

Science AMA Series: We're Drs. Kelly Weinersmith, Andrew Forbes, and Scott Egan! We just released a paper documenting a new case of parasite manipulation of host behavior. AMA!

Parasite_{AMA}¹and/ScienceAMAs¹

¹Affiliation not available

April 17, 2023

Abstract

Thanks for your awesome questions, everyone! We're going to start winding things down now. We had a ton of fun! We're scientists from Rice University and University of Iowa, and we recently described a new example of parasite manipulation of host phenotype, in which a previously undescribed parasitoid (*Euderus set*) manipulates the behavior of its cynipid gall wasp host (*Bassetia pallida*), which is itself a parasite of sand live oaks. The host, *B. pallida*, induces the formation of a crypt in sand live oaks, and undergoes development in these crypts. Upon becoming an adult, *B. pallida* excavate an emergence hole and emerge from the crypt. When *B. pallida* are infected by *E. set*, they excavate an incomplete emergence hole, block the hole with their head capsule, and then die. While many examples of apparent parasite manipulation of host behavior exist, in only a subset of these systems do we have strong evidence that the host's infected behavioral phenotype actually increases the fitness of the parasite. We experimentally demonstrated that this modified behavior benefits the parasitoid, as *E. set* that have to excavate their own emergence hole are about 3 times more likely to die trapped in the crypt relative to parasitoids that only need to emerge through their host's head capsule. Additionally, this system represents a novel case of hypermanipulation – where a parasite manipulates the phenotype of a host that is itself a parasitic manipulator. The parasitoid is also new to science! The parasitoid fell in the genus *Euderus*, and we decided to name the species *Euderus set*, after the Egyptian god Set. Set was the god of evil and chaos, and had control over evil animals like serpents. We thought this was fitting since *E. set* is the parasite of a parasite (which mirrors an evil being controlling another evil being). Additionally, *E. set* kills its host in a crypt, consumes the host's internal organs, and then scatters the exoskeleton of its host around the crypt. The Egyptian God Set trapped Osiris (his brother) in a crypt, and later chopped his body into small pieces. We gave the parasitoid the common name the crypt-keeper wasp. We're definitely biased, but we think the parasitoid is beautiful! The paper in which we describe the new parasitoid species and the paper where we document the manipulation are both Open Access. Here is artwork from the amazing Boulet that describes the system. We're happy to answer questions about gall-forming insects, identifying new species, and parasite manipulation of host behavior. We're excited to talk to you! We'll be back at 12:30 EST to answer your questions. Ask us anything! Follow us on Twitter: Kelly Weinersmith: @FuSchmu Andrew Forbes: @Lord_Forbington *Edited to include link to our paper, link to Boulet's artwork, and our twitter account info.

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Science AMA Series: We're Drs. Kelly Weinersmith, Andrew Forbes, and Scott Egan! We just released a paper documenting a new case of parasite manipulation of host behavior. AMA!

PARASITE_AMA [R/SCIENCE](#)

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[The paper](#) in which we describe the new parasitoid species and [the paper](#) where we document the manipulation are both Open Access.

[Here is artwork from the amazing Boulet that describes the system.](#)

We're happy to answer questions about gall-forming insects, identifying new species, and parasite manipulation of host behavior. We're excited to talk to you!

We'll be back at 12:30 EST to answer your questions. Ask us anything!

Follow us on Twitter: Kelly Weinersmith: [@FuSchmu](#) Andrew Forbes: [@Lord_Forbington](#)

*Edited to include link to our paper, link to Boulet's artwork, and our twitter account info.

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CORRESPONDENCE:

DATE RECEIVED:
January 26, 2017

Congratulations on your exciting discovery!

How significant is the discovery of this parasitoid in realm of science of parasites? With respect to unique behavioural phenotypes! In a lighter note, do you all expect more species like these yet to be discovered, and of course , are there any deterministic probabilities of such organisms in the wild??

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[earthaerosol](#)

Thank you!

