Explore Biomimcry

■ Student Activity: Take the Plunge
■ Student Activity: Biomimicry Provides Models
■ Student Activity: Sea Gliders
■ Post Informational Graphic: Scarlet Knight — First Glider to Cross the Atlantic
■ Student Activity: Design Challenge
■ Student Activity: Design Challenge Notes
et ready to build a sea glider using simple components such as a water bottle, syringe and weights. Using some electronics and a little programming, students can watch their glider “fly” through the water on its wings. Using buoyancy to glide through the water, very little power is used to cover a large distance.

Marine biology educator Lisa Lyle Wu has written the background information, activities and teacher notes found in this resource guide. Whether students are taking a plunge at neutral buoyancy, exploring biomimicry or accepting a design challenge, they can get started with the illustrated text.

ABOUT LISA WU: Lisa Lyle Wu currently teaches marine biology and is the lab director for the Oceanography/Geophysical Systems Lab at the Thomas Jefferson High School for Science and Technology. As a freelance science writer she has developed curricular materials for Discovery Channel and worked on exhibit development for the Smithsonian Institution’s National Museum of Natural History. She was a volunteer diver at the National Aquarium in Baltimore for ten years and served as Teacher at Sea for NOAA and is a member of the Corps of Exploration for the E/V Nautilus. Each year she takes students to study in, on, or under the sea surrounding Maryland’s eastern shore, the Bahamas, Florida Keys, Galapagos Islands, Bermuda and, most recently, Indonesia. She lives in Arlington, Virginia, with her husband and son.
Autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) are unmanned submersibles used to explore aquatic environments. ROVs are controlled by an operator who sits aboard a ship or on a dock and controls the vehicle by sending electrical signals through a cable. These cables are referred to as a tether. The depth, direction, and, sometimes, data are controlled by the operator. ROVs may carry multiple instruments on board, such as sensors to collect water-chemistry data, manipulators to collect samples, and cameras and sonar to gather images.

Autonomous Underwater Vehicles (AUVs) are untethered to an operator. Two types of AUVs include those that are battery operated and propeller-driven and those that are battery operated and buoyancy-driven. Both tend to be smaller and slower than ROVs and send their data remotely through satellite telemetry by surfacing periodically. These technologies allow scientists to explore and probe the oceans safely for scientific knowledge.

Exploration leads to a greater understanding of ocean health, human health, energy and climate change. Full-scale underwater gliders deploy for months at a time to collect valuable data about the world’s oceans. This data leads not only to solutions but also brings up more questions for research in this vastly unknown region of our planet.

Whether manned or unmanned, any submersible has to be able to move through water which exerts tremendous pressure because it is heavy. Gravity is the force pulling water to the center of the Earth. This means water has mass. One liter of water weighs 1 kg. (A 5-gallon bucket of fresh water weighs about 40 pounds!) One of the rules of building submersibles is that they have to be able to float before they are ballasted. Ballast refers to the weight that is needed to make the vehicle sink to depth. Vehicles should be able to make a controlled descent and ascent in the water column. Advanced gliders are constructed with enough buoyancy so that they will float up to the surface after they drop their ballast.
Greek mathematician Archimedes discovered how a submersible dives and surfaces. Archimedes’ Principle states that any object wholly or partially submerged in a liquid is buoyed up by a force equal to the weight of liquid displaced. Negatively buoyant describes a sinking condition. And positively buoyant describes floating. Thrusters (motors with propellers), ballast tanks, gravity and shape can adjust the buoyancy of an object in water. Buoyancy is a positive force.

Bathyspheres, diving bells and hard-hat diving suits were early inventions designed to explore, salvage and work under water.

For this activity, you will construct a simple diving bell that connects to the surface by an airhose. The mission is to see if neutral buoyancy can be achieved by adjusting the amount of air in the bell. Neutral buoyancy is when there is an equal tendency to float as there is to sink. When neutral buoyancy is achieved, the diving bell will hover in mid water.

**Construction Procedure**

1. Take one end of the string and tie it around the weight. Take the other end of the string and tie it around the open end of the bottle or small canister. Leave approximately 25 mm (1 inch) directly below the center of the opening.
2. Insert one end of the tubing into the container opening all the way to the bottom of the container. Bend the tubing where it exits the container, taping it to the outside of the bottle.
3. Cut 50 mm (2 inches) off the end of the tubing and attach this short piece of tubing to the aquarium pump.
4. Connect the middle opening of the three-way valve to the other end of the short tubing. This is valve #1.
5. Connect the long piece of aquarium tubing to the same two-way valve.
6. Cut a 25 mm (1 inch) piece of tubing and connect to the last opening of the three-way valve.
7. Attach the two-way valve to this piece of tubing. This is valve #2.
8. To sink the bell, close valve #1 and open valve #2.
9. To raise the diving bell, open valve #1 and close valve #2.
10. Now try to hover the bell. The key is to let just enough water into the diving bell to make it neutrally buoyant; then close valves #1 and #2. The bell should hover in mid water.
11. When you have accomplished hovering in mid water, try to get the bell to hover at different depths.
TEACHER NOTES

Building gliders and ROVs allows for an authentic application of math, physics, oceanography, electronics, engineering, and applied technology. Communication, teamwork, critical thinking, resource and time management are essential components of these projects.

