage ideas related to a given topic as possible.

Carbon is a specific atom that is found in living organisms.

Characteristic is a feature, inherited by offspring from their parents, that varies among individuals. It may help to think of a character as describing the "category of features."

Composting is the activity of turning old food waste or scraps into soil for plants.

Concrete is a hard building material that is made from cement, sand, and rocks. It is very durable but also heavy.

Conductors are materials that DO allow heat or electricity to pass through them.

Criteria is the list of things a design needs to do in order to be successful.

Drought is the condition when there is much less rain/snow than typical or than is needed by a community.

Ecosystem is the interactions between the living things and nonliving things in an area.

Entrepreneur is someone who turns ideas into their own business.

Enzyme is a special molecule (or particle) that living organisms use to decompose or deconstruct other molecules (or particles).

Erosion is the removal of the surface layer or dirt or ground by wind or water motion.

Founder/Co-Founder is someone who starts a company.

Insulators are materials that DON'T allow heat or electricity to pass through them.

Inventor is someone who comes up with new ideas. You are probably an inventor!

Investigation/Experiment is a set of plans and activities you do to learn about a question you have.

Living Organisms are all creatures that are alive big and small. Trees, animals, and humans are all examples of living organisms. Rocks and concrete are non-living.

Living wall is a wall with plants on it.

Microbes is a short form, sort of a nickname, for microorganisms.

Microbial fuel cells are a special type of "battery" in which microbes generate electricity instead of chemicals. (Note: Fuel cells are technically not batteries, but for young learners this comparison is helpful for overall understanding).

Microorganisms are very small living creatures that you need special equipment to be able to see. Bacteria are an example of microorganisms.

Molecules are a group of atoms that join together to make a bigger particle. Sort of like a couple of Lego® pieces put together.

Nutrients are part of food that helps a living organism grow. For plants nutrients are found in the soil (or sometimes added to the water).

Performance Criteria is the rules you use to evaluate your design or experiment.

Phenomenon is an action you see or observe.

Pollinator is a living organism – often a small animal or insect – that helps plants reproduce by spreading pollen from plant to plant.

Polymer is a particle (or molecule) that is made of up repeating smaller particles.

Prototype is a model or mockup that helps inventors visualize or test out an idea or concept.

Run-off is the name given to water that comes from rain but isn't absorbed into the ground.

Semiconductors are materials that DO allow electricity to pass through them under certain conditions (so not always)

STEM is an acronym for science, technology, engineering, and math.

Strategy is your plan for solving a problem or investigating a question.

Suet is the hard fatty tissue around an animal's organs. In the case of suet feeders for birds, suet refers to birdseed mixed with fat to make a cake or pellet. For this experiment we're using vegetable fat instead of animal fat.

Sustainability is to act or design solutions to problems that don't hurt the environment, people, plants, or animals.

Trait is a variant of a given character, in other words, the versions or examples that would show up in the category.

Unique is something about that is special or different from others.

Vertical garden is a garden that rises up vertically instead of horizontally.

Background

Green Architecture Design Strategies

Green architecture and green building design are focused on making more environmentally friendly buildings. This can mean different things to different people. For example, some groups focus on using natural and local materials to make sure that up front the environmental impact of the building is minimized. Others focus on minimizing energy usage during the life of the building with things such as good insulation and energy-efficient appliances. Still others focus on minimizing the impact of the building on its surroundings by carefully monitoring water management issues and using design approaches that actively support local biodiversity. While these three focuses are not mutually exclusive, builders and architects often focus on the area in which they have the most knowledge.

While by no means an exhaustive discussion, the next few pages contain more detail on some considerations for green building design organized into three categories: (1) integration with the local ecosystem, (2) minimization of energy usage and waste generation, and (3) water management.

Integration with the local ecosystem

Integration with the local ecosystem involves looking to local habitats for both design requirements and design guidance. For example, understanding the plants and animals native to an area influences both building-level landscaping choices as well as larger-scale urban planning decisions.

There are a lot of benefits to using native plants in landscaping:

- Native plants provide natural support for the insect and small mammal populations. In turn those insects and small mammals help with natural pest and weed control.

- Additionally, the use of native plants helps to ensure a more balanced relationship between plants, soil type/quality, and water availability.
- Using nonnative plants runs the risk of those plants out-competing native plants and becoming invasive due to lack of natural consumers. Alternatively, the nonnative plants may die out completely, leaving the area ripe for weed take over and/or soil errosion.

This video, https://www.asla.org/sustainablelandscapes/Vid_Wildlife.html (4:41 min), is an information-packed video that explains why it is important to consider the local biodiversity when thinking about construction and some ways builders, architects, and homeowners can support their local ecosystem. It provides a good summary and is well worth the approximately five minutes to watch even if you don't plan on showing it to your students.

Listed below are some other ways to actively integrate a new building into the local enviroment:

- Look to the enviroment to provide inspiration on materials and structure styles that work well with the climate of the region.
- Build on sites that have already been developed. This reduces the impact on senstive areas.
- Determine how waste, noise, traffic, etc., are going to impact the local population.
- Maintain wildlife pathways and corridors to help lessen the impact of the development on wildlife.

