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After Two Years Scientists Still Can't Solve Belly Button Mystery, Continue Navel-Gazing

By Rob Dunn | November 7, 2012

This is a confession. I started out as a respectable sort of ecologist studying rain forests and then at some point my road turned and I ended up where I am today, lost among the belly buttons.

I know how it happened. Two years ago we began to focus much of our lab's work on engaging the public. One way to make science public is to work with people to study their own lives (see yourwildlife.org). This is just what we did. Spurred by the idea of an undergraduate student, Britné Hackett and the microbiological skills of a postdoc, Jiri Hulcr (and funded by a grant from the Howard Hughes Medical Institute), we went boldly where few had dared or really wanted to go before: into the navel. We saw piercings, an infection or two, lint, and more hair than we were comfortable with. It was innocent, or at least it started out that way.

Image 1. We boldly went where few scientists have dared before: into the umbilicus. We promise you, they don't always look this nice. [Photo by Jalb, Flickr Creative Commons].

The idea was simple. We would culture the bacteria of people's belly buttons to provide folks with a visual measure of the life on them, a reminder of the mysteries everywhere. Then we noticed something more serious. It might have been a good moment at which to turn back, but collectively our crew seems to lack that capacity so we stormed ahead, deeper into the squishy unknown.

We quickly found that peoples' belly buttons differed in terms of which species live in them. They differed more than we expected. We were intrigued and so we decided to get a little more serious about our study. We teamed up with Noah Fierer (who I have still never actually met in person) to use molecular approaches to compile more complete lists of the species living in people's belly buttons. This is when things got weirder. We expected that in employing this more complete method of sampling that the species in different belly buttons would become more similar from one belly button to the next (as we got a more complete sample of who was present in each). They got more different.

We began to more seriously wonder what explained the differences from one person to the next. We were finding hundreds and then thousands of species, many of which appear new to science. They included strange species, such as one species found on my body that appears to prefer to break down pesticides. One can imagine many possibilities and over coffees and beers, we did. We started reading up on the many things we did not know about belly buttons. We asked dumb questions in order (we hoped) to be able to ask smarter questions. At one particularly dark juncture I asked primatologist Ann Yoder if I could sample her belly buttons. This was followed by an awkward moment during which I had to explain that I meant the belly buttons of the lemurs she studies and then an even more

awkward moment when she politely pointed out that lemurs don't really have belly buttons. At each turn, we were more ignorant than we thought, and yet at each turn the bacteria on skin (including the belly button) seemed more important. More and more studies seem to point to the conclusion that diverse skin microbiota helps us defend against pathogens and may forestall some immune dysfunctions (including allergies). The composition of our bacteria may even influence how we date and mate. But what determines which bacteria we have, which life forms are dividing on you as you read?

We solicited even more involvement—more students to help with research, more petri dishes and, more ideas from participants, and, of course, more belly buttons. People helped. Shirts were lifted. Swabs were inserted and wiggled about. The Internal Review Board at North Carolina State University was consulted again and again; they giggled and obliged. Belly buttons were a new horizon for them as well.

We wanted to engage as many people as we could in the endeavor, but we'd also become really curious about the causes of the differences in belly button bacteria among people. One can imagine many factors that influence which bacteria are on your skin; whether you were born c-section or vaginally, gender, age, weight, whether you are an innie or an outie, whether you live in a city or the country, what climate you live in, whether or not you have a dog, and maybe even where you grew up or where your mother lived when she was pregnant with you.

As we looked at belly buttons we saw a terrible, yawning, richness of life. The average belly button hosted 50 or so species and across belly buttons we found thousands of species (and as we sample more belly buttons, we continue to find more species). The vast majority of these species are rare. Right away something struck an ecological chord. The belly buttons reminded me of rain forests. In some tropical rain forests, even though there are many species of trees, a few species are both present in most forests and common when present. Those species have been called oligarchs; the belly buttons seemed to also have oligarchs too.

If we took two groups of people—in our case one group was participants from Science Online 2011, the other was visitors to the North Carolina Museum of Natural Sciences—the frequency of bacterial species in one sample predicted its frequency in the second. For example, if a species of *Staphylococcus* was found on many people at Science Online, it was also found on many people at the North Carolina Museum of Natural Sciences (e.g., check out 'portraits' of the different groups we've studied so far and compare for yourself here). These were the oligarchs. Conversely, infrequent species tended to always be infrequent. If a species was found on very few individuals at Science Online, the odds were that it would also be found on very few people visiting the Museum of Natural Sciences. In fact, the frequency of species at Science Online predicted most of the variation of the frequency of species in the Museum of Natural Sciences sample (and vice versa). The most frequent species also tended to be the most abundant (at least by our crude measure of abundance, the number of "reads" of a particular form in our genetic analyses). Even if we couldn't predict which species you would have, we could make predictions about which species were most and least likely in general.

Fewer than a dozen oligarchs accounted for the vast majority of the occurrences and abundance of bacteria in our study. And so while there are many, many, species found in belly buttons, a teeny subset seems to matter disproportionately. These abundant, frequent forms also tend to come from fewer evolutionary lines than we might expect by chance. Overall the species that can be found in our navels seem to come from all over the evolutionary tree of microbes, whereas those that are abundant and frequent are from a narrower subset of lineages, the clans with specific adaptations for the dry, nutrient poor desert that is your body (e.g., see species highlighted here).

