Chow, Carson 2020

Dr. Carson Chow Oral History

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ZIERLER: Okay. It is March 19th, 2020. This is David Zierler, Oral Historian for the American Institute of Physics. It's my great pleasure to be here with Dr. Carson Chow. Thank you so much for being here with me today.

CHOW: Thank you for coming.

ZIERLER: Would you tell us your title, and your affiliation here at the NIH?

CHOW: I am a Senior Investigator in the Laboratory of Biological Modeling in NIDDK, which is the National Institute for Diabetes and Digestive and Kidney Diseases at the National Institutes of Health. My section -- I have a section. It has a name. It's called the Mathematical Biology Section. We get to choose our own name, and I chose that one. It sounds pretentious, but I chose it for a specific point, because our branch, which is called the Laboratory of Biological Modeling, fifty years or so ago, was called the Mathematical Research Branch, and then it got relabeled about 20 years ago.

ZIERLER: Before your time.

CHOW: Slightly before my time. So, I just called my section the Mathematical Biology Section as kind of an homage to that old name. So, that's where that name comes from, even though I don't really do mathematical research, per se. It's kind of a little inside joke.

ZIERLER: Good to know. Alright, well let's start well before that. We're going to start right at the beginning. Tell us about your birthplace, your parents, and your early years.

CHOW: I was born in Toronto, in 1962. My dad is a Chinese immigrant, and my mother is Chinese, too, although she grew up in Indonesia. There was a Chinese migrant community in Indonesia, a pretty thriving community, but small. So, she came from that kind of background. They met in Hong Kong. My mother's sister introduced my dad to my mom. My Dad and Aunt were in Canada then. My Dad met my Mom, and then they got married, and then they came to Canada. I'm not even sure when they came. Sometime before I was born, obviously. So, they came to Canada, and --

ZIERLER: Your mom was born in Indonesia?

CHOW: Yes, my mom was born in Indonesia. My dad was born in Wenzhou, China. So, my dad was born in 1929, and my mom was born in 1934. So, they're about 5 years apart.

ZIERLER: Were your mom's parents born in China, or were they born in Indonesia?

CHOW: You know, I'm foggy in that history, but I believe my mom's parents were born in Indonesia, and maybe her parents immigrated from China.

ZIERLER: What was their business in Indonesia?

CHOW: That's also foggy to me. I think my mom's parents were textile -- either industrialists, or merchants.

ZIERLER: You never met them?

CHOW: I did meet my mom's mother. I never met either grandfather. Both my grandfathers died before I was born. So, I met my mom's mother, and my dad's mother before they died, but those are the only two. But I never really got a sense of the family history of my mother. What I got was they came from a well-to-do family in Jakarta. So, the Chinese at the time were generally merchants, or industrialists, and I don't even know what the business was, but supposedly they were well-to-do. They had a big family. My mom had, I think, in total, it was 9 or 10 brothers and sisters. Embarrassingly, I don't even remember, because they had an adopted son, too. So, I think it was like 10 natural born, and then one adopted. So, it might have been 11. She was, like, the 4th. So, it was daughter, daughter, daughter, and then twins -- my mother and her sister. So, that's five. And then six, seven - daughter, daughter. Then three brothers were born, so then came brother, brother, brother. The father really wanted a son to take over the business, so they just kept on having kids until they had a son.

ZIERLER: Culturally, did your mom feel Indonesian, or was the Chinese community there very inward facing?

CHOW: She totally identifies as Chinese, so it was definitely inward facing. Although, she has Indonesian cultural influence. So, she's not classical Chinese in many ways.

ZIERLER: What language did she speak growing up?

CHOW: So, her family dialect is called Hakka, which is a southern Chinese dialect. In fact, a lot of the migrants from China in the late 1800s were the Hakka people. That is an interesting community, because the Hakka -- that's in their language, but in Mandarin, it's Kejia, which is "the guest house". So, supposedly, what happened was that they were like -- I'm going to get the history backwards. I don't know. They were like a northern group that got ousted in some rebellion, many, many centuries ago. So, they moved as a community down to the south, and they settled in the south. So, they always considered themselves guests.

ZIERLER: And they retained their language?

CHOW: And they retained their language -- well, the language seems more southern to me, but I'm not really sure. But they have their own language, which is the Hakka language. So, that was her main language, but she also knew Mandarin. I didn't know how well she spoke, but she could speak two Indonesian dialects. So, she could speak four languages, and then she learned English and Cantonese later in life. So, she could speak six languages.

ZIERLER: Now, you said your parents met in Hong Kong. What was the connection? What brought them to Hong Kong? Was this his first stop from Mainland China?

CHOW: No, actually he escaped on one of the last boats in 1949, the revolution.

ZIERLER: With the Nationalists?

CHOW: Well, it was everyone for themselves. So, he wasn't escaping with the Nationalists, but he escaped to Taiwan.

ZIERLER: Okay. So, your father's family was not connected with Chiang Kai-Shek, as far as you know?

CHOW: Well, his father supposedly fought in the Nationalist Army. My dad, on the other hand, was a Marxist as a kid. He was a Trotskyist.

