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Introduction

This document contains activities and other resources for use with the Festo Bionics Kit. These activities should be completed after you or your instructor know how to assemble the three bionics-inspired robots you can make with the Kit (Fish, Elephant gripper, Chameleon tongue).

Most of these activities require that one of the Bionic robots are assembled. Your instructor will help you with putting together the Bionic robots when they are needed.

Instructor note: Throughout this guide, you will find notes outlined in red (similar to this one) that contain information for instructors. These notes contain additional information, guidance, or instructions not found in the regular Student Activities document.

This guide also contains answers for any questions posed throughout the activities. These answers will appear as red text.

In most instances, younger students will need assistance with the assembly of the robots. You may choose to demonstrate the assembly and operation of the robots to the class yourself if you think that method would work best.

Students, especially younger students, may need guidance as they work through the activities. As the instructor, you may need to take the lead with the activities and work through the activities as a group. This can help to ensure that the students comprehend the activities and concepts presented, and that if they run into problems, you can be of assistance.

With the exception of the Bionics Process activity, the activities in this document require one of the fully assembled Bionic robots in order to complete them. Refer to the bionics4education.com website for instructions on how to assemble and operate the three robots. Purchasing information for the Bionics Kits are also available on the site.
Bionics process

There is so much valuable information that humans can gain from studying nature and how different species of animals have evolved and adapted to their environments. So many different species of animals, over the course of millions of years, have developed characteristics and physical designs to help them thrive in their environments. These natural designs can be fascinating, and they can also be studied by humans to see if there is anything we can learn from them and use ourselves.

Bionics is the branch of science that studies these aspects of nature and how humans can use them. There are many ways that we can study living things and use them to solve problems we have.

How to think like a bionics engineer

Bionics engineers try to find "natural solutions" to problems that humans have or look to nature to try to find ways that humans can do something better. They then develop these solutions by designing machines or machinery that can do what nature does so well.

There are two ways to think like a bionics engineer and try to come up with a bionics solution. The first way is where "engineers look to biology":

Engineers look to biology: This approach begins by trying to think of a problem that humans have. Once that problem is identified, then the engineers look to nature to see if there's anything out there that solves this problem.

For example, look at the Bionic Chameleon tongue. If this was developed using the "engineers look to biology" approach, the engineers would first identify a problem; maybe the problem is "how can we make a machine that picks up objects that are difficult to grasp?". They would then look to nature to see if there's a solution to that problem. They could look at a chameleon and see that its tongue allows it to grab things that are oddly shaped. They can then design a machine gripper that works in a similar way as a chameleon tongue and solves the original problem.

The second way is "biology looks to engineers":

Biology looks to engineers: This approach is like a reversal of the first approach that was discussed. Here, we start by looking at things in nature and seeing if there's anything we can learn and use ourselves. We look at natural designs first instead of identifying a problem first.

Using this approach, we would first look at a chameleon in nature and the design of its tongue. Then we would see that the chameleon is able to grasp objects that are oddly shaped. We could then ask the question "How can humans use this?". The design of the chameleon's tongue can be used as a model to design a machine gripper that could pick up oddly shaped objects. So with this approach, we started by looking to nature instead of identifying a problem first, but still found a similar natural solution at the end.

Bionics project

For this activity, you will come up with your own ideas for a bionics solution using either of the two approaches that we discussed. Your solution should be based on a natural design (something that already exists in nature), and should solve some sort of problem humans have, or should make something humans do easier or more effective.

Your instructor will either split you up into separate groups to each work on a bionics solution, or your instructor might lead the entire class in working together to come up with a bionics solution.

Instructor note: Decide whether splitting the students up into separate groups or leading the project yourself while working together as a class will work best. This decision should be based on the size of the class and the age of the students. For younger students, it is probably best to take the lead yourself and help them through the steps of the process and the development of their ideas.
**Teamwork**

Working together in teams can help people come up with better ideas and help them achieve goals. For bionics solutions, people working together can help to explore all of the possibilities that exist in nature.

