NEWSCASTER 1: Today there's also breaking news from the White House where President Trump just revealed he's now taking the drug hydroxychloroquine to prevent being infected by the coronavirus…

FAUCI: …Remdesivir has a clear-cut significant positive effect in diminishing the time to recovery…

NEWSCASTER 2: …This is the American medical associations' COVID-19 update, today we're discussing what physicians and patients need to know about ivermectin…

CINDY: Hm, can you guess what these news clips have in common? Apart from COVID-19, of course.

MAGGIE: Stay tuned to find out if you're right!

[CTOR tag]

CINDY: Hi, welcome back to another episode of Carry the One Radio. I'm Cindy.

MAGGIE: and I'm Maggie. Today, we're talking about drug repurposing - the idea of using drugs that have FDA approval to treat one thing, and using it to treat something else.

CINDY: Like treating a respiratory infection with antimalarial drugs.

MAGGIE: …or parasite medication. But we're jumping the gun.

CINDY: Let's introduce you to our speakers, who will help us understand drug repurposing, why it's amazing..

MAGGIE: … what can go wrong, and what this means for everyone's favorite topic right now - COVID-19.

MARINA: My name is Marina Sirota and I'm an associate professor at the Baker Computational Health Sciences Institute at UCSF. My background is in bioinformatics and data integration, and we do a lot of analysis of multi-omics data, so integrating different types of information, both data from the public domain with collaborators, we study a number of different disease areas.

BRIAN: My name is Brian Shoichet. I'm a professor of pharmaceutical chemistry here at UCSF uh, we're a drug discovery lab. Uh, so we focus on developing new methods for drug discovery and a particular focus, um, right now is, uh, analgesics, new drugs to treat pain and new drugs treat COVID 19.

CINDY: So let's start with what drug development is normally like in the US. This process is regulated by the Food and Drug Administration, or FDA. Basically, if you want to approve a new drug for treatment, you have to prove that the drug is safe and effective in different *stages*.

MAGGIE: Let's say you wanted to cure *mad snail disease*.

Media clip: Fear and disease is spreading like wildfire as a killer snail has been biting the denizens of Bikini Bottom, infecting them with ***mad snail disease***!

MAGGIE: Well, one way would be to kill the toxin. So the first step is research and development - looking for small molecules and compounds that will kill the mad snail toxin in cells in Petri dishes.

CINDY: You might end up with a shortlist of, say, 20 compounds, from a list of originally hundreds, maybe thousands. Now, you'd pick the most likely candidate - say, compound A - the one that killed the toxin best in those Petri dish cells, and move on to stage 2: preclinical research. You'd confirm that compound A works an animal model - that could be invertebrates like fruit flies, to vertebrates like mice - but more importantly, you would make sure that compound A is safe in that model.

MAGGIE: After that, you'd want to bring compound A to clinical trials, which are themselves broken into 3 phases. In phase 1, you would be looking at the safety of compound A in a small number of healthy volunteers and patients who have mad snail disease, and determining the dosage. The FDA reports that about 70% of drugs move on from here.

In phase 2, you would look at the efficacy and side-effects of compound A over months in up to several hundred people with mad snail disease. There's about a 33% success rate in this phase. Then, in phase 3, you look for efficacy and adverse reactions in a few thousand people. About a quarter of drugs pass this phase.

CINDY: Finally, in phase 4, you look at safety and efficacy in the largest group of people. If compound A has passed all phases, the FDA then reviews all the pre-clinical and clinical data to determine if the drug is safe enough, and if its pros outweigh its cons enough, to be approved. And once a drug *has* been approved and made available to the public, the FDA still monitors its safety.

MAGGIE: So basically, there's a *lot* of time and effort - not to mention money - that goes into approving one single compound for treatment. Every step looks for safety and efficacy, and each stage is longer and involves more people than the one before. And that's assuming that your compound passes each step, or even that you can identify an appropriate compound to begin with!

