Smologies #37: PROTEINS + DNA with Raven "The Science Maven" Baxter
Ologies Podcast
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Oh hey, it's the half a cookie you forgot you saved from lunch, Alie Ward, and we're here with a *Smologies* episode. If you don't know what *Smologies* is, *Smologies* are shorter, kid-friendly episodes that we have cut together and put out, per parental requests, for some cleaner versions that they can listen to with the whole fam. So, these are for smologites, for the small people in your life, or if you've just got to listen to something shorter with a wide audience who doesn't want to hear me swearing. This episode is great, I loved it.

Let's get right into it. Molecular biology. So, 'molecule' comes from the Latin for 'mass' or 'moles', or 'extremely minute particle.' Biology, of course, is the study of life so molecular biology is the study of the little itty bitty squiggly intricate structures that keep us alive and breathing and fighting off illnesses and falling love and digesting a pizza. So, molecular biology is how molecules interact with each other to perform life processes and how proteins do a lot of our dirty work.

This ologist has been an Assistant Professor of Biology and a STEM college coordinator for high school students, has worked in a private lab researching cancer cures, and has done a TEDx Talk, and has been recognized by *Fortune*'s "40 Under 40." Now, I have been a fan of hers for quite a while, so we hopped on a call to talk about what a molecular biologist does, the grossest parts of her lab work, protein folding, DNA strands, and more, with science communicator and molecular biologist, Dr. Raven "The Science Maven" Baxter.

Raven: My name is Raven Baxter, and my pronouns are she/her.

Alie: You're not the only Raven Baxter that people maybe have heard of. [*chuckles*] It's such a good name.

Raven: You know, I loved having it until the Disney channel came in and decided they were going to do their own thing. [*laughs*] [*clip of theme song of the television show, That's So Raven*]

Alie: I think a lot of people think of you as Raven the Science Maven. A lot of times I don't even think about you having a last name, I just think of you as Raven the Science Maven. [*laughs*] Have you always been kind of science-minded?

Raven: Absolutely. Quite often I would find that I just get drawn to the natural environment and looking at the clouds or digging in the dirt, things that kids do. But I feel like I engaged in scientific inquiry from a very young age. When I went to college, I tried different majors out and as I transitioned in my academic journey, found genetics and was so thrilled to learn that our bodies are so cool that they speak their own language which is the genetic code. I'm sitting in this class like, "Oh my gosh, none of my friends are in this class, they have to learn about this! This is so cool! Our bodies are speaking a language and we're the only ones who are taking a class on it." So, not only did I think it was super cool, but I wanted to share that with everyone that I knew. I just went down that rabbit hole of genetics and molecular biology and I never came out.

So, the language is our DNA, the genetic code, and it is a sequence of nucleotides that contain instructions for proteins, yes, and those proteins are doing the work inside of ourselves to generate our life processes. The way that I like to see it is just a scaled-down version of how cities work where you have the mayor, he's at City Hall and that's often the central point of a city. And the mayor has, like, his staff that he talks to, and he tells so-and-so to do this and then they go do that, then tells another person to do another thing and they go do that job. And everything that happens out from city hall affects the entire city and that's how I think about molecular biology. [*Alie laughs*] It's a super simplified version of it where your DNA is the mayor and the mayor's staff are like proteins that are carrying out different functions.

Alie: Augh, that's amazing. They look, from what I've seen, kind of like gift wrap, right? Are there are lot of spirals happening? What are these proteins shaped like?

Raven: [*laughs*] That's hilarious. So, proteins are really interesting, they have different shapes and sizes. They fold into these different shapes that determine their functions, but they don't start folded.

Aside: Okay, let's back up a little. [*beeps of reversing truck*]

Raven: We can just start from the beginning. We have our DNA which is inside of our nucleus, it's very neatly packaged in the nucleus, and it gets read by other proteins inside of your nucleus into a different code called RNA which is almost the same as DNA, but it uses a slightly different code. And then the RNA is read by proteins called polymerases and the polymerases then translate the information from your RNA to create a protein. As a protein is being made it's basically like a spaghetti noodle, as it comes out of this polymerase, and then as it's coming out, it folds into these different shapes, but the two basic shapes are beta sheets which kind of look like a brick of ramen noodles, [*both chuckle*] or Alpha helices which are those curly pieces that look like, I don't know, rigatoni. I actually don't know, is rigatoni even the curly one?

Alie: I don't...

Raven: No, it's fusilli.