ZIERLER: So, he was on the other side?

CHOW: No, see, the thing about the Communist Revolution is that the first people Communists kill are other Communists. So, the Trotskyists were not Maoists, so my dad -- so, they were in Wenzhou, which is relatively south. The Revolution is coming from the north. The Nationalists are retreating from Beijing, because Chiang Kai-Shek, you know, one of the worst generals of the 20th century -- you know, one of the worst people. He was a terrible human being. Mao was a terrible human being, but he was a principled terrible human being. Chiang Kai-Shek was an unprincipled terrible human being. So, he's just bailing, right? He's just leaving everyone behind. My dad comes down, he starts to panic, and he's a high school kid, so he doesn't know anything.

ZIERLER: Where is he developing his ideological foundation from?

CHOW: I don't know. Communism was just flourishing in the 30's, when he was growing up. The thing was, the Chinese Civil War -- what happened was my dad's father was supposedly in the Chinese Nationalist Army, as an officer, supposedly. Although, we can find no trace of him, so we don't know what's going on. But according to my dad, he was a high-ranking officer, supposedly. Then, during the Civil War, and when the Japanese invaded -- so, the Japanese invade China in the '30s. So, the war in China has been going on in the '30s. Then there's a Civil War, and the Nationalists, there's a split. The Civil War is on hiatus when they're fighting the Japanese, but my dad's father took the family to the countryside for safekeeping.

ZIERLER: In the response to the Japanese invasion?

CHOW: Yeah, to the war. But he leaves my dad behind with the grandparents, because my dad's a sickly child. He's too sick to travel.

ZIERLER: What's his illness?

CHOW: I don't know. He just kind of was a sickly child. So, he was two brothers, and a sister, and his mother, and my grandfather. So, my grandmother, grandmother, my two uncles, and my aunt, they go to the countryside. My dad, meanwhile, is being raised by his grandparents. He really loved his grandparents. He's much closer to his grandparents than his father. He never really liked his father that much. He wasn't close to his father, I should rather say. In Chinese culture, there's no "like". That concept doesn't exist.

ZIERLER: You're either all in, or you're not in at all.

CHOW: Yeah. It's like he was not that close to his father. Personal preference is not part of the deal. Anyway, he was very close to his grandparents. So, he went to this local school, and at that time, all over the world, young intellectuals were all embracing communism. It was like the fashion of the time, so my dad is like caught up in this.

ZIERLER: So, he had a sort of international worldview? He was aware of what's going on globally.

CHOW: Yeah. Oh, yeah. They're reading stuff -- the Russian Revolution was really highly influential in China. Mao was highly influenced. A lot of his lieutenants were educated in Russia after the Russian Revolution. So, at that time, the world is -- it's unclear whether Communism is going to work. We don't know it's a massive failure until much later, but in the 1930s --

ZIERLER: It's an exciting experiment.

CHOW: Americans were -- there was a big Communist movement in the United States. Everywhere. England is a big hotbed. Nobody comes out of Oxford in the '30s that's not Communist. That's a joke.

ZIERLER: Okay, so his first move was not to Hong Kong?

CHOW: He goes to Taiwan in '49, penniless. Somehow, he survives seven years. He gets a degree.

ZIERLER: No family?

CHOW: No family.

ZIERLER: What's his move? Why does he go to Taiwan? Just because everyone's fleeing, he jumps on board.

CHOW: Yeah, I think it was like you can go to Hong Kong or go to Taiwan. Some of his friends went to Hong Kong. He just happened to be -- Wenzhou is across the strait to Taiwan.

ZIERLER: Right. But '48, '49, he's fleeing for his life? This is not in search of a better future, kind of thing?

CHOW: No, no. He's fleeing to get away. His mom gives him some money and some jewels, and they go. He has to bribe some guy and gets on a boat. He sneaks in there, and he has to hide on the boat when they dock, because he's not even officially there.

ZIERLER: How old is he at this point?

CHOW: 19. He's 19. He sneaks out, and he's in Taiwan, and he's on his own. But at that time, because so many people come, and then there's a big -- Taiwan was a province of China at that time. Chiang Kai-Shek just comes and takes over. He's a tyrant. He's terrible to the Taiwanese people that were there. There's massive resentment towards China in Taiwan because of the way the Nationalists treated them. My dad kind of just is there. He somehow enrolls in college. He enrolls in a teacher's college there, where the tuition is free, but then the agreement is you'd become a teacher afterwards, so he goes through college. He then serves in the Taiwanese military for a few years, and then he starts applying for grad schools in the West, which is what people his age were doing. So, they're trying to immigrate to the U.S. and Canada. Somehow, he gets in -- my dad was in math, but he wasn't really passionate about math, and he wasn't that great of a math student, so he doesn't really get into that -- he's not getting into Harvard, or anything. So, he gets into -- I think he gets into some college in the U.S. Oregon, maybe? Something like that. But there's an immigration hold-up, where he can't come up with -- he had to buy something, or -- I don't really remember the story. Then he gets into the University of British Columbia. So, he goes to the University of British Columbia.

