Host: Robert Frederick
Sometimes, a hypothesis is correct. Sometimes it's not.

Speaker: Michele Johnson
Now, I told you we spent eight years collecting these data — this is not the result that we expected to see.

Host: Robert Frederick
On this episode of The Conjectural, lizard sex, behavioral evolution, muscle size, and how science generates knowledge even when the hypothesis turns out to be wrong. I'm Robert Frederick.

You may have heard or seen the quote before. I saw it on a monthly calendar in a lapidary workshop outside of Phoenix, Arizona. Nearly overwhelmed by the sounds of grinding and polishing of rocks and gemstones, when I read these words my mind blocked out everything else. The quote comes from James Madison, who served these United States of America in a number of capacities, including as our fourth president during years 1809 to 1817. He wrote: "A popular government without popular information, or the means of acquiring it, is but a prologue to a farce or a tragedy, or perhaps both."

You may have heard that quote before because it has been used to argue for many legal efforts in this country for giving us — the general public — access to what our government is doing, including the Freedom of Information Act, which turns 50 years old in 2017. But the true meaning of Madison's quote is quite different. Like a lot of quotes, its context makes the quote's true meaning perfectly clear. In the sentence before that famous quote, Madison wrote: "The liberal appropriations made by the Legislature of Kentucky for a general system of Education cannot be too much applauded."

In other words, Madison was talking about the need for public education.

Speaker: Michele Johnson
My work is on social interactions. And there's a lot of different ways that social interactions can occur. One form of social interaction is the distribution of resources within a dominance hierarchy.

Host: Robert Frederick
Michele Johnson is an evolutionary biologist studying animal behavior. She works at Trinity University in San Antonio, Texas.

Speaker: Michele Johnson
Or defending a territory from possible intruders. Courting a potential mate. And caring for your offspring.

Host: Robert Frederick
The particular lapidary workshop where I read Madison's famous quote was in a community that only allows people who are 55-years old and older to live there. Their taxes are exceptionally low because their community doesn't support any public schools. Of course, for that population, there weren't any public schools built.

Later on in the same letter that has the famous quote, Madison wrote: "Learned institutions ought to be favorite objects with every free people. They throw that light over the public mind which is the best security against crafty & dangerous encroachments on the public liberty."

Speaker: Michele Johnson
So with all of the critically important issues in our world today, why should you care about the field of animal behavior?

Host: Robert Frederick
In the absence of continued public education, which many American's stop once they finish high school or college, when it comes to, as Madison put it, throwing "that light over the public mind," that's the job of journalist — informing the public. But when it comes to informing the public about science, I think we've been focused on the wrong things. The question "why should you care" betrays that wrong focus. We journalists have been focusing on the latest scientific results, and the "why should you care" question presumes that the facts or the knowledge gained from the latest research is what matters most. Indeed, that's the kind of questions Michele Johnson is accustomed to answering because it's that kind of answer the public is expecting to hear from a story about science.

Speaker: Michele Johnson
One of the questions I get commonly is "Well, how is this going to solve medical problems in humans?" And my answer is that's not what we're directly trying to do. We're basic scientists trying to understand the diversity in the natural world. But the kind of work that we do could ultimately help us understand how muscles degenerate and it could give us different, new ways, to think about how evolution has built muscles to be strong or to have a lot of endurance. And so ultimately, down the road, in someone else's lab, this kind of information may later help us to develop new medical treatments.

Host: Robert Frederick
As refreshing as Johnson's answer is to hear — that she does basic science and other scientists might figure out ways to apply it to human health — her answer still presumes the importance of that question in the first place. But I think the question "Why should you care" is the wrong question for journalists to ask, betraying the wrong focus on the results of the latest research, because the knowledge that results from the latest scientific research can and often does change. And it's hard to care about such news — literally, the newest knowledge — when that knowledge could turn out to be wrong later on. So I think we journalists who cover science should be focused on informing the public about something other than the newest knowledge gained. That kind of news — the latest result — is just a consequence of the curiosity or interest that led to a scientific question and how scientists went about trying to answer that question in the first place. It's that understanding of science — as a process of asking and trying to answer questions — that may best inform the public about science. When you "throw that light over the public mind," you inform the public not merely of the result of a scientific investigation, but how to question — thoughtfully question — the process that led to that result. You invite curiosity.

