BiteScis

Science Bite

Fins, Wings, and…Fractions?

During the summer of 2011, I worked at the Marine Biological Laboratory on Cape Cod, Massachusetts. It's a great place to for an aspiring marine biologist be in the summer—right on the ocean, perfect for catching jellyfish or watching fish swim. And while I did get to do that, my main research project was very different.

I was part of a group of scientists studying how animals move, and we were thinking about how, unlike our man-made boats and airplanes, which move using rigid propulsors like propellers or airplane wings, swimming and flying animals move using flexible propulsors—fins, bodies, tails, and wings. We wanted to know how these animals work, and why their movement was so different than our machines.

The first task was to measure how these animal propulsors bend. I worked with another undergraduate, Nate Johnson, and between us, we watched countless videos of about sixty species of animals, including insects, fish, whales, birds, bats, and really cool animals called sea butterflies, which are not butterflies at all but swimming mollusks (relatives of clams, snails, and octopuses that swim instead of crawling). As we watched, we measured where each propulsor was bending. Much to our surprise, it didn't matter if an animal swam or flew, or whether it was tiny or huge. All the propulsors were bending at a point about two-thirds (as a decimal 0.67) of the way down its length, like you can see in **Figure 1**. Our measurement process is summarized in **Figure 2**.

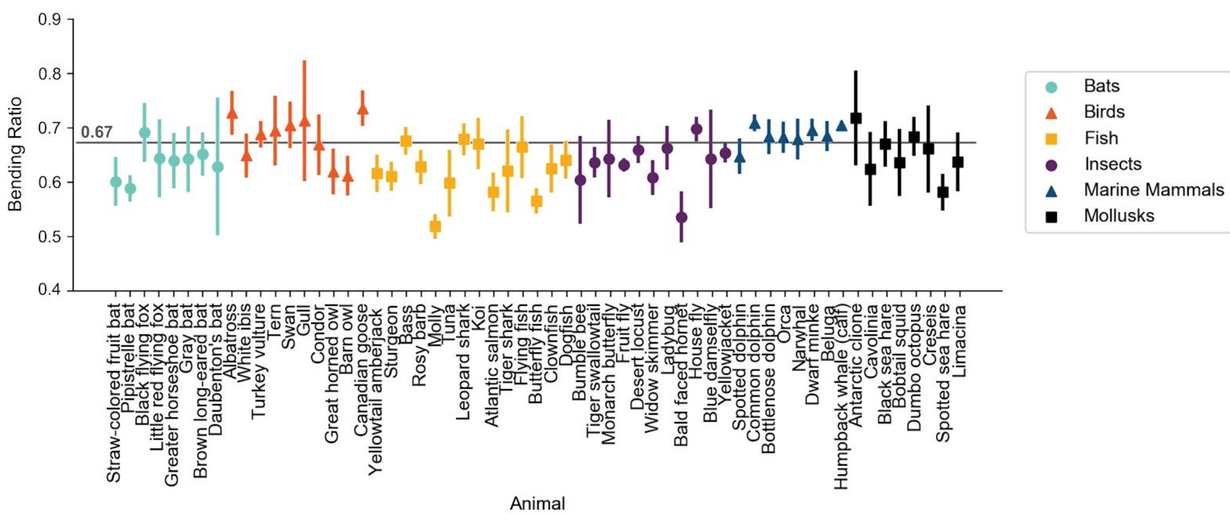

Figure 1. Bending Ratios of Fifty-Nine Animal Species. The other researchers and I were astonished to find very similar bending ratios in all the animal groups. Shown here are fifty-nine species we measured, including bats (teal/circles), birds (orange/triangles), fish (yellow/squares), insects (purple), marine mammals (dark blue/triangles), and mollusks (black/squares). Error bars show one standard deviation. Recall that 0.67 is ⅔ written as a decimal.

