What Fungi Can Teach Us About Life

What can fungi reveal about evolution, biodiversity, and life on Earth? In this episode, Dr. Jason Stajich, Professor of Microbiology and Plant Pathology at UC Riverside, discusses how genomics and computational tools are used to study fungal evolution. We also explore the role of library resources in enabling open, collaborative scientific research.

Jing - Welcome to the Reference Desk, a biweekly podcast exploring the frontiers of academic research here at UC Riverside. I'm Jing Han, your host and digital scholarship librarian in the UCR Libraries' Division of Research Services and Technology. In each episode, I sit down with UCR's leading researchers or emerging student-risk scholars to explore the questions driving their work, how they use library resources and services to shape their discoveries, and the books and articles that have influenced their thinking. Today, we are talking about fungal genomics, evolutionary biology, and how computational tools are helping researchers understand the foundations of life on Earth. Our guest today is Dr. Jason Stajich, professor of Microbiology and Plant Pathology at UC Riverside. His research investigates the evolutionary fungi using comparative, computational, and experimental tools, with applications ranging from ecosystem science to infectious disease. Dr. Stajich, welcome to the Reference Desk. Thank you for joining us.

Dr. Stajich - Hi, welcome.

Jing - So, what first sparked your interest in fungi and evolutionary genomics, so how did you stumble upon this very specific research topic?

Dr. Stajich - Yeah, it happened in graduate school, and I had started out in my college studies in computer science and had really been interested in data. How do we kind of manage data or interact with data? And I was looking at different data sets that were kind of interesting, and at the same time, I got a job as a programmer before graduate school, in the medical school, to work on data sets related to human genetics. And so I got really interested in thinking about genetics. My dad is a physician's assistant and did research, and so I kind of was exposed to research genetics. And I decided that it would be really fun to keep working in that space. And when I did my rotations in graduate school, I ended up in a lab that worked on fungi, worked on yeast, and I kind of was struck by all the questions we could ask in the lab, but how at that time genomic sciences was building these big data sets. And how we interacted with that data was going to change how we could interpret some of the science. And so I just got excited because it was like a time kind of in the earlier days of some of that work, and we were starting to sequence many different species of fungi. And so the data set was growing, and I was like, oh, my computational tools and training could work here. So I wasn't actually even sure I liked working on fungi at that time, but what kept me or drew me in was also this community, this set of people that I interacted with in graduate school, at conferences that were just really welcoming, passionate about what they did. And there wasn't a lot of pretentiousness that I had to have some background that justified why I was there. It was like they welcomed me in, and I learned things, and then I felt part of that community, and then I became more of an expert in the organisms and kind of fell in love with the breadth of biology that fungi do and interact with. And so it became this flower that kept opening. I kept looking at, oh, wow, I know about mushrooms, but I didn't know about how the molds worked. I didn't know how some of these fungi have really different morphologies. How did that evolve? And so really getting deeper into just like this many layers of things that we just didn't even know how they had originated, and we were learning some of the rules of the evolutionary processes that drove that. And so genome science was another tool in studying that, and so it was really fun to be able to kind of take what I was mastering from a computer side and bring that into these other questions. And yeah, I fell in love with both the fact that we can go out into the woods and find these organisms and kind of think really deeply, like, why is it growing here? What is it– what was the signal that told this mushroom to grow at this time versus later? Why are these species here not there? And so that starts to open up these questions about ecology, about where species are found, and then how do they interact with these different organisms? How does it interact with the plant? My graduate lab worked on a fungus that causes disease in humans, and so it was, well, did it evolve to be a human pathogen, or is it just happenstance that it was being introduced to humans, and it happened to have the tools or the ability to cause infection? And so is that really kind of a co-evolutionary process where it became very specialized on attacking a human, or is it really just the other pressures in evolution that drove some of those traits? And so can we get to the bottom of that? Can we learn more about that by contrasting different species? So anyways, that's– both fascinated by the biology, as I learned more, and a community of people that were really helpful in mentoring, and welcoming, and kind of making it a really fun place to do science.

Jing - So if you have to estimate, give it a number, like a percentage, how much do you think the community, including yourself, actually know about the world of fungi?

Dr. Stajich - How much do the specialists know about fungi, or even the rest of the world?

Jing - No, no, just like specialists. Because for some disciplines, maybe it's at the beginning, but you mentioned that when you first joined this discipline, it's like early stage, so now probably we know a lot. So if you have to estimate how much we have learned in the past decades, several decades, do you feel like there's only like 1% of known to us, or like there's like 90% known already?