In my mind, the discovery is exciting because:

- 1) Parasites can change behavior in a handful of different ways. Behavior can change because a host generally gets sick (in this case neither host nor parasite benefit), because the host changes behavior to reduce the cost of infection (in which case the host benefits and the parasite suffers), or because the parasite is changing host behavior in a way that is bad for the host but good for the parasite. There are lots of examples of parasites that probably manipulate host behavior, but it's often hard to show that the parasite actually benefits from the host's weird changed behavior. This study was cool because we were able to show that the crypt-keeper wasp is about 3 times more likely to die without the host's weird behavioral change.
- 2) Also, it's an example of hypermanipulation, where a parasite manipulates the phenotype of another parasites that manipulates its host. The layers are exciting.
- 3) Personally, I'm excited because this was happening in the trees outside my office. I remember being an undergraduate student thinking about going into academia, and being super worried that I would never find anything new. But apparently (at least if you're an ecologist) something new and exciting can be as close as your office door.
- 4) The parasitoid is in the genus *Euderus*, and parasitoids in this genus infect some agriculturally important plants. So if this phenomenon is widespread then maybe the parasitoid could be used as biocontrol. But we're many, many, many steps away from being able to apply these findings in that way.
- 5) Finally, it's just cool. I think we underestimate the value of just letting Nature knock our socks off from time to time.

I'm not sure I understand some of the rest of your question. Could you be more specific about what you mean by "are there any deterministic probabilities of such organisms in the wild"?

-KLW

Are there clues about the mechanism through which parasites influence the behavior of hosts?
Secretions? Stimulation of reflex actions? Sensory spoofing?

[ArtifexPrime](#)

This is one of the things we're hoping to tackle next. It's hard to say what's happening here.

In some cases the mechanism of manipulation is pretty straightforward. For example, [Hoover et al. 2011 \(Science\)](#) found that one gene in a virus that manipulates gypsy moths explained the manipulation. The virus inserted that gene into the caterpillar's genome, and made the caterpillar produce a hormone that knocked out the caterpillar's usual cue to come down from the tree at night. The caterpillar then dies up in the tree, and rains virus particles down on the caterpillars that did leave the tree. The experiment was beautifully done, and the answer was fairly straightforward.

But then there are the [zombie ants](#), which are infected by a fungus that manipulates their behavior. Here the story seems more complicated, and the manipulation includes getting the ants to do behaviors that they don't normally do. The mechanisms seems to involve lots of different things happening ([see here](#) and [here](#) for example).

The manipulation in our system appears to be a behavior that the host was going to do already (i.e.,

the host already makes emergence holes to escape from the crypt when it becomes an adult), but the crypt-keeper wasp makes the behavior happen at a different time and the behavior is incomplete (i.e., the host doesn't completely emerge). So maybe the parasitoid is manipulating whatever physiological cue the host usually uses to decide when it's time to emerge and how hard they have to work to emerge. We really don't know right now.

-KLW

What a fascinating discovery! When parasites so negatively affect the host, how long does it take for selection pressure(s) to start causing a change in the host species? What are some mechanisms by which other hosts have overcome their parasitic threats? Or do the host and parasite tend to remain in an evolutionary arms race?

[shiruken](#)

Thank you! I was so blown away when Scott Egan first started telling me about this system. I feel so lucky that I get to work with these little critters.

I believe this is a fairly difficult question to ask experimentally, and definitely a fairly difficult question for which to have a general answer. The amount of selection pressure for parasite resistance to manipulation probably depends on things like exactly how bad the fitness consequences are of infection (in this case the host dies, so bad), how often hosts are infected by these parasites, and how much variability there is in the host population. We have evidence from museum specimens that this interaction has been happening for about 100 years, and [fossil evidence dates the zombie ant manipulation back 48 million years](#). So even these serious manipulators manage to manipulate for long periods of time, so in at least these systems there is likely an evolutionary arms race going on.

-KLW

Thanks for joining us today and congrats on your research!