Minimization of energy usage and waste generation

Energy usage and waste generation should be evaluated both during building construction and during building operation. Some ways to minimize energy usage and waste generated during building construction are detailed below:

- Build on existing sites and use as much of the original structure as possible.
- When possible use recycled materials to minimize the enviromental stress of pulling additional resources from the ground/forests/etc.
- Use local materials to minimize energy needed for transportation.
- Consider building and material durability when choosing materials and features. Consider the unique wear the local climate will have on the materials (e.g., extreme sun, high winds, wet conditions, etc.).

The list below outlines some ways to reduce the energy needed to run the building:

- Maximize the availability of natural light.
- Maximize levels of insulation in walls and windows.
- Take advantage of natural solar cycles to help with heating and cooling needs. Consider the direction a building faces to minimize or maximize the heat from the morning or afternoon sun.
- Implement automatic lights, faucets, etc.
- Make use of living walls and green roofs to reduce heating and cooling costs.

Water management

Water is critical for all living organisms but can be deadly and distructive at large volumes. When planning water management for a building design there are many different things to consider both inside and outside the building.

Outside the building:

- How much water is needed for landscaping? Will that put high demands on the natural amount of water available in the region?
- Run-off management during heavy rains (or light rains if it is a typically arid region).
- Rainwater harvesting to help with irrigation and other uses for gray water (e.g., washing your car).

- Water surges due to storms, heavy rains, or snow melt.

Inside the building:

- Installation of water-conserving plumbing including low-flow toilets, automatic faucets, and high-effeciency water heaters.

Protection from Wind and Water

Wind and water can have a profound impact on the shape of our land and on our safety in general. Both can take particles and materials away or bring new particles and materials in. Changes in the land due to wind or water can happen slowly, the way scientists believe the Colorado river has been carving the Grand Canyon over the last five to six million years, or very suddenly, as has been seen with many of the fierce hurricanes that have severely damaged portions of the Carribbean and South/Southeastern United States over the past few years. People who live in regions that are particularly vulnerable to wind or water damage, both slow and sudden, have a variety of precautions they can take to protect their homes and property. As with all aspects of construction, there is often an opportunity for a more enviromentally friendly, or green, design solution. We've described some of the most common solutions below.

Biomimicry

While copying from another student on a test is generally discouraged, copying from nature to solve individual and community challenges is always welcomed. The Earth is over 3.8 billion years old, so to say that various organisms have had a chance to optimize their designs is an understatement. Introducing your students to biomimicry is likely easier than you think. Students are often familiar with the idea of copying—mimicking—and a walk outside will likely introduce them to some of nature's variety—biology. Put the two together and you have the basis for biomimicry. Understanding the characteristics and traits of different living organisms—what unique things they do and how they do them—help scientists, engineers and inventors develop new products that work in harmony with the natural world.

Characteristics and Traits

Sometimes the words **character (or characteristic)** and **trait** are used interchangeably. To avoid any confusion simple definitions are provided below.

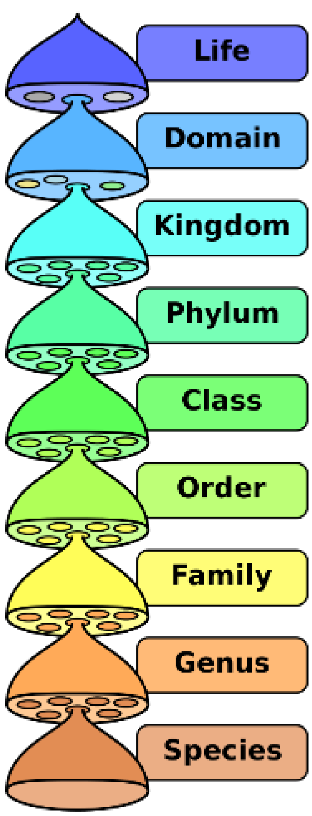
> A characteristic, or character, is a feature, inherited by offspring from their parents, that varies among individuals. It may help to think of a character as describing the "category of features." Some examples include hair color, flower color, and having fingers or toes.

> A trait is a variant of a given character, in other words, the versions or examples that would show up in the category. Example traits for hair color would be brown, blond, and black. Example traits for flower color might be red, purple, and white.

On average, **the characteristics of a given organism are dictated by the species genetics**. For example, dogs have legs, a tail, eyes, and ears. Birds have wings, claws, and a beak. Some snakes have fangs with venom while others do not. The variation within these characteristics, the traits, can be influenced both by the genetics of the animal (passed down from parent to offspring) and the environment. One common example of this is hair color. General hair color is determined by our genetics but can become much lighter when exposed to sun. Similarly, skin color, which is primarily dictated by the amount of a pigment called melatonin found in skin, has both a genetic and an environmental component to it. While those variations in traits can be a bit more temporary (our hair will darken and skin will lighten if we spend a lot of time out of the sun), differences in an environment can change how traits are passed down from parent to offspring. **Did you know that the white button mushrooms, brown cremini mushrooms, and the large portobello mushrooms are all the same species?** Different traits have developed based on different growing conditions (predominately age).