Dr. Stajich - So of course mycology study of fungi has been around for a long time. There are many famous naturalists that have spent time studying them. But how we brought the molecular biology to that has been more recent. So I don't know, I guess we know, yeah, I don't know, 25%? I have no idea how to estimate that one. I think as we get further in, you know, we go to new environments and we find microbes, fungi, bacteria, that we've never seen before, that no one's ever seen. So I mean, anywhere we go on Earth, we always find something new if we look carefully with these tools that we have. So that's pretty cool. Whether there's some shared, you know, whether finding this new version of a particular microbe is so different from another one that we know about, hard to say. Hard to say, what's this open space, or sometimes called dark matter, like what is the space that we don't know? And so I think that's been an interesting journey. But yeah, I'm not sure I could estimate it very accurately.

Jing - Yeah, I'm just curious because I also have friends who are just interested in just collecting mushrooms. They will go on trips, I believe in Pennsylvania, like every spring or like summer. I'm not sure the season. But it's just fun. I always want to join them. You know, they are not like scientists, but also they have just like butchers and collect them. Right.

Dr. Stajich - There's a fantastic community– or I mean, we might call it we might use the word amateur just because they're not professionally doing it for their job. But they– most of the amateurs that do this are more experts than many of them. I call it the professional mycologist because they're out there really fascinated by it and studying. And so I mean, we do know a lot of the mushrooms because that's the kind that we keep seeing. We're able to document those. There's a lot of microbes that are microscopic that are, fungi that are microscopic. And so those are ones that we obviously have. It takes more work to discover those.

Jing - Yeah. And then a fun fact I learned recently. So this is a part of China. It's called Yunnan. And then there are a lot of mushrooms and people love eating mushroom over there. But a lot of them are actually poisonous. So when you go to a restaurant, so all your utensils will be, you know, not given to you because you have to let the staff there to cook your mushroom for like 15 minutes. So because it smells so good, everyone wants to eat it. Right. But they don't want to be responsible for any incident. So they take away all your utensils until it's ready to eat.

Dr. Stajich - Well, it's important to know what it is that you're collecting. And certainly that takes a bit of expertise. So it's not something one should take lightly without knowing enough about what you're collecting.

Jing - Yes. Yes, definitely. So is there any really exciting project we're working on right now that you'd like to share with us?

Dr. Stajich - Sure. I mean, it's always hard to pick one, but I'll say something that we're really getting pretty interested in is trying to understand how fungi can live in an extreme environments or be really resilient to a lot of different extremes. So you might think about mushrooms, as you mentioned, there's a certain time of year when the mushroom comes up and that has to do with when the water, when it rains, what the moisture availability is. And sometimes the signals from the tree as to whether or not it's a good time for it to produce. The mushroom is really how it produces the spores to reproduce. But there are other microbes that we've– fungi that are microscopic that we find everywhere. And it's interesting to me whether those are really adapted to a lot of different environments. Like, are they really resilient or are they really specialized versions of that same microbe in different places? And so a fungus that we've been working on is a yeast fungus. So yeasts are usually single cell. They're single celled that many of them typically bud. So you can think of Saccharomyces that we use to make bread, or make or to brew beer, or our wine. That's a yeast. But there's a that's a that's a form. That's a shape. Right. And so there's the shape of or morphology of yeast is found in a couple of different places in the evolutionary tree of fungi. And a different part of the tree from Saccharomyces is where the mushrooms are. And within that group, there's a fungus. There are fungi that form yeasts. So you have things that make mushrooms, and then somewhat related to them are things that make yeast. So it's kind of interesting to think about how that transition occurred about shape. But we're working on a yeast. It's called rotatorula. It's pink, sometimes orange. It's that color comes from carotenoids, you know, akin to the orange color that you see in carrots. But it's a similar pathway to produce these. That's the pigmentation. And we can find it in food. You can find it in spoiled cheese. You can find it in the soil. But there are researchers who do all kinds of really exciting collecting in, you know, Antarctica and in the marine environments.

And you can isolate rotatorula in these in dry deserts, from rocks, from ice sheets or glaciers, even from– people do cloud sampling. And they can find it growing. They can find spores that are– that you can culture from there. So we're interested in that fungus because we might call it an extremophile because we can find it in really extreme environments. But it also grows in kind of normal environment, less, less extreme meso environments. And so that is fascinating to me because I don't know– I want to know, has it specialized in being able to be really good. The cultures that we get from rocks. So we have projects where our collaborators have broken open rocks from Antarctica that look like they have nothing on the outside. They might have little stuff on the outside, but they break it open and they can culture fungi from inside a rock. And there's a couple of different species that are in there, but one of those sometimes is rotatorula. And yet we can find rotatorula in– we go to Joshua Tree and crack open a rock or culture from some of the soils. We can also find rotatorula and I can find it in my refrigerator sometimes. Right. So, well, is it the same species? Sometimes it's different, but they're related. And are they really good at cold and hot at the same time, or have they learned, have they adapted to those different environments? And so we want to know that process. And, you know, there's some practical parts of it. So it turns out that it's really resistant to heavy metals like copper and iron and zinc and lead. And so we can grow that fungus in environments that most other fungi would not be able to survive in. And so what's the mechanism for that? Why? What did it gain? Maybe we can learn that– those adaptations and maybe we can use those and put them into another fungus that we do want to grow in an environment that's contaminated. What we're trying to do by remediation. So we want to be able to have it be able to resist the compounds that are there, let's say, and maybe produce an enzyme or something that could help bind or or ameliorate an environment that has contamination. So you want to learn how to make a more resilient fungus. So that's maybe a practical way that we would maybe try to learn from that biology.