My question is more human health related. *T. gondii* prevalence is fairly significant in the world, I'm wondering with its ability to modify behavior in mammals if you think people may be similarly affected. Do you think screening world leaders for *T. gondii* infection might be a worthwhile endeavor?

[PHealthy](#)

Thank you! There is [pretty good evidence that *T. gondii* impacts human behavior](#), and [one study found a correlation between neuroticism and the prevalence of *T. gondii* at the country level](#). This is a hard question to study in general though, because to really answer this question you would need to infect humans with the parasites and measure their behavior before and after infections. Otherwise it's possible that any correlations between infection and behavior that you do measure are caused because certain behaviors make people more likely to get infected (rather than certain behaviors change because of the parasite following infection).

I don't think we should screen world leaders for the parasite. I'm not sure what we would do with this information, since we can't kill the parasite once someone is infected. Though the results could certainly be interesting....

-KLW

Congratulations on the exciting and somewhat terrifying discovery!

Your paper notes that you believe the parasitosis occurs during the adult stage of *B.pallida*, but it led me to understand the actual contact between *E.set* and *B.pallida* was not observed (other than the the ones observed when the wasp was already contaminated). Is the life cycle of *E.set* still largely unknown?

[RioJjam](#)

Thanks! As someone who is mildly claustrophobic, I agree that the results are terrifying! Getting trapped in a hole while your insides get eaten by a parasitoid is a fairly unpleasant thought.

The life cycle of both *B. pallida* and *E. set* are fairly unknown. We did a lot of branch dissections, and we only ever found *E. set* in crypts with adult *B. pallida*. We found *E. set* at its larval and pupal stages, which led us to believe that the interaction probably started when the hosts were adults. We haven't observed the interaction in its entirety though, so we may yet be surprised by what we learn. Figuring out the timing of everything in this system is one of the big questions we're trying to tackle next. Of course it's tough, since the crypts and the critters are all so small, and they're patchily distributed on the trees.

-KLW

Can you tell us a bit on what you think the likely effects parasite influence on host phenotype might have on evolutionary or population genetics? Would there be detectable signatures?

[p1percub](#)

Great question. There is a long history of research on the co-evolution of parasites and their hosts and/or predators and their prey. This work has shown that evolutionary change in one can influence evolutionary change in the interacting partner. Specific to this system, manipulation of the crypt gall wasps, *Bassetia pallida*, by the crypt-keeper wasp, *Euderus set*, may drive changes in *B. pallida* that could lead to higher survival. Changes in immune function, timing (phenology), or crypsis are all possible. Our job in the next chapter of this work is to find out. - SPE

Are there any theories about what causes the host to dig an incomplete emergence hole? Something like reduced spatial awareness so it can't tell that it is incomplete? And how would the parasite induce that?

[kero von](#)

Good question! I wish I knew! It's possible that the parasitoid messes with whatever physiological cues the host usually uses to determine that it's time to emerge, and/or it's possible that the parasitoid weakens the host so it can only partly get out. We're hoping to tackle this question very soon.

-KLW

I'm not caught up at all on insect evolution, but do parasitic wasps all have a common ancestor, and did they eventually start preying on each other?

Also, what do these wasps eat during normal life and how long do they live?

The *E. Set* is absolutely gorgeous btw.

[dem0n0cracy](#)

Forbes: With respect to the common ancestry of parasitic wasps, I believe the current evidence suggests a primary origin of parasitic lifestyles back in the Jurassic, with subsequent losses in some lineages, and possibly new gains later. What that means is that the common ancestor of all parasitic wasps is also the common ancestor of bees and ants, which are generally not parasitic, and of stinging wasps.

Hi folks! What is your most interesting unpublished observation that you don't think you'll get the chance/funding/time to pursue?