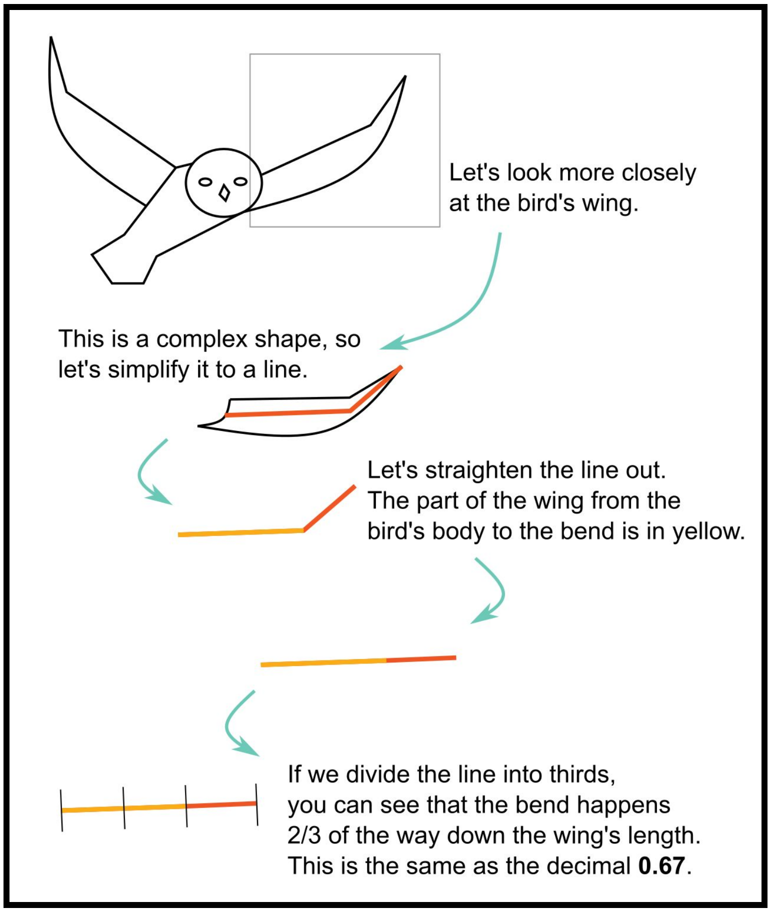

Figure 2. Uncovering the Two-thirds Bending Pattern. Here's an example of how we measured where bending occurs. When we simplified the propulsor to a line, we found that the point of bending was around ⅔ of the way down the propulsor's length. Recall that ⅔ is 0.67 when written as a decimal.

We knew that the bending pattern was heritable. Parents with the trait produce offspring with the trait. Does the bending pattern have a function? Well, bending enables the animal to move through the air or water and certainly being able to move would provide an advantage over an animal of the same species that cannot move! But why that *same* ratio? What's special about a propulsor that bends two-thirds down the body? Those questions are harder to answer.

Let's think again about the first criteria of heritability. It is very unlikely that these animals all inherited the bending pattern from the *same* common ancestor. Why? Because the common ancestor of all of these animals would have lived about 900 million years ago and is the common ancestor of *all* bilateral animals, including *all* animals we commonly call mammals, insects, fish, reptiles, and amphibians—not to mention crustaceans, worms, mollusks, and echinoderms, as shown in **Figure 3**! Most of these animals do *not* swim or fly as their primary mode of movement. So either the trait was inherited and lost by nearly all groups of animals, or—far more likely—a few groups of animals evolved the trait independently.