Alie: Okay, you're right. Okay. So, then they're in those two different beta or alpha helix shapes and then, what do they do from there?

Raven: From there, all of these shapes and structures are determined by the protein's amino acid composition and so depending on the composition of the protein itself, it'll fold and shape into different levels of protein folding. So, there is primary structure, secondary structure, tertiary structure, and quaternary structure.

Alie: And those different proteins, the complicated ones or the simpler ones, are they bouncing around in our bloodstream to send messages or are they packaged to form different organelles and different organs? What happens to those curly, folded, very specific proteins?

Raven: I mean, they do so many different things, where do we even start? They get packaged in the Golgi apparatus and shipped out to different parts of the cells. One place where they can go is they can get packaged out in a vesicle which is basically just a little, you can call it like a little fat bubble. The proteins can get packaged into vesicles and get sent into the cell membrane, where they can release proteins out into the extracellular environment or present the proteins onto the cell surface.

Aside: Okay, so right now, no matter what you're doing, there are tiny proteins cruising around your cytosol, which is the ooze that makes up the cytoplasm in your cells. A Golgi apparatus is sorting some of them and just popping 'em into fat envelopes and you just have no idea how hard they're working in trillions of tiny factories, just attaching labels to things and passing chemical notes back and forth, like two teenage lovers in an after-school detention. [*small grunt*]

Raven: So, cells use molecules to communicate. For example, there are certain cell pathways that cause cancer or there are certain cell pathways that we can study to understand cellular responses to immunity, things like that.

Alie: Mm-hm. And now, you have worked in cancer research, you have worked around big vats of *E. coli*, you have done some really awesome work. What was it like getting your master's and then studying on a corporate level? What types of things were you looking at? How does a molecular biologist do their work? Do you need the most gargantuan microscopes to look at these curlicue proteins? How do you do it?

Raven: Yes, you do! [*laughs*]

Alie: Really! Okay.

Raven: The kind of work that I was doing looked a lot different almost on a weekly basis or monthly basis. I was doing cell transfections which is a fancy word for running experiments to insert DNA into cells, or I was doing CRISPR projects, or I was trying to generate a new cell line that expresses a particular protein that we're interested in, or isolating DNA from bacteria by the gallon, [*splat*] which is why I had to make, you know, basically, gallons of poop, like you just said, because I was using *E. coli* as an expression host for the DNA and had to get the DNA out of them. It was really interesting. You know, I was working with different types of cell lines, breast cancer cell lines, skin cancer cell lines, and even neuronal cell lines which is really cool. I did some work on trying to understand or find the best drugs to treat Parkinson's disease or brain diseases like Alzheimer's as well and that involved some really interesting and fun work using neuronal cells.

Aside: Neuronal cells, side note, are types of neurons in the brain and now, when we think of a neuron, you might picture a kind of hand at the end of a long arm that has a bulbous other end. Or maybe it looks like a tree, hence the word 'dendrite' from its root, 'tree.' But some research estimates that there may be up to 1,000 different types of cells in our nervous system depending on their structure and function or location. So, okay... What...? My point is, our brains don't know everything about our brains, and studying our brains with our brains requires machines devised by our brains to study themselves, which is creepy and also not cheap.

Raven: The equipment that we use is often very expensive. I had the pleasure of working with a super cool machine called the PerkinElmer Opera, I think it's called. [*male voice reads, "Introducing the Opera Phenix high content screening system from PerkinElmer, for the sensitivity you need. No compromise."*] It was super cool because it's a high-content screening system so we were able to test hundreds and thousands of drug compounds on different cell lines to find out what drugs work the best against a certain type of cancer and then we would formulate the drug.

Alie: And so, you're just low-key curing cancer when you go into work. That's how it gets done, right?

Raven: Yeah, that's the very beginning part of it. When you talk about clinical trials, that's where it starts, with the molecular biologist trying to find what drugs you should even be looking at in the first place.

Alie: I have so many questions from patrons. Can I just lob some at you?

Raven: Wooo! Yes.

Alie: Okay.

Aside: But before we pepper her with curiosities we will, of course, donate to a cause of the ologist's choosing. Raven said she didn't have a preference, she'd just like the money to go to whomever needs it and as it happened, our mutual buddy, Hank Green's Project for Awesome happened to be at the final couple of seconds as they reached the $2 million mark! So, we made a donation in Raven's name. Project for Awesome is a project of the Foundation to Decrease World Suck and you can learn more about them at ProjectForAwesome.com. That donation was made possible by sponsors of the show, whom I shall now yammer about, very briefly.