[the yellow peril](#)

Forbes: For me (Scott and Kelly likely have different answers), the big question I'll probably never answer is: "how many different species of parasitic wasp are there?" Parasitic wasps attack essentially every other kind of insect, and most of them are incredibly small, rarely studied, and do not have names. Basically everywhere we look we find new species, even (and this is amazing to me) here in the U.S., where I think most people would assume we had named everything already. For instance, in another paper that Scott and I worked on together recently, we reared parasites from a different species of oak gall wasp and found 24(!) insect enemies. Of these, several species had never been described before. As far as I have been able to tell (studies like this one are rare), this situation is the norm and not the exception; when you look, you find new species of parasitoid. Also, many of them are probably doing weird and horrible things to their hosts (like *E. set*).

[1] How does the parasite manage to make the host stop and die out midway? What I mean is, as you mention, the wasp starts creating the tunnel but does not fully come out, thus making the parasite make its way out *through* the wasp. How does the parasite force this behavior of the wasp? Is it through secretion of chemicals/toxins at the appropriate time that enables this process?

[2] Why doesn't euderus (the parasite) simply wait for the wasp (the host) to make its way out through the tunnel? That way both of them will get to use the same tunnel to escape the "crypt".

[zakoda](#)

Thanks for your questions!

The answer to question [1] appears higher up in the thread. The short answer is we don't know yet, but I speculated a bit.

Pandaninja gave a good answer to [2]. *E. set* does eat the insides of its host, so it needs its host to stick around. Plus, we think *E. set* stays in the crypts while the host undergoes a life stage found in the leaf veins of live oaks and then emerges when the hosts make new crypts in the stems. So basically if *E. set* emerged with the host then the timing would be off.

-KLW

What is the process for naming a new species? Is there a regulatory body that manages everything and ensures that two organisms that actually are the same are not accidentally (or intentionally) classified separately?

[shiruken](#)

Forbes: to a large extent it is up to the authors to try to make sure they are not naming a creature that already has a name. There is quite a bit of research one needs to do to ensure this: consulting

previous species descriptions, museum collections (when possible), running your specimen through various taxonomic keys, etc. And then once you have decided that it does not have a previous name and you decide to name it, you then have to submit your argument and evidence in the form of a paper to a journal. The evidence that it is really a new species gets reviewed by independent scientists and by the journal's editor. So everyone involved tries their hardest to make sure the authors aren't giving multiple names to the same critter. Now, certainly double-naming is something that still happens, but the review process is intended to minimize such things.

I apologize if I missed it in the paper, but when and how exactly does the E-set manipulate the host wasp? Is it that the larvae is already inside the host wasp manipulating it when the crypt is tunneled, or is it as the diagram shows and the wasp is already under manipulation prior to the tunneling and independent of the larval parasite already in the tree? If the latter, what is it that manipulates the host?

[HerbziKal](#)

The details of the timing and the mechanism still need to be worked out. I speculate on the mechanism stuff above.

As for the timing, E. set appears to be ovipositing an egg into the crypt when the host is an adult. We don't know if the egg is deposited directly into the host, or if it is deposited in the crypt next to the host. During our dissections we found E. set larva and pupa halfway inside of manipulated hosts (half of E. set's body was in the crypt, and half was in the host). So we don't know if E. set ate its way out, or ate its way into the host at this point. But it does look like the host is manipulated by the time the parasitoid is at its larval stage. We're hoping to catch the system sooner in the season next time around to get a better handle on this.

-KLW

Definitely not going to ask about SMBC.

I haven't read the paper yet but the abstract and intro don't seem to definitively answer this: how was this discovered? Did someone come upon something weird in the forest one day? Were they looking for something else?

[BlackBloke](#)

Great question. My lab (SPE) works on gall wasps that attack oak trees across the Gulf Coast of the U.S. I was on vacation with my family in this region, near Inlet Beach, FL, and I am always keeping an eye out for my critters. As I was walking to the beach with my daughter, I found an unusually high number of one gall wasp species, *Bassetia pallida* (the crypt galler) in a stand of scrubby oaks on the backside of the sand dunes. Upon further inspection, I noticed the head plugging phenomenon, which led to this very interesting collaboration with Kelly, Andrew, and others. In general, I can barely walk from the train stop to work without digging in the dirt or looking in the trees. -SPE

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[BlackBloke](#)

Great to "meet" you, SMBC reader! :) I'll refrain from answering the question [since Scott discovered this](#), but I wanted to say "hi". So "hi"! -KLW

Thank you for sharing this amazing research.