Biological Classification

Scientists have been working to organize and classify the world around them since the beginning of recorded history. By grouping living things together based on their similarities—how they look, what they are made of, or how they behave—they can search for patterns and predict things around benefits, dangers, and potential uses. This activity of biological classification is called **taxonomy** and is a field of science that is continually evolving.



The image to the left describes the basic strategy for classifying all living things. In general, the United States follows a biological classification system that includes six kingdoms: Animalia, Plantae, Fungi, Protista, Archaea, and Bacteria. To help you understand the big picture, the chart on the following page contains a simplified description of the key attributes for each kingdom.

	Animalia	Plantae	Fungi	Protista*	Archaea	Bacteria
Organisms	Mammals, birds, reptiles, fish, amphibians, sponges, insects, worms.	Moss, ferns, and flowering plants	Mushroom, yeast, molds.	Amoebae, green & brown algae, slime molds	Methanogens, Halophiles, Thermophiles, Psychrophiles	Bacteria, Cyanobacteria (blue-green algae), Actinobacteria.
Cell type	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Prokaryotic	Prokaryotic
Metabolism	Oxygen is needed for metabolism.	Carbon Dioxide is needed for metabolism.	Oxygen is needed for metabolism.	Oxygen is needed for metabolism.	Depending on species—oxygen, hydrogen, carbon dioxide, sulfur, sulfide may be needed for metabolism.	Depending on species—oxygen may be toxic, tolerated, or needed for metabolism.
Nutrition acquisition	Ingestion	photosynthesis	Absorption	Depending on species—may be by absorption, photosynthesis, or ingestion.	Depending on species—may by absorption, non-photosynthetic photophosphorylation, or chemosynthesis.	Depending on species—may by absorption, photosynthesis, or chemosynthesis.
Reproduction	Sexual in most and asexual in some.	Sexual in most and asexual reproduction in some.	Sexual or asexual (asexual through spore formation)	Mostly asexual. Meiosis occurs in some species.	Asexual reproduction by binary fission, budding, or fragmentation	Asexual

**Recent classification systems have divided the kingdom of Protista into Protozoa and Chromista. For simplicity we suggest keeping them combined if you introduce them to your students.*

Animalia, Plantae, and Fungi

There are many ways animals can be sorted, and it is up to the Classroom Specialist and Scientist-Facilitator to decide what criteria they feel most comfortable with as the goal of the activity **IS** to practice identifying and comparing traits and finding patterns and **NOT** to classify animals according to the most updated rules of biological classification. With that in mind, here are some ways that animals can be grouped:

According to Skeleton	
Invertebrates (without a backbone)	Vertebrates (with a backbone)
Arthropods: insects, arachnids, crustaceans, etc. Mollusks: chitons, snails, clams, octopuses, etc. Annelids: leeches, earthworms, etc. Cnidarians: jellyfishes, sea anemones, corals, etc.	Mammals Fish Reptiles Birds Amphibians

According to Class (in this case, invertebrates are often grouped together)
Mammals Fish Reptiles Birds Amphibians Invertebrates

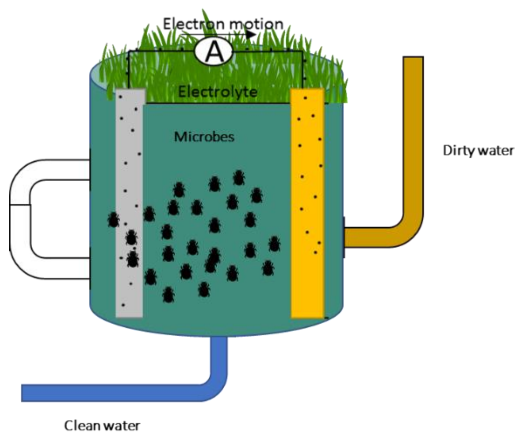
What's Covering Its Body
Hair/furry skin Feathers Tough skin with scales Scales Soft skin that needs to stay wet

Microbiology

Biology is the study of living things big and small. It helps us understand what makes us tick and how we interact with the living world around us. Microbiology is the study of the VERY small creatures that we can only see with special equipment. These are called microorganisms. Some microorganisms are helpful—like antibodies, yeasts, and geobacters—that help our immune systems, make our food taste good, and even produce energy. Some microorganisms are harmful—like germs and viruses—and these can make us sick. As we learn more about the microorganisms around us, we can develop beneficial relationships with them and our environment. Scientists, engineers, and entrepreneurs working in the field of microbiology often work across traditional boundaries—with physicists, material scientists, and mechanical engineers (to name a few)—to find new and innovative applications for the things they are discovering. Below we've described several of new areas of technology development in the field of microbiology.