Therefore, you should work in small groups or together as a class to develop your bionics solution. Multiple minds working together to come up with ideas is likely to be much more effective than individuals working alone.

Whether you work in small groups or together as a class, everyone should contribute their ideas and thoughts to the bionics solution. It is important for everyone to cooperate and communicate with each other throughout the project.

**Brainstorming**

Brainstorming can be very helpful as a starting point when attempting to come up with an idea or concept. The main goal for brainstorming is trying to come up with as many ideas as possible, then afterwards you can narrow them down or select the ideas that may work best. Some questions to ask yourself or work through with your group are listed below. Answering these questions could help to develop ideas for your bionics solution.

**Brainstorming questions:**

**Approach 1:** Start thinking about animals that have characteristics that you think are interesting or effective. What do these characteristics let the animal do or achieve?

Once you identify what the animal does with these characteristics, try answering questions like: How does the animal do or achieve these things? Can we design a machine that mimics these characteristics? Are there any problems that this could help solve for humans?

**Approach 2:** Or you can take the opposite approach: first try to think of a problem that humans have or something that humans have trouble doing. Are there examples in nature where natural design has solved this problem?

How can these natural examples be used by humans to help them solve problems?
Notes and organization:
You can use the table on this page to help organize your group’s ideas and take notes. Once your group is finished brainstorming ideas, decide as a group which of the ideas you want to use and move forward with.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Natural design</th>
<th>Human use</th>
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Presentation of your solution
Once your group has developed your bionics solution, the final step is to present your work. If you worked in individual groups, you can explain what your group came up with, what animal or example for nature you used to design your solution, and how humans can use your solution to solve problems.

If you worked as a class with your instructor, your instructor can summarize the solution that everyone came up with and you can discuss all of the different aspects of it together.
Instructor note: This activity requires a fully assembled Bionic Fish. It is also suggested to have a tank filled with enough water to buoy the Fish.

Different types of fish move in different ways, and there are three general types of fish motion. Even though the types of motion are different, they all allow a fish to move effectively through the water.

**Eel**

The first example of a fish that uses a specific type of motion is an eel. An eel uses what is called anguilliform motion, where it moves all of its body, from the head down to the tail. The flexibility of an eel's body allows it to move this way.

![Eel](image1)

**Tuna**

The second example is a tuna. A tuna uses a type of motion called thunniform swimming. Fish that use this type of motion move only their tail to propel themselves forward through the water.

![Tuna](image2)

**Mackerel**

The third example is a mackerel. A mackerel uses carangiform motion to swim. A mackerel will move its head slightly while swimming, but most of the motion is generated by the tail. You can think of this type of movement as in between the movements of the eel and the tuna. This is the motion that is used by most fish.

![Mackerel](image3)
The Bionic Fish is based on the design and movement of a real fish. Observe how the Bionic Fish moves through water and how it is shaped and put together. Can you identify what type of the three real-life fish motions it uses? What type of fish would you say the Bionic Fish most-closely resembles? Explain your answer.

Movement of the Bionic Fish

Students should identify that the construction and movement of the Bionic Fish most-closely resembles that of a tuna. The Bionic Fish is propelled only by its tail, and its head is not involved in the motion of the Fish.
Instructor note: This activity requires a fully assembled Bionic Chameleon and objects of various shapes and sizes that the Chameleon gripper could feasibly pick up.

The stretchiness of a chameleon’s tongue allows it to form to the shape and size of the object it is trying to grab. For example, when the tongue is about to reach an insect the chameleon is trying to eat, the tip of the tongue moves inward and the outside of the tongue move outward. This lets the chameleon’s tongue surround the target and grab hold of it.

The Bionic Chameleon gripper works the same way, where the center of the tip moves inward when grabbing an object, while the outside of the tip outwardly surrounds the object.