Does this parasitoid interact in any way with *Wolbachia* sp., e.g. is it more common in areas where *Wolbachia* infections are likely?

[Trolske](#)

Wolbachia is a common bacteria found in many insects, where it can have wide ranging effects on its host biology. For E. set and its host, *Bassetia pallida*, we don't know if they are infected. There are other species of gall wasp in this area attacking the same trees that are infected with *Wolbachia*. To be continued . . . -SPE

Hi!

So, we characterize behavior using language. Calling it "manipulation" of host behavior has negative connotation because the parasite is obviously altering the host organism's behavior against its own self-interest (i.e. the host dies with the parasite, while the host wouldn't have died without the parasite).

My question is, when searching for the mechanism for how these parasite/host relationships develop, are you taking any cues from research of symbiotic relationships in nature, like for example barnacles on whales or labridoes? It seems like we call it "manipulation" because the host dies, but don't symbiotic relationships also describe a sort of 'manipulation' of the host?

[ATG77](#)

Sometimes scientist co-opt popular language to describe a phenomenon, and then we slightly change the definition. Manipulation of host behavior is defined by scientists as a situation where the parasite induces a change in host behavior, and this changed behavior has fitness benefits for the parasite while being detrimental to the host. It's nice to not have to learn a brand new word, but sometimes co-opting popular language makes discussing science with the folks outside of the specific scientific field a bit confusing (like may be happening here).

But we do think about parasitism under the general framework of symbioses. Symbiosis can generally refer to any 2 organisms that live together and interact closely for long periods of time. These interactions can be bad (e.g., when one is a parasite of the other), good for both (in which case they're mutualists), or whether or not these interactions are good or bad can depend on outside conditions (like something about food availability). The symbiosis we study seems pretty clearly to be parasitic, since the host suffers a lot while the parasitoid seems to benefit.

-KLW

Once we confirm the fitness effects of a host behavioral change (letting us confidently call it a "manipulation") the next question is often "So how does the parasite do it?" How do you think the parasite is doing this? Could it be that the first light the host's photoreceptors register as its chewing its way out of the crypt triggers the parasitoid to kill it? Have you tested the phenotype in a dark lab? Or do you think the manipulation is less reactive than just flipping a kill switch part way through the crypt-emergence process?

[Macracanthorhynchus](#)

Good question! I talk a bit about what we think is happening in terms of mechanisms above, but it would be super interesting to look at the role of light in this interaction. We have not yet done anything like what you describe in the lab. Partly it's because we haven't gotten that far in the system (this was our first season working with it in the lab), but also it's going to be hard to do something like this. Most of the crypt-keeper wasps emerged in a time period spanning about one month, and we only observed a crypt-keeper wasp eating its way out of the host's head on one occasion. It would be hard to know when a crypt-keeper wasp was starting to emerge since everything is hidden within the branch. That said, we're looking into getting branches CAT-scanned so we can see what is happening inside of them. So hopefully we can do something like this in the future.

-KLW

Hi! Fascinating study.

Why does the parasitoid need the host to die?

If its goal is to be safe in the hole for its initial development, and then to be off in the wild, couldn't it simply let the host dig a way out, and use it?

Or does it need the host's nutritional value?

[espadrine](#)

Forbes: You've hit the nail on the head with your last thought. Parasitoids (insect parasites of other insects that eventually kill their hosts) are primarily in it for the food. In this case, *E. set* also appears to be gaining an advantage from attacking a concealed host, but its greatest need is still the nutrition it gains from its host's tissue. Once it eats its way through the host's head and flies off into the world it likely won't eat very much more at all so the *Bassetia* wasp constitutes the one big meal it will eat for the duration of its life.