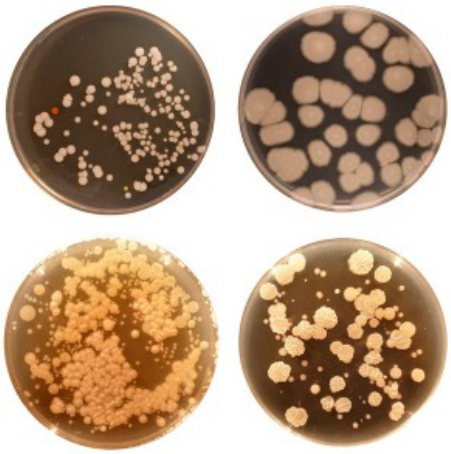

Image 2: Portraits of belly button oligarchs. Clockwise from top left: *Micrococcus*, *Clostridia*, *Bacillus*, *Staphylococcus* [Photo by Neil McCoy]

There were other discoveries too. One participant self-reported he had not washed in years (On its own, this was a "find," though not really the type we anticipated). Interestingly, he was one of just two people on which we found not only Bacteria but also Archaea; he hosted two species! We would love to sample (albeit with longer swabs) more folks who never wash. Such individuals are probably more representative of the state in which our bodies existed until a few generations ago when it became popular to bathe regularly. In other words, our one bathless participant is closer to being like a king or queen of ole than the rest of us will ever be. Maybe we need to go to Burning Man to find others of the hygienic royalty.

All of this is what we report on in our new paper in PLOS ONE, but I'd like to tell you what is not in the paper, our real problem, the rest of the story. While it is interesting to be able to predict which species of bacteria are frequent and/or abundant in belly buttons in general, what we cannot seem to account for is which species are present in any particular belly button, say that of Carl Zimmer (who has written about his own hairy nub here). We would love to know what accounts for why I have a belly button dominated by one set of species and Carl Zimmer has a belly button dominated by another. This should be easy to figure out. We can test for whether the differences in belly button bacteria tend to be associated with other differences in peoples lives.

Mandi Traud in my lab has started to do this work; Mandi is a biomathematician, she looks at the living landscape outside her window and sees ones and zeros. She looks at belly buttons and sees more of the same. As Mandi started to consider the ones and zeros of the belly button data she saw something very intriguing that then led us down a rabbit hole from which we have not yet escaped. Mandi did an analysis in which she examined whether individuals could be grouped into clusters according to the composition of their belly button bacteria. You can see an example of Mandi's analyses below. Overall, across many different analyses, Mandi tends to find that people cluster into groups based on their bacterial species. Some people's belly buttons have beech forests, or at least their bacterial cognates, others have maple forests. We suspect those different forests work in different ways, which is testable though we haven't yet done the test. That is the cool part. The not cool part is that none of the variables we have considered appear to explain these different groups; not age, not gender, not ethnicity, not innie vs. outie, not where you live now, not where you grew up, not whether or not you have a dog. No, no, no, none of it. We see hints of things (a hint, for example, of an influence of the region you grew up in), but such hints have so far proven illusory and depend on just how we run the analysis. They have taken us down long roads only to circle back around to where we began, the stubby knot of the umbilical cord.

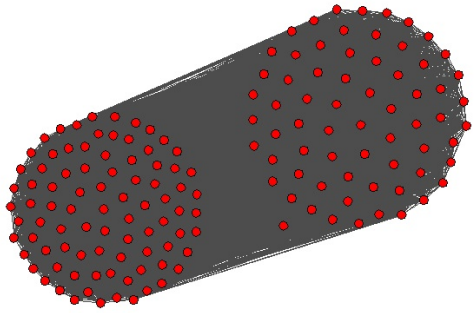

Image 3: In this image, each red circle is a person (or really, a person's belly button). The lines represent bacteria species shared among people, the darker the lines the more species are shared. Network analysis suggests there seem to be at least two basic types of people, according to their belly button bacteria. If bacteria were trees, this is analogous to their being some people with beach forests in their navels and others with maple forests. This much is true, we just can't say why.

We have now sampled more belly buttons in the hope that in seeing more variety we might be able to disentangle what is going on. Instead of the 66 samples we included in our first paper, or the 300 we have now, we will soon have over 600 samples of people processed, people from all over North America. With this variety, we may well begin to explain the differences among people in terms of the intimate forests of their umbilicus. On the other hand, we may still be unable to account for our differences; it may be that part of what determines who lives on you is *stochastic*, a fancy scientific word for what happens when fate and the universe's contingencies come together in your navel. And of course although everything I have said so far is confined to the navel, we look to the navel as an example of the skin more generally. The same mysteries lurk in ears, noses, eyebrows, toenails and especially armpits (armpits are the body's real antipodes, where few have really gone before). Although we have come to understand how we inherent our precise genetic make-up we are still a long way from explaining the composition of the much greater diversity of genes on you, the genes of your microbes.We know these species are important; they affect your health and odor each and every day. We just don't have a clue what determines who they are, yet.

Note: If you would like to be involved in our studies in the future, you can sign up at yourwildlife.org to be on our email list. We are now seeking participants for studies of ants in backyards, camel crickets in basements, bacteria all around your house and more. Armpit exploration is on the horizon, as may be more belly button sampling if–when we finish our next batch of samples (we are always much slower than we hope to be)–we see more clues as to just what is going on. For more context on some of these projects and what we and others have found in other realms of our everyday life see www.robrdunn.com.

About the Author: Rob Dunn is a science writer and biologist in the Department of Biology at North Carolina State University. His first book, Every Living Thing, told the stories of the sometimes obsessive, occasionally mad, and always determined, biologists who have sought to discover the limits of the living world. His new book, The Wild Life of Our Bodies, explores how changes in our interactions with other species, be they the bacteria on our skin, forehead mites or tigers, have affected our health and well being. Rob lives in Raleigh, North Carolina with his wife, two children, and lots of microbes. Follow on Twitter @RobRDunn.

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