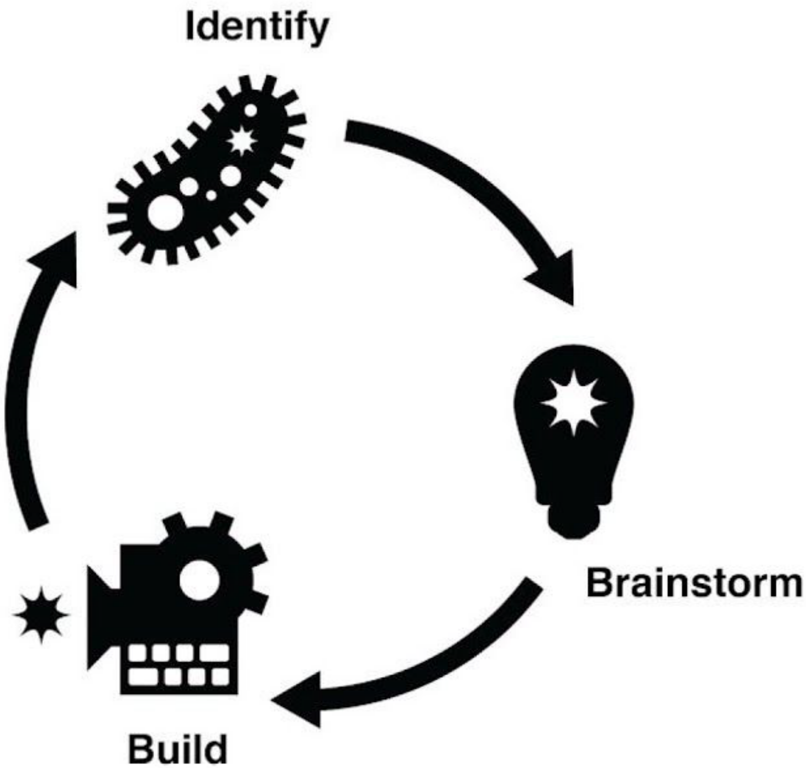
Invention × Nature



Evolving Creatures

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Program Overview

Dates and Times

July 2 – August 8, 2019
Monday – Thursday
8:30am – 2:30pm

In total, there will be 20 instructional days of Invention X Nature. There will be two additional field trip days.

Your Team

You will each lead this program in your own classroom, but you are part of a site-wide team that includes CUNY Tutors, Beam Center Program Managers, and Beam Center Program Assistants.

Beam Center Program Managers can provide support with pacing and scheduling, tool and material use, coordinating between classrooms, and can help clarify design challenges and curriculum design. Program Managers are also experienced educators and can help work directly with students. You can expect Program Managers to pop into your classroom and seek out ways to help. **We are not here to lead the class *or* evaluate your performance, we are only here to help. If you feel unprepared, please reach out.**

Beam Center Program Assistants can provide additional support with tool and material use as well as coaching students through the process of troubleshooting and building prototypes.

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Who We Are

This summer, Invention X Nature is brought to you by Beam Center in collaboration with Mouse.

BEAM CENTER

Beam Center's mission is to crystallize self-directed growth through ambitious, collaborative project-making.

We support and celebrate young people as producers of learning, culture and change who take bold steps towards personally meaningful futures and help guide compassionate, equitable, and vibrant communities.

We use old and new tools, technologies, and craft to honor the individual voice, celebrate the joy of producing something larger than ourselves, and inspire lasting wonder. We value the exchange of knowledge, perspective, and experience between youth and professional creators.

mouse_

Mouse designs computer science and STEM curriculum on their online learning platform Mouse Create, trains K-12 educators, and engages students through the Design League and maker events. Mouse is committed to fostering greater diversity and humanity in STEM and empowering youth -- and all those that educate them -- to access and amplify technology as a force for good.

Invention X Nature Timeline

Your schedule will differ slightly day by day, but our recommended flow for the program is as follows.

DAY 1	AM	SESSION 1	Vertical Gardens
	PM	SESSION 2	Vertical Gardens
DAY 2	AM	SESSION 3	Vertical Gardens
	PM	SESSION 4	Orientation
DAY 3	AM	SESSION 5	Fundamentals: Journal
	PM	SESSION 6	Fundamentals: Journal
DAY 4	AM	SESSION 7	Fundamentals: Animatronics
	PM	SESSION 8	Fundamentals: Animatronics
DAY 5	AM	SESSION 9	Fundamentals: Animatronics
	PM	SESSION 10	Fundamentals: Animatronics
DAY 6	AM	SESSION 11	Fundamentals: Animatronics
	PM	SESSION 12	Fundamentals: Animatronics
DAY 7	AM	SESSION 13	Domain 1: Plants
	PM	SESSION 14	Domain 1: Plants
DAY 8	AM	SESSION 15	Domain 1: Plants
	PM	SESSION 16	Domain 1: Plants
DAY 9	AM	SESSION 17	Domain 1: Plants
	PM	SESSION 18	Domain 1: Plants
DAY 10	AM	SESSION 19	Domain 1: Plants
	PM	SESSION 20	Domain 1: Plants
DAY 11	AM	SESSION 21	Domain 2: Cephalopods
	PM	SESSION 22	Domain 2: Cephalopods

DAY 12	AM	SESSION 23	Domain 2: Cephalopods
	PM	SESSION 24	Domain 2: Cephalopods
DAY 13	AM	SESSION 25	Domain 2: Cephalopods
	PM	SESSION 26	Domain 2: Cephalopods
DAY 14	AM	SESSION 27	Domain 2: Cephalopods
	PM	SESSION 28	Domain 2: Cephalopods
DAY 15	AM	SESSION 29	Synthesis: Evolved Creatures
	PM	SESSION 30	Synthesis: Evolved Creatures
DAY 16	AM	SESSION 31	Synthesis: Evolved Creatures
	PM	SESSION 32	Synthesis: Evolved Creatures
DAY 17	AM	SESSION 33	Synthesis: Evolved Creatures
	PM	SESSION 34	Synthesis: Evolved Creatures
DAY 18	AM	SESSION 35	Synthesis: Evolved Creatures
	PM	SESSION 36	Synthesis: Evolved Creatures
DAY 19	AM	SESSION 37	Showcase
	PM	SESSION 38	Showcase
DAY 20	AM	SESSION 39	Celebration
	PM	SESSION 40	Celebration

Invention x Nature Program Description

The program consists of three phases: **Fundamentals**, **Domains** and **Synthesis**. Each phase introduces new skills and challenges that students combine with what they learned in the previous phase.

- **Fundamentals:** (4 days) introduces the basic tools, materials, skills, and safety involved in the prototyping routine. It also includes the means by which students will document their work, which consists of a handmade journal and digital photography.

- Two **Domains** (4 days each): introduce specific design challenges inspired by the way living things move and react to their environment. Students will combine what they learned in Fundamentals with new circuits that include Arduino coding and physical computing.
- **Synthesis** (4 days): challenges students to bring together any tools, materials, skills, and code they choose from the previous phases to create an evolved creature prototype.

In Beam Center's Summer In the City program, **Invention x Nature**, Teachers will guide students through an iterative engineering design process themed around hands-on prototyping of interactive objects inspired by the natural world.

To prepare for the program, teachers will be trained by Beam Center Instructors to become **lead learners** and apply a set of skills, tools, and materials to a theme from nature.

Students begin the program by assembling their own **Prototype Journal** that they will use to develop projects over the summer.

During the first few days, students will be introduced to the **Fundamentals** of prototyping, which will include electronics, physical computing, and building cardboard mechanisms.

Students will then complete two **Domains**, design challenges inspired by the way that different creatures survive and thrive. During this part of the program, they will be introduced to the particular fabrication skills, tools, and materials of that Domain and will create prototypes in collaboration with a partner.

In the final **Synthesis Project** project, students will design interactive prototypes that bring together a selection of everything they've learned to create a final prototype in response to a specific biome of their own imagining.

Online Resources

This public folder contains curriculum content in PDF format for Middle School and High School.

SITC.beamcenter.nyc

This public folder contains Arduino code and circuit diagrams for Middle School and High School.

Arduino.beamcenter.nyc

Prototyping in the Classroom

Safety Guidelines

1. No open toed shoes. Keep long hair, dangling clothing or jewelry tied back.
2. Put tools down and give teachers your full attention during demonstrations.
3. If you don't know how: ask for help. If you do know how: offer help.
4. Respectful and clear communication is essential.
5. Everything in the space is a tool. Use them properly.
6. Keep work surfaces organized.
7. Use tools at designated stations.
8. Keep your fingers away from hot tips and sharp blades.
9. Be aware of your body in the workspace. Keep your eyes on the tool you're using.
10. Set a good example. Do what you expect others to do.
11. Materials are shared by everyone. Use them purposefully.
12. Do not distract others when they are using tools.
13. Clean up is everyone's responsibility.

Behavioural Guidelines

Beam Center trusts students to learn how to use real tools to make real things. To keep our trust, we ask students to listen to and follow instructions for how to use tools appropriately, and to treat every object in the shop as a serious tool.

Unsafe behavior is typically the result of student disengagement. Most behavioral issues can be resolved by redirecting energy back toward the project or by clarifying the project criteria.

If a student makes an *unintentional* mistake, we show them how to use the tool again and ask them to demonstrate correct usage. If a student makes an *intentional* mistake, we give them a chance to use the tool properly. If they continue to misuse the tool, they may lose the privilege of using that tool.

Guidelines for Teaching Safety

1. Set a good example.
   - We are always on stage when using tools. Do exactly what you expect your students to do. If you do it, they will too. If you don't do it, you can't expect them to.
2. Provide clear instructions and discuss safety first.
   - Demonstrate how to use each tool properly - tell them AND show them.
   - Be intentional about what's on the table when. Only hand out the tools and materials students will need within that work period.
3. Don't hesitate to ask for help.

- We want to create an environment in which everyone is comfortable asking questions if they don't know how to do something. If you don't know how to use a particular tool or approach a task, just ask the Beam Center Program Manager.

What is a Prototype?

Invention X Nature is all about making **prototypes**.

A **prototype** is a first attempt at building something or realizing an idea. **Prototypes are like first-drafts**, but they should be functional, durable, and interesting to look at. They don't have to look perfect or polished. They are a way to share ideas with other people!

Invention X Nature is divided into three phases of collaborative prototyping. Each phase introduces new tools, skills, and materials and poses a design challenge for students working in groups.

During each phase, students follow the same **prototyping routine** for making prototypes:

1. Learn the circuitry, tools, skills, and materials
2. Hear the challenge, prompt, or theme
3. Brainstorm and play with materials
4. Make a plan and a diagram
5. Build
6. Revise
7. Reflect

The Prototyping Process

Often projects that involve making or prototyping begin with a problem to solve or a question to answer. Before beginning to create, think about whether you understand the prompt you've been given. Play with materials and explore ideas, and not to start with an idea of what you want to finished product to be. Some questions to consider.

- What is the problem/challenge I am trying to solve?
- Are there multiple ways to approach a solution?
- What is my end goal?
- What materials and ideas interest me?

You can help students by facilitating full-classroom brainstorms or grouping students based on their interests.

Drawing

Drawing is another way to communicate an idea and is especially helpful when you're working with other people. Artistic skills aside, information diagrams are a way to show someone how something might work, as a first step in building it. As long as the idea is communicated, the sketch is successful.

Guidance and prompts for making informational drawings

- Show how the circuit connects.
- Where is it interactive? What does it do?
- What's the scale? Write down measurements.

- How is it worn/held/attached or used?
- Add a title and label the parts.

Finishing Prototypes

When is a prototype finished?

Prototypes are “first draft” physical manifestations of an idea. A prototype is finished when it demonstrates the idea successfully. If you can’t find something to do on the prototype you were working on, improve or expand the idea, make it look better, make a version two, help someone else, or make something new.

Iterating on a prototype means that you’re improving on the function rather than improving the aesthetics.

Aesthetic decoration always comes last.

Prototype Presentation Guidelines for Students

Presentation Tips

- Face the crowd.
- Explain the steps you took to make it.
- Demonstrate how it works and what it does.

Prompts for Discussing Prototypes

- What’s the most interesting feature of your design? Why?
- What were the different steps you took to get your project to work?
- What was the hardest problem to solve?
- Did you have to do something a few times to get it to work? What?
- If you had more time, how would you improve your project?

Facilitation Guidelines

How to Demo Tools

Before demonstrating step-by-step instructions, lay an example of each of the components out on a table and explain what each is, what it does, and how to use it safely.

Classroom Management

Build Trust
Students need to feel safe before they allow themselves to take creative risks. Building trust is essential for fostering a sense of safety. Teachers can earn the trust of students by sharing knowledge of tools and materials and by communicating respectfully using constructive criticism. Students can earn the trust of teachers by listening closely and following instructions for using tools safely.

Redirect Energy
Disinterested students may just need a change of role. Help students who are disengaged become students who have skills that no one else has. Ask questions in order to help them figure out what interests them and give them entry points. Many behavioral issues can also be resolved by clarifying the design challenge criteria.

Constructive Criticism
Non-working prototypes do not indicate failure. To build prototypes, students must experiment, take risks, and try things that might not work. If a student's prototype does not work, it is important to provide constructive criticism rather than call it a failure.

Prompts for Constructive Criticism

- I like the way you ___
- I think ___ is successful
- This made me interested in exploring ___ more.
- I'm wondering about ____. Can you say more?
- What would you do differently?
- ____ but _____ because _______. (Compliment Sandwich).

Tool and Safety Mistakes
If a student makes a mistake using a tool, show them how to use the tool again and ask them to demonstrate correct usage.

Losing Tool Privileges
If a student repeatedly uses a tool in an unsafe way on purpose, they may lose the privilege of losing that tool.

Student Participation
If a student is visibly disengaged but is not creating a distraction, they may need a break. Interrupting long work periods with intentional breaks can be helpful. It is OK for students to quietly take a break to listen to music or check their phones as long as they remain in the classroom.

Students who aren't engaging with the main activity are welcome to work on alternative activities, tasks, or challenges that are constructive and non-disruptive.

Taking Breaks
Students may need to take breaks during prototyping periods.

Supporting Collaboration

Forming and Maintaining Student Groups
All of the projects in Invention X Nature are collaborative by nature. We recommend that every project is created by a group of 2-3 students. It is important that students work in consistent groups for the duration of a project. We recommend keeping a record of student groups to support consistency. It is OK for students to create new groups after each project.

Students Working Individually
If a student expresses the desire or need to work individually, it is up to your discretion as to whether this is appropriate.

Distributing Materials to Students
Don't give students all of the materials at once. Only give out materials for the current project. CUNY Tutors may be helpful in distributing materials.

It is recommended to only offer paint markers towards the end of a project. Students should spend the first few sessions focusing on form and function, and save color and decoration for last.

Music and Photography

Listening to Music
Listening to music can help create a positive laboratory environment. We recommend creating a system for students to take turns choosing music to listen to aloud in the classroom. If students listen to headphones during work periods, they must only have one earbud in. Students should not use headphones during instruction or while using any power tool.

Student Photography
Photo documentation is an important part of this program. It is OK for students to use their phones to photograph their work and each other, as long as they have permission.

Prototype Policies

Taking Projects Home
Student prototypes are collaborative, and this complicates the idea of a student taking their project home. Students may also need to disassemble earlier prototypes and reuse materials. For these reasons, it is important that students do not take their projects home until the last classroom day of the program. If the final day of STEM Summer In The City is a field trip, students should take their projects home the previous day.

Evaluating Students

Criteria for Success
There is no formal criteria of success for students in Invention X Nature. Success looks like students making something that they're proud of, gaining skills, and becoming part of a community.

Positive behavior to look for:
- Skills using tools and materials
- Expressions of confidence
- Expressions of curiosity

- Understanding of how things work
- Ability to explain how they did something
- Ability to respond constructively to other people's work

Classroom Setup Guidelines

Setting up Spaces

Students will often work standing and will move around the classroom during Invention X Nature. They will also work collaboratively using tools. To accommodate this, there are several spaces that will need to be prepared before the program begins. They are:

Meeting and Demonstration area
In-Progress Prototype Storage
Tool and Material Storage
Prototype Gallery
Personal Item Storage
Work Surfaces
Code Upload Zone
Hot Glue Zone
Cardboard Cutter Zone
Recycling and Garbage

Meeting Area

Designate an area that stays (or can be made) clear which can be used to present ideas and demonstrate tool usage. This area could also serve as a spot where students can share their projects with the group. It should include a tabletop and a place to exhibit freestanding or wearable projects.

Prototype Gallery

Set up a gallery area where finished prototypes are displayed. Prototypes may need to be disassembled to re-use their parts after they are exhibited. If they are not disassembled, they should remain in the gallery until the end of the program.

Tool and Material Storage

Set up a "Materials Store" Using Trays
All materials should be stored in small trays. Create clearly labeled storage spaces for each type of material. Label each tray using masking tape and a marker.

It is recommended that you only pull out trays of materials that relate to the specific project that is happening. Materials for other parts of the program should be kept out of reach, unless specifically requested.

Group Similar Materials Together in Labeled Locations
Labeling a clear home location for every tool and material type will help kids clean up.

Examples of Storage Categories:

- Electronic Tools
- Electronics Parts
- Arduino
- Cardboard and paper scraps
- Glues and Tapes
- Fabric and Notions
- Cutting Tools
- Clamps

Personal Item Storage

Clothing and Bag Storage for Students
Students will not be able to keep their belongings at their specific desk as they would in a normal school class. Their bags and clothes will get in the way and create stress or danger if piled on tables and the floor. Designate a clear area for this stuff to go, preferably near the entry door, so it doesn't even really enter the room with kids and create distraction.

Work Surfaces

Select Appropriate Tables

Identify large tables that are good for working collaboratively on projects. Students will mostly work while standing, so tall tables are best.

If those are lacking, combine smaller desks together in groups of 2 and 4. Secure the desks together with tape or zip-ties, so they don't drift apart while kids are working on them.

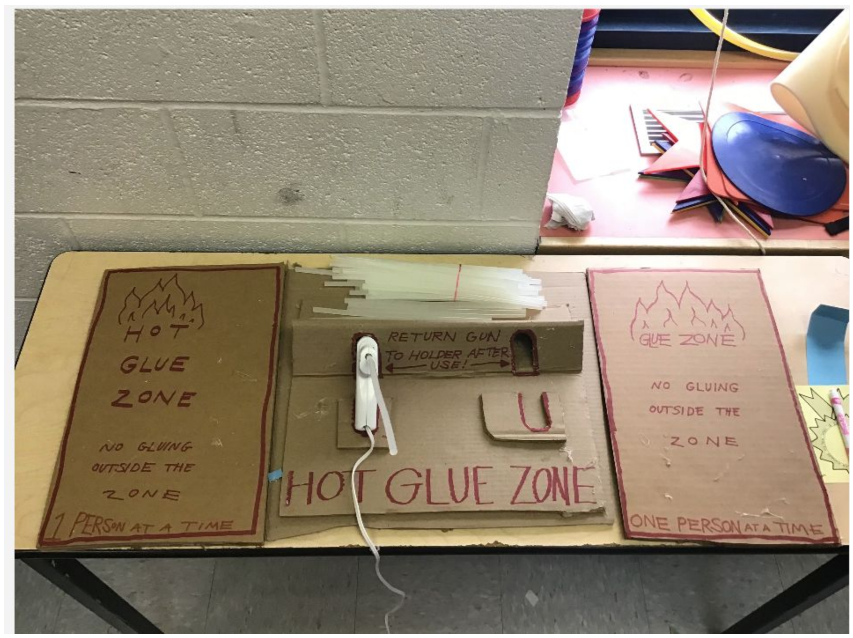
Protect Table Surfaces
Place brown butcher paper or cardboard sheets on top of tables to protect the tables from glue and tool scratches. There will be two rolls of brown paper at each site.

Leave Space Between Tables
Students will be moving around the room more than in a typical classroom. Move chairs to the side of the room to create extra space between tables.

In-Progress Prototype Storage

In-progress prototypes should be kept on the work surfaces where they are being built at the end of the day. Small parts or pieces may be kept in a labeled bag or box alongside the project.

Hot Glue Zone



Use cardboard sheets to create a clearly labeled hot glue zone. As pictured above, it is also possible to fabricate a simple hot glue gun holder by bending a sheet of cardboard into a triangular shape and cutting holes for the glue gun using a cardboard cutter.

Cardboard Cutting Zone and Scrap Bin

Also create a clearly designated cardboard cutting station where students can clamp their work down. You can cut pieces of cardboard to the exact size of the table surface and tape them down securely in the corners.

If you have an empty bin or bag, use it to collect usable paper and cardboard scraps.

Code Upload Zone

Set up three Windows or Mac OS laptops with power supplies plugged in and with WiFi connected in a designated place in the classroom. Ensure that each laptop has a USB port and the appropriate USB cable for connecting an Arduino. Ensure that each laptop is equipped with the Arduino IDE software and can access the Arduino Web Editor. This is your Code Upload Zone.

Recycling and Garbage

Identify and label a container for paper recycling and garbage. Clean cardboard and paper scraps should be collected as recycling. Scraps with lots of glue must be discarded as garbage. It is wise to salvage any reusable electronic components or metal hardware from discarded prototypes.

Program Lesson Plans

Session 4: Orientation - Lab Culture

Objectives
Build community, establish a safe space
Write community covenant
Establish idea of prototyping
Introduce toolkit and safety guidelines
Establish storage and cleanup routines

Project details
Students will introduce themselves, play a drawing game, make a community contract together, and share stories about their experience of making or fixing things.

Project Flow

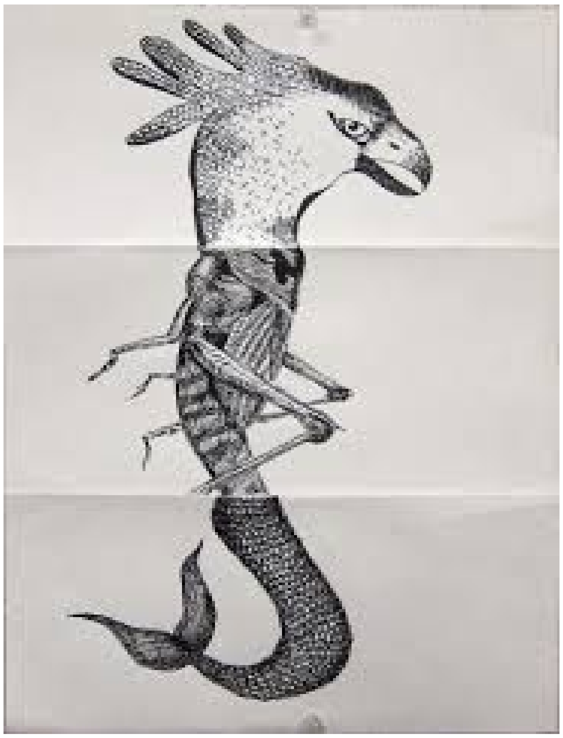
Session 4: Orientation to Invention x Nature

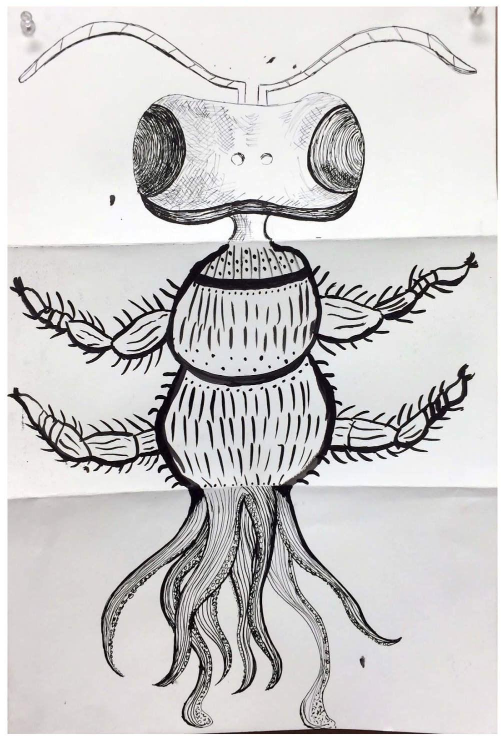
Classroom Setup
Chairs, open space to gather in a large circle
Markers and small paper for exquisite corpse game
Markers and one large paper for community contract

Welcome and thank you for choosing to be here!

Start with names or a name game.

Opening Ritual: Exquisite Corpse





Explain that you are going to play a collaborative drawing game.

Ask students to fold a piece of paper in three equal parts. **Demonstrate**.
Ask students to draw a head on the top part of the paper. Fold it so that you can no longer see the drawing, and pass to the left.
Ask students to draw a body/torso in the next part of the paper. Fold it so that you can no longer see the drawing and pass to the left.
Ask students to draw legs/feet in the next part of the paper. Fold it and pass to the left.

Ask the students to unfold the piece of paper, observe the character, name it or think about who it is. Share the results.