CINDY: Yes, exactly. Compound A might not pass phase 1 of clinical trials, compound B might not pass pre-clinical checks, and you'd have to go down your list until you finally find something that *does* work. So, now that we understand how drugs are traditionally developed, we can finally dive into drug repurposing. Here's Marina.

MARINA: It's expensive and it takes a long time to take a drug and bring it to market. And many, many of the drugs fail in clinical trials. So we often see that a certain drug might work well in an animal model or a cell line. And then once it's applied and tested in humans, it might not be efficacious or it might not be as safe. The whole idea is, can we take compounds that are already FDA approved and identify new uses for those drugs? Drugs that are already approved means that, well, maybe they're already safe enough to be used for a certain indication.

CINDY: In medicine, an *indication* is a reason to use a certain procedure, test, or medication.

MARINA: So the chances of success are much, much higher. Also the timeline is much quicker because again, many of these testing have already been done. So that's why the idea of drug repurposing is, is so exciting, and so, I guess, timely. And, of course, with the COVID 19 pandemic in the last few years, we really need drugs quickly. We need therapies that might work in, you know, combatting this disease very, very quickly, and there's no time to do a 10 year clinical trial. So these are all the reasons why drug repurposing is an important approach to consider,

MAGGIE: Okay, that makes a lot of sense. It's cheaper and faster to repurpose an FDA-approved drug for a novel purpose than to develop a new molecule and go through that whole song and dance again.

CINDY: And that's assuming that it has any efficacy in humans at all! Here's Brian.

BRIAN: So on the one hand for approved drugs, you've got maybe 2000 and then 10 to 20,000 that have been tested. So they're safe enough to actually put in a human, even if they haven't been approved for general use versus 3 billion, which is the, the unknown territory where you're looking for something really new.

MAGGIE: So it's a much smaller starting set for drug repurposing.

BRIAN: Tiny. Yeah. Uh, the reason why people like it is that, um, you, uh, is they have magical properties, right? From the 3 billion molecules. You can get something really new and it's great. And it's exciting. And, and I mean it is really, really great and exciting, but you don't know how it's gonna be metabolized in the body. You don't know if it's gonna get, you know, into the general circulation. Uh, and you don't know if it's gonna be toxic. Whereas a drug has these magical properties and it's got these magical properties, not because of any magic, but usually because, you know, large teams of scientists have worked on polishing the molecule for a decade and have engineered these properties into it. And now people think, wow, we've got these great properties in this drug. Let's see if we can use it for something else.

MAGGIE: Er, can we back up a bit? I want to go into the "magic" of drugs a little bit more.

CINDY: Oh yeah! I mean, when you think about it, drugs *are* pretty magical. Like, if you take aspirin, the drug first has to avoid being digested and excreted; then, when it gets absorbed in the small intestine, it can't get recycled by cells into amino acids; and, of course, it has to get into your bloodstream to get to where it needs to go.

MAGGIE: Well, when you put it that way, drugs really are magic!

[music break]

MAGGIE: So how do you find new uses for old drugs?

CINDY: In the past, drug repurposing was mostly done through observation. Doctors would notice that a certain drug had some unexpected effect and would begin to wonder whether they could use it to treat a different disease.

MAGGIE: Aspirin, for example, was originally created to treat pain but in the 80's, a doctor at Glendale Memorial Hospital noticed that it also prevented blood clotting. Now aspirin is commonly used to lower the risk of heart disease.

CINDY: But thanks to high-speed computing, scientists are able to identify multi-purpose drugs way more quickly using huge datasets of patient data, from physiological metrics to differences in DNA, which is what Marina's lab looks at. And specifically, they look at changes in *gene expression*, which refers to the process by which pieces of DNA, called genes, get turned on in a cell to make proteins. So, for example, even though the cells in your muscles and skin contain the exact same DNA - because they're *your* muscles and skin - the proteins that they make are different - which is what *makes* them different cell types - which means that the gene expression between your muscle and skin cells are different. So, you can imagine what kinds of changes there are between people.