Jing - I'm just thinking out loud. So this specific fungi change color when it's like, you know, trying to remediate a kind of contamination. So it's like, you know, visible to lay people like me. So maybe when they first come into this very extreme, the environment was like a different color. And then when it comes out like purified is another color.

Dr. Stajich - That's a great idea. No, there actually are people working on sensors that can pick up whether or not– some researchers at UCR. In fact, Sean Cutler and Ian Wildenslab have developed plants and microbes that can express like a receptor that can detect certain kinds of compounds. And you can decide what compound– you can build that as to what you're looking for. And then it can turn on some sort of coloration or fluorescence or something. So, yeah, there are examples where we could engineer that and sort of say, oh, it's clear. There's nothing here, versus there's something in there. A lot of fungi produce pigments that you can– sometimes we have some that produce really black colors. And that's usually melanin. That's a production and melanin provides a lot of protective effects. It can absorb UV and it can also absorb reactive oxygen species, which are kind of damaging to cells. And so often when cells are stressed, they start to darken, and some of them will start to darken up as a way to protect. And the carotenoids are another type of pigment that can also provide some protective effects. So, again, yes. Not always, but sometimes the darker color does mean that it's, you know, it's providing some sort of protection. And that might be a signal that there's something in the environment to be aware of. Not always, but that can be the case.

Jing - So are you surprised when you're studying this fungi, is so resilient, you know, can survive under so many extreme environments? Are you even surprised up to this point?

Dr. Stajich - I am. Oh, yeah, I'm surprised by this one. And I think that's still the question of when you– ecologically, when you find something in the environment again, is it there because everything– there's one sort of theory that was kind of first put out there, is like everything is everywhere. But then the environment selects. But I think that in this case, that's not always. I don't know if that's really the case for all things. But I think in this case, this fungus seems to be able to disperse. Right. So it's able to be in a lot of places. And then when it's there, it seems to be able to survive, or at least thrive in those environments. Maybe it's not a great compete-er. So it might be– there are some strategies like grow really fast, take up all the resources and beat your competitors. And then, you know, you think about the origins of some of the medicines that we get from fungi. So like penicillin, the thought is, those are filamentous fungi that produce those. You've seen mold on your orange if you've ever let your orange lay out too long. That's a penicillin– penicillium relative or species. And so they grow in the soil and often it's about competing for resources. Right. So you produce a toxin that everybody else is like, oh, I can't live. And so that's the way to gain resources. But there may be other strategies which is like– live in– if you can survive in an environment in a niche where maybe you don't have to compete as much because nobody else can survive, because that environment's really hard. And so I think that's another strategy or another property that we might try to investigate. So I am surprised to find the same species in a lot of different places, but we'll see what that means as we go further down into researching it.

Jing - Yes, it's so interesting. So have you ever used any library resources or services that have helped your research or even helping your students complete any research tasks?

Dr. Stajich - For sure, for sure. I mean, a lot of the– so I'm sort of describing kind of research questions, but I mean, our tools and our and our approaches generate data. So a lot of that data is genome sequence data. And so there's a certain strategy for how we access that data in public resources, public databases, the National Center for Biotechnology Information. That's part of the NIH is an essential tool for us. That's a freely available government funded database that all publications around that have sequence data in the publication, that data has to be deposited in that database, or its sort of sister version of it that's in Europe or in Japan. There's sort of these three kind of replicates of that data set. And that's really important for transparency and for reproducibility, right? We want the data to be there because people ask additional questions of the data once it's been published. So that's a critical resource. But also the literature resources, of course, being able to search PubMed or Google Scholar or link to journals and being able to read those as I mean, 100% what we do to be able to interpret the findings that we might have. If we identify a gene through some sort of analysis work, then we're going to go and look at what papers have been written about that gene. Maybe not in our species, but in related species. And that will help us interpret our findings or design new experiments. And there are other curated databases of sequence information. There's a project that's called the UPathDB for eukaryotic pathogens database. And it also has a lot of important resources, so we subscribe to that database to help support it. But also it's an important resource that helps collate data and allow data mining from it. So it's not just important to have data in a place, but to have it actually, of course, accessible and intuitive in terms of how you can ask questions of it. So that's maybe a quick little slice of some of the things that we do.