Save these drawings so that images of them can be uploaded to Mouse Create

Reflect : While doing the exercise, what values did you observe in the space? Reflect on the importance of collaboration and shared creativity.

Ask: What is a community?

- An *ecosystem* in which everyone supports each others growth.
- A structured environment in which every voice is heard.

Make a community contract together. What are our values? How do we transmit those values in an explicit way?

Write it down on a big piece of paper.

Example Community Contract

- One mic: show respect by listening while others are speaking.
- Everyone comes from somewhere. Appreciate diversity and respect difference.
- Honesty is the best policy.
- Support and share ideas.
- Make safe choices.
- Give and receive help.
- If you don't know, say so.
- Take chances, make mistakes.
- Leave it better than you found it.
- Be here now.

If you reinforce these expectations consistently, they will help to support and strengthen your community.

Share stories of making and fixing.

- Have you ever followed a youtube video instructional to learn how to do something for yourself (dance moves, ikea, hairstyles)?
- What was the first time you learned how to do something on your own?
- What tools “count?” Everyone has used a tool. What are some examples? What’s your favorite tool?

Explain: What will we do this summer?

- We will collaborate to design and build things.
- We will learn to use a variety of real tools and materials.

- We will make interactive prototypes that help us share our ideas with others.

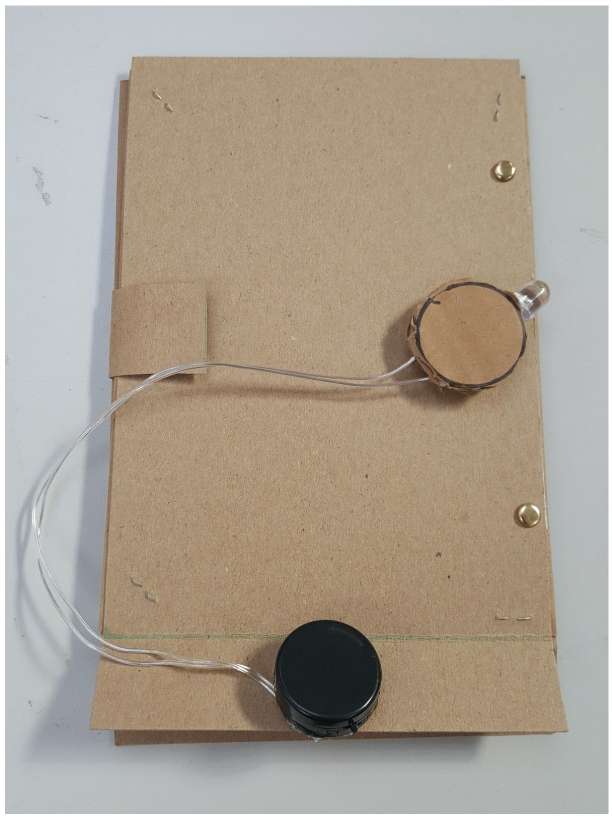
The focus of this program is to create a **laboratory environment** in which you will brainstorm, collaborate and build your own **prototypes** using real-world skills, tools, and materials. A **prototype** is a first attempt at building something or realizing an idea. **Prototypes are like first-drafts**, but they should be functional, durable, and interesting to look at. They are a way to share ideas with other people!

The structure of the program is as follows.

1. **The theme of our program is Evolved Creatures.**
2. **Fundamentals** include the skills and tools that will help you throughout the entire summer. Specifically, we will
   a. Make your own **Prototype Journal** using cardboard, paper, UV LEDs and basic circuitry.
   b. Connect code to circuitry while making **Animatronic** prototypes that imitate animal movement move using motors.
3. **Domains** are the application of skills from Fundamentals to a specific challenge and theme and include additional skills and materials. The domains are:
   i. Plants: movement and sensors
   ii. Cephalopods: visual communication and light
4. **Synthesis Project** is the final project that you will build. You will combine all of the knowledge you've gained during Fundamentals and Domains to build a final prototype.

We will work collaboratively throughout the program and share our projects with each other along the way.

Sessions 5-6: Prototyping Journals



Project Overview

Outcomes
Basic safety and fabrication tools training (staplers, hole punch, scissors, hot glue)
Tracing and cutting precise shapes, taking measurements and using a straightedge
Introduction to a series electronic circuit and basic circuitry tools (wire strippers, crimps)
Drawing models, schematics, and illustrations

Project details
Each student will make one journal, which is theirs to keep. Any personal thoughts or doodles can be drawn using invisible ink and kept private. They should customize the cover with their

names so that journals are differentiated. Students will display the journals at the end of the program during the showcase.

Prototype Journals include the following elements:

- **Cover** made from chipboard
- **Accordion** made from folded strips of paper
- **Tiny notebook** bound with brass tacks
- **Velcro binding** to hold it together
- **UV Lamp** for secret messages

Tools and Materials:

- Journal Fabrication
    - Chipboard
    - Larger white paper
    - Permanent markers and paint markers
    - Brass tacks
    - 4.25 x 7” paper
    - Binder clips
    - Scissors
    - Elmers glue sticks
    - Stapler
    - Cardboard cutters
    - Rulers
    - Hole punch
    - Masking tape
    - Hot glue station
    - Velcro dots
    - Laser-cut cover template
    - Laser-cut template for tiny notebook
    - Alphabet stencils
    - Spring clamps

- Secret Message LED
    - 10mm UV LEDs
    - 3v batteries (2 per project)
    - 2x3v battery holder
    - Crimp tubes

- Crimper
- Electrical tape
- Wire strippers
- Cardboard
- UV markers

Project Flow

Session 5: Intro to Prototyping Journals

Classroom setup
Example Prototype Journal, UV marker, shop safety slideshow.

Chipboard, large paper, permanent markers, scissors, staplers, tape, Elmers glue sticks, rulers, cover templates. Mini paper, hole punch, brass tacks, acetate, template for tiny cover, binder clips.

Go over complete instructions and demonstrations for making the journal first, then let students make journals at their own pace using your prototype journal as a reference.

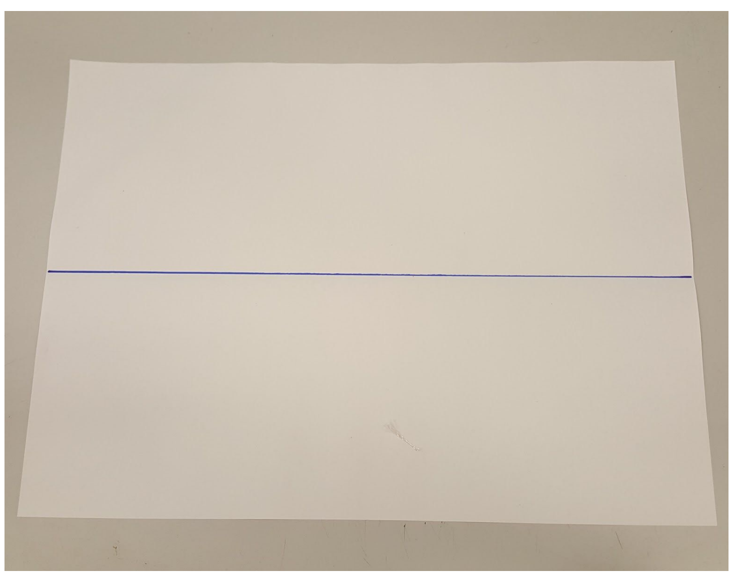
1. **Introduce** the project.
    a. The focus of this program is to create a **laboratory environment** in which you will brainstorm, collaborate and build your own **prototypes** using real-world skills, tools, and materials. A **prototype** is a first attempt at building something or realizing an idea. **Prototypes are like first-drafts**, but they should be functional, durable, and interesting to look at. They are a way to share ideas with other people!
2. **Journals**
    a. **Show** example journal or image.
    b. **Explain**: Why are we making this? What will we use our journals for?
        i. We'll be making prototyping journals that you can use throughout the program and keep when you leave at the end of the summer.
        ii. We're building an ***accordion*** style notebook that will make it easy to display our work at the end of the program. There's space in the journals for notes in the mini notebook, and for schematics and drawings in the larger accordion notebook.

iii. Even if you don't consider yourself a good artist, it can be important to make drawings in order to communicate your project ideas to other people or to instructors.
iv. There's also a way for you to keep personal thoughts and doodles that only you can see! Our journals will incorporate UV lights so that you can include doodles and thoughts privately using invisible ink.
v. The journal-making activity is your first opportunity to learn some simple fabrication skills, basic circuitry and safety guidelines while making something useful.

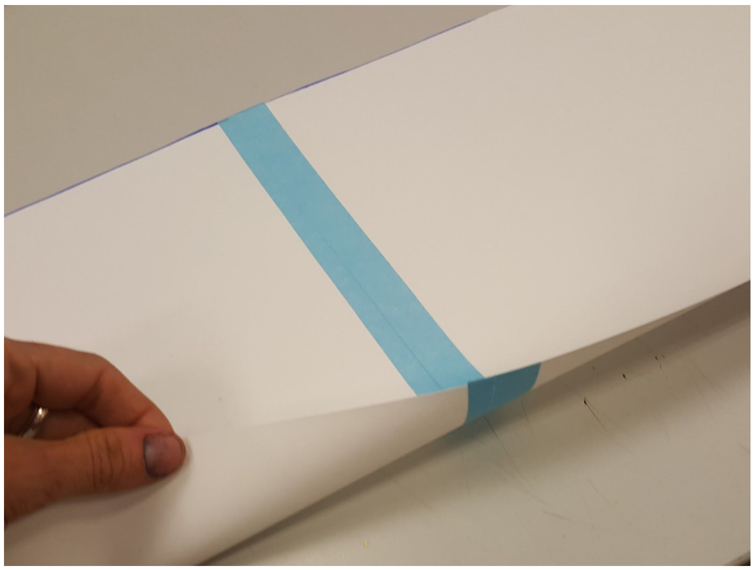
3. **Review** shop safety guidelines if necessary.
    a. This is a space where we make things together. It's important to always observe safety guidelines and use tools properly.
4. **Demonstrate** making the **accordion book**.
    a. Demonstrate how to hold and **use scissors to cut chipboard** after tracing the template of cover. Each student should cut *two* chipboard cover pieces using the template. They should both be 7" x 10.5." *Try to align the template with one of the corners of your cardboard to reduce waste and necessary cutting!*
    b. Using a ruler, mark a line straight across the bottom of each cover piece, about 1" up from the bottom.

c. Fold, using the ruler to help you fold a straight line.

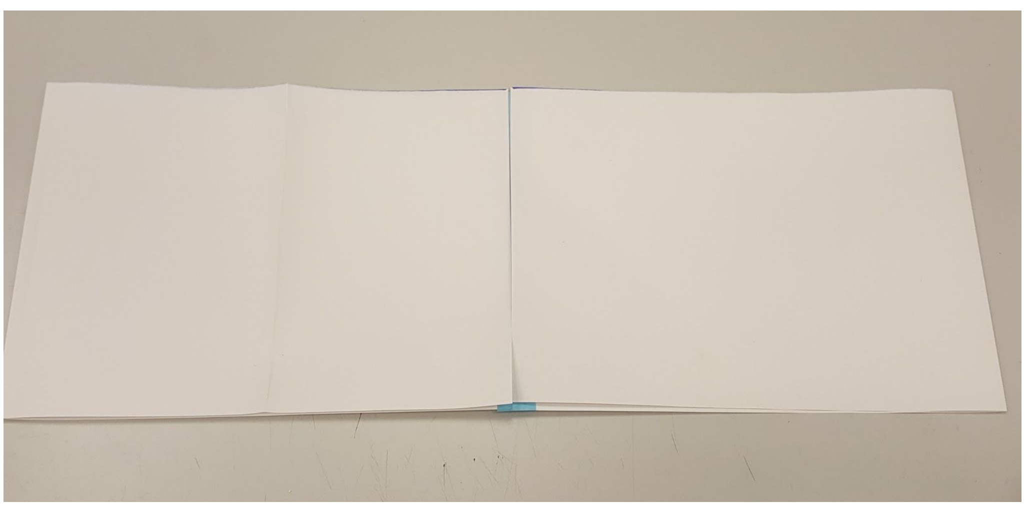
d. Take a piece of large paper and fold it in half ***lengthwise***. Unfold and emphase the fold line with a marker and ruler.



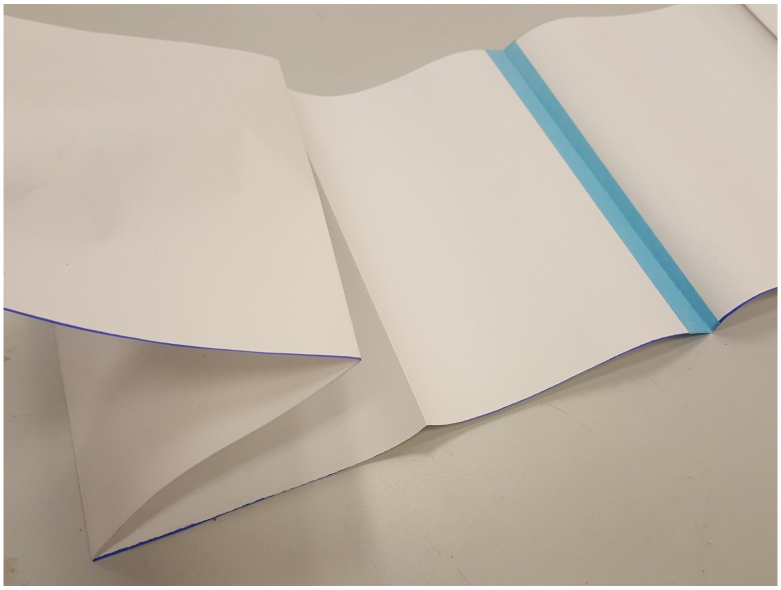
e. Cut along the line so you have two long strips of paper. Tape the two pieces of paper together, using masking tape on both sides. *It might be helpful to complete this step with a partner!*



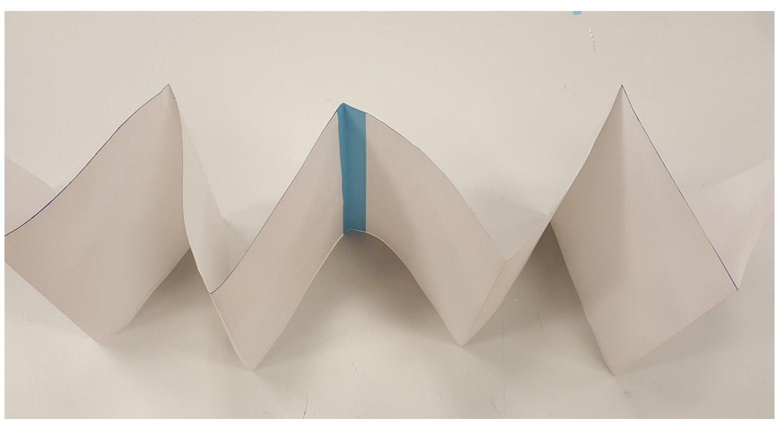
f. Fold the two paper "wings" in so they meet **in** the middle. Pretend the centerline is a mirror.



g. Fold the paper “wings” back **out**.

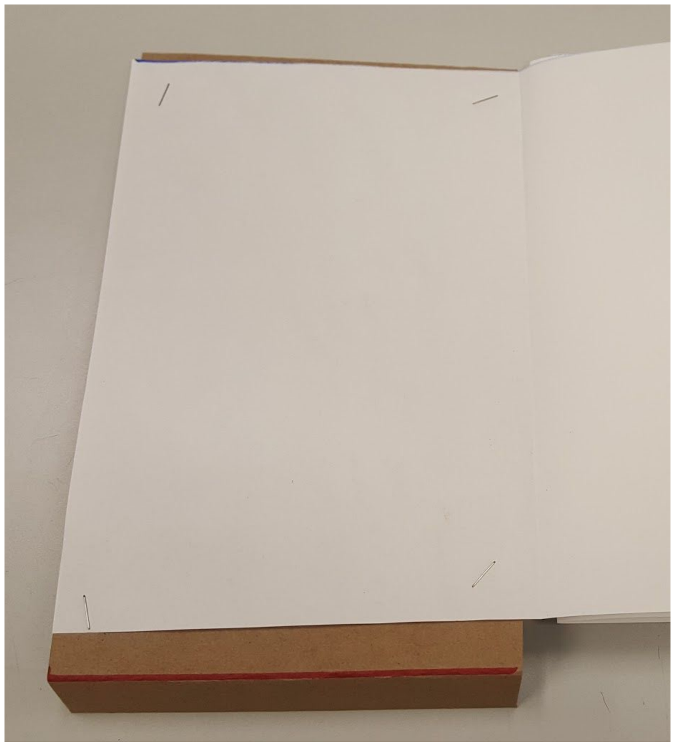


h. Flip it over, and fold **in**. Then, fold **out** the middle section to complete the accordion.



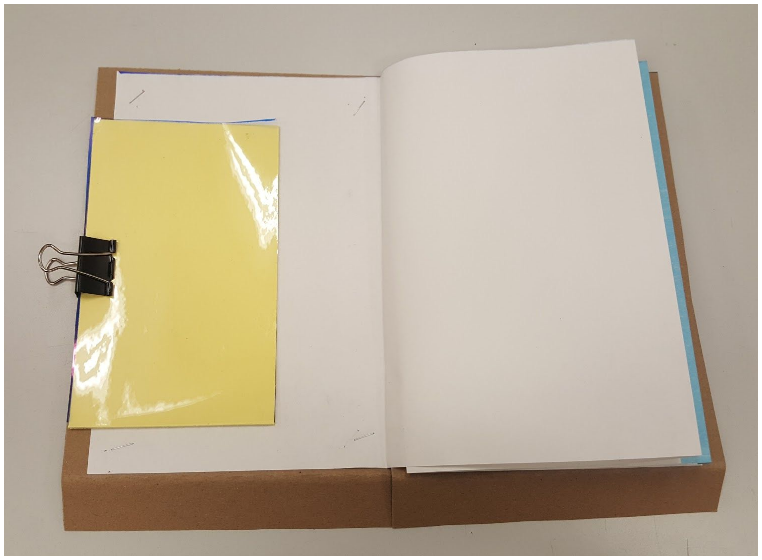
i. Align in this order: **cover**, **paper accordion**, **cover**. Glue the first page of each end of the accordion onto the covers using Elmers glue sticks, making sure the pages are glued *above* the folded line you made.

j. Reinforce the glue by stapling each corner. Make sure <u>not</u> to staple more than one page of the accordion to the cover! Try to position your staples so the sharp points are on the inside of your journal.

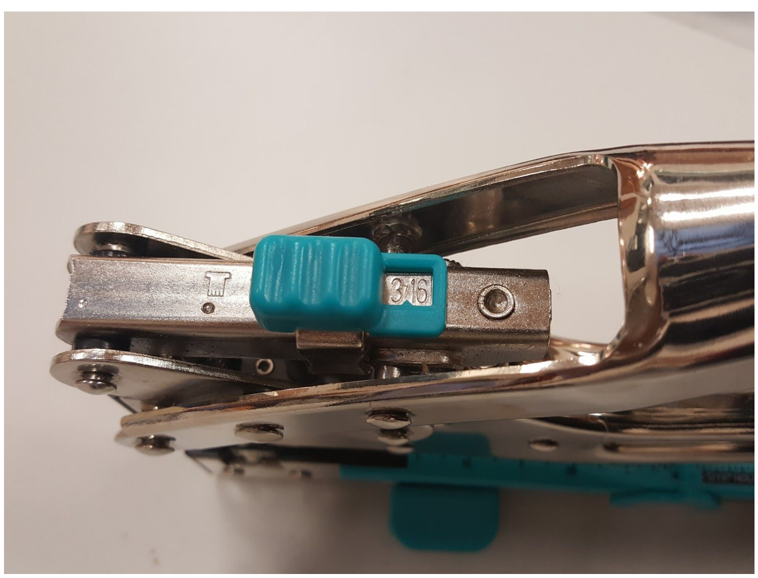


5. **Demonstrate** the following journal-making steps for making and binding the **tiny notebook.**
   a. Collect about 15 sheets of tiny paper. Trace and cut a cover for the tiny notebook out of acetate. Again, try to reduce waste by cutting close to the edge!
   b. ***Align*** all the pages and the cover by tapping them gently on the table top.

c. Hold the mini notebook in place on the inside of the front cover using a binder clip. *It might be helpful to complete this step with a partner to help hold the paper while you clip it!*



d. Set the hole punch to the 3/16” hole setting using the turquoise adjuster on the top. You can use the measuring device on the base of the hole punch (set it to about ¾”) to ensure that your holes are aligned along the edge of the notebook. It may also be helpful to mark where the holes should go beforehand.



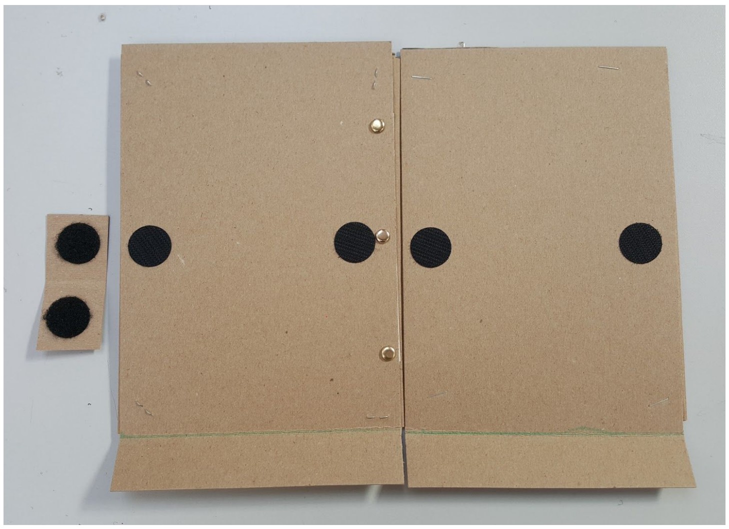
e. Use the hole punch to make two holes down the side of the tiny notebook. *Do not remove the mini clips after cutting holes!* They'll help keep everything aligned until the brass tacks are in.
f. Insert brass tacks into the holes to bind the tiny notebook to the rest of the journal, with the legs of the brass tacks on the inside of the journal.

g. Remove and return the binder clip.

6. **Demonstrate** the following steps to add **velcro binding** to your journal.
    a. With the person next to you, **determine** who is going to be a velcro ***hook*** and who is going to be a ***loop***. There should be an even number of hook and loop people at each table! If you're a hook, all of the velcro pieces on your journal will be hooks, and you'll put loops on everything that *connects* to your journal (the binding, the LED).
    b. Add a piece of *your* kind of velcro in the middle of each side of the journal - if you're a loop person, you should use loops for this! Each student will need four pieces of velcro to do this.
    c. Then, cut one roughly 1" x 3" tab of chipboard out of your scrap, and put a piece of the *opposite* type of velcro on each end.
    d. **Demonstrate** hot glue gun use and safety precautions.

i. Hot glue gun tips and fresh hot glue can burn you. Never touch the tip or any un-cooled hot glue. Hot glue turns white when it's dry.
ii. Only use hot glue guns in designated areas. Never play with hot glue.
iii. Glue slowly. Rushing can lead to injuries.

e. Reinforce all velcro circles using a ring of hot glue around the outside.



f. This velcro tab can be switched back and forth from one side to the other in order to create two back-to-back books! It can be removed altogether to unfold the accordion for display, and stored by sticking it to the front of the journal.

7. While waiting to use the necessary tools, students can add names to covers and personalize journals using UV or permanent markers and stencils.
8. **Clean up** and save any useful cardboard scraps for later.

Session 6: Secret Message LED

Classroom setup
UV LEDs, 3v battery clips, coin cell batteries, wire strippes, crimps and crimpers, cardboard, cardboard cutters, spring clamps, electrical tape, scissors, velcro, markers, electrical tape.

One table for hot glue and hot glue guns.

1. **Introduce** electrical circuits by showing students the physical objects.
    a. **Explain:** How does a battery work?
        i. *Electricity* is a form of energy we get from the movement of electrons.
        ii. A battery contains two materials; one has too many electrons and the other has too few.
        iii. This makes one side *positively charged* (+) and the other *negatively charged* (-).
        iv. It's a force of nature for the electrons to seek equilibrium, so if we connect a path from + to - the electrons will flow through it and make electricity.
        v. For our journals, we will be using two 3 volt batteries.
    b. **How does electrical wire work?**
        i. Inside is *conductive* metal, outside is *insulator* rubber.
        ii. Conductors let electricity flow, insulators resist it.
        iii. The color of the wire doesn't matter; it's just to help you stay organized.
        iv. Sometimes wire is *stranded* and sometimes it is *solid-core*. The wire inside of our journal battery clips is *stranded*, which means that it’s made up of a bunch of tiny strands that can separate from each other.
    c. **What is a circuit?**
        i. The pathway from plus to minus is called a *circuit*. Electrons flow through the pathway in a *circle*.
        ii. The ***components*** in a circuit are there to perform a specific action (light up, spin, etc.), and absorb a specific amount of voltage in order to do this.