MARINA: Let's say you have a group of healthy individuals and a group of diseased individuals, and we can compare their expression to identify a disease signature. If we can take that disease signature and query it against a number of different drugs and see which drugs might be reversing that expression signature back to normal.

MAGGIE: What's a disease signature?

CINDY: A disease signature is like a genetic fingerprint for a disease. Most of the genes in your DNA turn into RNA which turns into proteins, which are the machinery of the cells. But how *much* RNA gets made from an individual gene can vary based on different factors.

MAGGIE: Ah, so the recipe stays the same, but you adjust the number of servings every time you make it.

CINDY: Exactly. So different diseases can change how much certain genes are expressed. If you look at these patterns across the entire genome, you can understand the genetic signature of the disease. Marina's lab looks for drugs that target those genes. They can query thousands of drugs to try to find ones that will fit the right signature.

MAGGIE: And they don't just look at RNA either. They look at all sorts of 'omics', which is a biology buzzword for an area of study. Proteomics is studying proteins, metabolomics is studying metabolism, you get the gist.

MARINA: Transcriptomes is just the beginning. You can use proteomics data. You can think about venturing into other omics, methylation, microbiome…many measurements or types of measurements and integrating all of those for therapeutic discovery.

CINDY: So once they find a drug that might reverse the disease signature, they can also dig into medical data to see if the drug actually has this effect when it's given to patients.

MARINA: Because now, once you have a therapeutic prediction, or a therapeutic hypothesis, you can go into the clinical data. And of course these data are incredibly messy, they're originally collected actually for billing purposes, you know, not collected for research at all, but you can start asking, "are patients on a certain drug at a lower or a higher risk for a certain outcome that you're interested in?"

MAGGIE: Looking at the genetic signatures of diseases is a great way to find drugs that might treat them, but it's not the only way. Brian's lab uses the *shapes* of proteins and drugs to find which ones might physically fit into each other.

BRIAN: So we try and start with the structure of a protein-proteins are the machinery in cells and they're really small. So maybe there'll be 3000 atoms in the protein and we'll get a structure that will tell us where every single one of those atoms is, based on that structure, we'll try and find a small molecule that'll fit it.

And what we do is we'll do that for not just one molecule, but for 3 billion molecules on a computer. And the computer is basically taking these little puzzle pieces and trying to fit it into this hole in the whole puzzle

CINDY: Brian's lab mostly uses this jigsaw puzzle method to find new drugs but it can also be used for drug repurposing. In drug repurposing, there are far fewer pieces to work with.

BRIAN: So I talk about 3 billion molecules that we're looking from this vast space to find something new. But when you think about drugs that have been approved, there's like maybe 1800 of them, 1,800 that have been approved and there might be 10,000 that have been tested in humans.

MAGGIE: Brian's lab has had what he describes as a "love-hate relationship" with drug repurposing. It all started when Mike Keiser, a graduate student in his lab, who is now a professor at UCSF, began using the structures of drugs to predict what other proteins they might affect.

BRIAN: He developed a method for saying, I've got a molecule, take a molecule, any molecule, like for instance, drugs and predict all the things that it could be active on. And then we would test them on those things. And actually 50% of the time they would work and 50% sounds like a coin toss, but it isn't, it's like this amazing hit and so we found really we would take drugs and we'd find really potent activities for them on unexpected targets. And then we would pursue those.

CINDY: But it turns out that just because a drug affects a protein, doesn't mean it's going to be a perfect treatment

BRIAN: The drug, you know, it already does something else…and it usually does that other thing better, which means at lower concentrations. So you have to put…your drug…for…the

second disease in, at a high, higher concentration where it's gonna be flooding the first thing, and it's hard to disentangle those things.