Jing - Yes, it seems like the data is active focus. So last episode, we actually had the STEM collection strategies from the library. I came to do episodes with us for the holiday special. And then we discussed so faculties and students, you do have the power to request any databases or journals that we don't have access to. So I just want to mention that. So if there's any resources you want us to require, acquire, then we can take a look on that. And also related to data. So within our department research services. So we help students and faculty with their research. So we do have a data scientist on board. So I imagine bio informatics is part of their work. So I believe she can also help you with data related stuff when it comes to analyze, visualization, and also finding data. But I believe you probably know where to find the data already.

Dr. Stajich - Sure. But I think also what's what you're mentioning is this sort of teaching about how to access and organize data. And I think one of the key skills that students and trainees can learn is how to organize the data that you have. And or as you kind of learn something or build something from a recent search, how do I continue to collate that data in my own collection so that I can– it's logical, right? So again, if we're producing a lot of data files, how do you name them? How do you organize them? Right? How do you imagine that someone else will use that data, is something I always try to emphasize so that it can be reusable. It's not just about your project. I mean, that's important. That's where you're focusing. But could you imagine where this data would be useful to someone else? How would you like them to find it? You know, it would be great if you had metadata that describes where it came from or, you know, reproducible methods. So we build workflows to process data. And the importance of the workflows is that's essentially a documentation of how the data were managed and or manipulated and processed to get to another answer. And so that's critical. So I think the library also provides training on things like the software carpentries and data carpentries. Sometimes there have been examples where teaching methods that are just general, about how to interact with organizing.

Jing - Yes, yes, my colleague, Barbara, definitely did a workshop on that last quarter. And she has upcoming ones for the winter quarter. And then for the winter quarter, there's also UC wide data related events called love, UC Love Data Week. So it's a whole week of different workshops online. So offered by different UC colleagues. I believe it's in February. Specific days, I kind of forgot, but you know, information will be online available very soon. So that's a whole week of events like learning different methods. I'm not sure if this one is for bio informatics specifically, but you know, try to cover as many areas as possible. So for students or like, just listeners who are curious, you know, want to get into your field, what do you suggest them to do? Maybe the first thing or just, you know, general recommendations?

Dr. Stajich - Yeah, I think if they're wanting to get into bio informatics, genomic sciences, there's definitely some classes that give introductions to that. There's both some online classes that one can kind of follow along with at their own pace. We do have some introductory classes offered at UCR for introduction to bio informatics. That's, I think, offered almost every quarter. And I think for mycology and study of fungi, there are a couple of classes that are offered through my department that are for– there's an undergraduate mycology class, and there's some graduate level ones. The microbiology major’s where probably where one might find a home if you were interested in microbes like that, including fungi. And I am teaching a class in the spring called food microbiology. So we're going to focus on how microbes are both beneficial and how we, you know, how we ferment foods, how we also do things to prevent microbes from growing in our food. So that was from a safety standpoint, and kind of thinking a little bit about how as humans, we've had this long standing interaction with the microbes as part of the food that we eat, and so, and prepare. And so I haven't– it's a new class for me. So it's going to be kind of a fun, a fun quarter in the spring to see how that goes. But that's something if you're interested in that aspect of things.

Jing - What about any books, kind of come from like science communication background? So it's easy for lay people to understand or even like videos or like, you know, any kind of media series?

Dr. Stajich - Yeah, I mean, Merlyn Scheldrake wrote a book that's about fungi. I have to– we can put the link in the notes for that. That's kind of a nice introduction. You know, it kind of depends if you're interested in... A lot of the introduction to mycology is often from a mushroom standpoint. So there's a couple of different books that folks that have written about, kind of getting excited about the study of fungi and where they learn how that interaction occurs. But then I think there are several, again, we'll put some notes. I'm going to probably blank on which ones I should recommend first. But there are a couple of kind of introductory, more textbook-y, like background books that could be helpful. But there are some that are written in a more approachable way that might be good starting places.

Jing - Well, thanks so much. Thank you for giving us a glimpse into how genomics and computational methods are advancing our standing of fungi evolution about diversity. And thanks to our listeners for joining us on the Reference Desk. Again, our guest today is Dr. Jason Stajich, professor of Microbiology and Plant Pathology at UC Riverside. You can find more about today's conversation, including links to Dr. Stajich's recommendations in the show notes. This episode is produced by Elliot Fung at KUCR. Until next time, happy researching.

Show Notes:

Books:

- Merlin Sheldrake. Entangled Life
- Nick Money. Molds, Mushrooms, and Medicines

Amateur Mycology resources / societies:

- SD Mycological Society
- LA Mycological Society

Classes:

- Field Mycology, MCBL128
- Introduction to Mycology. PLPA 134
- Food Microbiology. MCBL 122