It's true: Varroa feed on fat bodies, not hemolymph

For this month's "*Notes from the Lab*," we're going to highlight the worst-kept secret in honey bee research for the past year. If you're a beekeeper who watches YouTube videos (which is pretty much every beekeeper I've ever met, including myself), you've probably seen Sammy Ramsey's award-winning "Three minute thesis" video on *Varroa*, which can be viewed here: **https://www.youtube.com/watch?v=Fyfyj-2O47Q**. As I write this, the video has been viewed 14,411 times.

If you've ever met Sammy, you'll know the video is spot-on at capturing his dynamic oratory skills. But what about the science underneath the exciting rhetoric? Well, the work that Sammy describes in the YouTube video was finally published in a peer-reviewed paper last month. So, for our seventeenth "Notes from the Lab," we highlight **"*Varroa destructor* feeds primarily on honey bee fat body tissue and not hemolymph,"** written by Sammy Ramsey and colleagues and published in the journal ***Proceedings of the National Academy of Sciences of the United States* [116:1792-1801 (2019)].**

Ramsey and colleagues' study was inspired by several astute observations. First, while it may make sense for blood-feeding parasites of humans to get their nutrients from blood (think about ticks latching onto your leg and engorging themselves), it actually makes little sense for parasites of insects to feed on hemolymph. Why? Because human blood is rich in nutrients, but insect hemolymph is generally quite poor in nutrients. Indeed, several previous studies of insect parasites have found they do not use hemolymph as their main source of nutrients.

Second, the initial work determining that *Varroa* feeds on hemolymph was conducted over 40 years ago and used outdated techniques that are known to be flawed. Essentially, the radioisotopes that were used to test where *Varroa* obtained its nutrients while feeding on different honey bee tissues don't work as well as we thought they did in the 1970s.

Third, if you look at where *Varroa* typically latches onto honey bees, it's not in an area with easy access to hemolymph. Instead, it's in close proximity to the fat body. Furthermore, if you look even closer at *Varroa*, its digestive system and mouthparts are organized in such a way that would make it difficult to feed on liquid (such as hemolymph) vs. semi-solid tissue (such as the fat body).

Finally (*and this is a key point for why Ramsey and colleagues' study is more than just interesting biological trivia*) many promising varroacidal drugs that have been developed for honey bees over the years haven't worked. However, several of these drugs have been developed to utilize hemolymph — the tissue that *Varroa* was assumed to be feeding on. If *Varroa* feeds primarily on fat body tissue instead of hemolymph, there would be no reason to expect the drugs to work.

With these observations in mind, Ramsey and colleagues set out to test whether *Varroa* feeds primarily on honey bee fat body tissues vs. hemolymph. The authors used an elegant array of methods to test their question, including observations and scanning electron micrograph (SEM) images of *Varroa* feeding locations