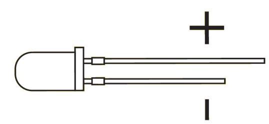
iii. A ***short circuit*** happens when the pathway of the circuit bypasses the components it is meant to go through. Because it skips the components, the circuit not only won't work but could get very hot. This usually happens when two conductive surfaces touch each other that aren't supposed to.

iv. Short circuits can be avoided by ***insulating*** exposed wires and crimps with electrical tape or hot glue, and by trimming off stray wires that could create unwanted pathways for electricity to flow.

d. How does a LED work?

i. The LED uses a small amount of electricity and emits it as light.

ii. These UV LEDs are extra large and can take six volts of electricity, the combined voltage from our two 3 volt coin cell batteries.



iii. Most LEDs will take less voltage than this. If you give an LED too much voltage, it burns out. When an LED burns out, the entire circuit will stop working.

iv. LEDs are *polarized*, and only work on one direction. The longer leg is *plus* and the shorter leg is *minus*, or ground. So in a circuit, the longer leg should always face the + side of the battery.

2. **Demonstrate** *prototyping* the UV LED circuit. Each student will need an LED, a 3v battery clip, and two 3 volt batteries. Tables will also need wire strippers and permanent markers.

i. ***Wire strippers*** are for stripping the insulation off of wires to expose conductive wire.

ii. Demonstrate how to use wire strippers to strip the ends of the wires on the battery clip to about ½" - or, the width of a finger. The size of the hole needed to strip wires will vary with different types of wire - the best approach is to try different hole sizes until you find the right one.

iii. This is ***stranded*** wire, which means there are a bunch of tiny wires inside. It's a good idea to twist the ends of the tiny wires together using your fingers.

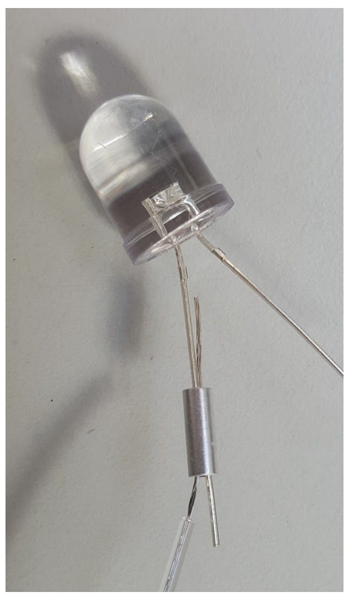
iv. Put two 3v batteries into the clip with the plus side facing up. Screw the top back on and turn the clip *ON* using the tiny switch on the side.

v. Separate the legs of the LED. Touch the ends of the wire to the legs of the LED to see which is positive and which is negative. You may need to reverse which wire touches which leg. ***Mark*** *the end of the wire with permanent marker once you know which is positive.*

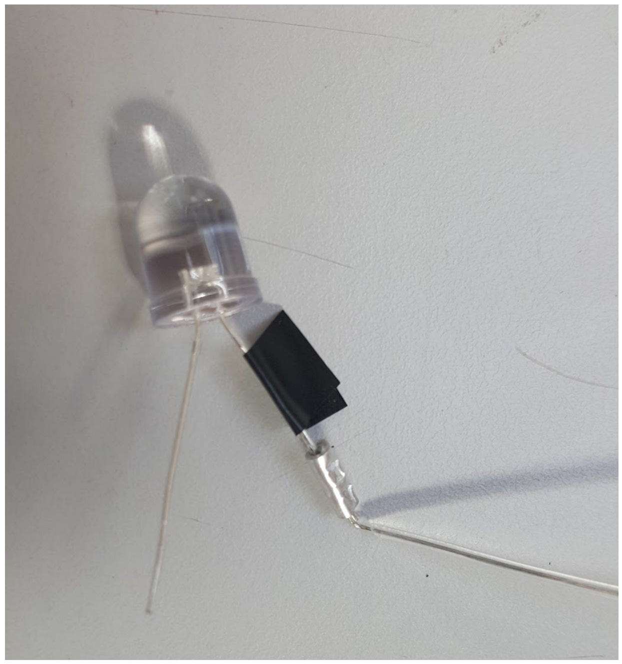
vi. Make sure to keep the legs of the LED from touching, otherwise you'll get a ***short circuit***!

vii. *Students should all prototype the circuit so that they know which wire on the battery clip is positive and have marked it. Once they're done, they can turn OFF the battery switch.*

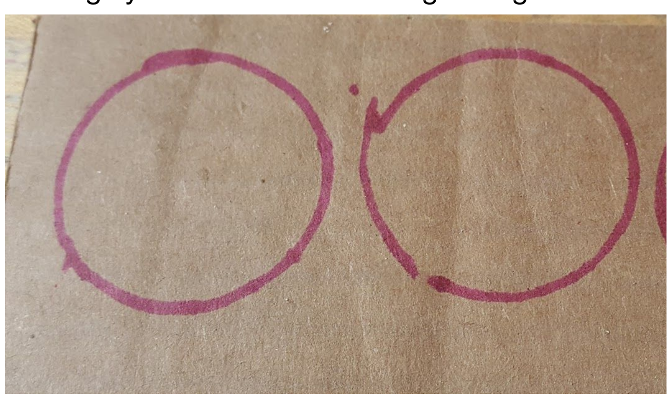
3. **Demonstrate** crimping the circuit together to make it semi-permanent.
   a. ***Crimpers*** are for squeezing wires together inside tiny conductive crimp tubes to make more permanent connections. Make sure to squeeze all the way down when crimping otherwise it will lock.
   b. Match the positive leg of the LED with the positive wire on the battery pack. Put both wires through a crimp tube so that they meet in the middle and come out opposite sides.



   c. You can use a little bit of electrical tape to help hold them together while you crimp. ***Electrical tape*** is used to insulate wires and can be cut with normal scissors. Alternately, you can bend the wires backwards once inside the tube to help hold them in place.
   d. Crimp them together using the crimp tool. Squeeze hard! Do this for both legs of the LED.



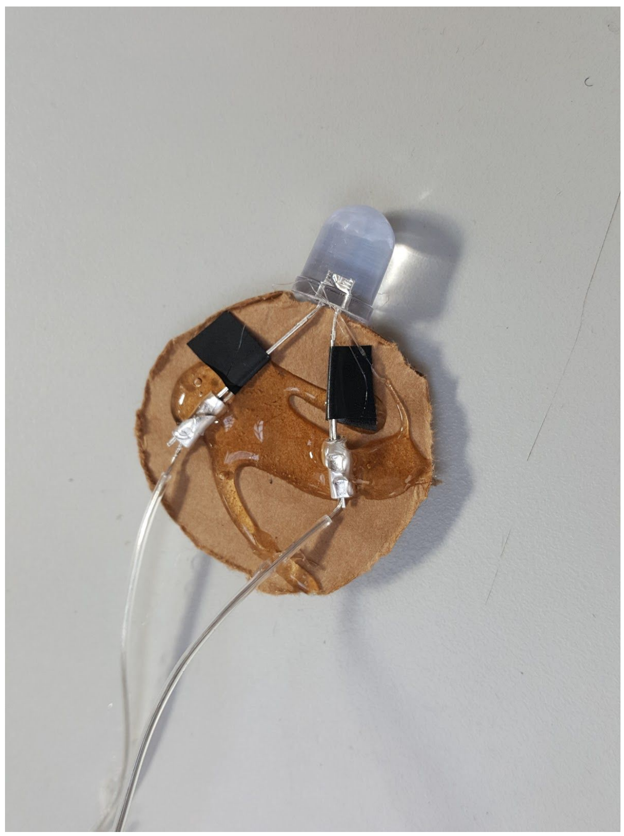
4. **Demonstrate** making a LED sandwich to mount on the journal.
    a. Demonstrate how to trace and cut two cardboard circles (or any other shape!) out of cardboard using an electrical tape roll as a template. Your two circles should be roughly 1.5” in diameter or big enough to cover the legs of the LED.



    b. **Demonstrate** clamps and cardboard cutter safety precautions. Clamp your cardboard down to the table and use cardboard cutters and/or scissors to cut our your two circles.
        i. Hold the cardboard cutters like a butter knife.
        ii. Cut slowly. Rushing can lead to injuries.

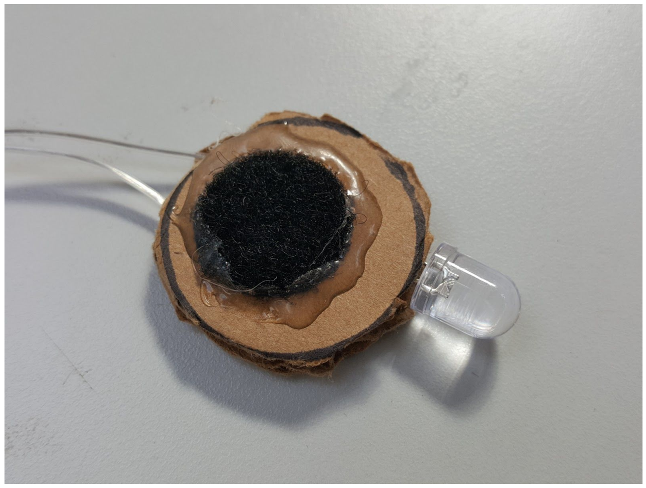
iii. Always cut away from your hand and never place your hand anywhere near the pathway of the blade.
iv. You can always use scissors to finish your cut.

c. Sandwich the LED in the middle of the two cardboard circles using hot glue, making sure the legs of the LED are not touching. You can insulate the LED legs with electrical tape first to be extra sure. Hot glue the two pieces of cardboard together to make an LED sandwich.

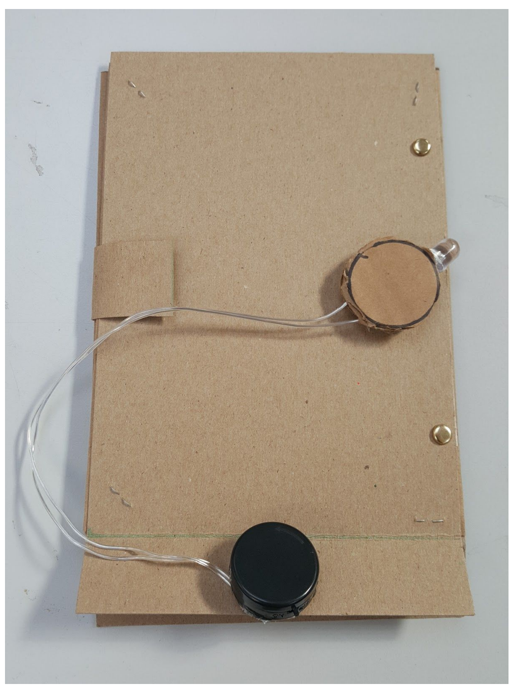


d. Put a piece of the opposite type of velcro on one side of the LED sandwich. This way you can stick your LED sandwich to the front of your journal.

e. Reinforce the velcro by drawing a ring of hot glue around the outside of it.



f. Hot glue the ***base*** of the battery pack into place on the middle of one foot of the journal. Your journal should look like this:



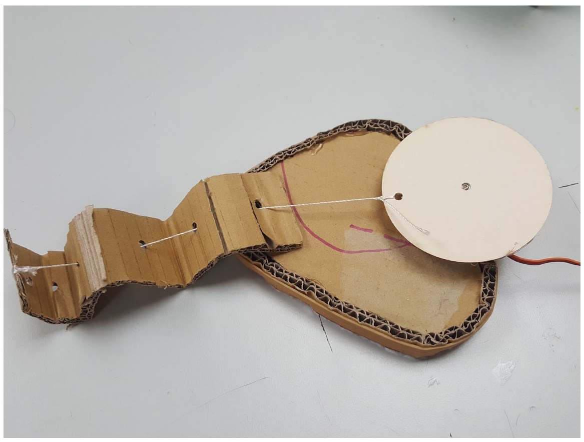
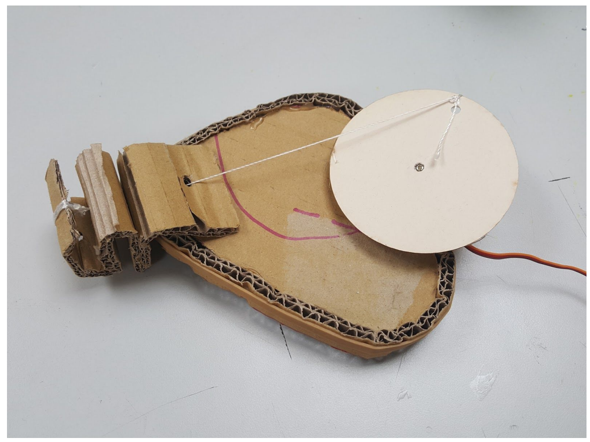
g. Test it to make sure the LED turns on! Then turn your battery clip off again.

5. **Clean up!**
6. **Introduce** drawings and schematics. Throughout the summer, we will be using our journals to make diagrams and collaboratively plan our projects.
1. **Explain**: Using your journals

a. You can use invisible ink anytime to doodle or store personal writing that you don't want other people to see. The UV light will allow you to make this text visible, when you want to.
b. Journals can be used as a place to paste printed images from the internet using glue sticks. The accordion part of the journal is what visitors at the showcase will see - include printed inspiration images or sketches here.
c. You can use your journals after a project is finished to record your own or other people's ideas that you think worked well. Sharing ideas and building off of other people's discoveries is an important part of being in a prototyping community.
d. You do not need to be a "good artist" to make an interesting and useful drawing or diagram!

7. **Explain**: Informational drawings
    a. A ***drawing*** is an illustration of something - something from inside your head or something from life. A drawing can tell people someone something funny or interesting about your project. Your exquisite corpse creature is an example of a drawing.
    b. A ***diagram*** is an informational drawing, and is really important for communicating your ideas when you're working with other people, making a detailed plan, or keeping track of important information relating to building your prototype.
    c. Guidance and prompts for making useful diagrams.
        i. Draw the object.
        ii. How big is it? What are the ***dimensions*** or exact measurements?
        iii. Show how the circuit connects. Where is the motor, LED, or sensor going to go? Where are the "brains", or the Arduino?
        iv. What are you making? Title your schematic or name your project.
        v. What are the steps you need to take to make it? List them in order so you know how to begin.

Sessions 7-12: Animatronics

Project Overview

Objectives
Connecting to an Arduino using jumper wires and following circuit diagrams
Using journals to sketch and record ideas
Cardboard building techniques, building moving parts
Extending the motion of servo motors to create interesting movement

Project details
Students will work in pairs or groups and use servo motors and Arduinos to make animatronic creatures that move. They'll first learn how to connect and power an Arduino and motor, and will then build simple puppets that move using string and cardboard. Finally, they'll automate their puppets using the servo motors, and give them a scientific name.

It's recommended that students work in pairs.

Tools and Materials
- Electronics and Circuitry
    - Arduinos

        - Mini screwdriver
        - Servo motors
        - Jumpers
        - Solid core wire
        - Wire strippers
        - AA batteries
        - 4AA battery clips
        - Screw terminals
        - Breadboard
    - Fabrication
        - Cardboard
        - Brain box template
        - Zip ties
        - Rubber bands
        - Brass tacks
        - Tape
        - String
        - Skewers
        - Popsicle sticks
        - Craft circles
        - Cardboard cutters
        - Cardboard perforators
        - Cardboard tubes
        - Hole punch
        - Squeeze clamps
        - Markers
        - Scissors
        - Staplers
        - Hot glue sticks and gun
        - Journals and pencils

Project Flow

Session 7: Intro to Animatronics and Arduino Circuits

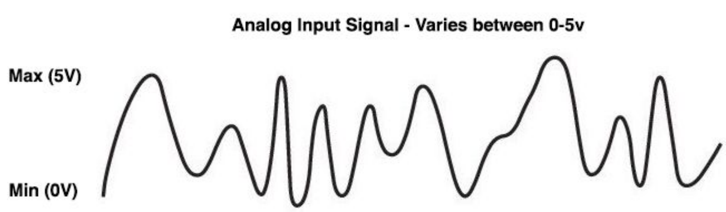
Classroom setup

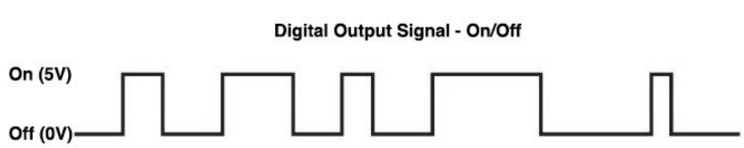
Mouse Create, screw terminal, battery holder, AA batteries, breadboards, Arduinos, jumper wires, servo motors, mini screwdrivers, circuit diagrams. USB cables, laptops.

1. **Explain**: What are we doing? Use Mouse Create to introduce the project.
    a. The theme of our overall program is Evolved Creatures. Throughout the summer, we will be learning the skills needed to prototype objects inspired by the way that creatures in the natural world move and interact.
    b. During the Fundamentals part of the program, you will learn the basic, *fundamental* skills needed to build prototypes that imitate the way a creature moves.
    c. This fundamental is inspired by some of the oldest evidence of multicellular animals from the Metazoan era, which were simple wormlike organisms that could squirm and move. Scientists theorize that it wasn't until hundreds of millions of years later that organisms developed skeletons and the ability to move from one place to another on legs.
    d. During this Fundamental, you will be working in pairs and using ***servo motors*** in order to make animatronic creatures that move. ***Animatronics*** is using movement to bring lifelike characteristics to non-living objects. We'll start by exploring the Arduino and motor alone, then we'll learn how to use simple building techniques to extend the movement of our motors to do more interesting things.
2. **Explain:** What's an ***Arduino***?
    a. Before we make animatronic creatures, we will build the central nervous system of our creature using an Arduino. The ***central nervous system*** is where information is stored and activity is coordinated.
    b. An Arduino is a small computer that controls the behavior of a circuit. The Arduino controls the behavior of electrical circuits using code. Code is a set of instructions written in language a computer can understand. For example, "turn this motor on and off every second". For this fundamental, the code has been pre-written to make the servo motors move back and forth. Code is edited on a computer and sent to an Arduino using a USB cable.
    c. Arduino also has pins for jumper wires to go into it. ***Jumper wires*** connect the servo motor to the circuit. Jumper wires come in different colors and lengths, but all work the same way. *It doesn't matter what color you use.*

3. **Explore** the Arduino. Arduino also has input pins for jumper wires to go into just like the breadboard does.

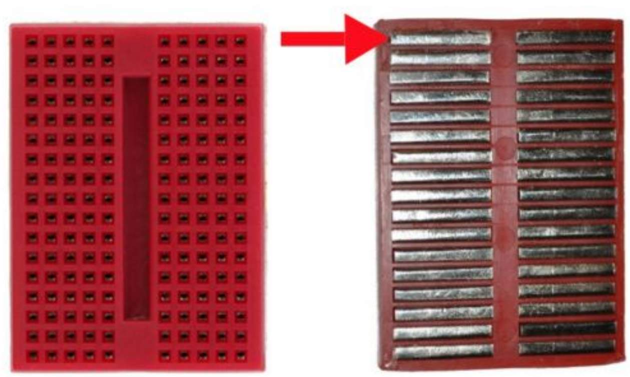
   a. Arduinos take inputs and give outputs. ***Inputs*** are incoming information that the computer uses, and ***outputs*** are what the computer uses the information to do.
   b. ***Digital pins*** are typically used as ***outputs***. They are either on or off. When they're on, they send a 5V signal like the + side of the battery. When they're off, they don't send any voltage. *Our servo motor will be controlled using digital pins.*
   c. ***Analog pins*** are ***inputs***. They accept *varying* electrical signals between 0V and 5V and translate the voltage into a number that we can use in our code. 0V = 0 and 5V = 1023. *We won't be using the analog pins for the fundamental.*





d. The ***5V pin*** outputs a steady 5V signal like the + side of the battery, the difference between this pin and a digital pin is that it is always on.
e. ***GND*** pins are ground pins and are similar to the negative (**-**) side of a battery. We will always need to end our Arduino circuits at a GND pin.

2. **Explain:** What's a breadboard and jumpers?
    a. ***Breadboards*** are a tool to connect electrical components for testing out circuits. Arduino projects usually connect to circuits on breadboards.
    b. Breadboards have a grid of ***pins*** that give us conductive pathways along which to connect our different components. We build circuits by connecting the pins on the breadboard using ***jumper wires*** and components like servo motors or LEDs.
    c. Each row of the breadboard is a set of 5 horizontal connections, kind of like a series of power strips - the lengthwise indent along the board divides the two sides. For example, the first five pins in row one are connected and the second five pins in row one are connected to create electrical pathways.



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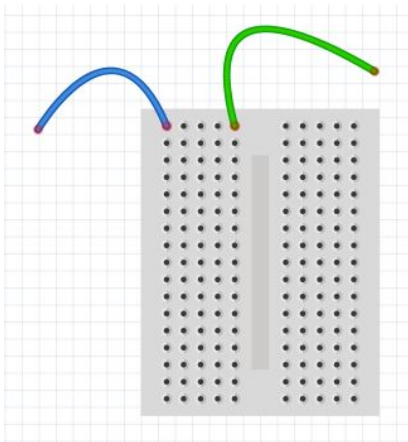
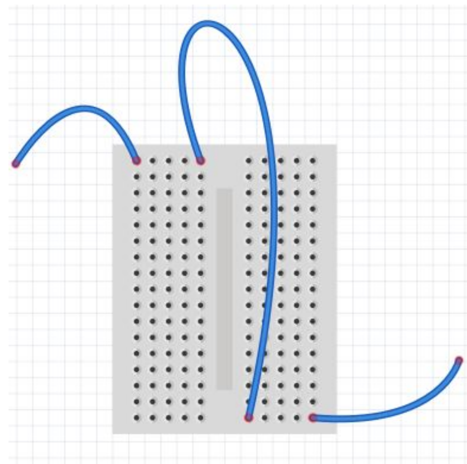
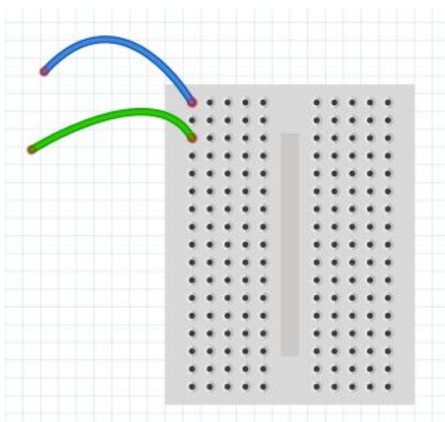
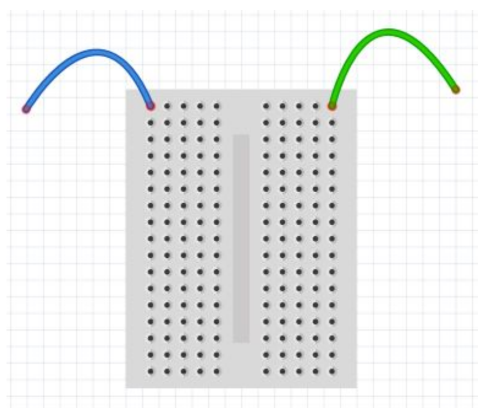



These are **not** connected:

4. **Explain: Servo motors** are small geared motors that can be programed to spin in a specific speed or direction.
    a. The servo motors that we'll use for this fundamental move back and forth 180°, or half of a circle, rather than moving all the way around in a complete circle like the wheel of a car.
    b. There are two parts to a servo motor:
        The ***body*** of the motor, which drives the movement of the shaft and should be glued down to a base.
        The ***shaft*** of the motor, which is the moving part.

c. Servo motors are not strong and can only move very light materials. Keep in mind that your projects should be as small as possible while still be interesting and functional.