[Ad Break]

Okay, you had questions for Raven.

Alie: A lot of folks had questions, including Brandon Butler and Ashley Emanuele: Is the mitochondria actually the powerhouse of the cell? What is the mitochondria doing?

Raven: [*laughs*] Aaaah! So yeah, I mean, it definitely is the mitochondria of eukaryotic cells, meaning not bacteria, basically. What mitochondria do is they break down sugars and turn them into energy. [*chuckles*]

Alie: It's almost like something that breaks down gasoline in our car?

Raven: Honestly, yeah... Pretty much. [*both chuckle*]

Aside: Okay, I looked this up and wouldn't you know it, molecular biology happens to be a little bit more complicated than a Honda Civic engine. But still, mitochondria do sort of burn our food fuel and produce a source of energy. This whole process is called oxidative phosphorylation and it does require oxygen, just like a combustion engine. Also, there can be a bunch of mitochondria shoved into one cell. Your hard-working heart muscles right now are really jam-packed with mitochondria. So yes, mitochondria is the powerhouse of the cell; it *is* useful information to know if you're into breathing and being alive and stuff. Now, as long as we are gossiping about spiral structures, let's get into the heroic helix, shall we?

Alie: Kiana Spinelli asks: I was told several times when I was younger that there were 6+ feet of DNA strand in just one cell, is this true or is that flimflam?

Raven: Oh my gosh, so I don't know the exact answer to this, but I would not be surprised because DNA is supercoiled inside of your nucleus. I mean, it doesn't just hang out in there like spaghetti, it's wrapped around itself, it's wrapped around things called histones, and it's very tightly and neatly packaged inside of your nucleus. So, I wouldn't be surprised if you stretched it all out that it did end up being 6 feet or 6.5 feet.

Aside: Okay, I was so curious, I had to double-check this, and geneticist Dr. Barry Starr does confirm that it's about 6 feet or 2 meters of DNA strands inside each cell. And then he calculated that each human being has about 10 billion miles of DNA in them meaning that your DNA – your DNA right now just as you're sitting here eating pirate's booty or whatever – your DNA could stretch to the Sun and back [*low pitch voice effect*] 61 times. What?! You beautiful freak. You just living, pooping work of magic. All of us!

Alie: A few people asked about motor proteins. Penney wants to know: Can you tell us about motor proteins? How the heck do they work?

Raven: They carry cargo, basically, the cargo that are containing molecules, proteins, whatever. It could be anything. They could be carrying organelles, they can carry different structures within the cell, they can move chromosomes. They're just working hard, okay? They're working hard. And they move in particular ways. Think of this as a highway and one end of the highway is a negative side and the other side is positive. Dynein walks toward the negative end and they're carrying their cargo from the peripheral side of the cell to the center of the cell and then kinesin is like dynein's sister, and they are walking in the opposite direction. So, they're walking toward the positive side, and they carry their cargo from the center of the cell to the periphery of the cell. So, in order to move their little feet, they use ATP, which is the energy currency of the cell, which comes from the mitochondria, so now we've come full circle back to the mitochondria. They're going so fast!

Alie: John Sansone has a question: Where did DNA even come from? How did random bits of atoms and molecules know to build themselves into proteins and then assemble into DNA strands which now tell other things to build other DNA strands?

Raven: This is something that I think about too much and it freaks me out. [*both laugh*] [*"My brain is melting."*] That's a question about the origin of life because all living organisms on Earth use DNA to generate their life process and we don't necessarily know exactly how this all started and this will be a question that we are likely trying to answer for many, many years to come. But I love thinking about it because of all the possibilities.

Aside: So, for years the hypothesis has been that DNA started with the simpler, single-strand RNA. But in the past decade or so, other scientists are just begging to differ and say that DNA, which kind of has a trickier sugar molecule, as well as that double helix shape, could have arisen at the same time. It's even possible that a hybrid RNA-DNA molecule first arose and then split off into two forms. Who's to know? If you have a time machine, let us know! Now, one thing we are sure about is that these replicated codes have been encased in cellular goo and structures for billions of years, billions with a B.

Alie: Okay, a few people, Katrina Nguyen, Adèle Maisonneuve, *en français*, and Davis Born asked: Epigenetics, what's going on? How does it change DNA expression and pass it on to the next generation? Katrina asked: Will my children have the same weird quirks and habits?