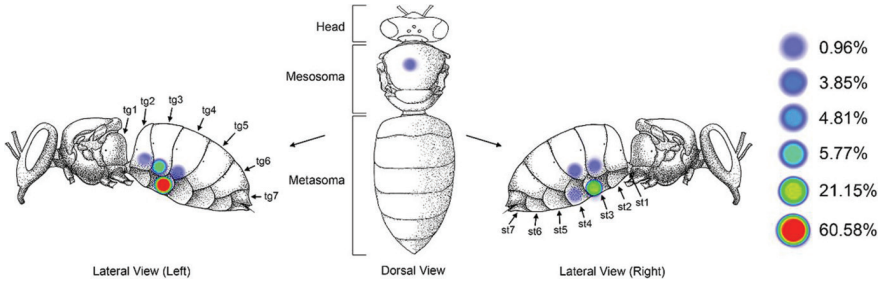
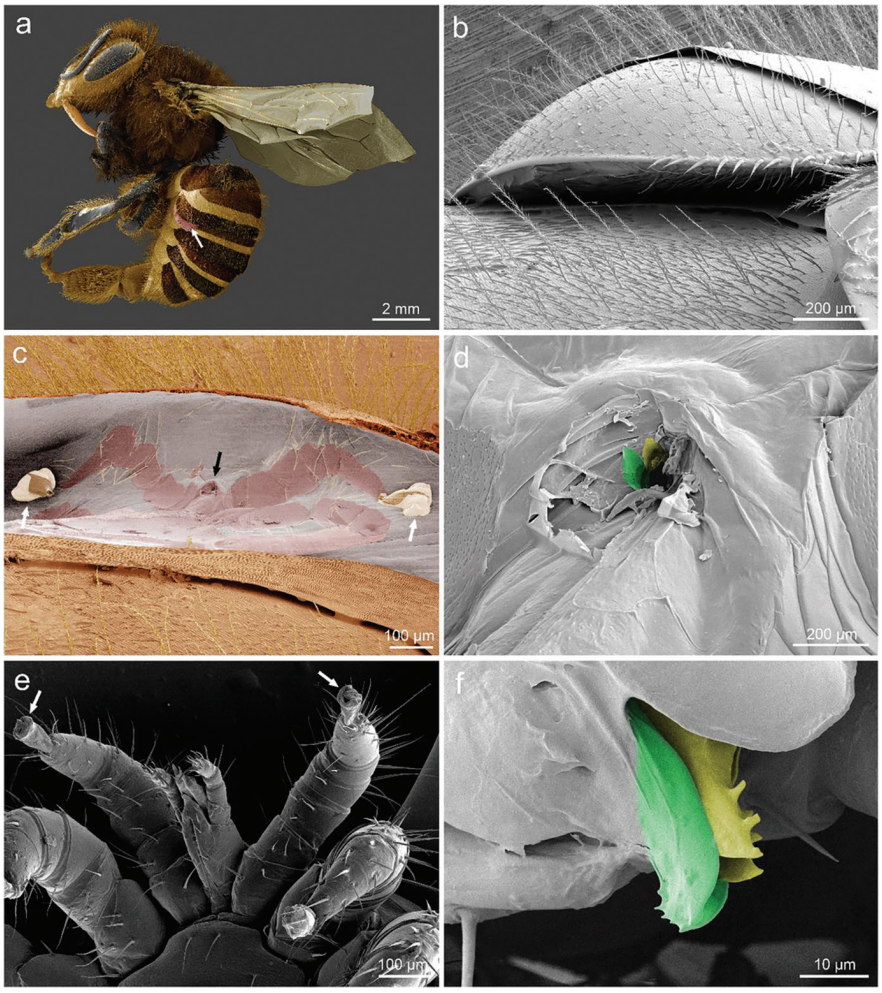
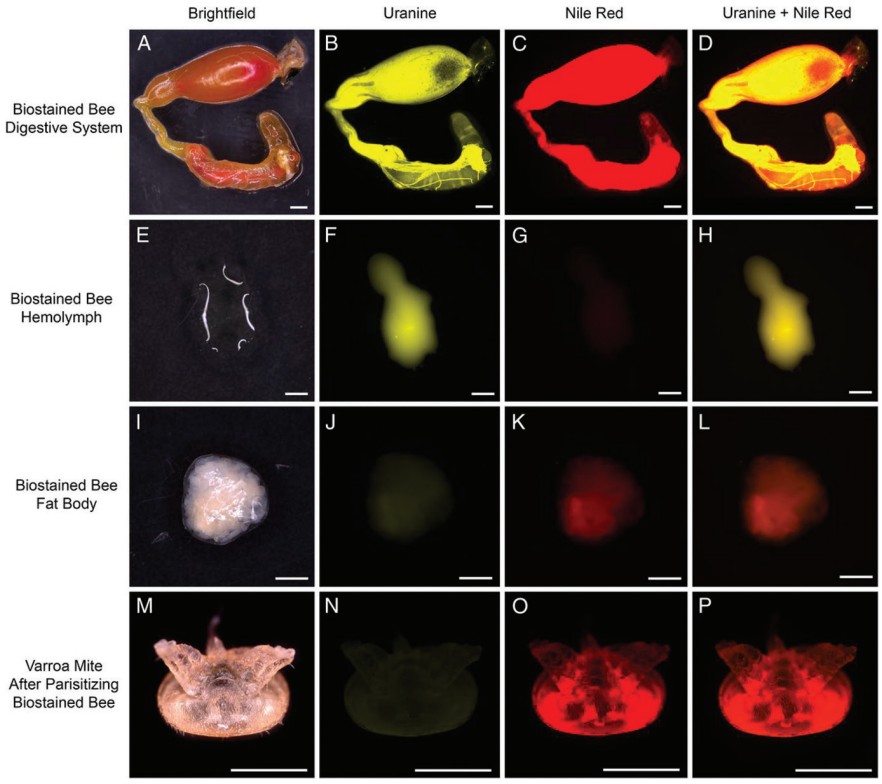