Microbe-based energy generation and storage

Microbial fuel cells use bacteria to digest food waste and sewage to create electrical energy and clean water. This technology is used today in many applications, including cleaning up the water used in wastewater treatment plants and breweries.



Amazing algae that can generate oil from the sun

Algae are tiny microorganisms that live in the water and, like plants, can generate their own energy through photosynthesis. While there are thousands of different types of algae, some contain a large amount of lipids—or fatty oils—that can be used in a number of commercial applications. In the early 2000's there was a lot of interest (and money) invested in trying to see if oil from algae could replace oil from fossil fuels. That has turned out to be a lot harder than everyone thought—although companies like Exxon are still trying—and a lot of companies that were looking to generate energy from algae oil are now looking into other applications like make-up, pet-food additives, or pigments.

The growing world of fermented foods

Do you like yogurt? How about sauerkraut, kimchi or bread? Although people have been using microorganisms to produce fermented foods for thousands of years, scientists, chefs, and entrepreneurs continue to develop new and tasty things to eat as they learn more about the food, microorganisms, and equipment. Originally, fermentation was used as a method to preserve food so that it wouldn't go bad. While new products and methods still accomplish those goals, today's entrepreneurs are taking it one step further and turning the practical into a delicious treat.

Materials Science

Materials science is the study of various materials, such as metals, ceramics, and plastics, that are used in science and technology. In the past our ability to modify and design materials was limited to basic activities like heating and cooling (as was done to forge steel) or mixing and baking (e.g., with ceramic bricks). Today scientists and engineers are modifying materials at the atomic and molecular levels—as with many polymers, plastics, semiconductors, and specialty metal alloys—or getting plants/bacteria/cells/etc. to do the modifications for them! Below we list several areas for materials developments and some examples of innovations in those fields.

Biomaterials

Mushrooms have mycelium, the vegetation part of the fungus which consists of very strong "root-like" cells called hyphae. It is by allowing this mycelium to interact with other biodegradable materials that allows a new product packaging to be created.

Polymers/plastics

Polymers are generally flexible materials that are comprised mostly of carbon. Having said that, the possibilities for chemical composition are almost infinite as the polymer molecule is generally created by combining small groups of two to six atoms. Novel polymers can span the range of insulators, semiconductors, and conductors, and researchers and engineers are finding many new materials and applications each day.

Composites

Composite materials are materials made up of more than one raw material, creating properties that are different than the original materials' properties. Although composite materials have been around for a long time (straw/mud brick, concrete), the advancements in both fiber technology (thin glass or carbon "strings") and polymer technology have revolutionized what can be achieved with composite materials. Incorporating multiple layers of materials can create a product that is lighter in weight (significantly reducing shipping costs) and durable.

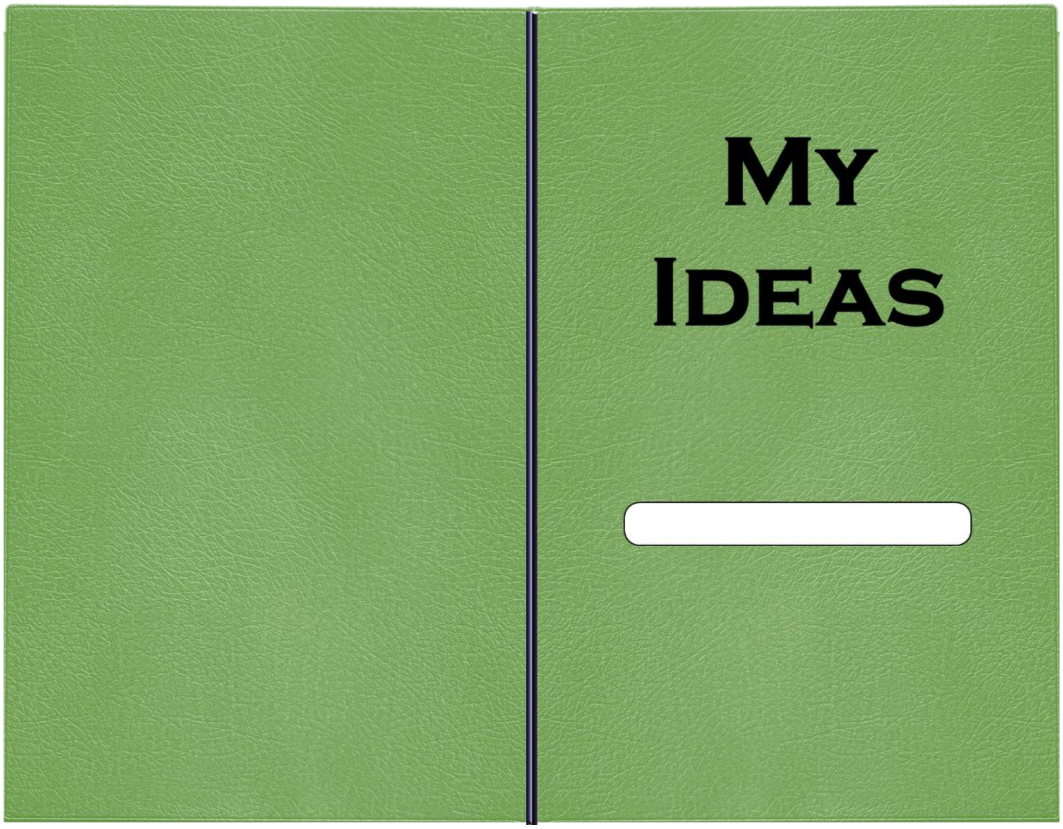
Metallurgy

Metallurgy is a domain of materials science and materials engineering that studies the physical and chemical behavior of metallic elements, their intermetallic compounds, and their mixtures, which are called alloys.