CINDY: Marina's lab deals with the issue of side effects too, but looking at gene expression patterns can help ensure that the drug you're repurposing won't have other effects

MARINA: You know what gene or protein they're supposed to target - doesn't mean they only target that, but hopefully - and you can look at the expression, both protein and RNA expression of that target, across different tissues. So you could look at, let's say at what is the expression of a certain target? In normal cells, where else is that target expressed? And that is a great indication of potential toxicity.

You wouldn't want to target something that's expressed also in the heart, let's say, or liver, right? Like in the vital organs. Now, if you think of a compound, a small molecule that might be affecting transcriptional programs across the board that's something that we can model and try. You can combine the drug repurposing, computational approaches together with, let's say, predicting adverse events or adverse effects of drugs and see the way to balance reversing the signature that we would like to reverse yet not affecting others that might be important

[music break]

MAGGIE: So we've learned about two ways to identify drugs for repurposing…what are some current applications?

CINDY: Well, like we've already heard, treatments for COVID-19 have been all over the news. But let's talk about some broader uses first. Have you ever heard of "precision medicine"?

MAGGIE: I think so…is it like treating patients based on their personal biology and medical history?

MARINA: Disease populations are heterogeneous. So maybe a complex disease like lupus or Alzheimer's disease is maybe not one disease, but maybe they're different flavors of that disease. And maybe patients who can maybe into different subgroups might respond to treatment differently. There might be different diagnostic markers for those patients. Um, the disease progression might happen differently. And if we can identify treatment that would be more, I guess, efficacious in a certain subgroup of people then maybe we can be more successful in identifying therapies.

MAGGIE: Okay, so individual differences in biology might play a role, but it's also that disease labels might be too broad. So, how does Marina's lab use those "omics" approaches that she talked about to better understand something like Alzheimer's?

CINDY: A major focus of Marina's research *is* Alzheimer's, and recently they've been using transcriptomics. Remember how we talked about how everyone has the same DNA "recipe", but the number of servings we make is different?

MAGGIE: Yeah…so Alzheimer's changes the number of servings that you make of a particular gene recipe?

CINDY: Yes! Well, actually, it changes a *lot* of genes, and a really important one that people are interested in is called ApoE4, which regulates a ton of cellular functions in the body. In Alzheimer's, you have 3 times more copies - or servings - of ApoE4 than normal, and that messes up the recipe-making for a whole host of other genes as well.

So, Marina's lab looks at the genes that change in the brain cells of patients who had Alzheimer's, and specifically they look for differences in the cells that have extra ApoE4 - Apoe4-positive cells - versus normal cells with the normal amount of copies.

MAGGIE: And they can do that because not every cell in the brain of an Alzheimer's patient has extra copies?

CINDY: Exactly. Now, the thing is, ApoE4 is a very popular target for Alzheimer's research, so Marina's lab isn't the only one studying it. What sets them apart is a kind of unique angle.

MARINA: So diseases such as Alzheimer's disease. And many of these diseases are actually more common in women than in men. So we study ways to diagnose disease better using data. So predictive modeling, how do we impact therapeutics through identifying new uses of existing drugs? And how do we understand the disease?

MAGGIE: Whoa, I don't think I knew that sex differences played a role….is that something that people talk about?

CINDY: Well, Marina does! So not only are they looking for gene changes in ApoE4-positive cells, they are *also* looking at whether these changes are sex-dependent. They recently published a paper showing different disease signatures between men and women with Alzheimer's, which could be a game-changer for how we treat Alzheimer's going forward - and for drug repurposing, that means making sure that the drug will be safe and efficacious for men *and* women, and other biological factors.

MAGGIE: I mean, not just Alzheimer's, right? So much of biomedical research, and the way we treat patients, focuses on "the average male". And in this case, I guess, the "average disease"?

CINDY: Right! So in this case, they found that the disease signatures in women with Alzheimer's have this immune component that doesn't exist in men with Alzheimer's. So they're really honing in on the disease complexities that separate men and women, both in this project and in others in the lab.