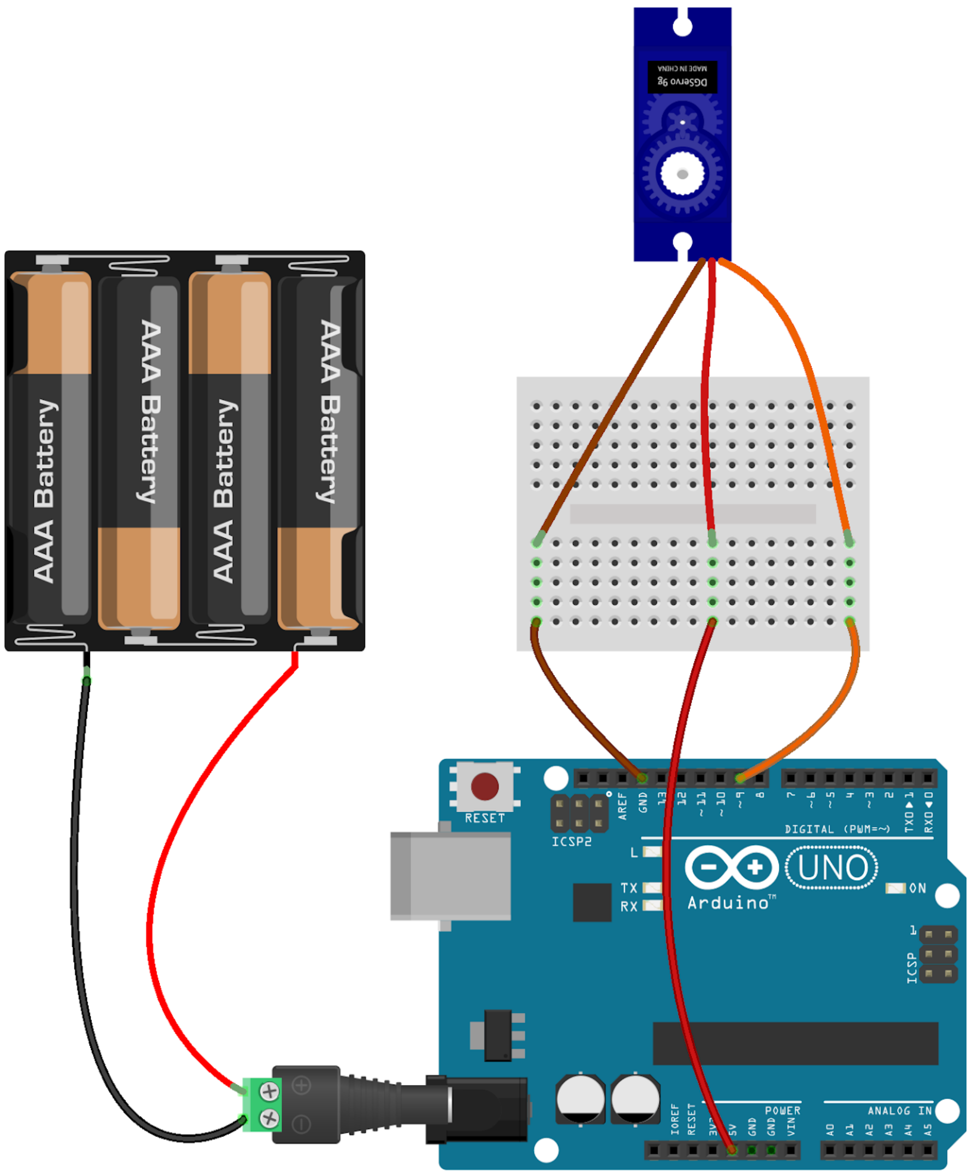
d. Be extremely careful: these motors can break if you over extend them or turn them too much! There are gears inside that can break. Don't try to move it further than it wants to. Never force it. Don't turn it too fast. If you hear a funny sound, stop turning it.

e. You can play with the motor to get a sense of how it moves, but treat it like a tool and be careful with it.

f. Servo motors always have three wires - power and ground (just like an LED), and signal. ***Signal,*** or *data,* is how the computer tells the motor what to do.

5. **Upload code to Arduino.** Each pair of students can build one circuit.
    a. Plug your arduino into a laptop using a USB cable.
    b. Open the Arduino program on a laptop and create a new sketch. Select all and delete so the sketch is empty.
    c. Copy the code in Mouse Create and paste it into the blank sketch.
    d. Hit the check mark in the upper left-hand corner to verify the code was written correctly.
    e. Under the *Tools* bar, go to *Port* and select the option that has *USB* in it. This will allow us to upload code to the Arduino.
    f. Once you're connected through the port, hit the arrow button in the upper left-hand corner to send the code to the Arduino.
    g. A message should appear at the bottom of the sketch once the code has successfully been sent.
    h. Unplug the Arduino from the laptop and put the USB cable away.

6. **Demonstrate building circuit step-by-step**: in pairs, follow the diagram to make connections between the Arduino and servo motor using jumper wires.



   a. Connect a ***screw terminal*** to a battery pack using a mini screwdriver. Plug it into the Arduino. The lights on the Arduino should turn on when you put batteries in the battery pack.
   b. Connect pin 9, GND, and 5v on the Arduino to different rows of the breadboard.

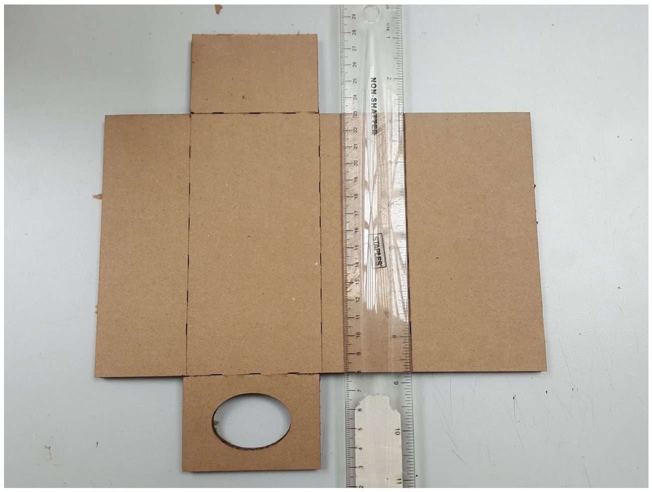
    c. Connect the servo ***motor shaft*** to the motor using the mini screws and screwdriver.
    d. Connect pin 9 on the Arduino to the yellow wire of the servo, via the breadboard. The yellow wire is for signal and pin 9 is for digital motor control data.
    e. Connect 5V on the Arduino to the red wire of the servo via the breadboard. Connect GND to brown wire in the same way. The red wire is for power, the brown wire is for ground.
7. **Demonstrate**: You can extend the wires of the servo motor when necessary by stripping and using solid core wire instead of jumpers. You can use zip ties or binder clips to hold loose wires together.
8. **Give students time to build their Arduino circuits in pairs.** Test to make sure they work.
9. Clean up.

Session 8: Brain in a Box

Classroom setup

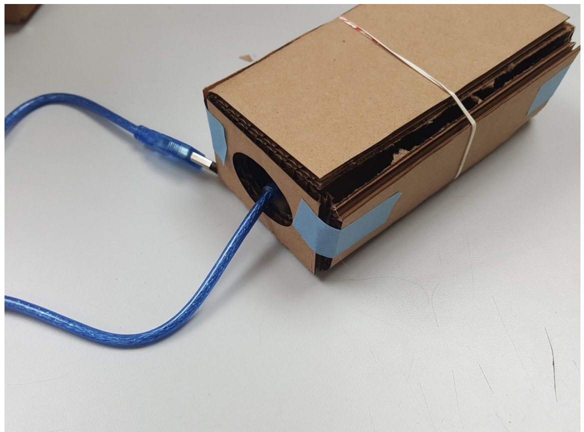
Cardboard, box template, cardboard cutters, scissors, rulers, tape, markers, rubber bands, circuit building supplies.

10. **Continue** building Arduino circuits in pairs if necessary.
11. **Demonstrate: Build cardboard Brain Box**
    a. Many of our projects this summer will involve making some kind of box to house and protect parts of our projects.
    b. A complete box needs six sides and be made up of 90° angles. Trace the template box provided. Cut it using cardboard cutters and/or scissors.
    c. ***Score*** along the interior lines of the box.
        i. ***Scoring*** cardboard refers to slightly cutting the internal support system of the cardboard without creating a complete cut, allowing it to bend more easily.
        ii. When you trace the template, mark the perforated bend line on the face of the cardboard with a marker. Align a ruler with the marks, and cut with perforator OR press the end of a cardboard cutter toward the surface of the cardboard. Gently pull it along the ruler edge.



d. Tape or glue the box together... It can be helpful to temporarily tape it together from the outside while you hot glue it on the inside.

e. Hold the Arduino and breadboard in place inside the box using tape, velcro or a tiny bit of hot glue. Make sure the power input on the Arduino is near where you cut the hole in your cardboard box, so you can access both the USB plug and battery pack plug.
f. Make a top for the box by tracing its outline onto cardboard. Use a rubber band to hold the top of the box in place.

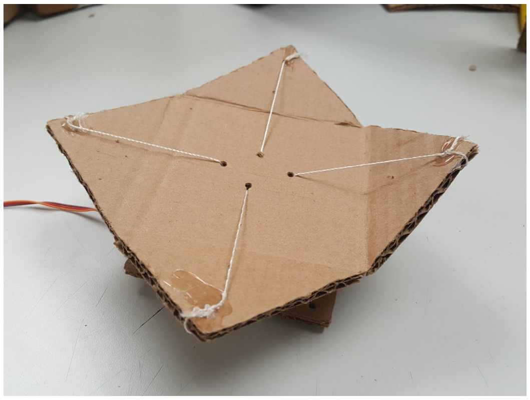
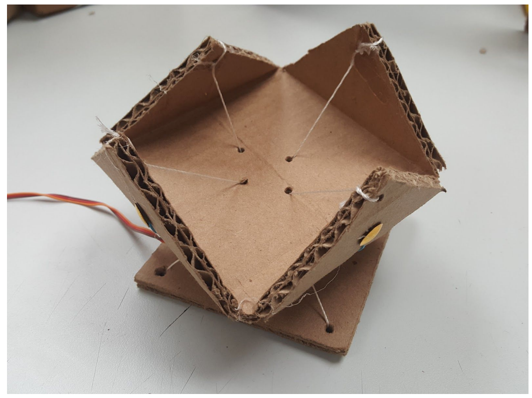


2. **Give students time to build casing for their Arduino circuits in pairs.** Make sure students put their names on the box that holds their group's circuit.
3. **Clean up.** Unplug the screw terminal from the Arduino to turn it off, and set aside. Students will not need their Arduino circuits for the following part of the fundamental.

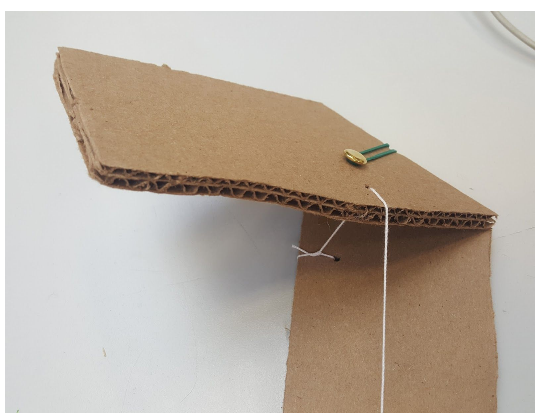
Session 9: Body-Building with Cardboard

Classroom setup
Prototypes and GIFs, cardboard, cardboard cutters, cardboard tubes, skewers, hole punch, string, brass tacks, scissors, staplers, rubber bands, markers, tape, squeeze clamps.

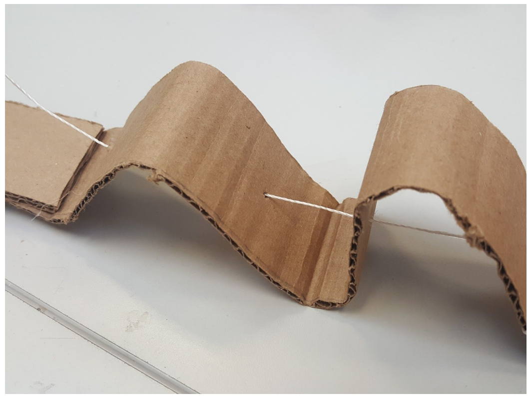
1. **Explain the main objective**: During this fundamental, we'll be using simple building techniques to ***extend*** the motion of the tiny servo motor to bring a mechanism to life. Servo motors can move back and forth in a semi-circle only (180º), but using string, levers, rubber bands, and other materials you can translate this back-and-forth movement into more complex and interesting movements.
2. For this fundamental we'll be exploring basic ***movement***.
   a. ***Movement***: changing position or gesturing - moving. This is what our first creatures will do.
   b. ***Locomotion***: the ability to move from one place to another - moving around. We aren't doing this... yet.

3. **Explain *anatomy*** of creatures.
    a. ***Limbs*** are parts of the body that will move or bend - like wings, legs, or arms on animals.
    b. ***Joints*** are the points on the limbs that open and close - like knees and elbows.
4. **Point out** the following **joint types** and anatomical parts using GIFs or physical prototypes.
    a. ***Elbow joint****s* are made by ***scoring*** cardboard to get a sharp hinge. You can score elbow joints straight across or at an angle, and on one or both sides of the limb.



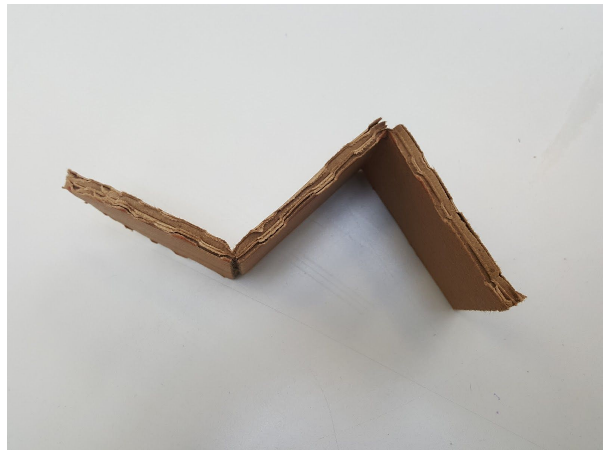
    b. ***Curved joints*** are made by bending cardboard.



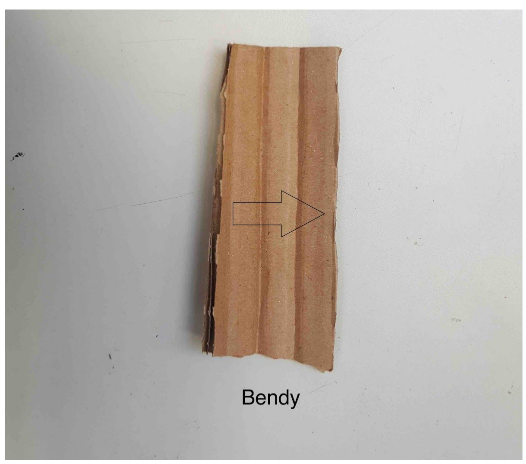
c. A ***Compound*** joint means that a limb bends in more than one place.

a. ***Muscles*** and ***tendons*** make the joints move using string and rubber bands. The string (with help from a motor) pulls a joint closed, and the rubber band snaps it open again.

4. **Explain:** what are we doing?
    a. We'll start by building simple contracting limbs *without* servo motors. These small practice prototypes will help us understand how to build moving parts.
    b. Then, we'll use what we learned to combine and expand our prototypes and *automate* them using levers and servo motors.
5. **Demonstrate** step-by-step how to make a limb. Students will make their own joints after you've demonstrated the steps.
    a. Draw the shape of your limb and cut it out using cardboard cutters. The moving limb will need to be the same piece of material as the body, or at least connected to it.
    b. Make a compound joint by bending or scoring your cardboard in one or both directions. Where are the joints? In which direction do they move? For example, does it fold like an accordion or open and close like a finger?
        i. ***Double ply*** cardboard is great for creating rigid motion like this. You can reinforce hinges with tape if you cut too far or if it's starting to rip - just make sure to tape the opposite side from the one you scored.

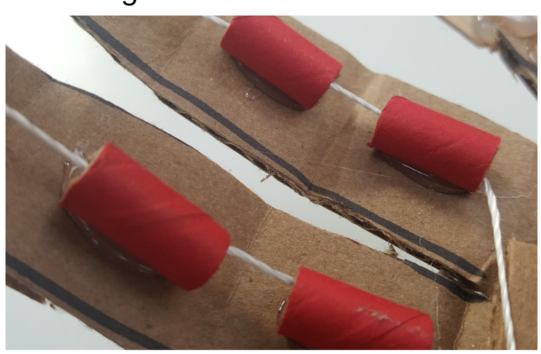


ii. Demonstrate ***bending*** for ***curved joints*** using the edge of a table. ***Single ply*** cardboard is great for non-rigid, wavy motion. Consider ***grain direction*:** cardboard bends along with the corrugation - the lines and hollow grooves should align with your bend.



c. Make a ***tendon*** by attaching rubber bands to the ***outside*** of the joint using brass tacks. The ***outside*** of the joint is the open scored side. You can adjust the strength of the tendon by moving the brass tacks closer or further from each other.

d. Poke holes through the center of each joint for string to go through. Close the joint, decide where the string needs to go through the two sides, and mark the points. Use a hole punch or pencil to punch through both sides of the cardboard.
e. Make the limb string-operated by threading strings through the holes you just made. You can tie string to the ends of limbs or use staples to hold it in place. Imagine a motor at the *other* end of the limb, where you're holding it, pulling and releasing the string to make the limb bend and contract.
f. Try pulling the string. Does the limb bend in the way you want it to? How could it be improved?
g. Cardboard tubes can be used to guide the string along the joint. Cardboard tubes can be cut using scissors and connected to limbs with hot glue.



6. **Build limbs!** Students should work in pairs or groups, and each student should make one practice limb with one or more joints.
    a. Start by making a simple limb that expands or contracts *without* a servo motor. Small practice prototypes will help us understand how to build moving parts.

    b. It's important to play first to get a sense of what's possible, rather than starting with an idea and trying to figure out how to build it.
7. Clean up.

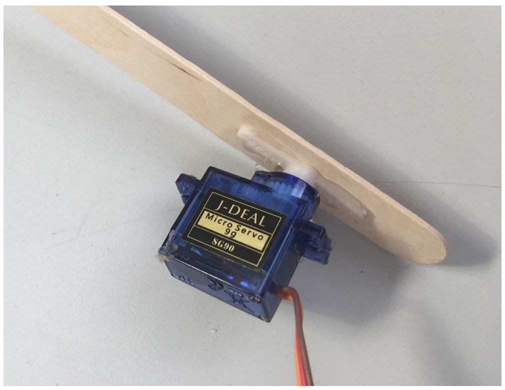
Session 10: Combine Joints, and Build

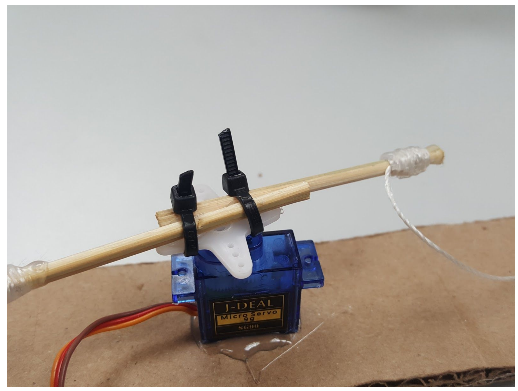
Classroom setup
The same as session 9.

1. **Continue** building practice limbs *without* motors.
2. **Combining joints: evolving creatures**
    a. **Share** puppets with each other within groups.
    b. **Explain**: In your group, you will now take what you learned from your practice prototypes and build a new creature *together* that combines your successes.
    c. This time, add more detail and make your prototype more interesting. For example,
        i. You can cut and add shapes out of cardboard to add character or connect the limbs to a bigger body.
        ii. You can use additional structure to help the creature stand up or give it "feet".
        iii. You can use rubber bands to increase friction on table surfaces.
        iv. Add levers to control multiple limbs.
8. **Introduce *leverage***
    a. **Point out** funcion of levers using a prototype or GIFs.
    b. ***Levers*** extend the motion of the tiny servo motor as it pulls the string.
    c. Where does the lever go? When it's fully extended, the end of the lever should be close to the first joint. When it's fully retracted, it should be far away from the joint, pulling it closed.
    d. What plane is the lever moving along? For example, does your string need to move up and down, or from side to side? Consider how your motor would need to attach in order for the lever to move in this direction.
    e. How long does your lever need to be? You can punch holes in popsicle sticks or tie string to skewers for longer levers, or punch holes in craft circles for small sturdy levers.
9. **Demonstrate:** how to incorporate servo motor. Bring arduino circuits back out.
    a. In one hand hold your prototype and in the other hand hold the end of the string. Notice where you're holding the prototype - that's about where the motor will

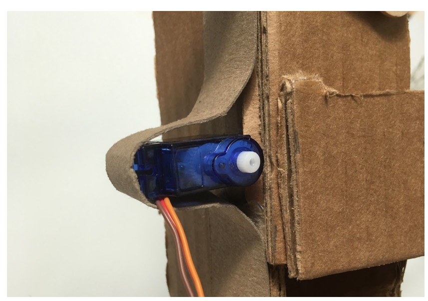
sit. Notice the path of the string as you pull it with your hand - that's the pathway of the tip of the lever.

b. ***Hot glue*** or ***zip tie*** levers to motor heads. Glue, staple or tie string to levers.





c. Where does the motor need to be based? Mark the spot on your project. Until you're sure the motor is in the right spot, it's best to use tape. A chipboard or cardboard strap can be glued or stapled onto a structure to secure a motor.

d. Avoid getting hot glue in or near the motor shaft otherwise it could clog the motor and prevent it from moving!

e. You can control multiple joints with one motor by attaching string to multiple points of the same lever.

10. **Test and improve!**
    a. Once you've built a prototype and connected it to a servo motor, test it by plugging in the Arduino to power. Does it move the way you want it to? How can the design be improved?
    b. Ask other people about what they did and incorporate the ideas of people whose projects you liked. **Cooperation and sharing are important parts of natural evolution!** We're all part of the same ecosystem of ideas.

11. **Build** final prototypes.

Session 11: Taxonomy

Classroom setup
The same as session 10. Paint markers, journals, pencils.

1. **Explain:** Creating identity
    a. Give your creature at least one eye.
    a. Add color and identity to your prototypes using paint markers, armature wire, cardboard shapes, or any other material you find useful.
2. **Continue building!** Complete projects in preparation for Prototype Fair.
3. **Define: *taxonomy***
    a. **Taxonomy** is the branch of science concerned with the classification of organisms.
    b. Find a few words to describe your creature. Find the Latin translation and create a new scientific term by squishing those words together!
4. **Journal Activity**
    a. Make a schematic of your project in your journal that illustrates how it works. Label the parts.
    b. Name your creature with the scientific term you've created.
    c. Describe what your creature is and what it's movement indicates.

Session 12: Prototype Fair

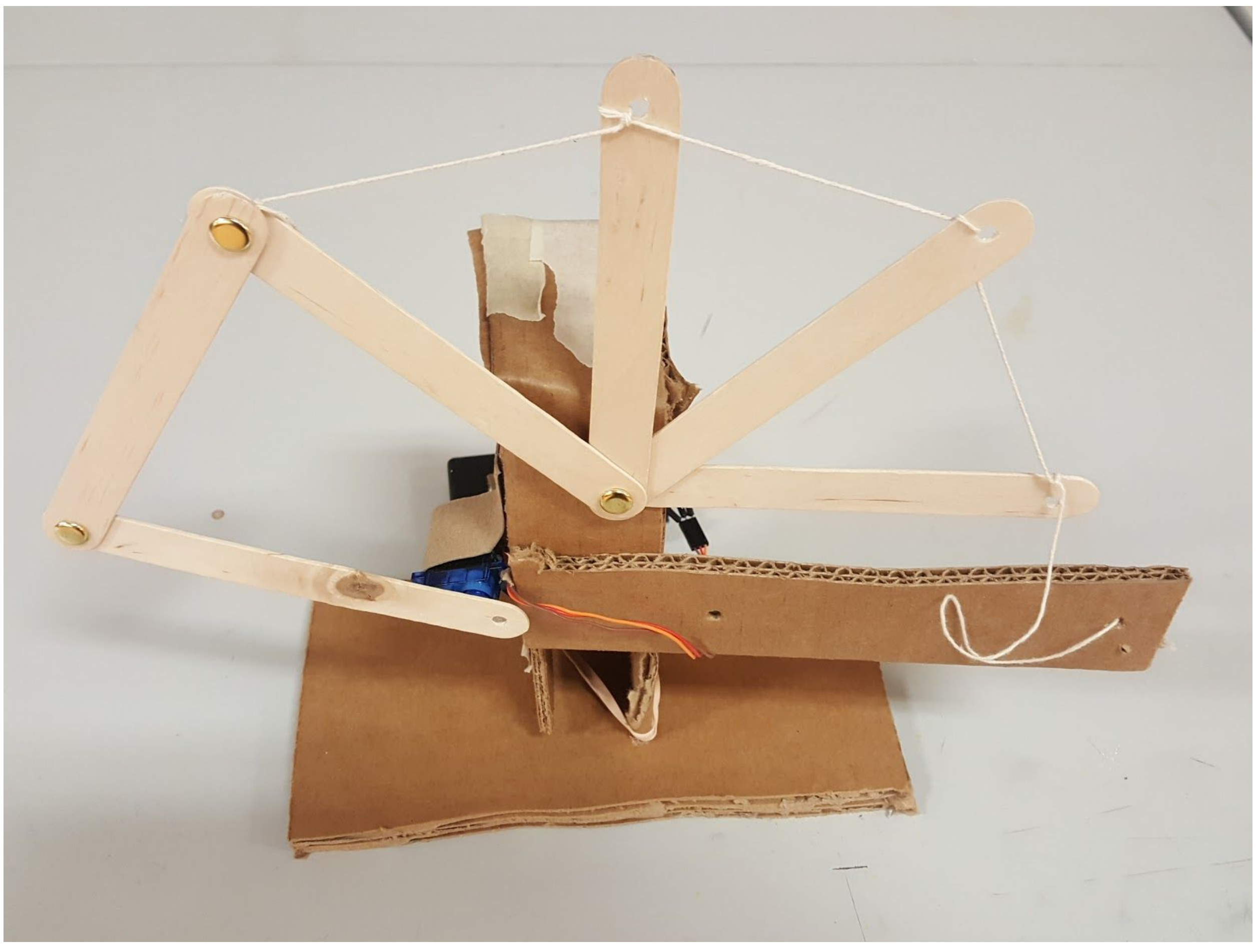
Classroom setup
Prototypes, cameras or phone cameras, Mouse Create.