This activity was adapted from Build Your Own Underwater Robot and Other Wet Projects.

FOR FURTHER READING

Underwater Robotics: Science, Design & Fabrication
Paperback – 2010
Steven W. Moore, Harry Bohm, Vickie Jensen

Build Your Own Underwater Robot and Other Wet Projects
January, 1997
Harry Bohm

www.seaperch.org
SeaPerch
Complete your SeaPerch underwater robot, and learn how to start a SeaPerch program in your classroom or after-school program. Information for competitions and teacher resources.

http://www.seaglide.net/
SeaGlide
The miniature underwater glider moves by changing its buoyancy, taking in or expelling water. This change in buoyancy causes the glider to rise and sink in the water. As the glider travels up and down, its wings generate lift, which propels the glider forward.

http://ocean.si.edu/ocean-photos/scarlet-knight-showcased-smithsonian
Ocean Portal
The Scarlet Knight, as the glider is called, made nautical history as the first submersible glider to successfully cross the Atlantic Ocean. With no propellers these gliders move forward in the ocean by rising and falling with changes in their buoyancy. Every eight hours the glider surfaced to check its GPS position and send back data. E-mails from technicians in a control room at Rutgers University guided the craft toward Spain.
Can spider silk be turned into bulletproof fabric? Can the photosynthetic process that takes place inside a plant lead to chemically-based solar cells? Is the bonding of shellfish to surfaces in the intertidal zone a superior adhesive in wet environments?

The answer is yes.

Humans have for ages been inspired by nature to create objects and products. Although historically there are countless examples of bio-inspired materials, our modern technology provides a window to both chemically and physically analyzing materials in ways never before possible.

A recognized need to use sustainable materials, more efficient energy and creative design in our modern world has led to the field of biomimicry. Technology allows us not only to look to nature as a model, a standard of measure, and a mentor, but also to imitate the products of nature and nature’s materials and processes, according to scientist and author Janine Benyus who popularized the term.

**Biomimicry in Sponges**

The deep sea sponge is called the “Venus flower basket” as a reference to artwork depicting the Roman goddess Venus holding a cornucopia full of flowers. A filter feeding animal, it is attached to hard substrates in the deep sea and has a skeleton made of silica – a major element of glass. The skeletal structures, called spicules, protect the sponge from predators and form a unique latticework for structure and support. The live organism is covered with a thin layer of living cells that...
creates a current, drawing water through the sponge for feeding.

But it is only in examining their structure in terms of millionths and billionths of a meter that you can really understand how they are put together. The scanning electron microscope or SEM allows a view into this unique structure. According to research published by the American Academy of Arts and Sciences, these glass structures have seven levels of structural organization, many imitated in mechanical engineering.

This glass is actually silica with fiber-reinforced cements, bundled beams and diagonal beams running at 45-degree angles to reinforce structural columns. This is more complex than a simple glass rod made of silica and is similar to principles used by engineers and architects in the building of modern skyscrapers. This layering of materials in the sponge, allows for gaps to be filled providing flexibility to withstand deep water currents.

Sponges – simple multicellular animals—but nature has cleverly used just what is necessary to design one of the most complex skeletons in the animal kingdom.

**Biomimicry in Whales**
The humpback whale is one of the largest creatures in the ocean, yet it moves with surprising alacrity through the water. As some researchers have found, this is due to the uniquely placed tubercles on the leading edge of the whale’s flipper. These large bumps have been shown to provide a 32% reduction in drag, 8% improvement in lift, and a 40% increase in angle of attack over smooth flippers. The tubercles are able to do this by allowing for a more concentrated flow of water rather than the dispersed flow created by smoother flippers. This in turn allows the humpback whales to have a better “grip” on the water, providing for greater maneuverability at low speeds which allow it to properly catch its prey. These biological advantages for the whale have potential for applications in wind power and submersible research.
BIOMIMCRY STUDENT PROJECT

Sea Gliders

Sea gliders, a type of Autonomous Underwater Vehicle (AUV), may improve performance from whale research. AUVs like the Slocum glider have been widely used in the past few years as a relatively inexpensive, safe and efficient way to collect data.