MARINA: We do a lot of work in reproductive health, understanding pregnancy outcomes, disease areas, such as endometriosis, recurrent pregnancy loss, preterm birth. Taking a

precision medicine approach to drug repurposing, we've applied this method to preterm birth to identify a new drug for women who might be at a higher risk for preterm birth.

MAGGIE: I didn't know that preterm birth could be studied like that…I always thought it was up to chance. So, is there a genetic change associated with that, like there is with Alzheimer's?

CINDY: There is now, because of Marina's work! And that's what makes these big data omics approaches so powerful - you can generate *new* databases and identify novel disease signatures that can be used to develop treatments and therapeutics. So Marina's lab, along with fellow UCSF professor Dr Atul Butte, created the March of Dimes Database for Preterm Birth Research.

MAGGIE: So, what did they find?

CINDY: Well, in 2018, Marina's lab conducted the largest genome-wide association study on thousands of cases of preterm births and reported two genetic variants that were associated with preterm births.

MAGGIE: Wow! That might not sound like much, but that's *two* significant findings when there might have been zero and you were maybe hoping for even one. So when you query your databases against a preterm birth disease signature to look for drugs that might could be repurposed, you have not one, but *two* targets to query against and that might make all the difference.

CINDY: And honestly, that's just the beginning. This was one screen on one kind of data, and just a first pass. The lab has been analyzing transcriptomics data across all stages of pregnancy and from different sources to hone in on promising targets - everything from fetal transcriptomics to vaginal microbiomes to umbilical cord blood. So, who knows what's next?

[music break]

CINDY: So drug repurposing can be used to find treatments for lots of different diseases, but there's one disease that has really thrust drug repurposing research into the spotlight.

MAGGIE: COVID-19, maybe you've heard of it?

CINDY: When the world was rocked by a global epidemic, the quick turnaround time of drug repurposing became not just a perk but a necessity.

BRIAN: Everybody was really desperate to find a drug now for COVID 19, right. This idea that, okay, we're gonna start from scratch. And it's gonna take 10 years, you know, to find a drug, which is the high road There was this huge explosion of drug repurposing for COVID 19, cause everybody had the same thought we had, we can't wait 10 years.

MARINA: As soon as the pandemic started, we started asking ourselves…you know, what can we do as a research team, as a computational research team at UCSF. And we started diving into these related questions, and see what, what data is out there. So problem identified, okay, good. Well, not good, actually really bad, but, that's step one. Step two was to identify the right data sets, or what data exists out there. The shutdown happened in March, we started in April.

There were three transcriptomics datasets that were available on COVID 19 at the time. We developed and identified three disease signatures from these data. So once we identify the data and kind of generate these initial signatures, we query them against the drug data and that we already have a pipeline for.

And then we end up with a list of, uh, therapeutic predictions. So when, where do we go next? That's when we partner with experimental labs, who might be helpful in identifying and sort of figuring out what a validation strategy would look like. And this is another place where I really saw the scientific community coming together because we reached out to a few partners and everybody was on board and they were like, yeah…let's figure this out.

So we partnered with Melanie Ott at the Gladstone institutes and her team, as well as Adolfo Garcia- Sastre at Mount Sinai…we had 25 compounds that came up as reversing the signature in at least two of this, um, two of the queries that we did. And from those 25, we were able to, you know, purchase the compounds and actually like carry out the experiments for 16 and 11 of them showed some antiviral activity, which is pretty impressive because, you know, the success of a, starting a drug from scratch is much, much less than that.

CINDY: Meanwhile, Brian's lab was also looking for existing drugs that could treat COVID-19. Viruses like coronaviruses don't have many proteins of their own, but they are very good at hijacking our proteins to use for their own survival.

