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Biomimicry Project Teacher's Guide

Note: this project is based on an ***Olin College of Engineering*** *project called Design Nature that is run with first year engineering students. Professor Benjamin Linder was kind enough to share the syllabus and his insights with me. Olin is an inspiring place – I recommend checking it out.*

This project challenges students to design and build a machine that jumps using an animal of their choice as a guide. It ties together biomechanics and anatomy with physics, prototyping, and 3D design. It's part of our Design Engineering course, a science elective.

Materials and tools
basic wood shop
wood scraps and dowels
surgical tubing
springs
glue
rubber bands
wire and turnbuckles
recycled plastic bottles
duct tape
hard pink foam
miscellaneous hardware
optional – laser cutter and/or Shop-Bot

Method

We did this project in groups of 2-3 students. In introducing the project it makes sense to talk about how we use biomimicry across nearly all design disciplines. Here are a few sexy examples:

- Vibrisee bike whiskers **https://vimeo.com/92380820**
- MIT cheetah robot video: **http://newsoffice.mit.edu/2014/mit-cheetah-robot-runs-jumps-0915**

See what other echoes of biology students can find in invention and design. Have them choose an animal with a high jump-to-weight ratio. Which are these animals? Which animal has the highest? (Hint: they are all insects). Once they choose an animal, they have their first assignment:*Find out the relevant information about your animal: average weight, height and velocity of jump, and most importantly, how the animal jumps. By this I mean look at the anatomy – muscular and skeletal – and how these interact to launch the animal into the air. Create an 8.5 x 11" or larger sketch (no tiny sketches please) that illustrates the the different steps involved. We're not shooting for fine art here, rather, for clarity.*

Once they've worked out how their animal jumps, it's time to figure out how to build a jumping animal prototype that employs the same principles, using the materials at hand. This is a good time to look at the available materials and talk about their properties. Which are strong in tension, compression, both? Brainstorm on how to get their animal in the air. Save some class time for the different groups to share the results of their research and brainstorming, the class may have useful suggestions.

We're following a standard design pattern here: **Brainstorm, Draw, Prototype, Iterate, Build**. Once students have an idea of how to make their animal work mechanically, have them draw it in views. The level we're shooting for is you can fax the drawing to the other side of the world to someone who doesn't speak the same language and this person is able to understand your thinking and build your animal. Show some engineering sketches in views as an example.

One the students have a convincing drawing, students should fast-prototype their idea. This is especially tricky on this project because the animals will need to rapidly expend a fair amount of force to get off the ground. Prototype animals made of dowels and tape may self-destruct when you add stretched-out surgical tubing to the mix. This is ok – it's part of the process of figuring out what the animal should be made of and how it should be put together. Slow-motion cell phone video is a great tool for analyzing the jumps and their similarities and differences with the way the real animal jumps. Small changes in weight distribution can make a big difference.

Once they develop a prototype that gets nicely off the ground, it's **time for some physics.** Have the students try and model their animal's behavior using (at least) the physics below. It may help to work out the **elasticity (Hooke's) constant** of whatever spring material they're using.

A jump involves the application of force against a surface, usually the ground. Usually a parabolic path. Launch angle and initial launch velocity determine distance, duration, and height of jump. 45 degree launch angle makes for furthest distance. Kinetic energy at launch is proportional to the square of the jumper's velocity.Muscles have limitations (power vs weight, upper limit is aprox 375 watts/kg), so some animals pre-stretch elastic elements, e.g tendons, to store work over time. This leads to higher energy release at jump = longer distance. Grasshoppers do this. Like a bow and arrow – elastic storage.

Adaptations: long legs (= longer stroke), large leg muscles, elongated feet

Jumps follow rules of ballistic trajectories:

g – gravitational acceleration, 9.81 m/s2
theta – angle at launch
v – velocity at launch
d – distance

Can you calculate distance travelled over a flat surface?
So if a frog jumps at 45 degrees with an initial velocity of 1 m/sec:
d = 1 x sin(90) / 9.81

$d = 1 / 9.81$
$d = .101m = 10.1$ cm
Using the above, have students calculate the jump height of their animal.At this point the project can end, ideally with a public display of the animals and research (public displays are good motivation). Or you can take it to the next step- show the students how to use Sketchup or whichever CAD program you use and have them render their animals in 3D. The final (optional) step is to output the animals on a laser cutter or Shop-Bot. We did the latter, and then set up an exhibit in the library with the video below playing on a monitor.

Notes on exporting from Sketchup to Vcarve for a Shopbot:

- everything must be a component
- lay out pcs on flat board
- camera -> parallel projection
- camera -> standard view top
- view -> edge style -> turn off extensions
- select everything
- export 2D graphics -> dxf
- open in Vcarve, scale should stay same