Ceramics

To date very little can beat the strength, wear and deformation resistance, and corrosion stability of well-made ceramic materials. They are found throughout our life—from tiny electronic components to huge wind and hydro turbines. Ceramics research focuses on developing new, lighter-weight materials that are less expensive to employ but do not sacrifice functionality.

Participant Notebook



Your Natural Neighbors

Where does your food come from?

A cool place for a living wall would be...

Describe your invention

Your Natural Neighbors

What organisms do you interact with every day?

The Cornell Lab

Merlin

Download the Cornell Lab free bird ID app

https://merlin.allaboutbirds.org/

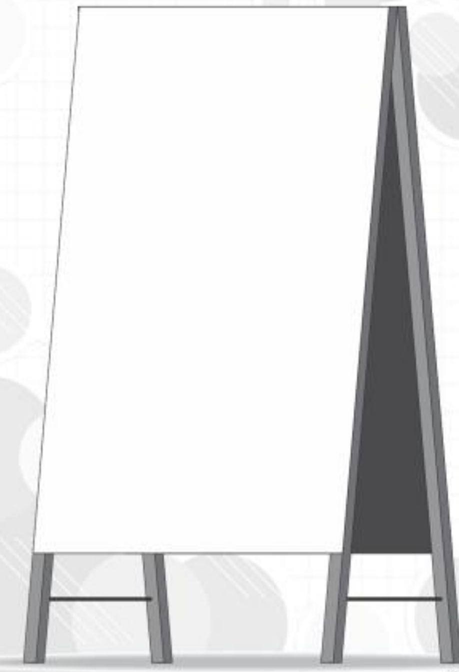
We could put an animal corridor...

Describe your invention

Harnessing Nature

What makes you unique?

Use the space below to sketch out or brainstorm ideas for your superhero.



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9

Harnessing Nature

What do you know about microorganisms?

Wouldn't it be useful if we could use microbes to...

10

Microbe Match

Thanks to *GIANTmicrobes* for Images

This white food has lots of bacteria that are good for your tummy.	A	1	Bad Breath *Porphyromonas Gingivalis*
This cell carries oxygen to all parts of your body	B	2	Salmonella *Salmonella Typhimurium*
Always remember to brush and floss your teeth to keep this guy away.	C	3	Sore Throat *Streptococcus*
This bacteria can make you sick if you don't clean up the counter after you prepare chicken	D	4	Red Blood Cell *Erythrocyte*
Lots of people catch this virus in the winter. Don't forget the Kleenex	E	5	Yogurt *Lactobacillus bulgaricus*
Sometimes when you have this you can stay home from school and eat ice cream	F	6	Common Cold *Rhinovirus*

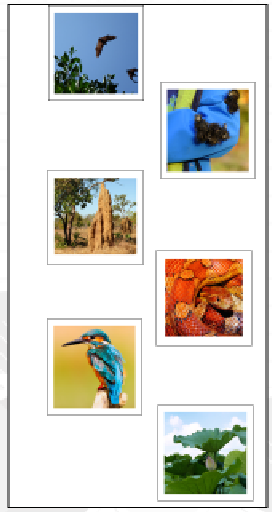
11

Harnessing Nature

What can we learn from plants and animals?

Innovation

Inspiration



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13

Use the space below to brainstorm ideas for your bio-inspired redesign.

Use the space below to sketch out ideas for your bio-inspired redesign.

14

15

Sustainable Materials

What do you know about plastics?

16

If I designed a polymer, I would make something that could…

Describe your invention

17

Sustainable Materials

What is concrete?

Observations

Clay	Soil	Rocks	Concrete

18

We could use this to replace the concrete in…

Describe your invention

19

Challenge

Over the past weeks we've learned about all sorts of things related to living with our natural neighbors.

Now it's time for your ideas and solutions to take center stage!

One of the biggest mistakes an inventor can make is to keep their invention a secret because they are afraid of having their idea stolen. You need to share it with as many knowledgeable people as you can. Why? To get their advice to make it better, to find partners to work on it with you, and finally, if for no other reason, so people will know that it was your idea!

—Ara Knaian
Co-Founder, NKS Lab

How It Works

1. Decide if you want to redesign an existing community space or make up a totally new community space.
2. Form a group.
3. Start inventing!

