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DATA Nugget

Sticky situations: big and small animals with sticky feet

Featured scientists: David Labonte, Christofer J. Clemente, Alex Dittrich, Chi-Yun Kuo, Alfred J. Crosby, Duncan J. Irschick, and Walter Federle. Written by: Travis Hagey

Research Background:

Travis catching lizards in the Dominican Republic.

Species are able to do so many amazing things, from birds soaring in the air, lizards hanging upside-down from ceilings, and trees growing hundreds of feet tall. The study of **biomechanics** looks at living things from an engineering point of view to study these amazing abilities and discover why species come in such a huge variety of shapes and sizes. Biomechanics can improve our understanding of how plants and animals have adapted to their environments. We can also take what we learn from biology and apply it to our own inventions in a process called **biomimicry**. Using this approach, scientists have built robotic jellyfish to survey the oceans, walking robots to help transport goods, and fabrics that repel stains like water rolling off a lotus leaf.

Travis studies biomechanics and is interested in the ability of some species to climb and stick to walls. Sticky, or **adhesive**, toe pads have evolved in many different kinds of animals, including insects, arachnids, reptiles, amphibians, and mammals. Some animals, like frogs, bats, and bugs use suction cups to hold up their weight. Others, like geckos, beetles, and spiders have toe pads covered in tiny, branched hairs. These hairs actually adhere to the wall! Electrons in the molecules that make up the hairs interact with electrons in the molecules of the surface they're climbing on, creating a weak and temporary attraction between the hairs and the surface. These weak attractions are called van der Waals forces.

The heavier the animal, the more adhesion they will need to stick and support their mass. With a larger toe surface area, more hairs can come in contact with the climbing surface, or the bigger the suction cup can be. For tiny species like mites and flies, tiny toes can do the job. Each fly toe only has to be able to support a small amount of weight. But when looking at larger animals like geckos, their increased weight means they need much larger toe pads to support them.

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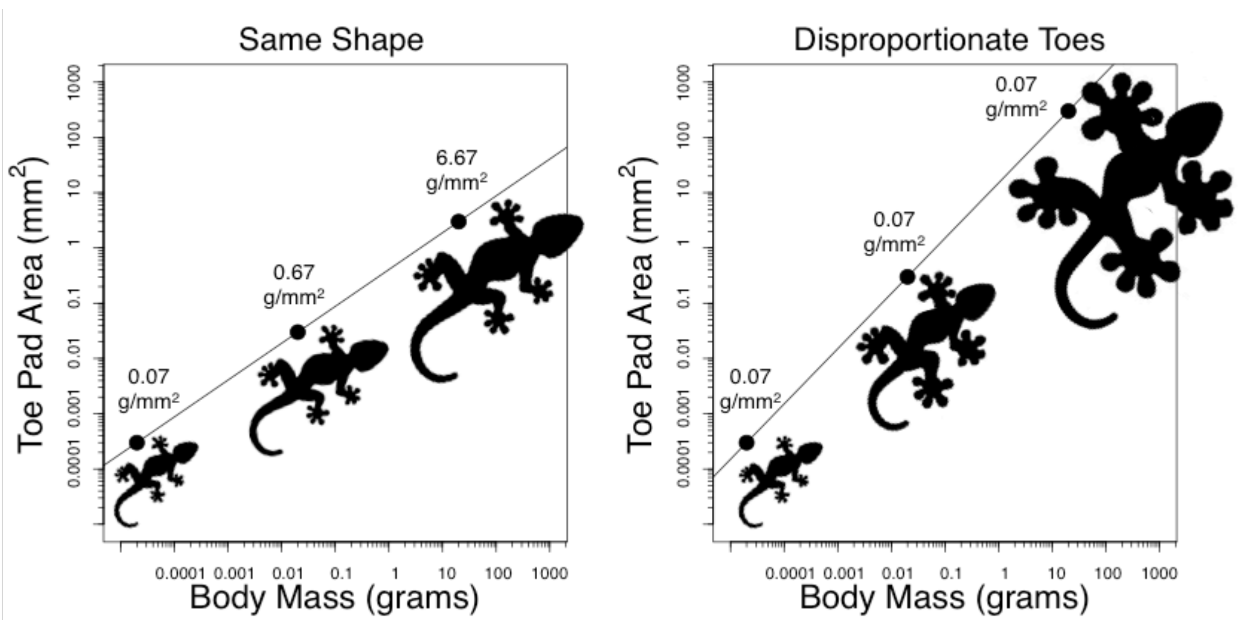
Travis in the lab measuring the stickiness of a gecko's toe.

