After the Fact | From Lab to Life: How to Heat-Proof Coral Reefs

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TRANSCRIPT

Phillip Cleves, principal investigator, Carnegie Institution for Science, Johns Hopkins University: The ocean is full of mysteries. When I look at the ocean, I think about all the different types of life, all the unexplored species, all the unexplored places. And it's really the last frontier.

Dan LeDuc, host, "After the Fact" podcast: Welcome to "After the Fact." For The Pew Charitable Trusts, I'm Dan LeDuc. We're back with another conversation featuring a scientist and their cutting-edge research in our "From Lab to Life" series.

In this episode, we're talking about coral reefs. The National Oceanic and Atmospheric Administration says these natural beauties support an estimated 25% of all known marine life.

Phil Cleves knows all about coral. He's a researcher at the Carnegie Institution for Science at Johns Hopkins University. And despite being a marine scientist, he actually doesn't go into the water all that often. Instead, he studies coral genetics in tanks at his lab to uncover potential treatments for human health and solutions to conserve the marine ecosystem.

That's why in 2023 he became the first-ever recipient of the Pew-Hoover Fellowship in Marine and Biomedical Science to support his research. From his lab in Baltimore, he shared the implications of this research and why the reefs are so important to protect.

Phillip Cleves: So, coral reefs are rather special places. They're biodiversity hot spots of extreme importance. It's estimated that 25% of all known marine life has a connection to coral reefs, even though they're only found in the tropics and the subtropics.

So, a rather small amount of the ocean is covered in reefs. And if you think about the major discoveries that have happened over the past several decades in terms of biomedicine, many of them come from aquatic organisms; the ability to see organisms under fluorescence came from jellyfish.

As a young kid I'd look into the oceans and I'd think: I hope I see a dolphin. Now I look into the oceans and I think: What genes are out there? What are the biomolecular machines out there that could revolutionize humanity over and over again? And also how do we protect them?

Dan LeDuc: These types of biomedical advances that Phil mentions could come from more closely studying what's beneath the surface. And these discoveries could have major implications for our health and the health of our ocean.

Phillip Cleves: I'm originally from Oklahoma City. Even growing up in a landlocked state, from a very young age I was interested in the oceans and also interested in jellyfish 'cause I was stung as a young kid by a jellyfish. And I was wondering to my dad, what is that, that just stung me?

And I wanted to be a marine scientist from as early as I can remember. My path has been rather meandering towards that. I did a study abroad experience in Australia where I did research on corals. I was scuba diving on reefs; I was blown away by how much life there is.

The Great Barrier Reef is the size of Italy. And just think about how much biodiversity is there, how much life, new species that we haven't even described are out there. You can do your entire hour dive just looking at 1 square meter of coral and see invertebrates, vertebrates, small little things, big things.

It kind of lit a spark that I could actually do coral sciences. And when I returned I spoke to my adviser and I said, I want to do the genome of a coral, which at the time had never been done. And having not known how to do a genome of a coral or of any organism. And recently we have done genomes of corals, you know? And so from this Australia trip, I realized that there was an avenue to merge molecular biology with coral biology.

Now after 15 years of training in molecular biology, we are doing that type of work in our lab. The sad thing about it is that we've lost a lot of the world's reefs. Thinking about how much life is actually being lost is a major motivator for the types of work that I do.

Dan LeDuc: While Phil may not spend a lot of time in the water, he sees corals up close in his lab. And he's looked closely at how coral interacts with another species in the ocean.

Phillip Cleves: One of the coolest things I think about corals is that they have this really interesting symbiosis with algae. So, symbiosis is when two organisms interact. And you can think about us being symbiotic with our dog because the dog relies on you and you also rely on your dog in some way.

But symbiosis is found across the tree of life, from microbes interacting with humans to clownfish and their anemones—if you ever watch “Finding Nemo.” And the fundamental feature is two organisms interacting and relying on each other.

So coral symbiosis is really interesting because corals have algae actually inside of their cells. And so, if you think about that, if we had that, we wouldn't have to eat lunch, we would just have plants growing inside of our skin. We'd go outside and instead of eating lunch, we'd just soak up the sun.

So when early explorers came across coral reefs, they were kind of shocked in how much biodiversity exists in these nutrient-poor tropical waters. 'Cause it's basically like seeing an oasis in a desert. And they undergo photosynthesis to get enough food to thrive. And so, they're essentially acting like trees in a rainforest, for all the biodiversity that they support.

Dan LeDuc: So, what happens when coral lose their algae? Or when the oceans start to warm? Phil told us more about the threats that coral reefs face—and how that can affect ecosystems and even human health.

Phillip Cleves: So coral bleaching is a phenomenon that unfortunately we're seeing over and over again over the past several decades, where water temperatures get 1 or 2 degrees higher than what a coral typically sees, and they undergo a process of bleaching. And that's a process where corals lose their really important algae. And so, when corals lose their algae due to heat stress, they can starve to death and die. It's like cutting down all the trees in a rainforest. You lose all that biodiversity that these organisms support. And that's leading to mass collapse of coral reefs over the past several decades.