Speaker: Michele Johnson
So the question that's driving my work — my current work — is it the same combination of traits underlies similar behaviors in unrelated species? But it's also possible that there's more than one

way to build a behavior. And so the alternative here is that different combination of traits may actually produce similar behaviors across species.

Host: Robert Frederick
That's the big-picture question. Narrowing it down a bit, Johnson asks this.

Speaker: Michele Johnson
Do species that use a muscle more often have larger muscle fibers in that muscle?

Host: Robert Frederick
The answer, as you might suspect, is yes, at least in some circumstances.

Speaker: Michele Johnson
That's why we go to the gym. We go to the gym to work out because exercise causes our muscles to grow.

Host: Robert Frederick
But that's not necessarily the case in all animals, or at least, not for all exercises.

Speaker: Michele Johnson
People have had crocodiles running on treadmills for, you know, hours on end, and not really seen very much at all of an effect on the muscle size.

Host: Robert Frederick
While you're contemplating a crocodile running on a treadmill, keep in mind that a crocodile doesn't just run on a treadmill just on its own. It's not a behavior they'd just do — in fact, running on a treadmill makes crocodiles rather aggressive. So what about the behaviors that animals do engage in on their own — like courting behavior or sex? Well, Johnson studies lizards, in part, because there are a wide range of lizard species.

Speaker: Michele Johnson
Lizards are incredibly diverse. There are about six-thousand species of lizards, and they have so many different ways of interacting with one another.

Host: Robert Frederick
Including a wide range of how much they court one another, by doing such things as pushups or extending a little flap beneath their necks called a dewlap. Lizards also represent a wide range of the amounts of sex that they have, from very rarely to several times a day. So what's already known about Johnson's question?

Speaker: Michele Johnson
Do species that use a muscle more often have larger muscle fibers in that muscle?

Host: Robert Frederick
Johnson says that within any one particular species, the pattern that other scientists have seen is that the individuals that, for example, do a lot of pushups have bigger muscles for doing pushups than the individuals of that species that do fewer pushups.

Speaker: Michele Johnson
But this kind of work within a single species doesn't directly tell us how muscles evolve with behavior. So we're looking across a group of 30 species. Will we see the same patterns across species that have been previously observed within a species?

Host: Robert Frederick
And that's the question that Johnson sought to answer directly through observations and measurements. That's the question that got support from the National Science Foundation — public money — for her to answer. Now, the muscles in question — the muscle that extends the dewlap flap beneath the chin of lizards, and the muscle that's called the *retractor penis magnus*.

Speaker: Michele Johnson
Retractor penis magnus, so you can probably figure out what its job is, right? It retracts the penis back into the tail.

Host: Robert Frederick
Her team's observations, then, as you might expect, meant watching a lot of lizards have sex and watching a lot of lizards court one another, extending their dewlaps. Her team's measurements also meant capturing and dissecting a lot of lizards, too.

Speaker: Michele Johnson
We have carefully dissected the cellular structures of muscles and brains of three hundred lizards — this is — huge effort. And we have collected over 1,100 hours of focal observation of animal interactions. We've worked across the Caribbean — we've done quite a bit of our work in the Dominican Republic where we've studied 14 different species of anoles. We've worked in Puerto Rico on a group of 8 species. Also in Jamaica we've studied 3 species. In the Bahamas, 4 species. And then in San Antonio, Texas, we've worked on the local green anole, *Anolis carolinensis*. So, this hasn't been the focus of our work for 8 years, but we've been working on this general approach for 8 years and by my count, this has involved 32 scientists, most of whom are undergraduates.