1. **Prototype fair!**
    a. Create a setting in which all students can come together and share what they've made with each other.
    a. Students should explain what their prototype is and demonstrate how it works.
    b. Encourage them to ask questions about each other's projects.
5. **Document** projects using a camera.
6. **Introduce:** photo documentation. A portfolio of good photographs of your work is really valuable! There are a different ways to take photographs for your portfolio.

a. A ***cluttered background*** distracts people from the thing you are trying to photograph. There are too many things for their eye to sort through to see the main subject of your photo!
b. A ***neutral background*** with nothing in it makes your project stand out. It's what most artists and photographers use to create images for websites. With a clear background anyone looking at your photo will find their eyes naturally focus on your project.
c. A ***portrait*** is a photo that focuses on a person and tries to communicate something about them. A portrait of you with your project shows how the project relates to your personality and sense of style. It shows your role as a creator and mastermind.
d. Have your friend take a portrait so they can back up and zoom in on you a little. Find a nice background with good light.

7. **Document projects!** Use phone cameras to take photographs of your exquisite corpse drawing, your journal, or yourself holding your project.
8. **Introduce** mouse create.
    a. Mouse Create will help us build an ***online portfolio*** over the course of the summer! We will start using Mouse Create next week. For now, save the images you took to upload later.
    b. **Demonstrate** for students how to log into Mouse Create and upload images to start building a **digital portfolio**.
    c. **Complete prompt**: Describe your prototype. Who is this creature? How do they function?

Sessions 13-20: Plants



Project Overview

Objectives
Using sensors and multiple motors with Arduino
Designing and building compound moving parts
Extending the motion of servo motors to create complex movement

Project Details
Students will work together to create compound movement that extends from a motor in *reaction* to environmental stimuli. Their "sensitive creatures" should include one sensor and mechanical moving parts built from scratch. Students can use up to two servo motors, either 180° or continuous rotation.

It's recommended that students work in pairs.

Tools and materials

- Electronics and Circuitry
    - Arduinos & usb cables
    - Breadboards
    - IR sensors
    - 360° servo motors
    - 180° servo motors
    - Jumper wires and jumper extenders
    - Solid core wire
    - Electrical tape
    - Crimps
    - Crimpers
    - Wire strippers
- Fabrication
    - Cardboard
    - Zip ties
    - Brass tacks
    - Nuts and bolts
    - Washers
    - Popsicle sticks
    - Craft circles
    - Skewers
    - Cardboard tubes
    - Colored paper
    - Masking tape
    - Laser cut box templates
    - Laser cut popsicle stick template
    - Permanent markers
    - Hot glue station

- Hole punch
- Cardboard cutters
- Scissors

Project Flow

Session 13: Introduction

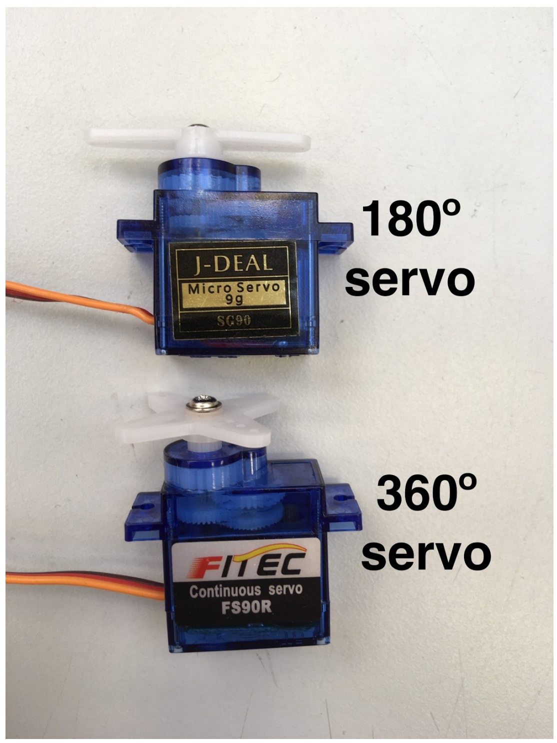
Classroom setup
Prototypes, Mouse Create, 360° and 180° servos, Arduinos, computers, USB cables, breadboards, jumpers, AA batteries, battery packs, screw terminals, brain box template, cardboard, cardboard cutters, hot glue, tape.

1. **Introduce**: Why are plants the inspiration for this challenge?
    a. Plants are constantly reacting to their environment in order to grow, change, open and close, trap insects or spread.
    b. Plants respond to their environment in a variety of ways. The response of a plant to an environmental stimulus is called a ***tropism***. Some common plant stimuli include light (phototropism), gravity (geotropism), water (hydrotropism), movement of the sun (heliotropism), and touch (thigmotropism). Plants have evolved to adapt their growth to take advantage of environmental conditions.
2. **Look** at images of plants and animals moving and responding.

3. **Upload code to Arduino.** Each pair or group of students can build one circuit. Students will learn how to edit the code during their coding class.

a. Plug your Arduino into a laptop using a USB cable.
b. Open the **Plants** code in the Arduino IDE and upload it to your Arduino.
c. *You will have an opportunity to edit the code later on in the domain.*

4. **Introduce** 360° servos and servo motor code
    a. 360° servo motors, or ***continuous servos,*** look and operate just like 180 servo motors except they can spin in a complete circle without stopping. You can tell them apart by the label on the side of the motor body, but otherwise they look extremely similar.



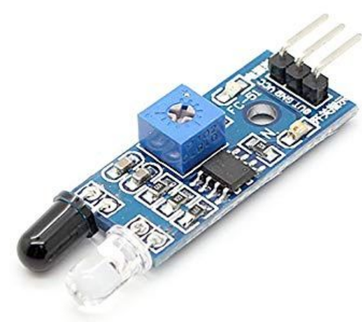
    b. 360° servo *speed* and *direction* (clockwise or counterclockwise) can be controlled by the Arduino using a new code.
    c. You will have the option of using either kind of servo for this Domain. They will be helpful for creating different types and directions of movement in response to the IR sensor.

2. **Introduce:** What is a sensor?
    a. With Arduino, you can control a circuit using real-world sources like sound, light, and temperature using ***sensors***. We will be using an infrared sensor, or ***IR sensor***. This sensor works by emitting infrared light and then calculating the distance the light travelled before bouncing back. This sensor will cause your

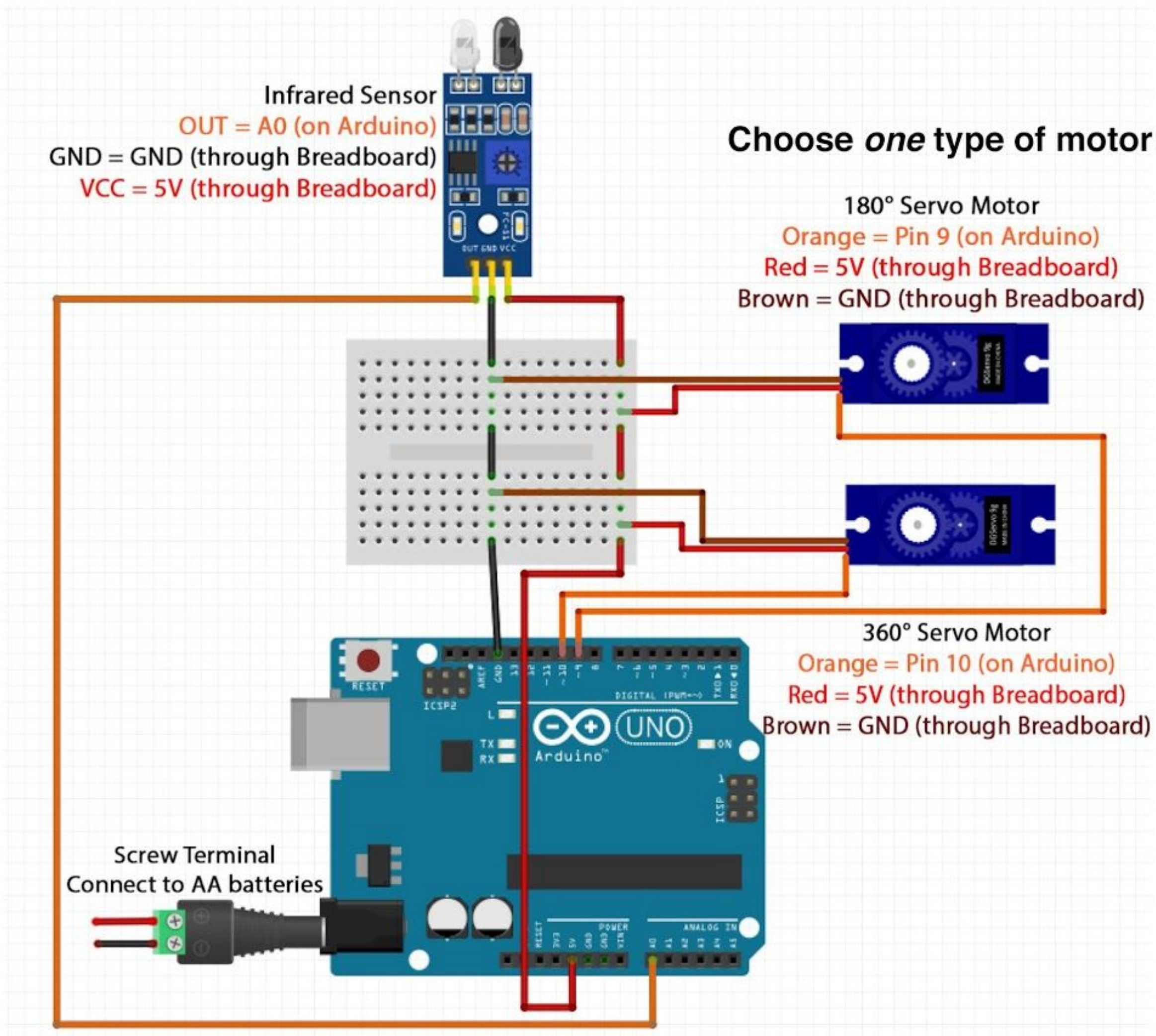
motor to move when the sensor experiences motion within a specific distance range.

b. *Beware*: the sun emits IR light! If your sensor is in bright sunlight, it won't work properly.

c. There is a little potentiometer on the top of the sensor that allows you to change the distance at which the sensor is activated, up to about two feet. A ***potentiometer*** is a knob that can be turned manually by hand using a screwdriver.



3. **Demonstrate building circuit step-by-step**: in pairs or groups, follow the diagram to make connections between the Arduino and ***one*** of the two types of servo motor using solid core wire or jumper wires.



a. Plug a battery pack into the Arduino. The lights should turn on.
b. Connect the servo ***motor shaft*** to the motor using the mini screws and screwdriver. Connect the servo motor to the breadboard using jumper wires.
c. Connect the IR sensor to breadboard and Arduino using jumper wires. Turn the potentiometer *all* the way in one direction so that the sensor is set to be *always* on. You'll know you've turned it in the right direction because both lights will be on when you plug it in.

d. Connect 5V on the Arduino to the red wire of the servo via the breadboard. Connect GND to brown wire in the same way. The red wire is for power, the brown wire is for ground.

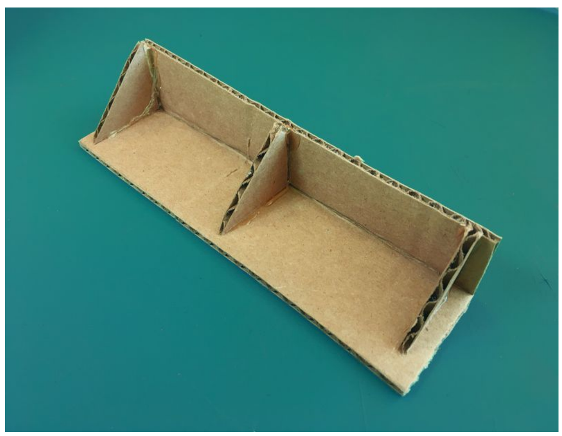
4. **Build** the servo motor circuit together in groups, and build a box to house it.
    a. **Give students time to build their Arduino circuits in pairs.** Test to make sure they work.
    b. **Build boxes** for brains, *or repurpose existing boxes*. Make sure students put their names on the box that holds their circuit.
5. **Clean up.** Unplug the screw terminal from the Arduino to turn it off, and set aside. Students will not need their Arduino circuits for the following part of the fundamental.

Session 14: Design and Fabrication

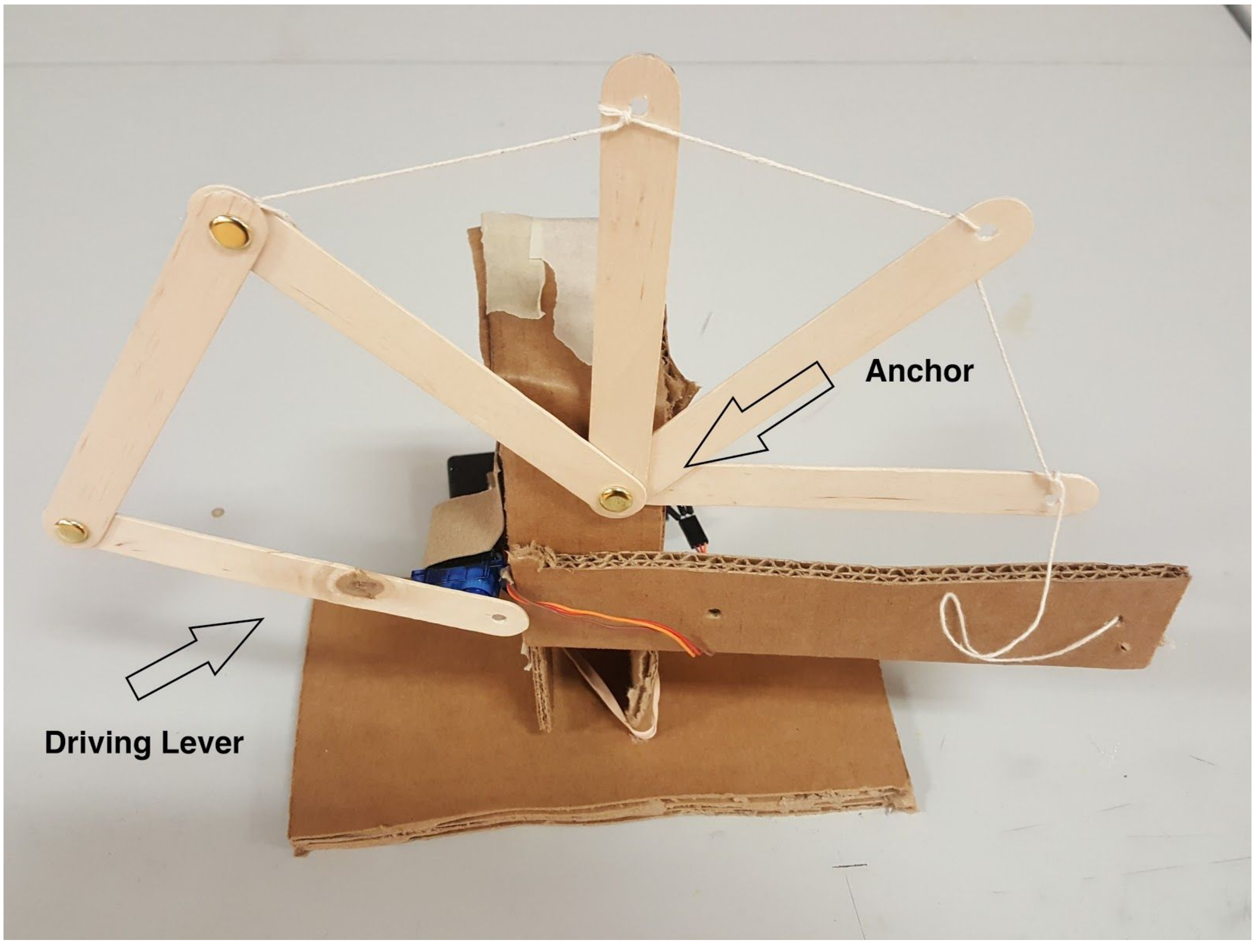
Classroom setup
Mouse Create, prototypes, cardboard wheels, popsicle sticks, brass tacks, washers, cardboard, nuts and bolts, cardboard cutters, cardboard tubes, zip ties, skewers, laser cut box templates, laser cut popsicle stick hole template, masking tape, permanent markers, hot glue and hot glue guns, hole punch, scissors.

1. **Explain** anatomy of sensitive creatures using GIFs or physical prototypes.
    a. The ***frame*** is the supporting structure that the motor is mounted to. The body of the motor needs to be fixed on a surface. You can mount the motor inside of a cube or box, or build a skeleton.
    b. The ***driving lever*** extends from the motor shaft, similar to the use of levers in the fundamental.
    c. The ***anchor***(s) are additional fixed points where joints are mounted on the frame. Anchors can either be stationary or move on a brass tack.
    d. The ***following motion*** is made up of all the joints connected to and controlled by the driving lever, including scissor joints and ladder joints.
2. **Explain** the domain challenge:
    a. You will work together to create movement that extends from a motor in *reaction* to movement detected by the IR sensor. Your "sensitive creature" should include one sensor and mechanical moving parts that you will build from scratch. You can use up to two servo motors but you should start with only one and add a second later. You can use either 180° or 360° servo motors.

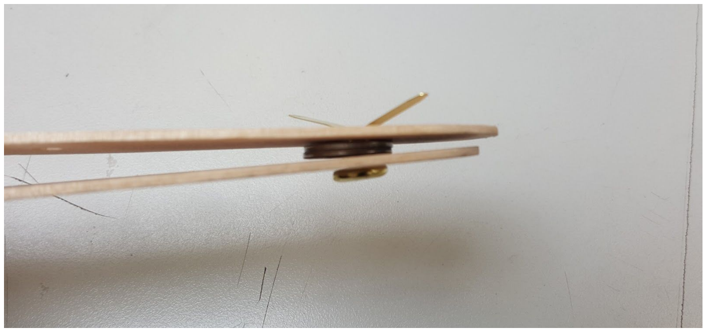
3. **Demonstrate** and explain the following techniques for building. Students will make their own projects without specific guidance after you've demonstrated these techniques.
    a. What ***frame*** supports the motor body?
        i. **Boxes** can be built to support the servo motors using the templates provided.
        ii. If you cut long pieces for ***supporting*** the structure, you can use triangles to help create strong skeletons.



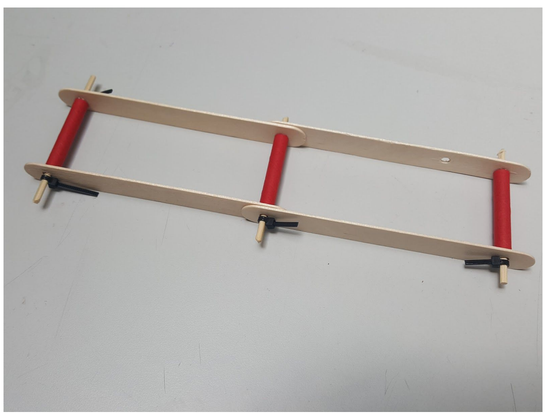
    b. What is the ***driving lever***? How does it connect to the motor shaft? Where is the anchor?
        i. Just as in the Fundamental, you can attach levers such as cardboard wheels or popsicle sticks to the motor shaft to extend the movement of the servo motor.



c. What is the movement?
   i. ***Scissor joints*** are made up of a series of connected joints that expand and contract. You can trace the holes of the ***template popsicle stick*** onto yours before punching holes if you want the holes to be evenly spaced. You can connect popsicle sticks using brass tacks. You can cut popsicle sticks with scissors but *not* cardboard cutters.
   ii. ***Washers*** do a couple of things - they can be used to reduce ***friction*** between two surfaces or to create space between two surfaces, as needed.
   iii. You can use tape to hold the back of the brass tack out of the way.



iv. ***Ladder joints*** can be built using skewers, cardboard tubes, and popsicle sticks, with zip ties or rubber bands to hold the skewers in place. These joints can bend and move just like scissors joints.




5. ***Play*!** Explore materials to find out what works and what's interesting.
    a. You'll eventually combine your ideas to make a prototype, but it's important to play first to get a sense of what's possible, rather than starting with an idea and trying to figure out how to build it.
6. Clean up.

Session 15: Continue Building!

Classroom setup
Same as session 14.

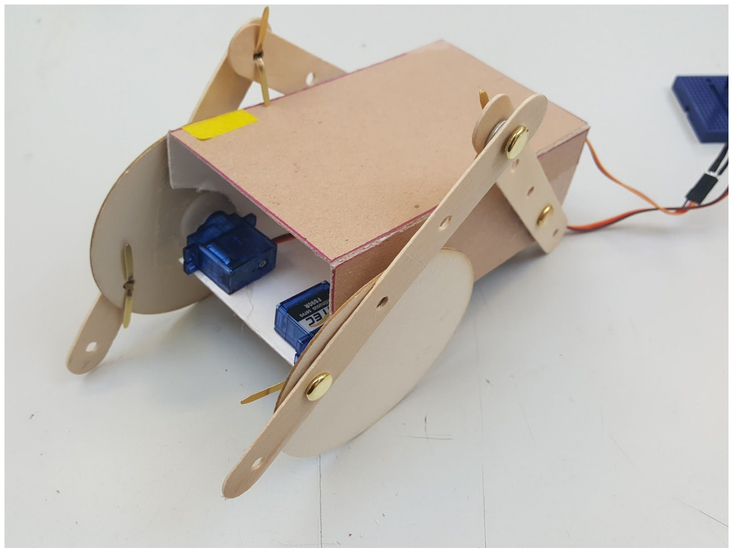
1. **Explain: Build guidelines!**

   a. Think about ways that plants, animals or humans react to negative or positive external stimuli. Can you imitate that movement? Waving, opening and closing, expanding and contracting, poking, gesturing?
   b. You can incorporate any other available materials you know how to use.
   c. We will later incorporate the Arduino circuit and add sensors to our projects that affect the movement of the servo motors.
2. **Journal Activity:** Draw a picture of the sensitive creature you want to build together as a group that combines your ideas. As you work and build on your ideas, add the following information to your schematic.
   a. Where is the motor? What kind of motor is it?
   b. How is the motor supported? Where is the anchor point?
3. **Build!** Test and improve.
   a. Build a simple mechanism together and move it using only your hands. What triggers the movement (what is the driving lever)? Where is it fixed (anchored)?
   b. Incorporate the motor when you're ready.
4. Clean up.

Session 16 and 17: Expand Your Design

Classroom setup
Same as session 15.

1. **Continue** building projects as necessary. Test them by hooking up to your Arduino to see if they move in the way that you want them to.
2. **Evolve**: Consider adding a **second servo motor.**
   a. Can you include different ***planes*** of movement? Do the motors operate on ***parallel*** planes, the same, or perpendicular planes?
   b. Are the motors 180° (back and forth) or 360° (continuous)?
   c. Do the motors move in ***alternate*** or ***simultaneous*** directions? Different speeds
   d. The example below shows a prototype that uses two motors to "crawl."



3. **Build!** Test and improve.
4. Clean up.

Session 18: Incorporate Sensors and Code

Classroom setup
Arduino circuits, jumpers and jumper extenders, servo motors, mini screwdrivers, laptops, USB cables.