BRIAN: And so Nevin's lab - Nevin Krogan is a professor here at UCSF …they mapped what human proteins interacted with, what viral proteins. And then we said, oh, look for some of those proteins, like a fifth of them, there's already drugs that we know about, so some of the human proteins that the virus was subverting for its own evil ends, we already knew about molecules for them. We thought, well, let's put those drugs on them. And we did. We found drugs that were active on those human proteins that were anti viral in cells.

CINDY: Great success! ...right? Well, Brian's team began noticing some troubling discrepancies in their findings.

BRIAN: We noticed two things. One was like, everybody else was doing this. And they were finding lots of molecules that were active on COVID 19, lots of drugs- like approved drugs. And, you know, that was weird. I mean, it was like, there were so many drugs that people were finding that had antiviral activities in cells, like in Petri dishes, that it was weird. I mean, the drugs should be more specific than that. What luck that they all worked on COVID 19.

There was this disconnect between how potent they were on proteins and how active they were as antivirals. For instance, there were some molecules that were super potent on the proteins. We knew from independent studies that had no effect on the virus. And then there were other molecules that were kind of mediocre on these proteins that were super potent on the virus, it

was a big disconnect. And that got us to thinking that it was a different target that we were hunting, we were digging in the wrong place. And…there was this pattern that emerged- a physical pattern in these drugs that I remembered from, you know, just years of being in this field, reminded me of drugs…that induce this thing called phospholipidosis.

MAGGIE: Phospholipidosis?

BRIAN: Phospholipidosis: it sounds really quite atrocious, but if you say it loud enough, you'll always sound precocious.

CINDY: Phospholipidosis is an imbalance of crucial molecules called lipids in cells. These lipids make up the membrane and inner structures of cells but some drugs have the side effect of throwing off how these lipids are stored and used. This is bad for a virus, because it relies on those lipids to build its own structures, but it's also bad for a person. And the antiviral effect that Brian's lab was seeing only occurs at high doses of these drugs, high enough to cause a serious problem for someone taking it.

MAGGIE: It's like seeing a spider and burning your house down in response. You'll probably kill the spider but you'll have much bigger problems.

BRIAN: And so we decided…to think, well maybe that's what's going on. Maybe our molecules aren't actually antiviral. Eventually we showed that our drugs that had been repurposed for COVID 19 weren't antiviral in any useful way. And that was true for a lot of the drugs that, that had been published, maybe about 60% of them were just acting through this mechanism. So it was a failure for repurposing those drugs.

CINDY: Brian's lab wasn't the only one to be fooled by phospholipidosis. Some very infamous drugs also appeared to cure COVID-19 in lab experiments for the same reason.

BRIAN: So hydroxychloroquine, ivermectin, for instance, much in the news, those drugs are phospholipidosis drugs. That's how they work. They might work some other way, too. None of it good. They're not antivirals.

MAGGIE: So if so many drugs that appeared to treat COVID-19 don't actually work, what does that mean for drug repurposing research?

CINDY: Well, all is not lost. There *have* still been many successes. Remember remdesivir? It's an antiviral that was originally developed to treat Ebola, but early in the pandemic, researchers showed that it was effective against COVID-19 too.

MAGGIE: Ok so some of these positive results are still valid, but both Brian and Marina agree that it's important to scrutinize your findings.

BRIAN: You know, there's a big suspicion of experts now and that's, you know, just the way it is but the thing is in, in real drug discovery the scientists and the physicians who are developing the molecules are hunting for all the reasons why they might be fooled. You say, okay, there's probably something wrong. What is it? And then you go onto the next thing. And if you do that

fast enough and well enough, you can separate the 2% of really promising things from the 98% of stuff that's just trying to fool you.

MARINA: But I would say, you know, to the general public and the folks who are trying to learn about this, you know, be critical of every step - I actually tell this to my grad students too. You, you should be critical of every step and like, try to break something. If you're working on your project or something like that, you should try and break every step of it.