When comparing large and small objects, the mass of large objects grows much faster then their surface area does. As a result, larger species have to support more mass per amount of toe area and likely need to have non-proportionally larger toes than those needed by lighter species. This results in geckos having some crazy looking feet! This relationship between mass and surface area led Travis to hypothesize that larger species have evolved non-proportionally larger toe pads, which would allow them to support their weight and stick to surfaces.

To investigate this idea, Travis looked at the data published in a paper by David Labonte and fellow scientists. In their paper they measured toe pad surface area and mass of individual animals from 17 orders (225 species) including insects, arachnids, reptiles, amphibians, and mammals. Travis used their data to calculate average toe pad area and mass for each order.

Travis then plotted each order's mass and toe pad area on **logarithmic axes** so it is easier to compare very small and very large values**.** Unlike a standard axis where the amount represented between tick marks is always the same, on logarithmic axes each tick mark increases by 10 times the previous value. For example, if the first tick represents 1.0, the second tick will be 10, and the next 100. As an example, look at the plots below.



Plots of small, medium, and large gecko species on logarithmic plots with each species' mass per toe pad area ratio. Species with proportionate toes in the left plot, species with disproportionate toes in the right plot.

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The left plot shows hypothetical gecko species of different sizes, but with proportional toes. Their mass per toe pad area ratio (g/mm^2) varies, with larger species having larger g/mm^2 ratios. In this case, larger species have to support more mass per toe pad area. In the right plot, larger gecko species have disproportionally larger toes. These differences change each species' mass per toe pad area ratios, so that all species, regardless of their size, have the same mass per toe pad area ratio.

Scientific Question: Do larger animals have non-proportionally large toe pads to support their heavier bodies?

What is the hypothesis? Find the hypothesis in the Research Background and underline it. A hypothesis is a proposed explanation for an observation, which can then be tested with experimentation or other types of studies.

Scientific Data: The numbers below are means for many different orders of animals with adhesive feet. Travis calculated these means using measurements, collected by David Labonte and fellow scientists, from many individuals of many species.

Use the data below to answer the scientific question:

Order	# Species Measured	Mean Body Mass (g)	Mean Toe Pad Area (mm^2)
Anura (frogs)	22	9.21	51.1
Araneae (spiders)	16	1.41	5.81
Mesostigmata (mites)	1	0.000453	0.0253
Trombidiformes (mites)	2	0.0000235	0.000561
Blattodea (cockroaches & termites)	7	2.15	1.23
Coleoptera (beetles)	27	0.201	0.598
Dermaptera (earwigs)	1	0.0061	0.07
Diptera (flies)	11	0.0525	0.37
Hemiptera (true bugs)	17	0.0333	0.0383
Hymenoptera (bees & ants)	7	0.0587	0.229
Lepidoptera (moths & butterflies)	1	0.032	0.0194
Mantodea (mantises)	1	0.0937	0.212
Orthoptera (grasshoppers & crickets)	4	0.566	1.47
Phasmatodea (stick insects)	8	7.56	2.39
Raphidioptera (snakeflies)	1	0.00689	0.0556
Chiroptera (bats)	1	9.18	68.6
Squamata (lizards)	98	13.1	91.9

Data from Labonte, D., Clemente, C.J., Dittrich, A., Kuo, C.Y., Crosby, A.J., Irschick, D.J. and Federle, W., 2016. Extreme positive allometry of animal adhesive pads and the size limits of adhesion-based climbing. *Proceedings of the National Academy of Sciences*, p.201519459.