Albert with his Ocean Garbage Cleaner Upper—Grade 3

Our Challenge:

Brainstorming

Let's start with **BRAINSTORMING**. This is when you write down or draw as many ideas as you can. The goal of brainstorming is to come up with as many ideas as possible. Try not to think of ideas as "good" or "bad"—even the wildest ideas can spark new ideas.

All the Ideas

Favorite Ideas

Backup Ideas

The best thing that ever happened to me was people telling me I was doomed to failure. It set the stage to prove them all wrong . -David Rabuka Founder, Redwood Biosciences

Design

In this step you pick the ideas from your brainstorming that you want to use and start putting them together to build your product.

Initial Sketch

Revised Design

Build a prototype! It doesn't matter if it is made out of wood or even cardboard, just keep it simple and focus on testing the core concepts.

—Robert Barron

Co-Founder, Embedit Technologies

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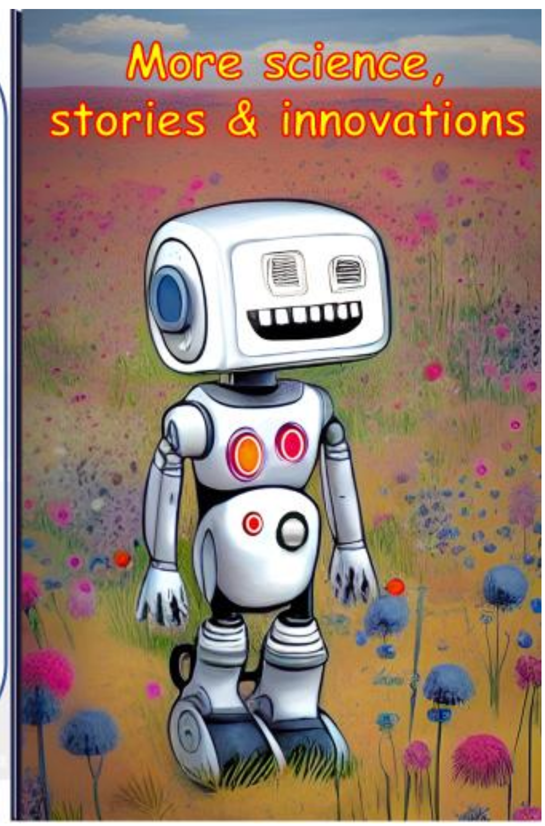
25

My Idea Space

26



Collaborative Communities

When you build something new it is important to think about two questions:

1. What does my building need to do?
2. How will my building fit in with everything around it—people, plants, and animals?

People who work on the first question are called ***architects***. People who work on the second question are called ***urban planners***.

Architects think about:

- How a building will be used.
  →This is called **function**.
- How long the building must last.
  →This is called **durability**.
- What the building will look like.
  → This is called **aesthetics**.
- How a building will work WITH the environment.

Urban Planners think about:

- *How people will get to a building;*
- *What other buildings are in the area; and*
- *How will the building fit into the environment.*

People also consider what was on the land before the building was constructed. They think about how the building might hurt the plants, animals, and people around it. This is called the ***environmental impact*** of the building.

Some things architects can do to reduce the environmental-impact of their building include:

- Install energy-saving lights and appliances;
- Use plants that need less water;
- Work with the natural environment;
- Use *renewable energy* for electricity; and
- Reuse parts of old buildings

Entrepreneur Profile: June Grant
Principal and founder of blinkLAB Architecture

The Challenge

June knew she wanted to be an architect since she was five years old. Growing up in Jamaica, she loved driving around the island seeing new homes and buildings under construction. June knew what it was like not to have enough water, electricity, or air conditioning, so when she finished school, she wanted to make sure the buildings she created didn't waste energy or resources.

The Solution

June uses her understanding of the environment and renewable energy (like solar) to design buildings that are better for the environment. She was profiled by the Sierra Club as one of the Faces of Clean Energy. You can see the video on YouTube at www.youtube.com/watch?v=_LOvAKw-m5U

Meet Some Entrepreneurs and Innovators Working with Their Natural Neighbors

Mikaila Ulmer

When Mikaila was four, she got stung by two bees in less than a week. At first this made her scared of bees, but then she started wondering why they had stung her in the first place. Mikaila started doing some research on bees, and learned how important they were to our ecosystems. At the same time, she was working on creating a unique lemonade for the Austin Lemonade Day competition. In her efforts to come up with something new, Mikaila decided to combine what she was learning about bees with her grandma's special flaxseed lemonade recipe—a unique lemonade that used flaxseed and honey to create a special flavor.

Photo courtesy of Me and the Bees Lemonade

From this was born what would become *Me and The Bees Lemonade*—a lemonade and business that gives a percentage of every sale to help save bee habitat. Over the last 10 years the product and the company has grown—with five different flavors that can be found in stores such as Whole Foods Market, The Fresh Market, World Market, H-E-B stores across Texas and Kroger stores in Houston.