Host: Robert Frederick
It's that extensive process that shows science for what it truly is: a process of asking and answering questions that usually takes significant effort, involves data and discussion of exactly how a scientist arrives at her conclusions, so the observations and measurements and data analysis can be repeated, if need-be. In an effort to rush to reporting the results, though, we miss telling the public that these are often very highly educated people who are struggling — often for years — for how to answer questions that are very tough both to pose and to address.

Speaker: Michele Johnson
Now, I told you we spent eight years collecting these data — this is not the result that we expected to see. Do species that use a muscle more often have larger muscle fibers? No. No. Not at all. So while this was initially somewhat disappointing, this is sometimes how science works. You learn that you were wrong.

Host: Robert Frederick
But in science — being wrong — that's still knowledge, and that's still exciting.

Speaker: Michele Johnson
The data have told me that my initial thought was wrong. So the really exciting opportunity here that we have with these data is that it's told us two things that we didn't know before. One is that the way muscles evolve in correlation with the behaviors that they produce is…, well, there's, we don't really see a relationship between the behaviors produced and the muscle physiology, or the sizes so far. So that's been a really surprising finding. The other aspect of this is that evolution of muscles and the behaviors they support — across species — seems to have a very different pattern than the pattern we observe within individual species. So this might give us a new way of thinking about the connection of muscles and the behaviors that they produce.

Host: Robert Frederick
And the 8 years of research as well as the data collected about the muscle that retracts a lizard's penis, or hemipene, it's going to help address new scientific questions, too.

Speaker: Michele Johnson
Of course we've been thinking about other ways to approach this question and thinking about other ways that behavior might be connected to the muscles that support them. And one possibility is that it doesn't matter how much you move a muscle, but it's, what's more important is how much force is produced to be able move that structure that it's supporting. So one way to think about that is if you have to lift a 2-pound weight many times through the day, maybe that doesn't require very strong muscle. But if you have to lift a 25-pound weight, or a 50-pound weight, even just a few times, that that might require much larger muscle fibers. So we've been looking at the size of the hemipene and the size of the muscles that move the hemipene…,

Host: Robert Frederick
Again, that's the term for a lizard's penis.

Speaker: Michele Johnson
… and this is incredibly exciting — none of this is published, this is all brand-new, brand-new story that I'm telling you here. But we see that after we control for differences in the lizard's body size, so some species are bigger than others — we expect them to have bigger muscles than others — but after we control for body size, we see a strong positive relationship between the size of the hemipenes and the size of the muscles that move the hemipenes. So it doesn't seem to matter how often you move that muscle, how often you use that muscle, what's important is how much force you have to generate the hemipene when you do.

Host: Robert Frederick
This is the eighteenth time I've made this monthly show, *The Conjectural* — an experiment to figure out a better way to decide what science news is and how we should talk about science. But this is something I've been thinking about ever since I became a science journalist over a dozen years ago, when I was first irritated by hearing another journalist ask a scientist "Why should the public care?" about a particular scientific result. Of course, focusing on the results rather than the scientific process makes for a shorter story. It gets at the newest news in a way that requires less time than telling the whole story. And answering the question "why should the public care" is also a shortcut to getting the public to listen rather than telling a good story that invites curiosity and truly throws "that light over the public mind which is the best security against crafty & dangerous encroachments on the public liberty."

Now, finally, you may not know, but back in the 1920s, scientists broadcasted long lectures directly to the public. Listenership grew from thousands to millions. Networks soon realized each listener represented a potential customer, and airtime — with commercial interests — became far more precious. The Internet has, in some ways, changed that. So encourage scientists you know to start podcasting directly to the public, or, you know, be in touch with me. Telling a good story that doesn't rely on any visuals, there's history to suggest that the public will love it. And after now over a decade of podcasting, there's data to show that we do.

You've been listening to The Conjectural. Thanks to Michele Johnson and to the Council for the Advancement of Science Writing for hosting her talk. I look forward to your feedback to TheConjectural.com, where you can also give the support that makes this show happen, download a transcript, and subscribe. I'm Robert Frederick. Follow me on Twitter @TheConjectural. Thanks for listening, and Happy New Year!