One of the notable characteristics of the Bionic Chameleon gripper is the material on its surface. It helps to maintain friction with the objects it picks up.
Your Bionic Chameleon gripper is designed to pick up objects that other types of mechanical grippers would not be able to. Experiment with the gripper by trying to pick up a variety of objects. You can use the table below to keep track of the type of objects you try to pick up, to track the characteristics of the objects, and to take notes on whether you were successful in picking up that object.

<table>
<thead>
<tr>
<th>Object</th>
<th>Object characteristics</th>
<th>Successful pickup? (yes/no)</th>
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Observations and analysis

What objects was the chameleon gripper able to pick up? Did these objects have anything in common in terms of what type of objects they were, their shape, or the material they were made of?

Answers will vary depending on what objects are used. Students should be able to find certain common characteristics with certain objects and identify them here.

Were there any objects that the chameleon gripper failed to pick up? What do you think prevented the gripper from successfully picking up these objects?

Answers will vary depending on what objects are used. Students should be able to find certain characteristics that prevented these items from being picked up, which possibly contrast with the characteristics of the items that were successfully picked up.

What types and shapes of objects was the chameleon gripper able to pick up that other more rigid and less flexible types of grippers would not be able to?

Answers will vary depending on what objects are used. The answers to this question can build off of the answers to the first question regarding the characteristics of the successfully picked-up objects.

Did you attempt to pick up anything that was fragile? How did the chameleon gripper’s design allow for a gentler grip on objects?

Answers will vary depending on what objects are used. The students could explain how the gripper surrounds the objects rather than squeezing or pinching them, and that allows for the gripper to pick up objects that are fragile.
Instructor note: This activity requires a fully assembled Bionic Fish and a tank of a sizeable length filled with enough water to buoy the Fish.

Most boats and ships are designed to move through the water by resisting as much unsteady motion as possible. This makes for smoother movement through the water, but it also requires a good amount of energy.

Fish have a much more efficient way of moving through the water. Instead of resisting the natural unsteadiness of moving water, fish embrace this unsteady movement and move their bodies with it. This movement of fish requires much less energy compared to the way boats attempt to resist the unsteady movements.

Fish are still able to move very well in the water even though they don't use a lot of energy to do it. The main reason fish are able to swim so well is the natural design of their tails. The tails push water in the opposite direction in order to generate thrust and move the fish forward.

These pictures show a fish tail’s movement in water. Just like a propeller on a boat generates a jet of water behind it to move it forward, a fish tail’s movement also generates a jet that moves it forward. The illustrations below represent the movement of a fish tail to propel it forward.

Step 1: Tail moves inward in one direction.

Step 2: Tail starts to move in the opposite direction.

Step 3: As the tail continues to move in that direction, a vortex starts to form behind it.

Step 4: Tail again moves in the opposite direction, forming more vortices and starts to propel the fish forward.
Step 5: Tail movement continues, with orderly vortices forming behind the fish to achieve propulsion through the water.

In order to propel itself forward in the water, a fish must overcome the drag on its body. To do so, it needs to push water in the opposite direction of its body. The movement of the fish in the steps above show that vortices (plural of "vortex") are shed from the tail. The formation of these vortices is what allows the water to be pushed away from the fish and allows it to move forward.

A vortex can be defined as a mass of swirling flow. The vortices that a fish generates and sheds behind it are actually very consistent. And because they are so consistent, a jet of water forms behind the fish from these vortices. This jet works much like a jet of water that the propeller from a boat would produce.

**Tail swing and speed experiment**

The way a fish tail moves allows a fish to move quickly and efficiently through water. The tail propels the fish as it moves back and forth. With the Bionic Fish, you have the ability to control both the speed of the tail and the size of the tail’s swing. Experiment with 5 different speed settings and 5 different swing sizes, and determine if this has any visible effect on how fast the Bionic Fish moves through the water. Use the table below to keep track of your results and notes.