Raven: This is really interesting and something that I wish I spent more time on when I was on my genetics kick. But epigenetics, it's a part of molecular bio that's looking at heredity but not heredity that's caused by actual alterations in DNA itself. DNA has a code and that set of code, again, codes for proteins and protein products. But epigenetics, it's like, they are changes on the DNA, literally on it, but it's really cool. It's a different way of looking at heredity.

Aside: So, for a very, very quick primer on epigenetics, your DNA is a big ol' long code, kind of like a recipe or an ingredients list and that double helix is like a big ol' long scroll, just meters of it, right, in each cell. So, how does a cell with all the instructions for all the other cells know to be a heart cell or grow me one bristly mustache hair, or line my guts? So, certain genes are turned on or off by signals or even proteins according to the function of the cell, but the proteins can also turn on and off other expressions of the cell in response to environmental factors and then replicate from there and that is called your epigenome.

Now, speaking of hearts, many patrons wanted to know what was closest to Raven's. Katie, Matt Ceccato, Earl of Greymalkin, Kathleen Sachs, Ira Gray, and Ashley Emmanuele, all had favorite questions. Essentially, favorite type of cell or protein or organelle or nitrogenous base. Just normal questions you'd ask really any celeb.

Alie: George Powell wants to know: What's your favorite protein?

Raven: Oh! You know what? That's a really good question. I, personally, am fascinated by how people name proteins. There is a protein called the Pokémon protein.

Alie: [*through laughter*] What?!

Raven: There is a protein called Sonic Hedgehog which is actually a critical gene involved in human development. There's a NEMO one, there's a Ken and Barbie protein, there's scramblase, which is an enzyme that scrambles phospholipids between the inside and the outside of a cell membrane.

There's Pikachurin protein, there's SPOCK1, that's in zebrafish and it causes the fish to develop pointy ears like Spock.

Alie: Nooo.

Raven: Yeah!

Alie: I mean, Earl of Greymalkin asked: Do you have a favorite protein or protein name? I had no idea why they asked about the name. Who gets to name these?

Raven: The scientists that discover them get to name them!

Alie: Oh my gosh. A lot of animation fans, apparently.

Raven: Yeah! Yeah, I mean, these are really funny.

Alie: And what about the thing you love the most about what you do?

Raven: I truly love building community. I think that because I am who I am, I tend to build communities that are very diverse because I show a lot of different sides of myself that I feel like people from different walks of life and different backgrounds can relate to. I try to be very transparent about who I am and what I'm interested in and what I'm passionate about so that people who even aren't in science can latch onto something about a scientist that they see and maybe be more willing to listen and learn about science because they do relate. I also love bringing these communities together in conversations about important things and watching people in my community learn from each other and teach each other. That's probably the best thing that I enjoy about what I do.

So, ask smart mavens, very simple, shameless questions because you only live once and maybe your molecules may get rebuilt and refolded into proteins and become a frog, but why not learn while you're a person? So, to follow or see Raven's videos or TED Talk, you can head to her website SciMaven.com, or find her on Instagram @RavenTheScienceMaven, or on Twitter @RavenSciMaven. Those links plus links to her YouTube and her videos will be up also at AlieWard.com/Ologies/MolecularBiology.

You can follow me, if you'd like, on Instagram and Twitter, I'm @AlieWard on both. We're also @Ologies on Twitter and Instagram. Also linked is AlieWard.com/Smologies which has dozens more kid-safe and shorter episodes you can blaze through. Thank you, Mercedes Maitland of Maitland Audio and Jarrett Sleeper of Mindjam Media for editing those, as well as Zeke Rodrigues Thomas. Since we like to keep things small around here, the rest of the credits are in the show notes.

At the end of the episode, I give you a piece of advice and this piece of advice is, if you're not sure what to read, ask your friends or ask your parents or elders what books they liked reading. There are books that I never would have picked up unless I asked, "Hey, you guys like any books lately?" and then I got really great recommendations for books that I ended up loving. So, sometimes you'll get out of your comfort zone a little bit and you'll read something and learn something that you never knew that you liked. So yeah, ask for opinions from other people! You don't have to take all the opinions but sometimes it's nice to jump into someone else's head and see what they like reading. Okay, until next time smologites. Berbye!

Transcribed by Aveline Malek at TheWordary.com

Links to things we discussed:

Dr. Rae Wynn-Grant's website, Twitter, and Instagram

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