One of the most shocking things that came out by studying some of the first coral genomes and their relatives is that corals, although they kind of don't look like animals, have more similar gene content to humans than some of the well-studied model organisms, for example flies and worms. And so, there's a lot of connection of gene function between corals and humans, including the immune system. Corals have an immune system. How are beneficial microbes impacting the immune system?

The key scientific interests that I have is trying to understand the properties of corals that are able to survive. We know that some corals are more resistant to climate change, and some corals are less resistant to climate change, but we have very limited ability to predict that. And I think that genetics should allow us to predict corals that are thermally tolerant by sequencing their genomes or looking at their gene expression. And then that would be a way for us to identify corals that we need to protect.

Dan LeDuc: As a principal investigator at the Carnegie Institution for Science, Phil leads a team of researchers in his lab. The lab's graduate students and researchers in the lab use advanced microscopes to capture what is happening to the coral and sophisticated gene technology to analyze the findings.

Lab Talk: IKBC3A is one of my favorite genes, and it's downstream of NFFP. It's downstream. It might also be upstream because the immune system is a circle. This is the algo autofluorescence in a symbiotic tentacle, and we're real zoomed in.

Why is it rippled like that?

It's wrinkled because this is a heat-stressed animal.

And so it's like scrunched up?

And so it's like physically stressed.

Dan LeDuc: Phil takes his role as a mentor seriously. He works to promote his staff to publish their findings or support them even if they don't end up pursuing a career in science.

Lab Talk: So this is basically looking at an optical slice of a tentacle of the animal. And so like all the red things are algae inside of host cells. Can you point to like a, a good example of a host cell, like maybe zoom into it?

So there it is. Right there.

It's a special event. I think that's like actually watching bleaching happen.

Phillip Cleves: From one side of our research, we're interested in how the algae get into corals. How does the beneficial algae reprogram the animal cell to form this symbiosis? The other side of the project is from the ecological level because coral bleaching is affecting the stability of coral reef ecosystems worldwide because of the loss of this algal symbiosis.

And so, we're interested in trying to understand the molecular basis of how the symbiosis forms and why it breaks down during heat stress at the molecular level to try to provide fundamental insights into what's happening out in the reefs to see if we can develop conservation efforts to help protect coral reef ecosystems.

And so, the real key is that by studying this one untapped model organism, we can gain basic insights into biomedical science and also basic insights into a reef ecosystem that's under collapse.

Dan LeDuc: One of the biggest scientific discoveries that has aided Phil's research is a set of genome editing tools and Nobel Prize-winning technology called CRISPR/Cas9 to study the traits of coral more closely.

Phillip Cleves: So CRISPR is a revolution; one of the most interesting things that's happened in my biological career so far is this discovery of CRISPR. And what CRISPR very simply is a way for us to edit genomes.

All of the discoveries, almost all of the discoveries that we know about what genes do, is basically breaking a gene and seeing what happens. This has led to discoveries in cancer research and cell proliferation in vaccine therapies.

Dan LeDuc: Phil took us into a basement room full of tanks. It was dark. There were small tanks and a few large tanks where they grew coral.

Phillip Cleves: So, we're in my lab in the basement of the Carnegie building in Baltimore. In Australia corals spawn once a year in the middle of the night by the full moon. They only do that for a few days in a row and one time a year. And so in order to be able to do CRISPR experiments, we had to fly to Australia and do experiments.

We're limited in the number of experiments we can do each year 'cause they only spawn once a year. So, what we're doing here is getting corals to spawn in the lab at different times to have access so that we can do CRISPR/Cas9 on them.

And so, what you're looking at here, are four independent coral spawning systems that have temperature and light control, that make corals think that they're in different times of the year. In three years, we've been able to do 12 or 15 years’ worth of coral experiments.

Dan LeDuc: And this research can have an even bigger picture impact for health and conservation.

Phillip Cleves: We're building genetic tools to allow us to functionally characterize genes, to find genes that are important for symbiosis, genes that are important for absolute coral heat tolerance, genes that are associated with bleaching.

And we think by discovering those genes and figuring out how the symbiosis works, we'll develop strategies for conservation to see if we can help corals survive. But there's a little bit of tension, because we want to do something now to save corals, but we don't know what to do unless we have fundamentals.

I could take a glass of water from the ocean and look at it under the microscope and see organisms that we can't grow in the lab. See organisms that we don't really even know what they are, and I think the real frontier of linking marine conservation to biomedical science is: Let's go into the ocean and let's discover new pathways, new genes, new machines that can help us solve some of the big crises that we have in our lives. How many undiscovered things have the potential to revolutionize humanity?

Dan LeDuc: Thanks for listening. To learn more about Phil and his research, visit pew.org/afterthefact. For The Pew Charitable Trusts, I'm Dan LeDuc. And this is "After the Fact."