Hey, just asking: May this result in a chain-reaction influencing plant production and thus bacteria which assimilate $\delta^{13}\text{C}$ in young soils? Where are the parasites present? Greetings from southern Germany/Swiss border

Jon

[Jonjon91](#)

Forbes: Hi Jon! Scott and Kelly may chime in here to tell me I am wrong (they know this particular gall wasp better than I do), but in general the effect of the galler on the tree (and the effect of the galler's parasitoid on the tree) is going to be minimal. With few exceptions, oak galler infestations are not going to kill an oak tree or dramatically affect production. For that reason I would not expect there to be any measurable effect of gallers or parasitoids of gallers on soil organic matter or soil bacteria. It's a neat idea though.

I would like to ask a question for Andrew unrelated to the paper.

I am currently a freshman at the University of Iowa (actually waiting for my next class to start in 45 minutes). My current major is not biology and I don't really have an interest in taking biology classes. However, I am quite interested in things such as this and other studies relating to widely varying topics. I was wondering, is there a way I can get involved in my free time to help people like you with research?

I'd love to do hands on things that could give me a view into certain careers and possibly pique my interest.

[BabyInAStraitjacket](#)

Forbes: Hah! Go Hawkeyes. Yes, absolutely there are ways to get involved with research, even if you aren't necessarily interested in pursuing biology as a career. Most of the time all it takes is contacting a professor and showing interest in their work. We (faculty) are almost always looking for people to help out in one way or another. For instance in my lab, our *big* gall wasp project in the lab involves collecting, rearing, cataloging, identifying, and photographing thousands of wasps and their parasitoids, and we have several undergraduate helpers who contribute to that effort. Some of them are not planning to go into entomology or evolutionary biology, but that's ok with me (one of my current lab members is majoring in Japanese, come to think of it).

This answer applies to all undergraduates everywhere, by the way. If you find something interesting that a professor is doing on your campus, go talk to them about it! College campuses are full of amazing things and this is your chance to get involved before you head off into the great unknown beyond college.

Oh sure!! I mean to ask , can you determine a number of such organisms in the world or even better a percentage! I know I am asking a difficult question, in relationship to evolutionary biology!! Anyway, thank you to all for answering the first part!! Once again, congratulations!!

[earthaaerosol](#)

Forbes: Well, we don't actually know how many species of parasitoids there are in the world, but we do know that there are more insects than any other kind of animal AND that parasitoids are almost certainly the most species-rich of the insects (sorry, beetles!). So while we don't have a percentage, we can say that parasitoids account for a decent-sized slice of the pie.

Do you have any information on the current state of parasitic infection in humans and our ability to get rid of these things? My mother has recently found out she has had worms for a while and none of the anti-parasitics seem to be getting rid of them.

[Oldkingcole225](#)

I'm sorry to hear that your mother has worms. None of us study human parasites and we aren't medical doctors, so we really can't answer your question. If your family practitioner doesn't have an answer, then a neglected tropical disease specialist may be worth visiting. -KLW

Question: What's your favorite behaviour-manipulating parasite? and, as a silly follow up question: How can we know for certain that the people choosing the *Toxoplasma gondii* as their favorite behaviour-manipulating parasite aren't just being manipulated by the parasite to make that very choice? XD (I don't think you're influenced by the *T. gondii* because I think you'll choose the *Ophiocordyceps unilateralis* as your favorite)

[quesadalejandro](#)

Forbes: I have always rather liked the jewel wasp that uses the antennae of its cockroach victim as reins and guides it to its lair: <https://www.scientificamerican.com/article/how-a-wasp-turns-cockroaches-into-zombies/>

Also, my cats have told me not to worry about *Toxoplasma gondii* and to just keep bringing food.

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[quesadalejandro](#)

My favorite two systems were California killifish infected by *Euhaplorchis californiensis* (which is what I studied for my PhD) and zombie ants, but now THIS is my favorite system.

How do we ever know that a thought we have isn't put there by someone/something else? ;)

-KLW

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[quesadalejandro](#)

My vote goes to *Euderus set*, but I am a bit biased! -SPE