We need to be cautious, but nonetheless, I feel like starting out computationally is a way to generate hypotheses and a way to at least advance something quickly, start looking in a new direction, identifying new pathways, new therapeutic, um, opportunities that then can be programmatically validated through these different steps from cell lines to animal models, to clinical trials.

MAGGIE: And that's the key: all of these findings from drug repurposing studies still need to be validated at every step, just like a new drug. Even if a drug is already FDA-approved, it's only approved for the disease it was designed to treat.

CINDY: *But* it is a lot faster, cheaper and easier to get FDA approval for a repurposed drug. 30% of repurposed drugs end up getting FDA approval, while only about 10% of new drugs do. And the timeline is quicker because a lot of the work has already been done.

MAGGIE: You already have all the data about safety, about how the drug is metabolized. You know what concentrations to shoot for and you know how best to administer the drug.

CINDY: Exactly. Because of this, repurposed drugs can get FDA approval in as little as 3 years. That's less time than it takes to get a PhD!

MAGGIE: And with no shortcuts. A repurposed drug is still subject to the same amount of scrutiny that any other drug would be.

BRIAN: A drug that's eventually made it to the FDA by a research oriented pharmaceutical company has been through hell, right? It's been through a lot of skepticism and a lot of counter testing. And, and we'd like to believe in the Wildcat prospector out on the range, discovering something that everybody else has missed- that does happen. But in drug discovery there's so many things that can go wrong….you really have to be careful.

[music fades in]

MAGGIE: So, drug repurposing. Developing treatments is costly, both in terms of money and time, and even though we need new treatments, it doesn't always make sense to make new drugs. Instead, there can be real advantages to finding new uses for existing drugs.

CINDY: Today, we learned how you can use all kinds of patient data, and even the physical shapes of drugs and proteins, to identify drugs that could help treat diseases that have been

tricky to pin down, like Alzheimer's disease and preterm birth. Drug repurposing is a really exciting field and we've been reaping the benefits for years - aspirin is just one example of many.

MAGGIE: But of course, every discovery, no matter how exciting, should be scrutinized. I think it's great to be learning about drug repurposing - I just kind of wish it didn't take a global pandemic to put a spotlight on it.

CINDY: Yeah, and it's especially scary in these times. But there are silver linings! Remdesivir is definitely a success, there are others on the way, and COVID has brought scientists together like never before.

MARINA: It's been really amazing to see this both, you know, my own lab, as well as the general scientific community come together in the context of, of the pandemic in the last few years. It's truly inspirational.

BRIAN: I love working with other scientists. I just learn so much and it's amazing to watch them light up with a new idea and that community aspect of science is just amazing for me.

MARINA: So for instance, one of the resources that my team has had access to was put together by the Center group where they've taken clinical data across COVID 19 patients from, I think over 60 institutions. It's 150,000 individuals and they made that data available de-identified of course, made it available for researchers and really aggregated it all in one place, which technically is not a small feat. …

BRIAN: So there have been some successes. I mean, people's instinct early on wasn't completely wrong. But, I think I rained on it too hard. <laugh>

END CREDITS

CINDY: This episode was written and recorded by me, Cindy Liu, and Maggie Colton, with help from the rest of the team at Carry the One Radio. Thank you so much to Marina and Brian for taking the time out of their busy schedules to speak with us.

MAGGIE: As always, we couldn't have done this without our Patreon supporters: Anne Colton, Mark Kunitomi, Katheryn Batchelor, Carly Van Orsdel, Meryl Horn, Levi Cai, Stephanie Redmond, Paul Breslin, Karuna Meda, and Columbo Ahmed. If you'd like to support the show and science communication too, just a dollar an episode goes a long way and we'd appreciate it so much.

CINDY: We also love hearing from you! And if you need more Carry the One Radio in your life, you can find all of our episodes on Spotify or wherever you get your podcasts, or head to our website at carrytheoneradio.com for more information.

MAGGIE: Thanks for listening! Stay safe and stay curious <3