Young Inventors from Kigali, Rwanda

Teams of young innovators from Kigali, Rwanda, were challenged to make an urban garden that would work in their community. One team repurposed readily available Jerry cans, that could be cut in half and loaded on a cart to create a mobile garden wherever it was needed.

Their garden grew carrots, onions, cabbage, and other green vegetables. Their team took Runner Up team with a Project of Distinction place in the innovation challenge competition.

Living walls—walls covered with plants—can make buildings more environmentally friendly and green in color! Living walls can be used on the inside and outside of buildings. Plant-filled walls help in many ways:

- Plants provide a source of fresh oxygen;
- They naturally absorb sound so people can work, talk, and think;
- Outdoor living walls provide homes and food for small animals, insects, and pollinators;
- It is a way for people to grow food for their household; and
- Many people find the color green relaxing.

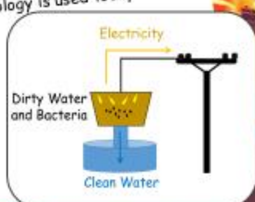
Microbiology

Biology is the study of the living things big and small. It helps us understand what makes us tick and how we interact with the living world around us.

Microbiology is the study of the VERY small creatures that we can only see with special equipment. These are called microorganisms (**or microbes**). Some microorganisms are helpful—like antibodies, yeasts, and geobacters—that help our immune systems, make our food taste good, and even produce energy. Some microorganisms are harmful—like germs and viruses—and these can make us sick.

Microbe-based energy generation and storage

Microbial fuel cells use bacteria to digest food waste and sewage to create electrical energy and clean water. This technology is used today in many applications, including cleaning up the water used in wastewater treatment plants and breweries.



Meet Some Microscopic Energizers

Brent Solina - MICROrganic Technologies

MICROrganic Technologies, Inc. is a company that was started in 2011 by Brent Solina while he was studying at Rensselaer Polytechnic Institute. At the time, he was only a couple of years out of high school!

He had a really great idea to take something that he had learned about in school, and turn it into a product that he knew would help all kinds of businesses around the world, as well as the environment. Armed with a sense of humor, the skills he picked up in the classroom, and some serious motivation, Brent has been pursuing his passion of using science to keep the world green! MICROrganic Technologies, Inc. is developing microbial fuel cell technology that cleans wastewater more efficiently. Microbial fuel cells use less energy than other technologies getting the job done with less impact and less expense.

Orianna Bretschger & Sofia Babanova - Aquacycl

Photo courtesy of Aquacycl

One third of the world's population doesn't have a good way to clean their dirty water. This creates an unhealthy environment for all the animals—including humans—and plants that live there. Two of the huge challenges with cleaning dirty water are the large industrial plants generally required for the cleaning the water and the complicated equipment used in those plants.

In graduate school, Orianna Bretschger, the co-founder and CEO of Aquacycl, studied how microbes can remove pollutants from water and produce energy at the same time. She realized that perhaps these tiny microbes could be the solution to some big problems. Aquacycl technology uses the bacteria that already live in the wastewater by creating an environment that helps them grow. When the bacteria grow, they generate electricity and also clean the water. Aquacycl technology is specifically designed to avoid the large plants, high costs, and complicated equipment normally associated with cleaning dirty water.

What is Composting?

When you compost organic matter, such as leaves and food scraps, it decomposes and turns into a nutritional material that can improve soil and feed plants.

To compost you need three basic ingredients:

- Browns - This includes materials such as dead leaves, branches, and twigs. These provide the carbon for your compost;
- Greens - This includes materials such as grass clippings, vegetable waste, fruit scraps, and coffee grounds. These provide nitrogen for your compost: and
- Water - Having the right amount of water, greens, and browns is important for compost development. The moisture helps the browns and greens to decompose.

Many people also add microbes to their compost to help speed up the process. Composting not only helps soil but it also reduces the amount of garbage that is sent to the landfill. Composting helps the planet in many ways!

Entrepreneur Snapshot: Jeremy Lang & Pela Earth

Growing up on a farm in Saskatchewan, Canada, Jeremy saw flax stocks being burnt and thought, "What a waste." Later, while on vacation at the beach, he saw plastic littering the shoreline and thought, "There needs to be a better way." At that point, Jeremy decided he wanted to spend his time solving, reducing, and reversing some of the harmful effects humans have on the environment.

Jeremy started the company Pela, with the lofty goal to create a waste-free future. One of the ways they are working towards this goal is with their new composting product, Lomi. A Lomi machine is about the size of a toaster and can turn a gallon of food scraps into nutrient rich soil overnight. The Lomi machine uses a mixture of chopping, heating, water and oxygen to speed up the composting process. This makes it easier for families to use and keeps waste out the landfill and puts it back into the soil.

Soil is more than just dirt

The soil is a mixture of many things. The soil includes organic matter, minerals, gases, liquids and living creatures. The soil keeps all these parts together by balancing the interactions with the world around it. For example, when plants are growing, they take nutrients (food) and water from the soil. When plants die, they return the nutrients (organic matter and minerals) and water to the soil through decomposition.