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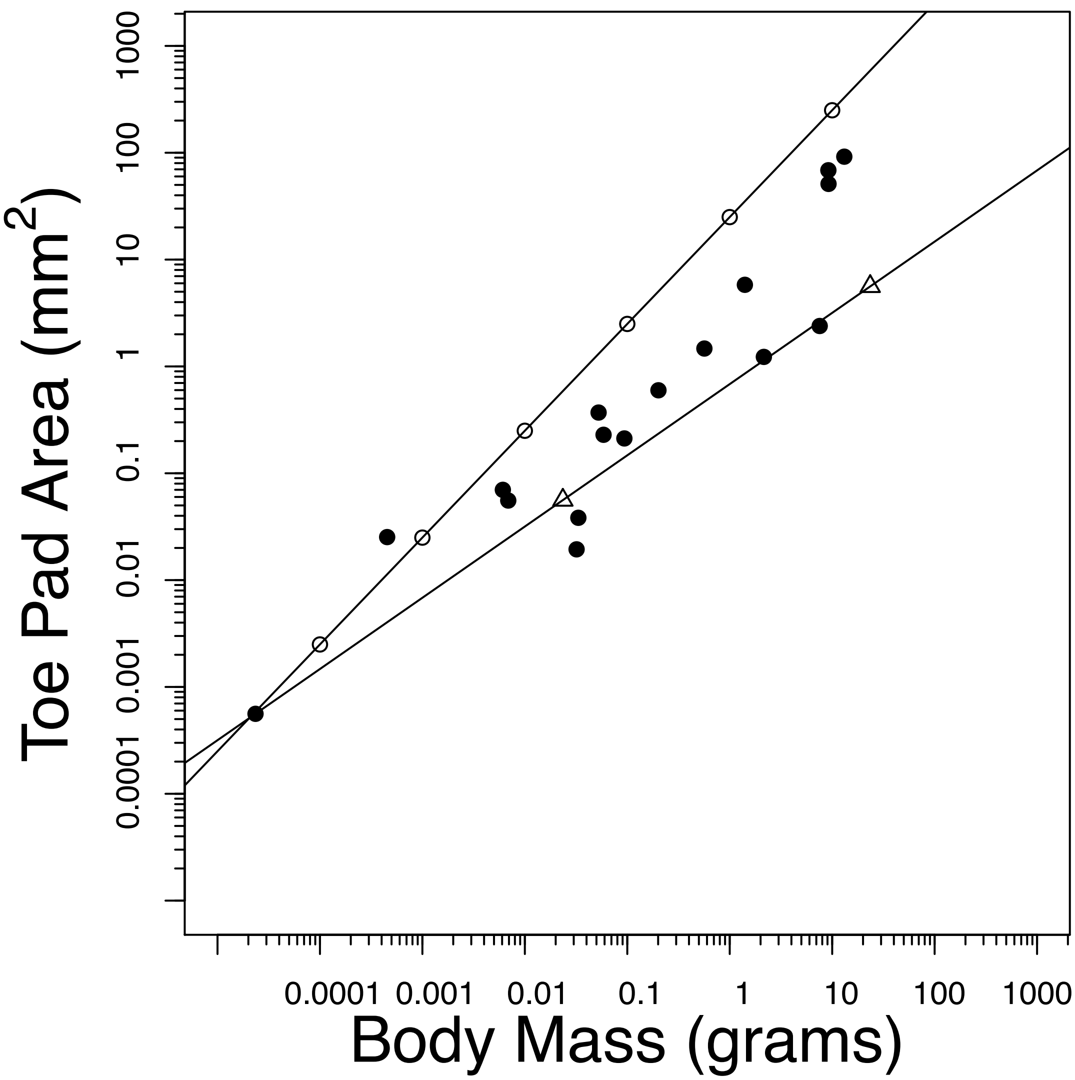
What data will you graph to answer the question?

Independent variable: ____________________________________

Dependent variable: ____________________________________

Below is a graph of the data: Identify any changes, trends, or differences you see in your graph. Draw arrows pointing out what you see, and write one sentence describing what you see next to each arrow.



Plot includes data from Labonte's paper (black points), hypothetical species with the same g/mm^2 ratio as Trombidiformes (white circles), and hypothetical species with the same shape as Trombidiformes (white triangles)

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Interpret the data:

Make a claim that answers the scientific question.

Support your claim using data as evidence. Reference specific parts of the table or graph.

Explain your reasoning and why the evidence supports your claim. Connect the data back to what you learned about the relationship between an organism's size and the surface area they need to stick.

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Did the data support Travis's hypothesis? Use evidence to explain why or why not. If you feel the data was inconclusive, explain why.

Your next steps as a scientist: Science is an ongoing process. What new question(s) should be investigated to build on this research? What future data should be collected to answer your question(s)?