1. **Explain:** how to incorporate sensors.
    a. Consider: where is the sensor located on your project? How is it activated, and at what distance?
    b. You can change the sensitivity of the IR sensor by using a screwdriver to turn the mini ***potentiometer***. The tiny LED on the board will let you know when it's sensed motion within its range.
    c. You can incorporate the IR sensor into your project by extending it using ***jumper extensions*** in combination with normal jumpers. You can also crimp or connect to solid core wires for much longer extensions.
    d. Test and improve!
2. **Explain**: If you haven't already, you should **adjust the code.**
    a. Consider: how do you want your prototype to move? What speed or direction?
    b. Physically move your prototype to model what you want the code to do.
    c. **Write or draw** this movement into you journal schematic.
    d. Code it.

3. **Build!** Test and improve.
4. Clean up.

Session 19: Character Building

Classroom setup
Paint markers, permanent markers, colored paper, general building supplies.

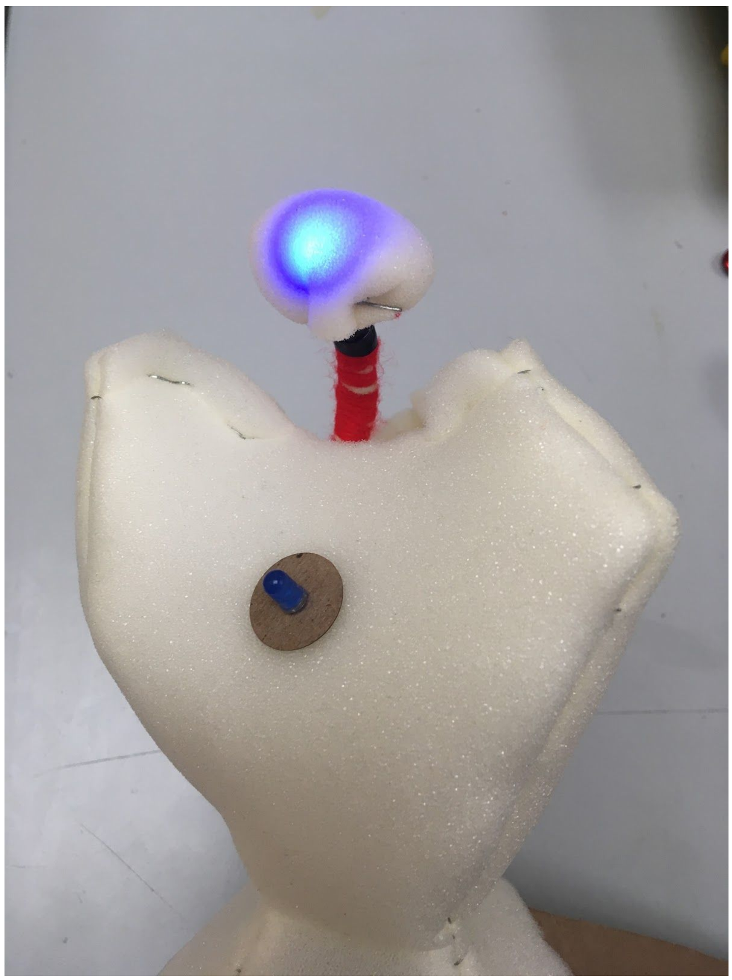
1. **Consider**: Who is your sensitive creature and what is it doing? Add color, words, or imagery using paint markers, paper, or any other available materials.
2. **Build!** Bring projects to completion and prepare to present.
3. Clean up.

Session 20: Prototype Fair!

Classroom setup
Prototypes, cameras or phone cameras, Mouse Create.

1. **Prototype fair!**
   - **a.** Create a setting in which all students can come together and share what they've made with each other.
   - a. Students should explain what their prototype is and demonstrate how it works.
   - b. Encourage them to ask questions about each other's projects.
2. **Document** projects using a camera.
3. **Upload** images to Mouse Create.
   - a. Describe your prototype. Who is this creature? How do they function?

Sessions 21-28: Cephalopods



Project Overview

Objectives
Creating interesting patterns in light using arduino
Creating colorful, textural 3D forms using paper patterns and foam
Using armature wire to create bendable forms
Sewing with yarn and staples

Project Details

Students will work together to design a creature made up of organic forms inspired by shapes from the natural world that can be moved in different positions to create visual light effects. Each creature should include at least one bendable limb and can include up to six LEDs.

It’s recommended that students work in pairs.

Tools and materials

- Electronics and Circuitry
    - Arduino
    - 220 and 10k ohm resistors
    - UV and colored LEDs
    - Photocells
    - Laser cut LED holders
    - Electrical tape
    - 4AA battery clips
    - Solid core wire
    - Crimps and crimpers
- Fabrication
    - Permanent markers
    - Paper
    - Foam
    - Staple pliers
    - Armature wire
    - Colorful yarn
    - Rubber bands
    - Acetate
    - Hot glue and hot glue guns
    - Cardboard
    - Brass tacks
    - Tape
    - Large sewing needles
    - Hole punch
    - String
    - Scissors
    - Cardboard cutters
    - Needle nosed pliers

- Paint markers

Project Flow

Session 21: Introduction

Classroom setup
Mouse Create, arduinos, breadboards, LEDs, photoresistors, jumpers, solid core wire, 220 and 10k ohm resistors, battery packs, laptops, USB cables.

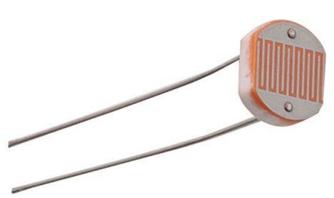
Cardboard, box template, cardboard cutters, perforators, markers, tape, hot glue station.

1. **Explain**: What's the main idea? Use Mouse Create to introduce the project.
    a. **Visual communication** is the conveying of information about a creatures identity in ways that can be seen. There are different ways that animals communicate visually, Cephalopods are just one category of creatures that use visual communication.
    b. **The 3D shape,** or ***form***, of an animal is important for how it functions in its environment. Form relates to size, shape, and flexibility of a creature. For example, consider the round prickly form of a poisonous puffer fish versus the long, soft form of a gentle caterpillar.
    c. Color and light ***signalling*** is another, more complex way that animals communicate visually. This is called ***bioluminescence***, which is the biochemical emission of light by living organisms.
    d. In the deep sea where it is pitch dark all the time, bioluminescence is found in virtually every type of animal and used in many different ways - by angler fish to trap prey by dangling a luminescent lure, by plankton as a kind of defensive burglar alarm, or by cephalopods (a family that includes octopuses, squid, and cuttlefish) in order to camouflage themselves.
    e. ***Color*** is another way that animals communicate. ***Camouflage*** is an adaptation that allows animals to blend in with certain aspects of their environment. Camouflage increases an organism's chance of survival by hiding it from predators. ***Aposematism*** is a biological means by which a dangerous or noxious organism advertises its dangerous nature to a potential predator using visual signalling such as bright patterns or colors that make them stand out.
    f. Can you think of ways that animals that use visual displays to communicate, defend or protect themselves?

2. **Explain**: in this Domain, we will use Arduino to create LED patterns in different colors that can be controlled using a ***photoresistor***. We will build a practice circuit that only uses one LED, but you can add additional LEDs to your prototype.
3. **Explain:** what are LEDs?
    a. The LEDs we'll be using are exactly the same as the UV LED we used for the journal, except they are smaller and they're colored.
    b. Remember to always keep the two legs separated, otherwise they short circuit.
    c. LED's are ***polarized***, which means that they are one directional. Pay attention to which side of the circuit the long leg goes on.

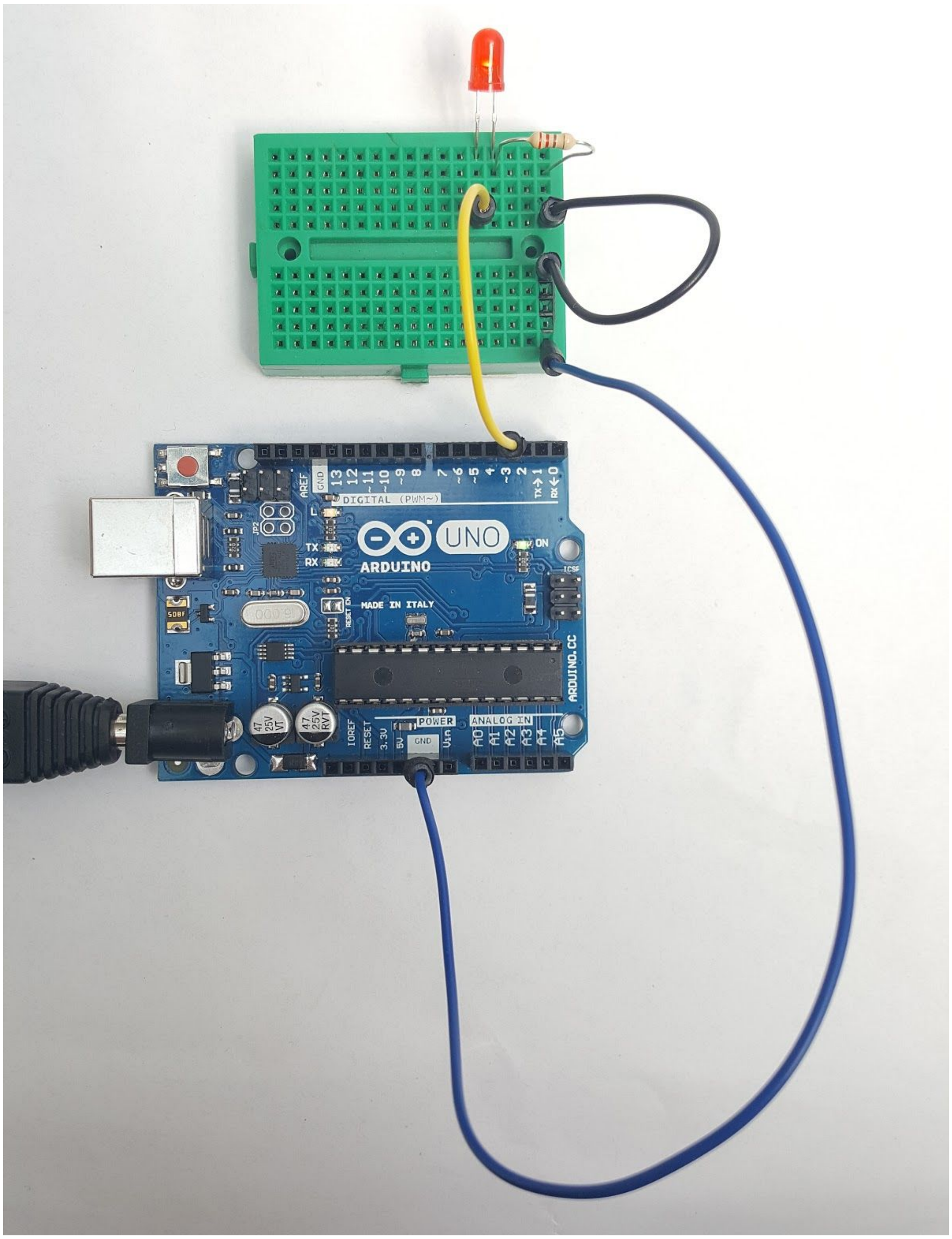
4. **Explain:** what's a resistor?
    a. We'll be using a ***resistor*** as part of our circuit. Resistors are often used to reduce voltage in circuits to prevent LEDs from burning out. They are also used here with ***photoresistors*** to create an anchor point for the sensor so it can compare its resistance readings to one baseline resistance reading.

5. **Explain:** what's a photoresistor?
    a. A light sensor, or ***photoresistor***, varies its resistance based on exposure to light in a way that is measurable by the Arduino. The Arduino can use values from the photoresistor to control other parts of the circuit. The code that we're working with will turn your LEDs on when they are in the dark.



6. **Upload code to Arduino.** Each pair or group of students should build one circuit.
    a. Plug your Arduino into a laptop using a USB cable.
    b. Open the **Cephalopods** code in the Arduino IDE and upload it to your Arduino.
    c. *You will have an opportunity to edit the code later on in the domain.*
7. **Demonstrate** building a sample LED circuit step-by-step. In pairs, follow the diagram to make connections between the Arduino, breadboard, one LED, resistors, and one photoresistor using solid core wire or jumpers.
    a. Plug a battery pack into the Arduino. The lights should turn on.
    b. Students can include up to *six* LEDs in their prototypes, but for now they will build a circuit with only one. Before incorporating LEDs into breadboard, make sure to test them by holding them to a coin cell battery to make sure they work!

    c. Connecting LEDs to breadboard:
        i. Use a wire to connect from GND to one corner of the breadboard. Then use another small wire to bridge the gap to the other side. These two breadboard rows will be your "ground bar."
        ii. Connect jumper wires from pin ~3 on the Arduino to the breadboard. In general, you can use any pin with a ~ symbol next to it to fade LEDs.
        iii. Put the positive leg of the LED into the same row as the ~3 jumper wire, with the negative leg facing to the right.
        iv. Add a 220 ohm resistor with one end in the same row as the negative leg of LED and the other connecting to the ground bar (All your LEDs will share the same ground bar). It should look like this:

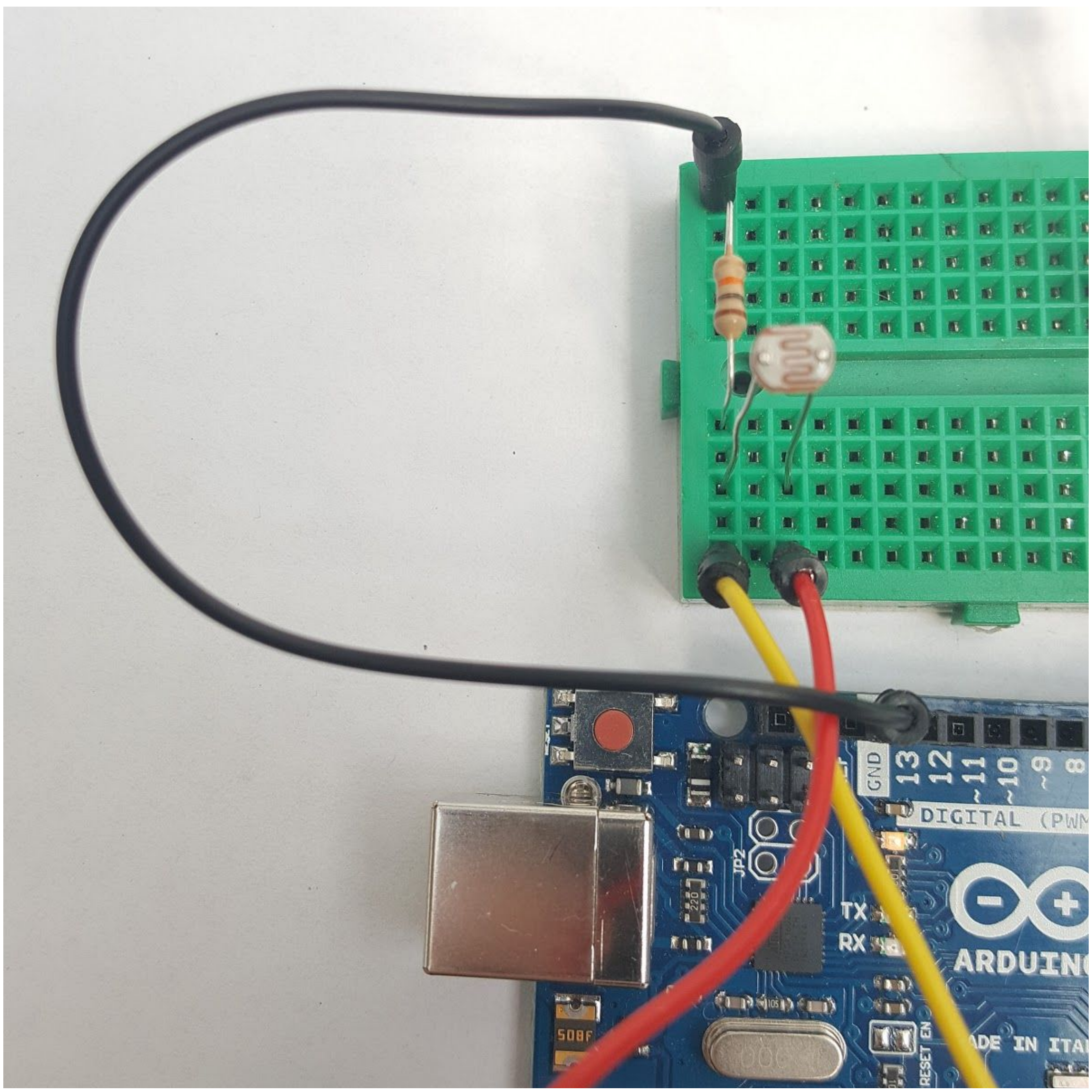


v. Use another wire to connect from the other Arduino GND to make another ground bar on the other side of the breadboard. This is where the photoresistor will go. The photoresistor part of the circuit is a little more complicated.

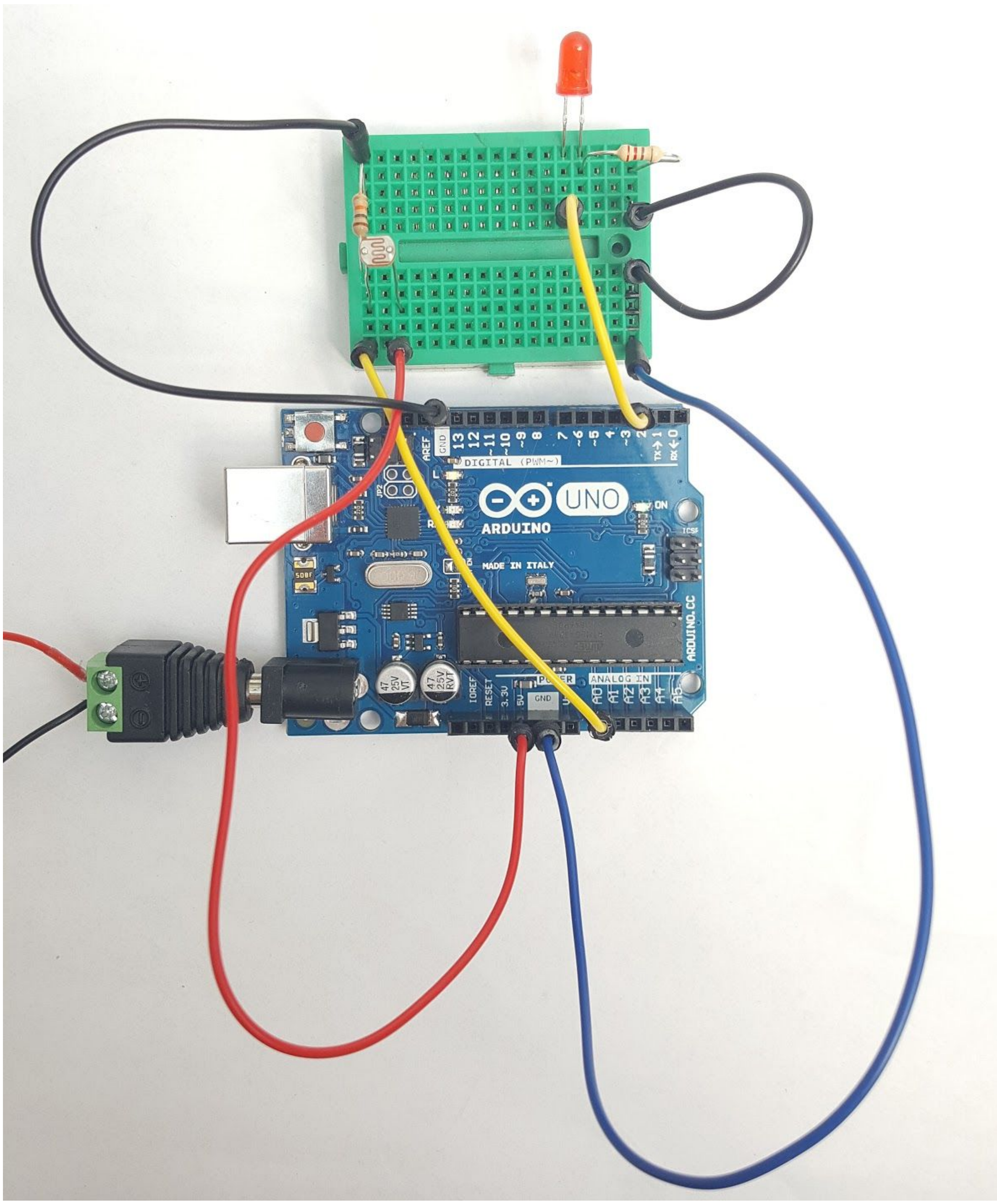
vi. Use a 10K ohm resistor to jump from the photoresistor ground bar to the *other* side of the breadboard. Then, in the same row plug in one side of the photoresistor - doesn't matter which one - and a jumper that goes to A0.

vii. Make a connection from the other photoresistor leg to the 5V pin on the Arduino.

It should look like this:



The completed circuit will look like this:



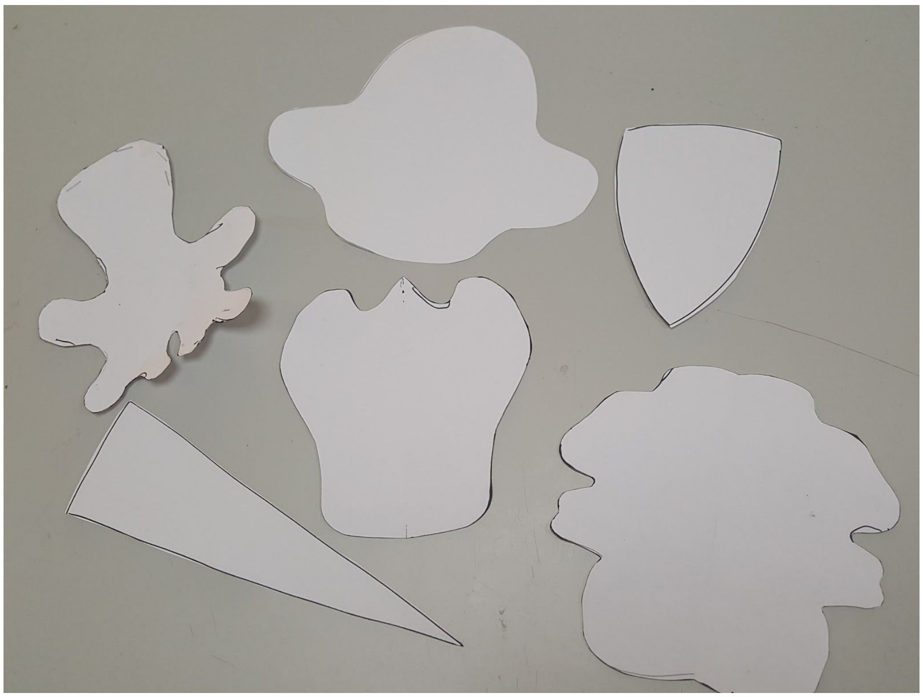
3. Give students time to build their Arduino circuits in pairs. Test to make sure it works.
4. Build or recycle a box to hold the arduino circuit.
5. **Clean up**. Put arduino circuits away for now. You will not need them for the following session.

Session 22: Pattern Making and Brainstorming

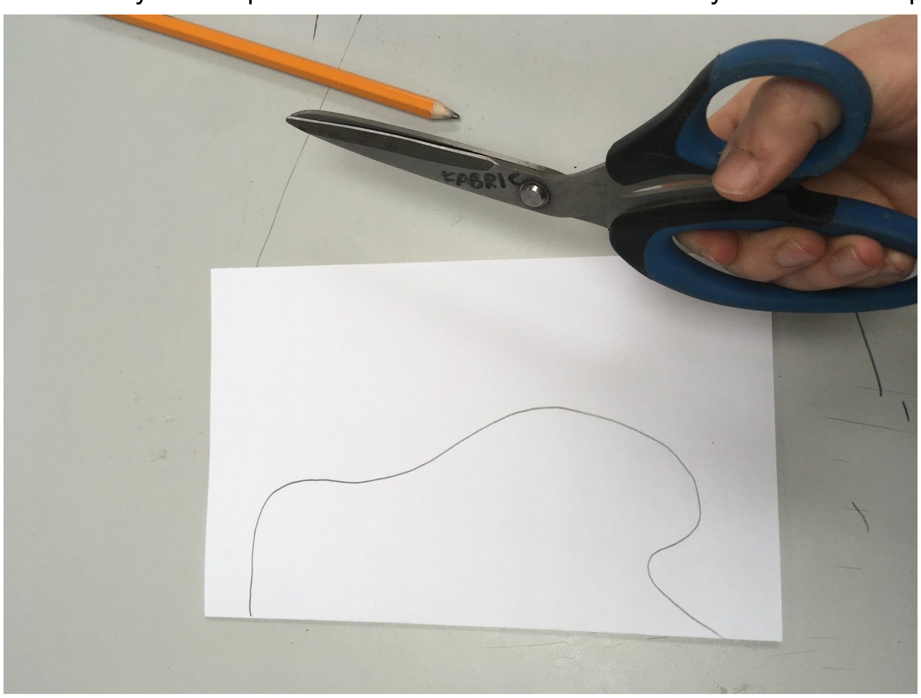
Classroom setup
Colored paper, foam, scissors, markers, staplers.