Inspired by this design, high school students at Thomas Jefferson High School for Science and Technology (Alexandria, VA) decided to build a glider in which they copied the fin design of the humpback whale. Using SeaGlide (www.seaglide.net) instructions as a guide, two gliders were built.

One glider had straight, smooth fins and the other glider’s fins were modeled on the humpback whale. In constructing both a smooth edged and tubercled set of wings, the speeds and distance traversed by the gliders in water could be compared to determine which was the more efficient design. To make the wings, a Computer Aided Design (CAD) program was used.

Frontal view of a humpback whale 3D math model drawn on a computer.

Side view of a humpback whale flipper with tubercles scaled on the computer to fit the glider.

The glider above features 3-D printed wings with tubercles. Circuitry is stored inside, with a buoyancy engine that controls water flow from the surrounding environment.

ALL PHOTOS BY LISA WU
Testing our glider in an 8x3x4-foot tank holding 720 gallons of water.

The submersibles were tested for changes in lift, drag co-efficient, and speed using each set of wings. The glider was placed in a tank and allowed to run autonomously through the water. The speed, position, and distance traveled per pump were recorded using a Vernier physics app designed for object tracking.

The picture above shows the early stages of AUV construction, involving soldering the electrical components onto the circuit board.

The circuit board and Pro Mini were attached to the exterior of the syringe, using a popsicle stick for stabilization. The component was bent at an angle in order to accommodate the compact design of the water bottle.

The image above illustrates how the syringe was connected to the lid of the bottle. Students secured it with a zip tie and waterproofed the connections using marine epoxy.

After attaching the syringe to the lid of the bottle, the components were placed inside the water bottle.
TEACHER NOTES

Detailed instructions and materials can be found using the Seaglide website for building the glider in a bottle. The basic glider provides for an autonomous system application of buoyancy and mass movement to propel diving and surfacing as well as forward movement using streamlined shapes (marine animal shapes and fins), surface treatment (microscopic “riblets” and soft adaptive surfaces), and various means of propulsion (wings and buoyancy engines, propellers, oscillatory fin movement). When equipped with other sensors, gliders can enable affordable collection of physical and biological information and do so more affordably than crewed expeditions aboard ships.

With remote communications capability, information including imagery can be sent back to shore or through the Internet to ship or shore-based laboratories or web-based control sites with minimal resources. Individual gliders can be tailored to study a particular research area, such as for collection of physical parameters in the Chesapeake Bay or estuaries and rivers, comparing methods of locomotion such as comparing propellers and fish-like swimming motions, or studying the hydrodynamics of body shapes and skin surface treatments, as well as autonomous system design. This activity is adapted from Philip A. Reed PhD, who wrote “A Paradigm Shift: Biomimicry,” an article about the paradigm shift in the way we view and interact with the natural world. Biomimicry, one way we use nature as inspiration in design, is an excellent example of the interdisciplinary nature of science and technology. (The Technology Teacher; Dec 2003/Jan 2004; 63,4 ProQuest Central pg.23)

You may find Biomimicry Global Design Challenge (http://biomimicry.org/) a helpful resource.

Teachers could ask students to consider the following:
1. What is your hypothesis?
2. Many marine animals, including seals, dolphins and whales use gliding to conserve energy allowing them to make longer, deeper dives. At depth, the bodies and lungs of these mammals compress and become negatively buoyant. They can rest while gliding downwards for extended periods and then swim to ascend. Is there another animal that you would use to model your wings (fins)? Explain.
3. Have you considered the tailfin?
SCARLET KNIGHT—FIRST GLIDER TO CROSS THE ATLANTIC

The barnacle-laden yellow tube Rutgers researchers pulled out of the Atlantic off the coast of Spain earlier this month may represent a sea change in the way we learn about the planet. The unmanned, information-gathering Scarlet Knight “flew” through the water without a propeller, becoming the first glider to cross the Atlantic. Scientists envision fleets of these unmanned gliders someday patrolling waters around the globe and reporting the state of the undersea environment.

How is it steered?
The glider phones home at set intervals (usually every six hours) using via a satellite modem in its tail. Because it relies on GPS for its location, it has to surface to see if it’s headed in the right direction. That’s when it sends data and uploads new instructions from pilots.

What does it tell us? Because Scarlet Knight’s primary goal was to get across the Atlantic rather than collect mounds of data, it carried streamlined equipment and measured only the water’s temperature, salinity and depth. But gliders can be programmed to gather all sorts of aquatic information, which eventually could help answer critical questions about global concerns such as fish stocks and climate change.