Soil is important to our lives. The soil performs four jobs that are very important to life on Earth.

1. Soil provides a home and food for plants to grow.
2. Soil provides a home, or habitat, for many different living creatures (animals, insects, good bacteria).
3. Soil cleans and stores a lot of Earth's drinkable water.
4. Soil interacts with the atmosphere and helps to balance the amounts of different gasses.

Biomimicry

While copying from another student on a test is not a good thing, copying from nature to solve challenges is always welcomed. The Earth is over 3.8 billion years old, so plants and animals have had a long time to learn what works and what doesn't work. **The field of STEM that focuses on learning from nature is called biomimicry. Bio means "from nature" and mimic means "to copy" so biomimicry means "to copy nature".**

People normally group types of biomimicry into three categories:

- Form → copying shape;
- Process → copying how something is done; and
- awesome

Biomimicry examples

https://www.learnbiomimicry.com/blog/best-biomimicry-examples

Form

Form is one of the most familiar types of biomimicry. It occurs when we copy a trait (shape, color, sound, etc.) of another organism to solve a problem or challenge. A common example of shape-based biomimicry is Velcro®. The idea for Velcro® came from the burr plant. The hook shape at the end of these burrs causes them to stick to clothing and animal fur.

Entrepreneur Profile: Eben and Gavin @ Ecovative

The Challenge

As long as humans continue to ship goods from one place to another there will be a need for light-weight packaging that protects the contents from getting broken. However, many packing materials are made from non-biodegradable materials like plastics.

The Solution

Almost all plants have some type of root system. The roots of many mushrooms are very special. Instead of a single long tube or bulb structure, they form a web-like structure called mycelium. It is the mycelium that enables Ecovative Design's mushroom materials. This technology uses mushroom roots (mycelium) to hold plant waste together to make strong new materials.

Entrepreneur Snapshot: Jon Wilker & Mussel Polymers

Jon is a professor at Purdue University who studies underwater animals like oysters, mussels, and clams. He noticed how strongly muscles can attach themselves to rocks and figured out a way to make the "mussel glue" in the lab. This glue is environmentally friendly and works 300 times better than products currently in use.

Process

The second type of biomimicry is process. In this type of biomimicry you copy HOW something is done not WHAT something is. You may not know this, but many plant leaves have small holes in them that allow old water to leave the plant. This allows fresh water to enter the plant through the roots bringing food to the plant that it needs. Some companies are copying this process to help purify water.

Entrepreneur Profile: Aaron Hall @ Intropic Materials

The Challenge

Plastics are super cool materials that can be designed and engineered with almost any set of physical properties you can imagine. One of the challenges with plastics is that most of them do not decompose—so they persist in the ground and oceans forever.

The Solution

Aaron Hall, the CEO and Founder of Intropic Materials, got the idea for the company when he was in graduate school. By adding enzymes (a substance produced by a living organism to make chemistry happen fast in the organism) to synthetic plastics they become self-degrading products that can be composted or perfectly recycled.

Ecosystem

The third type of biomimicry is ecosystem. This is when people design larger systems that copy the interactions from an entire ecosystem. One example of this are hydroponic systems. These can copy the plant and animal interaction you might find in a pond. In this situation the plants are grown, and fish are raised to feed people.

Entrepreneur Profile:
Evelyn Tickle @ GROW Oyster Reefs

The Challenge

Many coastal environments are suffering from erosion, which results in the wearing down or removal of rocks, soil, and other shoreline habitats. One approach to reinforcing coastlines is the use of large concrete bulkheads. Unfortunately, these concrete bulkheads do not provide suitable habitat for coastal plants and animals.

The Solution

Evelyn went to school to study architecture and has always had an interest in biomimicry and sustainable design. By adding specific chemicals to match the oyster shell composition, and producing concrete forms that allow for the integration of living organisms, Evelyn was able to develop a product with the strength of concrete but that also supports marine ecosystems. This is a great example of form, process, and ecosystem biomimicry working together.

Traits and Characteristics cards

 Fungi – mushroom	 Fungi –mushroom	 Fungi – lichen
 Fungi – mushroom	 Fungi – lichen	 Fungi – mold
 Plant – wildflower	 Plants – waterlily	 Plants – blackberry
 Plants – olive tree	 Plants – flower	 Plants – asparagus
 Plants – peppers	 Plants – lettuce	 Plants – prickly pear
Design your own	Design your own	Design your own

 Rabbit – mammal	 Frog – amphibian	 Owl – bird
 Fish – fish	 Lizard – reptile	 Snow leopard – mammal
 Parrot – bird	 Cat – mammal	 Snake – reptile
 Butterfly – invertebrate, insect	 Snail – invertebrate	 Spider – invertebrate, insect
 Sea Turtle – amphibian	 Red grasshopper – Invertebrate, insect	 Crab – invertebrate, crustacean
 Dog - mammal	Design your own	Design your own

CreositySpace

Connecting Kids to STEM Through Entrepreneurship