1. **Continue building Arduino circuits if necessary.**
2. **Explain** anatomy of Cephalopods using GIFs or physical prototypes. We will be building ***3D forms*** by creating a unique pattern.
    a. ***Pattern making*** allows you to ***trace*** and repeat a paper shape multiple times. Stapling three or more ***symmetrical*** shapes together creates a 3D form. Think of the way that all the panels on a football are the same shape and combine to create a rounded form. Rounded forms create football like shapes and sharp, straight edges create pointy forms like spikes.
3. **Demonstrate** pattern making exercise step-by-step:
    a. Each student should fold a piece of paper in half.
    b. Draw a shape. Does it have curvy or straight lines? Tiny details won't show easily, so focus on the overall shape. **Draw a simple shape - not an entire creature.**

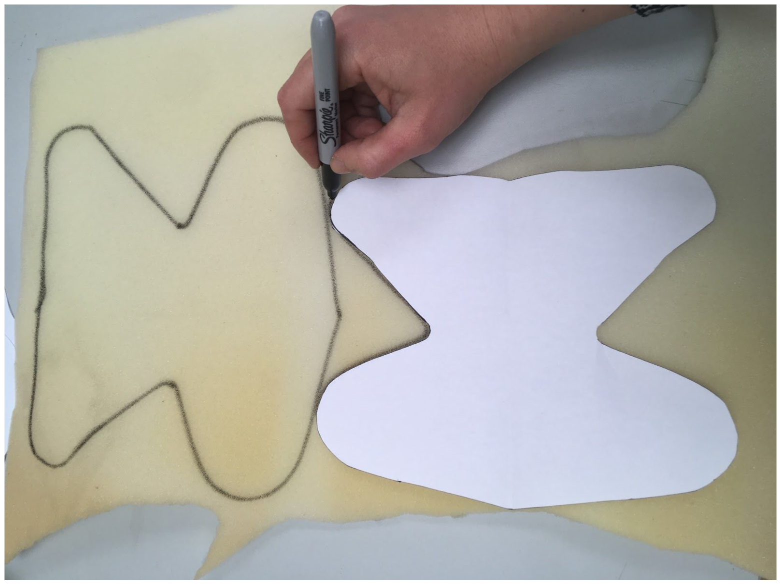
c. Some example shapes:



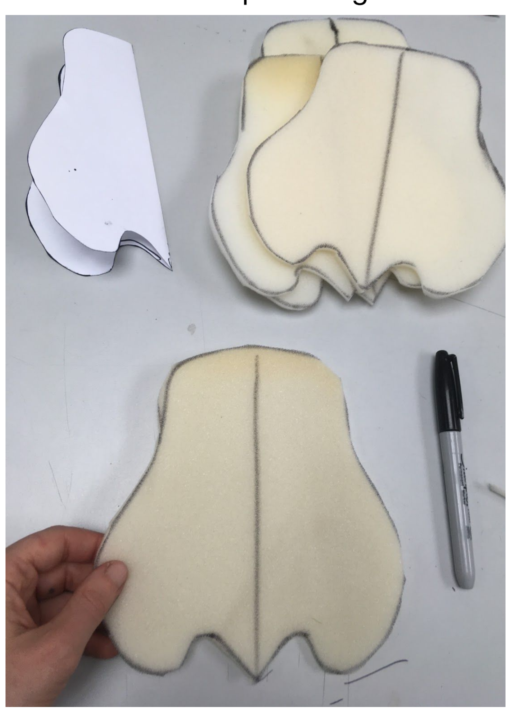
d. Cut out your shape and unfold. You should have a symmetrical shape.



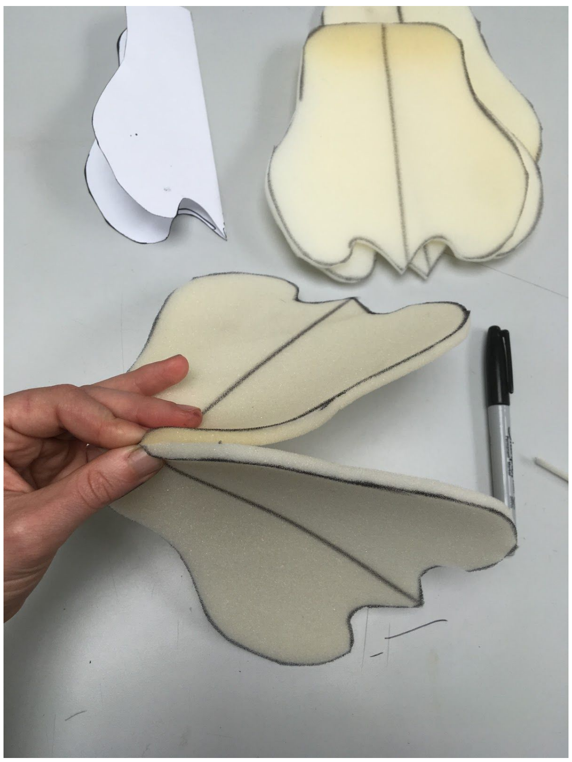
e. Decide how many ***panels***, or sides, you want your 3D form to have: Move the paper and trace it onto foam at least three times. You'll get different results with different numbers of panels. *Trace close to the edge of the foam to avoid waste!*

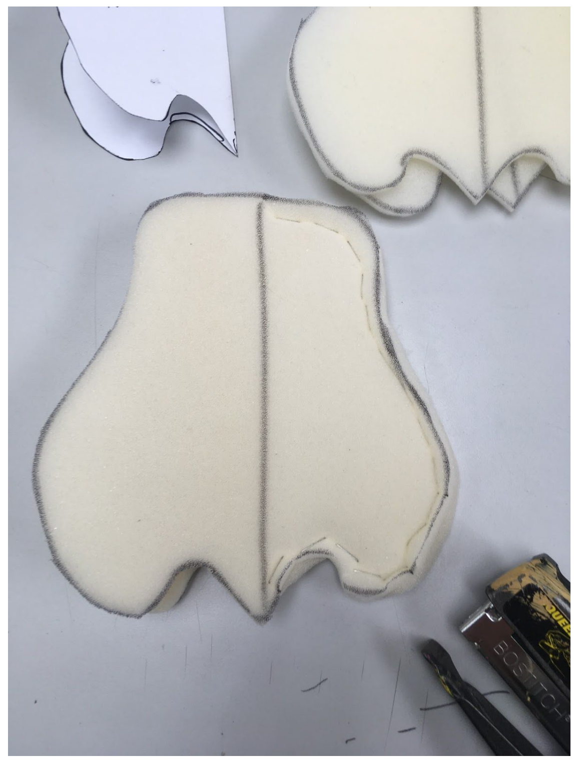


f. Refold the paper and trace a ***fold mark*** down the middle of each foam shape you just drew. Cut out foam shapes using scissors.

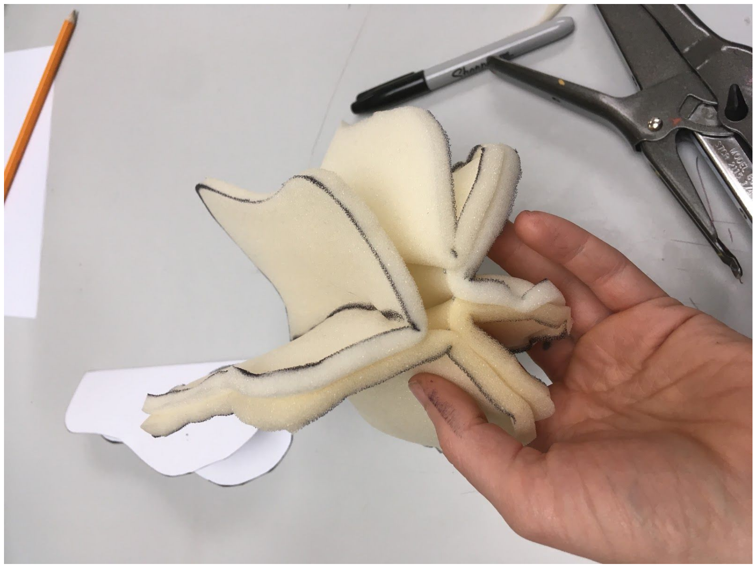


g. Line up the edges of two of the foam shapes with marker marks on the outside, and staple along the edge, starting at the top by the fold mark and moving all the way down one side. Remember to leave about a fingers-width of ***seam allowance*** as you staple. Seam allowance is the distance between the foam edge and the staple line on two pieces of foam that are being stapled together. Place staples right next to each other as you go. *If a stapler gets jammed, you can pull staples out using needle nosed pliers.*





h. Once you staple your way down to the bottom of the fold line, stop stapling. Match up the edges of the *next* cut-out foam shape and staple that shape to the previous one, again starting at the top of the fold mark and moving all the way down to the bottom. Do this for each shape until you've added all of your panels.



i. Before you completely staple your form together, turn it inside out to hide your ***seams***! Staple up the final side or leave it open for now.

j. You can use staples to keep modifying your form.

4. **Share** the results in your groups, choose one form you like, evolve a new form, or combine different forms to create a more complex hybrid.
5. Clean up.

Session 23: Sewing and Fabrication

Classroom setup
Foam, armature wire, colorful yarn, acetate, thin cardboard, cardboard cutters, scissors, permanent markers, paint markers, large sewing needles.

1. **Explain**: Now that each group has a foam form to start with, you can build off of this by building and connecting more 3D forms, incorporating at least one bendable limb using

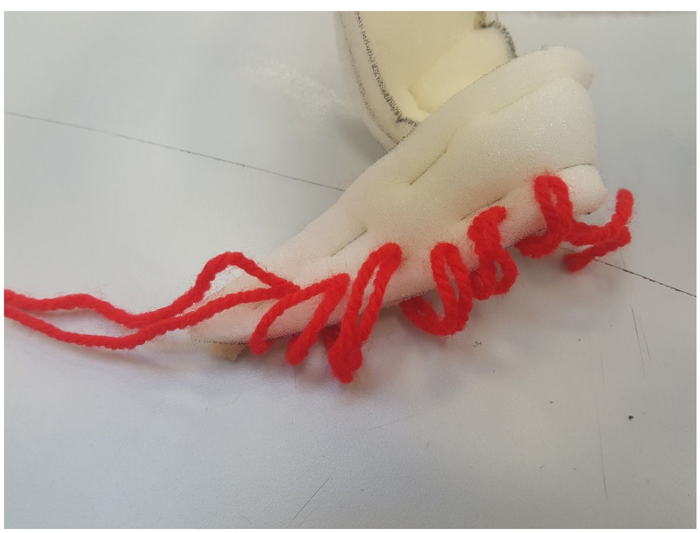
armature wire, adding character traits, and eventually incorporating LEDs and photocells. We'll start with a series of demonstrations.

2. **Demonstrate** the following techniques for working with foam to create appendages/limbs/tails/tentacles.
    a. Appendages or limbs can be made by using a paper pattern to cut out two of the same shape and stapling it together with ***armature wire*** inside it. The armature wire will allow the limb to bend and keep its form. *You can cut armature wire using wire strippers.*

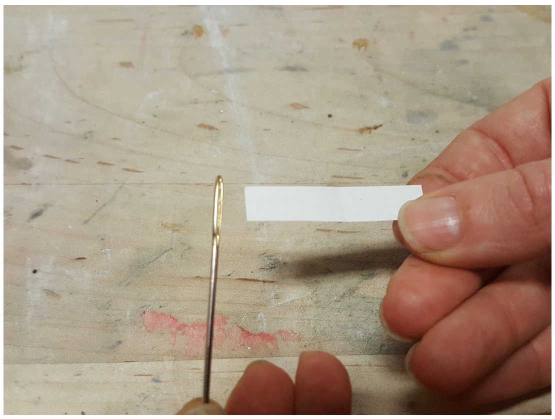
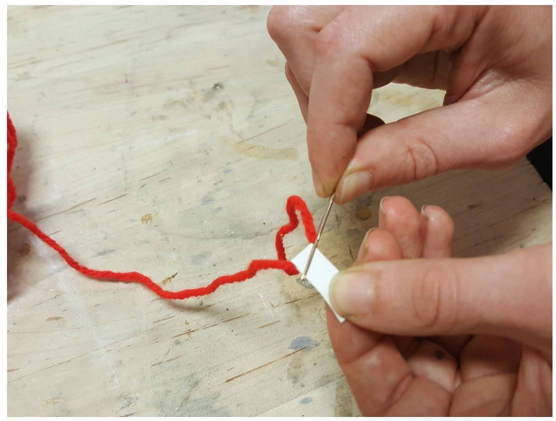
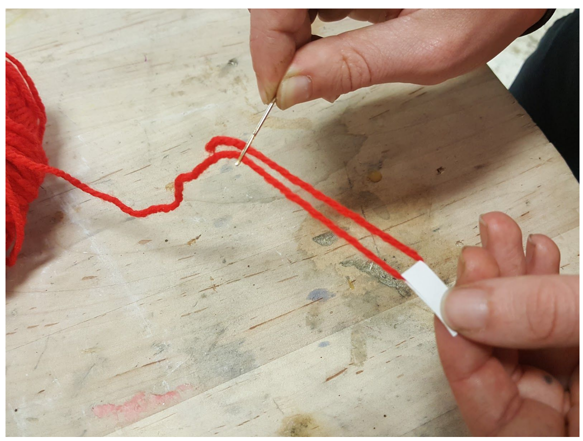
    b. You can place an LED or photocell on the end of a limb, but you'll want to incorporate the electrical wires into the limb before stapling it up. We'll get to that below!
    c. You can use cardboard to make a base or structure, or add more shapes.

d. You can cut smaller shapes such as warts, spikes, eyes, pom poms or tufts and poke them through holes in the foam or cardboard to create surface texture and add character traits. You can poke holes in the foam using a skewer or pencil.

3. **Demonstrate** sewing with yarn to add colorful detail, fur, or to help hold things together.



a. Thread the needle with yarn and pull it all the way through using a small piece of paper that can fit through the needle.

b. Pull the yarn through the needle and tie a knot at the end of the ***tail***. As you sew, hold the needle over the hole so that the yarn doesn't pull through.
c. As you poke the needle through the foam, support the foam from behind but be careful not to poke your hand.

4. **Build guidelines!**
    a. Work together as a group to make one prototype that combines your ideas. You should not build a pre-existing identifiable creature - focus on inventing and combining multiple shapes to create an imaginary evolved creature.
    b. After we build the soft form, we'll use LEDs and Arduino to create patterns in light and control the blinking patterns using a photocell.
    c. You can incorporate any other available materials you know how to use.
    d. **Draw** a diagram of the creature you want to build together. Make sure to include the following information:

   i. What does the main form look like? How many limbs does it have? What are the limbs like?
   ii. What other physical characteristics does it have?
   iii. Where are the LEDs located and what color are they?
   iv. Where is the photocell located? Can the photocell be covered and uncovered by a limb? If not, what's the movement or interaction that triggers the visual light effect?
5. Clean up.

Session 24: Build Prototypes

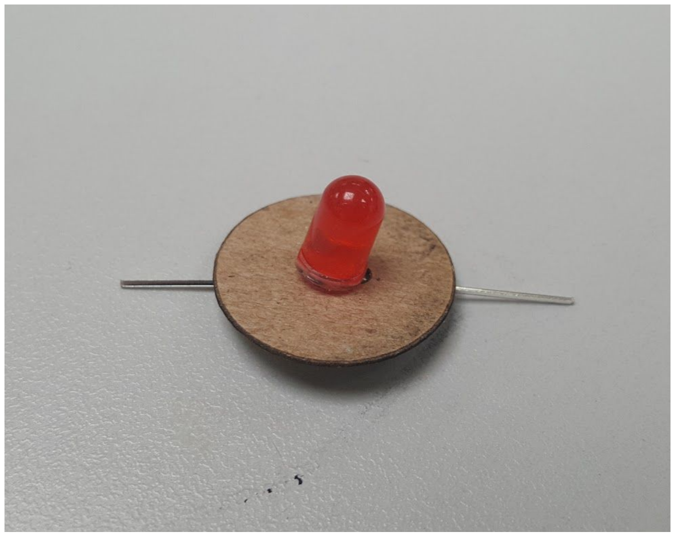
Classroom setup
The same as session 23.

1. **Build** creatures**!** Determine where you want LEDs and photocell to be incorporated.
2. Clean up.

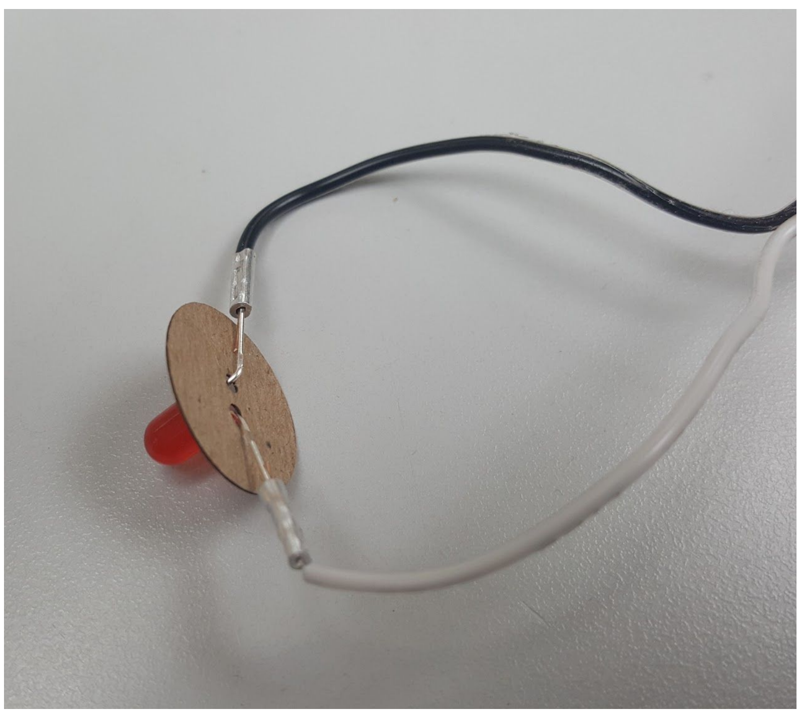
Session 25: Incorporate Electronics

Classroom setup
Wire, wire strippers, crimp set, colored LEDs, LED holders, photocells, electrical tape, Arduinos, breadboards, battery packs, 10k and 220 ohm resistors, 3v batteries (for testing LEDs).

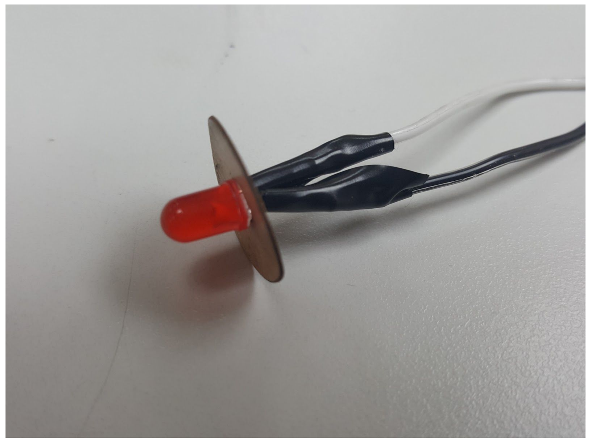
1. **Explain** how to incorporate LEDs into projects.
   a. First, consider how long your wires need to be in order to reach the arduino. Cut the wires *at least* 2 feet long. Strip both ends.
   b. Feed the legs of the LED through the LED holder and separate them to temporarily help hold the LED in place. Make sure to notice which leg is longer. (Students aren't required to use the LED holders, but they'll help for surface mounting LEDs onto foam).



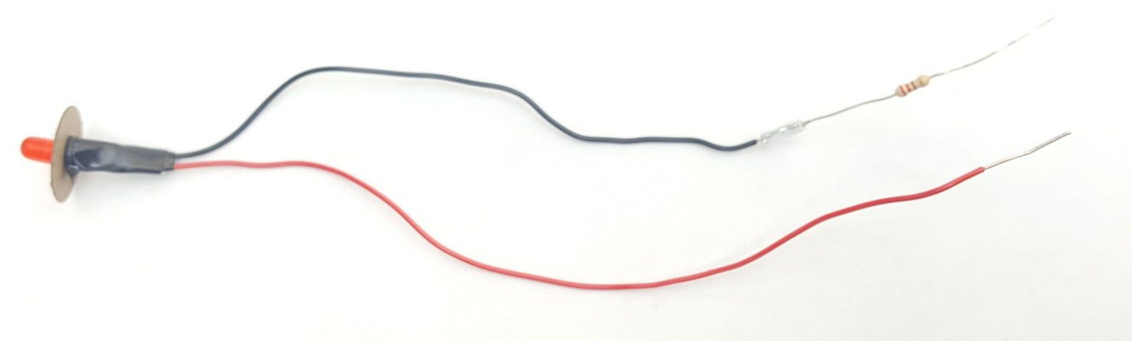
c. Connect the longer leg of the LED to a light color wire (positive) and the shorter leg to the black or darker color wire (ground). Crimp the legs of the LEDs to the wires as tightly as you can. Tug on them to check!



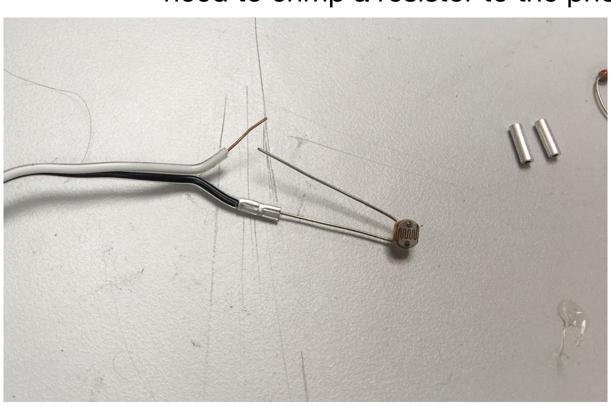
d. **Insulate** the individual legs using electrical tape so that you don't get a short circuit on the LEDs! Tape the two legs and wires together so that they fit through the foam more easily.

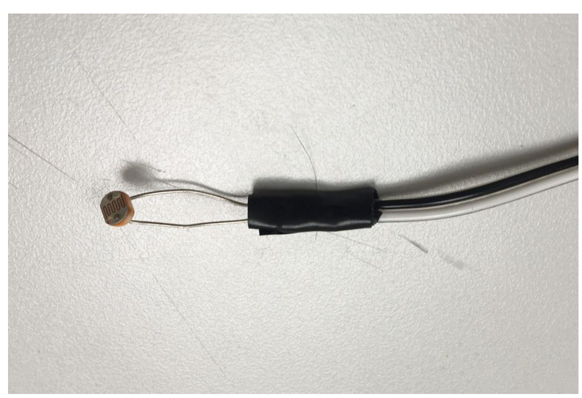


e. Crimp a 220 ohm resistor to the *negative* side of the LED.



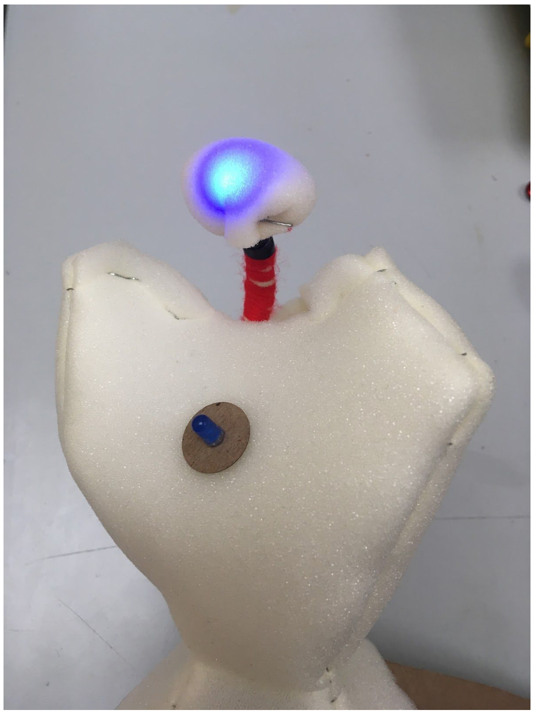
f. You can extend the photoresistor by crimping wires to both legs. You do *not* need to crimp a resistor to the photoresistor. Insulate the photoresistor as well





g. Using a skewer or a pencil, punch a hole in the foam where you want the LEDs or photoresistor to sit, and thread the wires through the holes.

   a. You can ***diffuse*** the LED light and create a softer glowing effect by adding foam over it or putting it inside of a form - like a lantern.