How does it fly?
1. When the glider is at or near the surface, a small battery-powered pump pulls about a cup of water in through a hole in its nose.
2. As this small shift in weight makes the glider dive, the wings propel it forward.
3. If the dive is too steep, a motor can shift the battery forward or backward to alter the glider’s center of gravity.
4. At a predetermined depth, the pump expels the water, the nose rises, and the glider ascends.

BONNIE BERKOWITZ AND PATTERSON CLARK / THE WASHINGTON POST
Be Inspired — Design for the Future

Look around you.
Almost everything you see around you that is not part of the natural world has been designed by engineers. The pencil sharpener, the tape dispenser, the stapler, the fire alarm, the bicycle you rode to school, the cell phone in your backpack and, of course, the apps on the phone. According to the American Society for Engineering Education website, engineering is the use of science and mathematics to solve problems to improve the world around us.

Scientists look at the world that exists and discover knowledge by investigating the unknown. Engineers make things, sometimes creating things that are new and have never existed before. Engineers tend to work in teams and follow what is called the design process.

Using the American Society for Engineering Education (ASEE) definition, there are six steps in the process. According to this process, you must 1) state the problem, 2) generate ideas, 3) choose the best solution, 4) create a prototype or object, 5) test, evaluate and improve it, 6) present the results and final solution. The engineers may repeat these steps multiple times until a good solution is achieved. Sometimes the design process is called the “design cycle” or “design loop.”

The design process is thought of as a cycle. You could start or stop at any of the steps. If you visit Rice University’s Institute of Biosciences and Bioengineering you will see white boards on all the walls – even in the elevator! Why? To facilitate that “a ha” moment when an idea comes to light, whether alone or chatting with a colleague to solve a problem, there is always a wall close by for sketching out a plan or making notes.

Consider energy, architecture, transportation, agriculture, medicine, communication. What do these topics have in common? Within these areas challenges confront modern society. In this activity, you are going to use the design process to brainstorm a problem and come up with a possible solution.

Any ideas?
When engineers use examples from the natural world to influence their design, we call this biomimicry. In working through your problem you will become familiar with the Biomimicry Institute. Visit http://biomimicry.org and click on Biomimicry 101. Although human engineers use their in-depth knowledge of science and math to solve problems, you will see that solutions to many problems have been solved by nature’s engineers — bacteria, animals and plants.

In Biomimicry 101 click on What is Biomimicry? Read through the section and watch the short video. Next select Biomimicry Examples. There are six examples: energy, architecture, transportation, agriculture, medicine, communication. You will find inspiration and ideas and find yourself saying “Why didn’t I think of that?”

In addition, you will learn about the new design challenge http://challenge.biomimicry.org/. Let’s see where your imagination takes you.

“I think the biggest innovations of the 21st century will be at the intersection of biology and technology. A new era is beginning.” — Steve Jobs
Design Challenge

Part 1  Examine the Design Process
1. Divide into groups by selecting a topic of interest. The topics are energy, architecture, transportation, agriculture, medicine and communication.
2. Go to the Biomimicry Institute (http://biomimicry.org/). Under the Biomimicry 101 tab, click on Biomimicry Examples.
3. Select one of the six topics or examples.
4. Practice the design process. When using the six steps in the “design process,” you can start or stop at any of the steps.
5. To practice the design process, complete the sheet following the diagram as you research the topic.

Part 2  Now It Is Your Turn
Using the same engineering design, go to the Design Challenge site.
1. What is the topic of the 2015 Global Design Challenge?
2. What is the goal of the competition?

Watch the video within this section.
3. What does biomimicry have to do with food systems? Click on the Learn More link.
4. Decide which area related to food problems your group is going to work on.
5. State the problem.
Part 1: Design Challenge Notes

Names of Team Members

Topic or Area of Research

What did the engineers do? Remember you are reading about a problem that has been solved by engineers turning to nature in ways that might surprise you. We are looking at the approach rather than “back engineering.” You will gather information to see how these teams used nature as inspiration and designed innovative solutions.

**State the Problem**

**Brainstorm Ideas**
(What were the inspiring ideas from nature?
What environment does the solution need to operate in?)

**State the Solution**
(In what specific ways did nature inspire the design to the solution?
What were the unique characteristics or adaptations that made it a solution to the problem?)
What was the Prototype created?

Test, evaluate, improve
(Is there a discussion or mention as to how this was done?
Are any statistics mentioned that demonstrate improvement?)

Present the Solution
(Who is the client? What audience benefits from this design?
Did that influence what materials were selected?
What are the limitations to this solution?)

Present your information to the class.