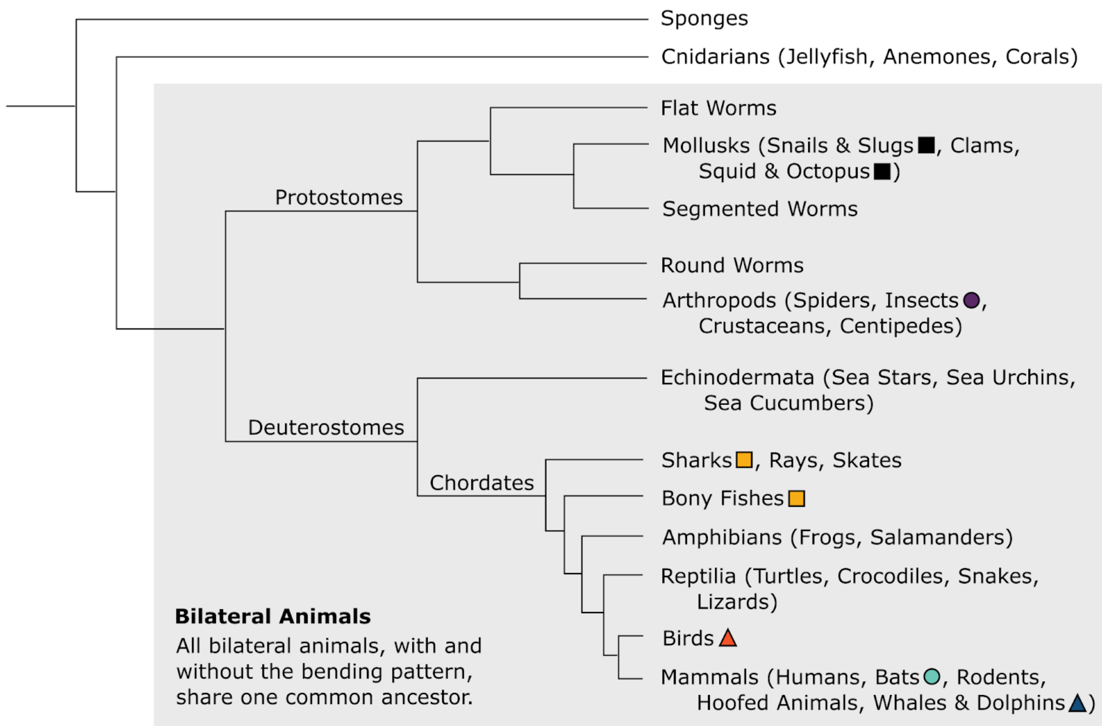

Figure 3. Phylogenetic Tree of Selected Animal Groups. The other researchers and I studied animals within the marked groups (colors and shapes match the legend from Figure 1). Because these groups are scattered across the tree, and don't have one common ancestor separate from all the other animal groups (their common ancestor is the common ancestor of all bilateral animals), the bending ratio is an example of convergent evolution.

When similar traits appear in different groups of organisms for reasons other than common ancestry, we say that **convergent evolution** has occurred. Convergent evolution happens when two unrelated species live in environments that are similar and experience similar survival challenges that are best overcome by one specific set of traits. So the bending pattern evolved and was passed down to modern animals from an ancestor in each group. The common challenge that the animals' ancestors experienced was moving, either defying gravity in the air or getting through thick, dense water that is tiresome to push against. Being able to move is incredibly important—movement enables animals to find food, mates, and shelter, and escape from danger—all of which you have to do in order to have offspring!

Can we be sure that the two-to-three bending ratio is an adaptation? No, but we're pretty confident that it is since it evolved independently in so many groups. And, engineers building animal-like robots have found that robots with bendable wings or fins can outfly or outswim robots with rigid wings. So, we think that the specific two-to-three ratio of propulsors helps animals to move fast and efficiently by maximizing thrust (force for forward motion) while using less energy. In the future, we hope that scientists like us can work together with engineers to understand how the incredible diversity of swimming and flying animals around us came to be.

Reference

Lucas KN, Johnson N, Beaulieu WT, Cathcart E, Tirrell G, Colin SP, Gemmell BJ, Dabiri JO, and Costello JH. 2014. "Bending rules for animal propulsion." *Nature Communication* 5: 3293.

BiteScientist Profiles

Kelsey Lucas is a marine scientist fascinated by how the amazing behaviors animals do arise from the inner workings of their bodies and the physical laws that govern them. By understanding animal behavior holistically, she strives to better understand how the nature works around us and how we can better care for, connect to, and learn from it. In her free time, she likes to volunteer for science education causes like BiteScis or at museums, and to be outdoors running, hiking, and sketching.

As a biologist studying evolution at Wellesley College and Harvard University, **Stephanie Keep**'s research focused on how vertebrates move. Since leaving academia, she has done everything from blogs, podcasts, and videos to textbooks, standardized assessments, and lesson plans. She has three daughters, loves sloths, and is a co-founder of BiteScis.

_v2: Figures 1 and 3 modified with shapes to help differentiate animal groups when printing in black/white, November 2019