Diagram showing frequency of Varroa found in each location on 104 worker bees in five trials: Varroa destructor consistently prefers to interact with the underside of the honey bee abdomen, an area predominated by bat body tissue beneath the cuticle. Mites were also found preferentially on the Left side of the host.



Scanning electron micrograph images showing: (a) honey bee with Varroa mite feeding at location indicated by the white arrow, (b) feeding mite wedged underneath a tergite of the abdomen, (c) feeding wound from the mite shown via the black arrow, (d) up-close image of the feeding wound with leftover Varroa mouthparts shown in green/yellow; corresponding mouthparts on Varroa shown in (f), and (e) foot pads of the Varroa mite shown via white arrows; note the foot pads remained on the bee when the mite was removed (white arrows in [c]).



The fluorescent stains uranine and nile red provide strong evidence that Varroa destructor feeds predominantly on honey bee fat body tissue. Note especially the near absence of yellow in (N) and (P) and the strong presence of red in (O) and (P).

(images taken at the Electron and Confocal Microscopy Unit at the USDA-ARS), fluorescent tissue-specific staining of *Varroa* feeding and nutrient acquisition, and survivorship experiments of *Varroa* feeding on diets varying in hemolymph and fat body tissue composition.

So, what did they find? Did *Varroa* feed on hemolymph or fat body tissue? All of Ramsey and colleagues' observations indicated that *Varroa* fed primarily on fat body tissue. First, *Varroa* spent the most time at honey bee abdomen locations that are nearest to the fat body, not hemolymph. Second, the locations where *Varroa* pierced the cuticle and fed upon honey bees was always directly above the fat body, not hemolymph. Finally, when Ramsey and colleagues used two different fluorescent stains to assess where *Varroa* obtained its nutrients, each stain provided evidence that the nutrients came primarily from the fat body, not hemolymph.

Did feeding on fat body tissue impact *Varroa* survival and offspring production? Yes, mites that fed on fat body tissue survived nearly twice as long as mites feeding on hemolymph. In addition, mites feeding on fat body tissue produced about eight times as many eggs compared to mites feeding on hemolymph. In other words, it makes a lot of sense why *Varroa* would choose to feed on the fat body rather than hemolymph — they survive longer and have more offspring.

Well this is interesting and the pictures are really neat. But why might this be important for me and my

bees? Remember, researchers have been trying to develop chemotherapies for honey bees to combat *Varroa* for many years, but most therapies have failed to be effective. To develop useful chemotherapies, it's critical to know how to get the varroacidal chemicals into *Varroa*. Given Ramsey and colleagues' results, you could say that previous work has literally been swimming up the wrong stream by assuming that hemolymph was the tissue to focus on.

Now that we know *Varroa* feeds primarily on honey bee fat body tissue, more effective chemotherapy drugs can potentially be developed. Similar to the great advances in chemotherapies to manage cancer in humans over the past several years, there is now great opportunity to develop more effective chemotherapies to combat *Varroa*. Will there be a silver bullet? Probably not. But beekeepers desperately need more tools to combat the *Varroa* epidemic, and Ramsey and colleagues' study has opened up a major door toward development of those tools.

Until next time, bee well and do good work,

Scott McArt

Reference:

Ramsey, S. D., R. Ochoa, G. Bauchman, C. Gulbronson, J. D. Mowery, A. Cohen, D. Lim, J. Joklik, J. M. Cicero, J. E. Ellis, D. Hawthorne and D. vanEngelsdorp. 2019. *Varroa destructor* feeds primarily on honey bee fat body tissue and not hemolymph. *Proceedings of the National Academy of Sciences of the United States* 116:1792-1801. **www.pnas.org/cgi/doi/10.1073/pnas.1818371116**

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