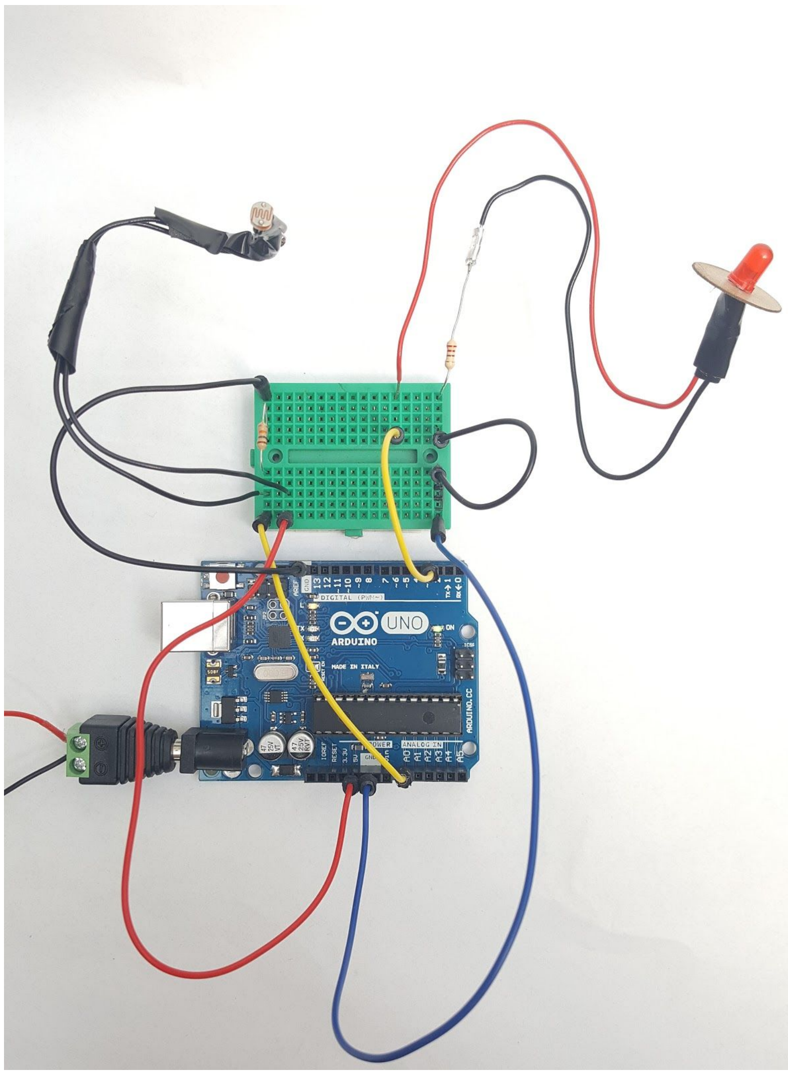

2. **Students should incorporate LEDs and photocells into their projects before moving on to connect them to the Arduino and breadboard.**
   a. Bendable appendages or limbs are a great way to incorporate LEDs or photocells that can move.
3. Clean up.

Session 26: Creating Light Patterns

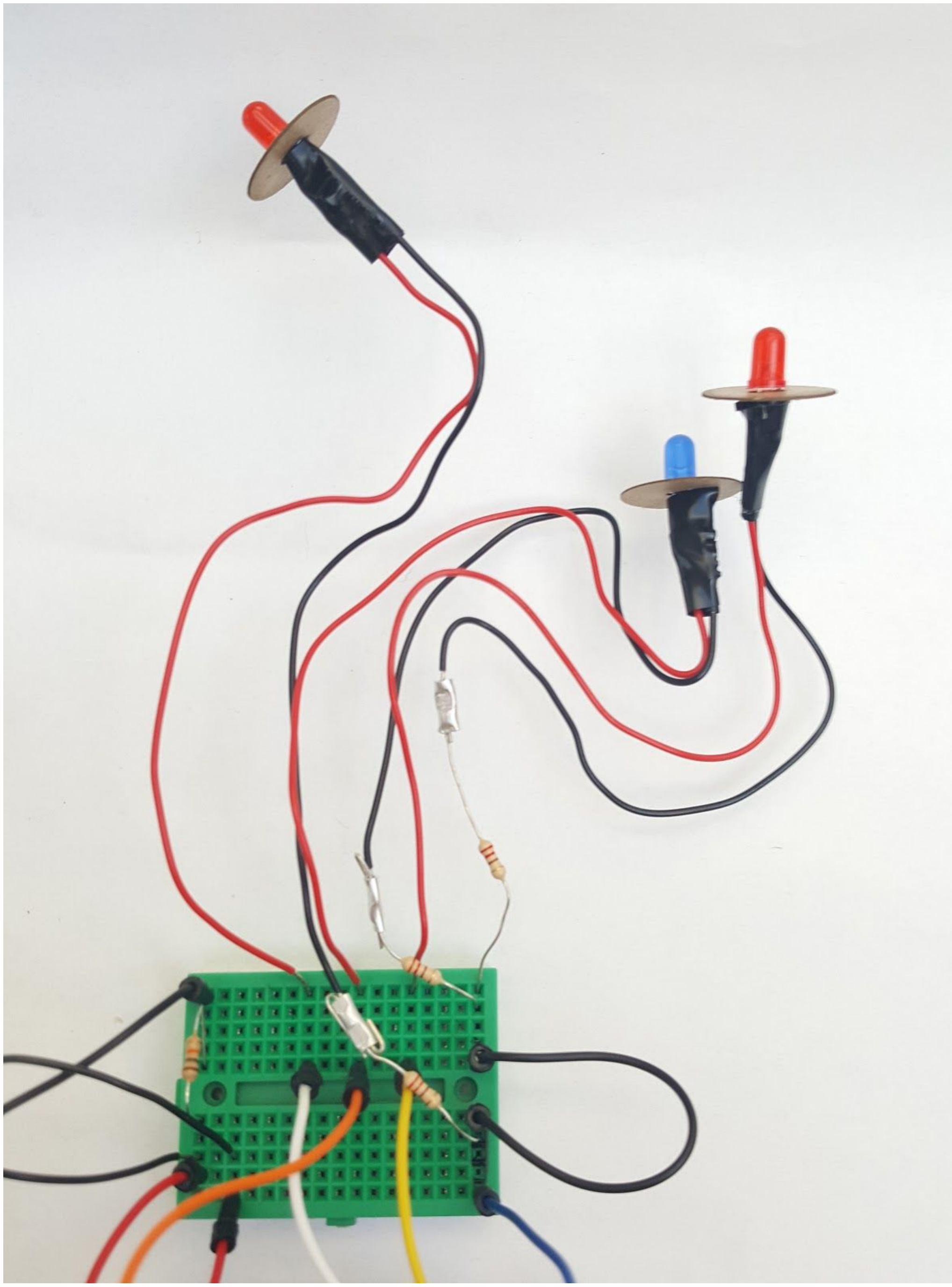
Classroom setup
Laptops, USB cables, arduino circuits, prototypes, building supplies.

1. **Explain**: Now prototypes have been built and LEDs and photoresistors incorporated, it's time to connect the wires to the Arduino and breadboard.

a. Use this image to help you connect your LEDs and photocell to the breadboard. The circuit will be the same, except that negative leg of the LED (with the resistor on it) can go straight to the ground bar.



b. Any additional LEDs will follow the same pattern: the positive leg connects to a ~ pin, and the resistored leg goes to the ground bar. **Make sure to insulate any exposed wire!** *Plug your LEDs into the Arduino in the order that you want them to turn on.*



   c. If you've tweaked your code at all, upload it now.

2. **Evolve**: Once you've built a prototype and connected it to an Arduino, test it. Does it function? Does it look good? How can the design be improved?

3. Clean up.

Session 27: Complete Prototypes

Classroom setup
Markers, journals, paint markers, yarn, sewing needles.

1. **Explain:** Create identity
    a. Add color and identity to prototypes using yarn, markers, and any other materials available.
    b. **Consider**: What world does your prototype exist in? Who is your creature and what is its relationship to other creatures?
2. **Build**! Finish prototypes and test to make sure they work.
3. Clean up.

Session 28: Prototype Fair!

Classroom setup
Prototypes, cameras or phone cameras, Mouse Create.

1. **Prototype fair!**
    a. Create a setting in which all students can come together and share what they've made with each other.
    a. Students should explain what their prototype is and demonstrate how it works.
    b. Encourage them to ask questions about each other's projects.
2. **Document** projects using a camera.
3. **Upload** images to Mouse Create.
    a. Describe your prototype. Who is this creature? How do they function?

Sessions 29-36: Evolved Creatures

Project Overview

Objectives
Bringing together everything you've learned to create something that synthesizes your knowledge.
Building imaginary evolved creatures that have unique characters and are part of a *biome.*
Designing ways for evolved creatures to respond and react to each other or their environment.

Project Details

Students will work together to design and build an evolved creature, using the tools and materials of their choosing.

Session 29: Introduction

Classroom setup
Synthesis Worksheets, Mouse Create, selected building materials.

1. **Reflect** on the skills you've learned from past prototypes. What was exciting?
2. **Explain** synthesis.
    a. In Synthesis, you will build a creature that's informed by all of the projects that you've made, but is totally new. You'll work together to design and build something that ***synthesizes*** your knowledge and expertise!
3. **Explain: Synthesis criteria**
    a. You can't make an existing creature. You can combine creatures that already exist *or* invent new creatures.
    b. You should build something new from scratch.
    c. You can combine two types of electronic components, form any area of the program. For example, LEDs and IR sensors, OR motors and photocells, OR…..
    d. Your evolved creature must ***interact*** with other creatures, humans, or objects somehow.
    e. You must be able to explain who your creature is and where it lives.
4. **Share** Synthesis Worksheet

    a. You can use the Synthesis worksheet to review all the materials you've used and skills you've learned. As a group, you can use this worksheet to help develop ideas about what you want to build.
5. Make a drawing!
6. **Build**!

Session 30-35: Build!

Classroom setup
Selected tools and materials.

1. Students will continue to build their synthesis projects. Test and improve!

Session 36: Prototype Fair

Classroom setup
Prototypes, cameras or phone cameras, Mouse Create.

1. **Prototype fair!**
    - **a.** Create a setting in which all students can come together and share what they've made with each other.
    - a. Students should explain what their prototype is and demonstrate how it works.
    - b. Encourage them to ask questions about each other's projects.
2. **Upload** images to Mouse Create.
    - a. Describe your prototype. Who is it?
    - b. Reflect on why you made the choices you did.

APPENDIX

Electronic Circuits

Introduction

Electricity is energy created by the movement of electrons through a circuit. *Electrons* are the part of atoms that make them stick together to form molecules. *Electricity* is a form of energy we get from the movement of electrons.

A battery contains two materials; one has too many electrons and the other has too few. This makes one side *positively charged* (+) and the other *negatively charged* (-). It's a force of nature for the electrons to seek equilibrium, so if we connect a path from + to - the electrons will flow through it and make electricity. The path from + to - is called a *circuit*.

A circuit is a pathway for electrons to move from a negatively charged material to a positively charged material. Circuits are designed to make electrons flow through electrical components to do some type of job, like emitting light or making sound, and absorb a specific amount of voltage in order to do this. The amount of voltage they need to function will be designated.

A circuit is made of *conductive* materials such as wire or copper that have a crystalline structure that allows electrons to easily move through them. Insulators, such as plastic, surround wires in order to keep electricity flowing only where we want it to. Conductors let electricity flow, and insulators resist it.

A *short circuit* happens when the pathway of the circuit bypasses the components it is meant to go through and circles back to the battery too soon. Because it didn't pass through the components in the circuit, it will have excess heat and could start a fire. Short circuits can be avoided by *insulating* exposed wires and conductive material with electrical tape or hot glue, and by avoiding stray wires that could create unwanted pathways for electricity to flow.

Typically, circuits are prototyped using breadboards and jumpers*,* which are tools for making temporary circuits and trying things out. Crimping tools can be used to create more permanent connections between conductive materials such as wire and the *terminals* on electrical *components*.

Electrical Signals and the Body
Beam projects typically only involve low voltages and low currents that are not dangerous. It is perfectly safe, for example, to touch the + and - poles of a battery with one hand. However, it is wise to avoid running electrical signals through the body and especially from one side of the body to the other.

Circuitry Tools and Materials

Crimpers and Crimp Tubes

Crimping is the practice of joining two or more pieces of metal or other ductile material by deforming one or both of them to hold the other. The bend or deformity is called the crimp. There is a locking mechanism on the crimp tool that engages if you don't compress the grips all the way down.

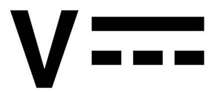
It is best to use the smallest crimper on the crimp tool, with the yellow dot on it.

You crimp using **crimp tubes.** When crimping, it may help to bend the wire tips to help hold them in place in the crimp tubes while you crimp and avoid getting fingers near the crimper.

Multimeter
Multimeters are prototyping tools that can be used to test circuits in various ways.

To test for *continuity* in a circuit or to see if an LED has burnt out, hold the metal probes to the circuit and set the multimeter to the *continuity* setting. It will beep to indicate if there is a connection between two points.

To test to see how much voltage is left on a battery, set to *2 Volts DC* and touch the probes to either side of the battery. The remaining voltage will be displayed on the screen of the multimeter. The DC voltage symbol is to the right.



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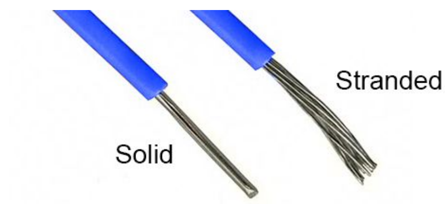
Wire Strippers are for stripping plastic coating away from wires before soldering. Match the gauge of the wire you're stripping with the correct numbered hole on the wire strippers. Wire strippers can also cut wire.

Pliers are for holding wires. They cannot be used to cut or strip wire. Less commonly used in electronics.

Wire is a conductive material, like copper, encased in an insulating material, like rubber or plastic. There are two types of wire: stranded and solid. Stranded wire is flexible and is good for moving parts, but solid wire is much easier to insert into small holes. The color of wire is for organizational purposes only.



A **battery** is a container that holds a negatively charged material and a positively charged material. Negatively charged means the material has too many electrons. Positively charged means the material has too few electrons. When the negative and positive poles of the battery are connected through a circuit, electrons flow until the system reaches equilibrium and the battery "dies."

Voltage is the force or pressure of electricity in a circuit, coming from a battery. Different parts of a circuit use up different amounts of voltage. Amperage or current is the volume or amount of electricity in a circuit. The current is the same everywhere in a circuit.

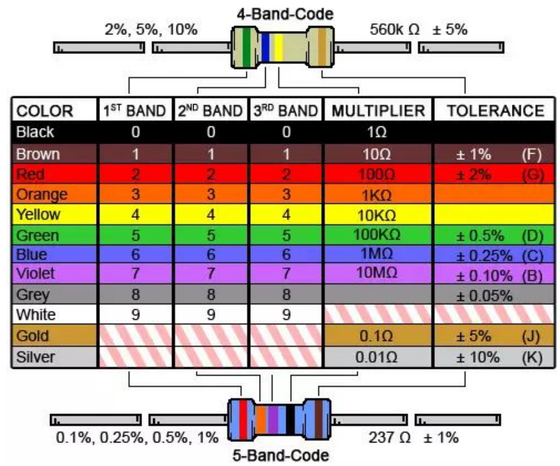
Projects will typically use either AA (1.5v) or coin cell (3v) batteries. Batteries are incorporated into circuits using their associated battery clips.

It is safest to store batteries in their packaging or with tape over one or both terminals. If the batteries short circuit while in storage, they will overheat and could start a fire.

Components

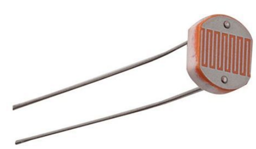
A **resistor** is a component that resists the flow of electricity and reduces the overall voltage of the circuit. Resistors are used to protect components in cases where the amount of voltage needed by a component is less than the amount stored in a battery. A resistor contains a very long piece of wound conductive material that dissipates electricity as heat.

Resistors are labeled with color bands that indicate their resistance as measured in Ohms. The first two bands indicate the first and second numbers of the value, and the third band indicates how many zeros follow the first two numbers. Typical electronics projects will use resistors between 220 Ohms and 10k Ohms. Ohm's Law can be used to determine what value of resistor should be used to protect a circuit when it is not given.

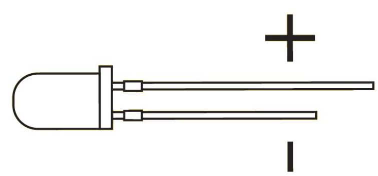


COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

A **photoresistor** is a form of variable resistor that restricts the flow of electricity in response to light.

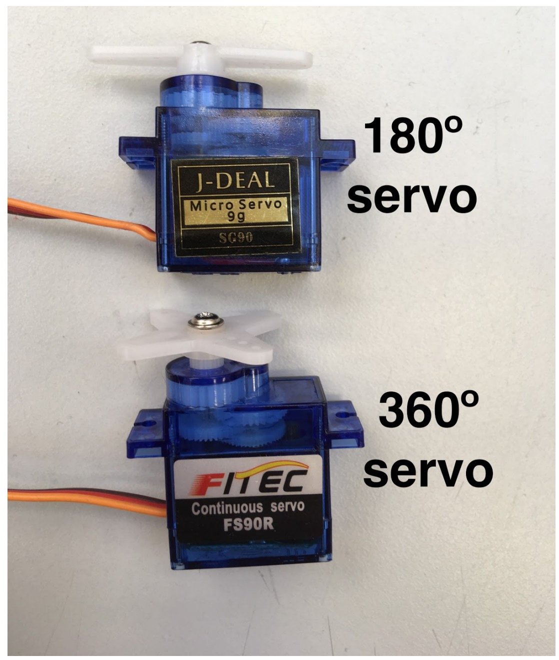


LED stands for Light Emitting Diode. A diode is an electrical component that controls the direction of the flow of electrons. Because of this, LEDs are *polarized* and have a positive and negative terminal. The negative terminal of the LED must be installed in a circuit facing toward the negative terminal of the battery, otherwise the LED won't emit any light and the circuit will not work.



The LED uses a small amount of electricity and emits it as light, typically between 2 and 4 volts. The LED can only handle a small amount of electricity, so if we're using a battery that has more than 3 volts, we need to add a resistor to absorb some of the excess or else it will burn out. When it burns out, a small piece of metal melts inside it. The entire circuit will stop working because electricity can no longer flow.

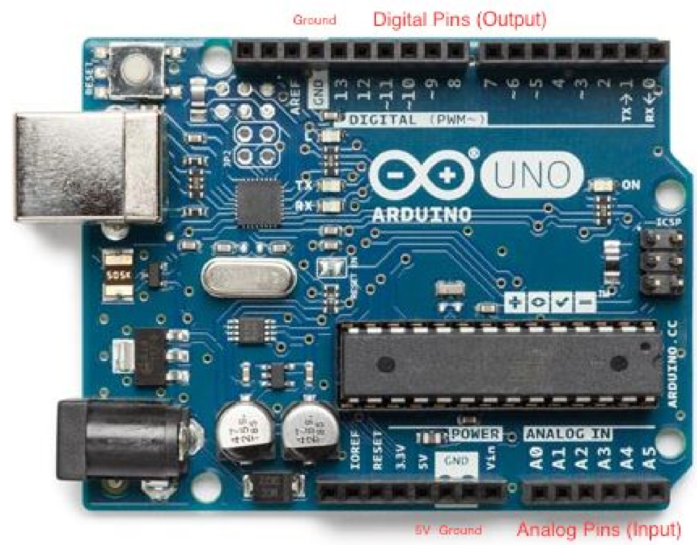
A servo motor is a motor that can be precisely controlled using an Arduino. Servos come in two types: 180° and *continuous,* or 360°. They look very similar and the stickers can be removed, so it may be helpful to label them with permanent markers.



The red wire is always power, the brown wire is always ground, and the yellow wire is always data.

It's recommended that you attach the servo heads to the motors using a mini screwdriver before building projects.

Physical Computing and Arduino Basics



What is physical computing?
Physical computing is the practice of controlling the behavior of electrical circuits using sensor-controlled computers and microcontrollers.

What is a computer?
A computer is a machine that physically organizes patterns of electricity to represent information. This information is measured in a unit named "bits." One bit is represented by a single electrical charge in the computer's processor microchip. For reference, 8 bits = 1 byte, and 8,000,000,000 bits = 1 gigabyte.

When we type on a computer, we are causing physical changes inside the computer's hardware. For example, typing a single letter in a plain text document creates 1 byte of information, which is represented by 8 electrical charges. If we type a second letter and save the file, the file size becomes 2 bytes. For every letter we type, more electrical switches are turned on inside the computer.

What is a microcontroller?
A microcontroller is like a tiny computer that has input and output pins that can be connected with an electronic circuit on a breadboard. We can control the circuit using real-world sources like sound, light, and temperature using sensors, which would be considered *inputs*.

Writing code
Arduinos control the behavior of electrical circuits using code. Code is a set of instructions written in language a computer can understand. For example, "turn this light on and off every second" or "turn this light on only when it's dark outside."

You use the Arduino IDE to create a *sketch* (a little block of computer code) that you upload to the arduino board through USB in order to tells the board what to do.

The programming language uses words and numbers to organize logical instructions for how our circuit will behave. The Arduino has a built-in program called an assembler that knows the Arduino language and translates our code into electronic behavior.

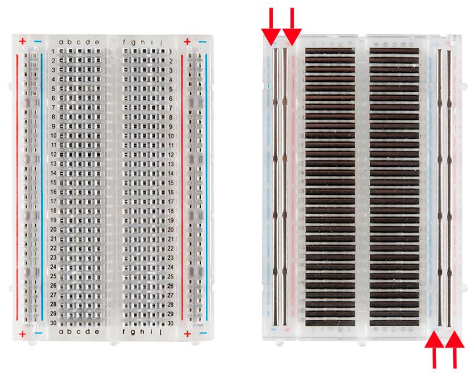
When something isn’t working in a program it’s called a bug. Finding, identifying and fixing the problem is called *debugging*. Grace Murray Hopper coined this phrase when she traced the cause of a malfunction in her computer to an actual moth that had gotten into the hardware. A bug may be a *syntax error* (a problem with how you wrote your code) or a *logic error* (a problem with the flow of your application).

Arduino Code Editing Software
There are two ways to write and send code to an Arduino:

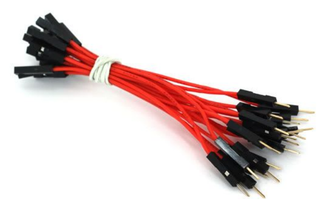
- Arduino Web Editor. Recommended because it saves your code online so you can access it from any computer. You must create an account and install the Arduino drivers. We recommend that you create an account with a simple password for each class to be shared by the students.
- Arduino IDE (Integrated Desktop Environment). This is a downloadable app that does the same thing as the Web Editor, but it does not save your code online.

Electronics and Coding Tools and Materials

Breadboard
Breadboards are another tool for prototyping circuits. They contain columns and rows of input pins that are used for connecting jumper wires and components. The photo on the right shows the conductive paths going along the two columns on either side and along the rows in the center of the breadboard.



Jumper cables
Jumper cables plug into arduinos and breadboards and can be used to prototype and make temporary circuits.



Sensors
A sensor is an electronic component that either varies its electrical resistance or generates a voltage based on physical conditions of the real world. For example a photoresistor varies its resistance based on exposure to light, and an IR sensor varies it's resistance when something is moving nearby.

In most Arduino circuits, you will be connecting a sensor into one of the Analog Input pins labeled A0-A5. The Analog Input pins measure voltage between 0V and 5V and translate that electricity into a number between 0 and 1023. We can use the

changes in those sensor readings to control
the behavior of our circuit.

Fabrication Tools

Cardboard cutters are for cutting cardboard only. They can cut skin, so use them with care.

Cardboard perforators can be used to score cardboard without cutting all the way through.

Spring clamps can be used to hold cardboard in place while cutting with cardboard cutters. Make sure to clamp so the area you're cutting is *off* the table. Two clamps are better than one.

Hot glue guns are useful for quickly joining pieces of wood together, or for joining wood, plastic, and other materials.

- Glue guns are made of plastic and look like a toy, but they are actually serious tools.
- Glue guns tips can cause burns.

- Hot glue remains hot for several seconds after application.
- Glue guns must be unplugged after use.

Long Reach Hole Punch can punch holes in paper, cardboard, popsicle sticks, and many other materials. There are multiple settings on the top, but you will only really need to use the 3/16” setting. You can change the settings by moving the turquoise button. There is a moveable measuring tool on the bottom of the hole punch if you want to be more precise.

Staple pliers can be used to staple paper, foam, cardboard, and felt. They require a specific kind of staple, which can be loaded from the top by pulling the “tail” on the back of the handle. They get jammed sometimes - use pliers to pull the staples out of them.