<table>
<thead>
<tr>
<th>Swing size 1 (small)</th>
<th>Swing size 2</th>
<th>Swing size 3</th>
<th>Swing size 4</th>
<th>Swing size 5 (big)</th>
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<tbody>
<tr>
<td>Tail speed 1 (slow)</td>
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<td>Tail speed 2</td>
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<td>Tail speed 3</td>
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<td>Tail speed 4</td>
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<tr>
<td>Tail speed 5 (fast)</td>
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</table>

**Analysis and conclusions**

Based on your results, what effects do the tail speed and the tail swing size have on how fast the fish is able to move through the water?

Students should draw their conclusions based on how fast the perceived speed of the fish was under the differing conditions. They optimally should explain the conditions under which the fish moved slowest and fastest (e.g., fastest tail speed and biggest swing size), and touch upon how the tail speed and swing size ultimately affected how fast the fish was moving.
Elephant trunk activity

**Instructor note:** This activity requires a fully assembled Bionic Elephant trunk and objects of various shapes, sizes, weights, and materials.

The trunk of an elephant is fascinating for many reasons. The trunk is very unique, especially the way an elephant is able to move it. It is sensitive but also strong. An elephant can bend and stretch it to reach things above its head, so high that it can even reach things the elephant can't see. The trunk allows elephants to access food that is out of the reach of many other animals that share their habitats.

Not only is it amazing how far elephants are able to reach with their trunks, the way the elephant is able to pick items up is also very impressive. The tip of the trunk functions much like a "hand". The trunk tip is very sensitive (it contains a lot of nerves) and it is very dexterous (this means that the trunk tip is very skillful and can pick up objects very delicately).

Different types of elephants have slightly different trunk tip shapes. For example, the Asian elephant has one "finger" at the upper half of the tip of its trunk. If an Asian elephant wants to pick something up, it usually "grasps" the object by curling the object under and around the tip. The African elephant has two "fingers" on the tip of its trunk. Think of it like a thumb and index finger on a human hand. This allows the African elephant to "pinch" objects they want to pick up, holding the object between the two "fingers".

Look at the characteristics of the Bionic Elephant trunk and use the trunk to try to pick up an object. Does the design of the Bionic Elephant's trunk tip most closely resemble an Asian elephant's trunk tip or an African elephant's trunk tip? What method does the Bionic Elephant trunk use to pick up objects?

Students should identify that the Bionic Elephant trunk resembles the African elephant trunk more closely, because the Bionic Elephant has two "fingers". Therefore, the students should also identify that the Bionic Elephant uses the "pinch" method to pick up objects.
Scientists have studied how real elephants are able to pick up and carry objects of different shapes, sizes, and weights. Elephants are able to bend their trunks in a way that allows them to support the weight of an object while pointing the tip of their trunk downwards to better grip it and pick it up. Elephants can adjust the amount of downward pressure they apply in order to pick up more delicate objects.

Your Bionic Elephant gripper is designed to mimic the functionality of a real elephant trunk, where you can pick up objects of different shapes and sizes, and even items that are delicate (without breaking them). Experiment with the gripper by trying to pick up a variety of objects. You can use the table below to keep track of the type of objects you try to pick up, the characteristics of the objects, and a section to take notes on whether you were successful at picking up that object.

<table>
<thead>
<tr>
<th>Object</th>
<th>Object characteristics</th>
<th>Notes</th>
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Observations and analysis

Once you have picked up a number of objects, analyze your results. Are there similarities between the objects that the gripper was successful in picking up? What about any similarities you can find between objects that the gripper could not pick up?

Answers will vary depending on what objects are used. Students should be able to find common characteristics between certain objects and identify them here. They should also identify common characteristics between objects that the Bionic Elephant could not pick up.

What kind of objects do you think the design of the gripper allows you to pick up that other gripper design may not be able to?

Answers can vary here depending on what objects were used and whether the students have seen the industrial version of this gripper being used in the videos on the website, etc. Possible answers can include fragile objects since the design allows it to more gently grip objects, round objects, spherical objects, etc.