ZIERLER: How's his English at that point?

CHOW: I don't even know. I don't know.

ZIERLER: But no English training in Taiwan, as far as you know?

CHOW: He probably took it in college. I think, at that time, English was starting to become lingua franca, so I think he might have learned English. You know, it's probably poor. He goes to University of British Columbia, and he's in the graduate program. So, he's taking a masters. He does that for two years, maybe? Three years? He tells me his advisor goes to him and -- you know, my dad's name is Jih-ou Chow, but at that time, he adopts Jerry, just so that people can give him a name they can pronounce. So, he just goes by Jerry as his nickname. He says that his advisor took him, as he's finishing his master's and he goes, "Jerry, you're just not PhD material." My dad knew that. He had no passion for math, really. He was pretty good at it, but he knew it wasn't his thing. So, he goes, and he finds out that the Canadian Federal Government is looking for people to do stats -- I guess, the precursor to Stats Canada. So, they're starting to compile mortality tables, and things like that. Basically, actuarial work. So, he applies for that job, and he gets the job. So, he moves to Ottawa. When he's in Ottawa, I joke that there are ten Chinese people in Ottawa at the time. Whatever, there's a small number.

ZIERLER: But in British Columbia, there's plenty of Asians, even then.

CHOW: There are Chinese people left over from when they were building the railroad and the Gold Rush. So, there's that community, and then there's the new immigrant community. There's a divide. They don't really -- my dad doesn't really interact with them. He mostly interacts with the expatriates, like himself. People that come over, the graduate students. Kind of like that generation. So, those are most of the people. So, he goes to Ottawa. He meets a group of these people. One of them is my aunt, whose husband has a PhD in electrical engineering, and he happens to be in Ottawa. I don't even know why he's in Ottawa. He's either working, or doing a post-doc. Anyway, so my aunt says, "Oh, I have a sister." Meanwhile, my mom has now moved to Hong Kong. So, my mom's family was well-to-do, and her three sisters got sent to Europe for college. So, the way it worked would be the well-to-do -- their kids would go to Europe for university. The oldest goes to England, the second one goes to Holland, the third one goes to England, and my mom's turn, my grandfather dies. I don't know what happens, but somehow, the family fortune is gone. I don't know what happens. So, anyway, the option of my mom going to Europe is gone. My mom was not a stellar student anyway, the way she said it. So, it wasn't clear what she would have done anyway. So, she goes instead -- I think she runs a sewing school in her house.

ZIERLER: In Hong Kong?

CHOW: No, in Jakarta, still. They're still in Jakarta, so she teaches sewing for a few years. Then, I think the sister -- yeah, so I think what happens is that then she goes to Hong Kong, because the sister -- so, my dad meets her sister, and then the sister then goes to Hong Kong, because her husband takes a job at a university in Hong Kong. So, he already knows my -- and then, when my mother's sister is in Hong Kong, she says, "Oh, my sister," which is my mom, "is now in Hong Kong. You should come and meet her." So, he flies out to meet her.

ZIERLER: Like, as a potential wife?

CHOW: Yeah. And then, I don't know how long it was, but then they get married in Hong Kong. So, this is after a courtship of I don't know how long. Several months, or something.

ZIERLER: But your dad's only going there for the marriage, not to move his life there?

CHOW: No, my dad goes to visit my mom, and then I don't know if he goes back to Canada, and they write letters, or -- I don't know how it happens. Anyway, at some point they get married, and then they immigrate to Canada. So, my mom is now with my dad.

ZIERLER: Right. Does your dad have citizenship at this point? What's his status?

CHOW: He doesn't have citizenship at this point. He has some kind of landed immigrant, permanent resident kind of status.

ZIERLER: Okay. So, is he a citizen of China, PRC, Taiwan? What does his passport say?

CHOW: Yeah, good question. I don't even know what his passport says at that time. I guess, Taiwan. I mean, it's unclear because at that point, Taiwan is China. PRC, after the Revolution, does not exist. It has no status in the world. So, I think he's a Chinese national with a China passport. But China is the Republic of China, which is Taiwan, at that time.

ZIERLER: Right, but coming and going from Hong Kong is not an immigration and border issue for your father, as far as you knew?

CHOW: Well, he's able to do it based on his Chinese passport. Hong Kong is officially part of China. Hong Kong never leaves China, ever, right? So, even when it was under British rule, with a 99-year lease, it was still China. So, Hong Kong is China. Taiwan is China. Then, maybe some other small islands are China. Then, there's the mainland of China, which is communist, and that's not recognized by any country other than the Soviet Union, and the Eastern Block.

ZIERLER: Right. So, they meet, and they're married in Hong Kong. Your father has a life for himself setup, and this convinces your mom to go with him to Canada.

CHOW: Right. So, she just takes the risk, they go to Canada. Meanwhile, he finds a job in an insurance company in Toronto, and he moves to Toronto. So, then, my mom and my dad are living in Toronto. They have a small apartment in Downtown Toronto. I am born in 1962. So, somehow between '56 and '62, this happens. Then, I'm born, my sister is born two and a half years later in '65, and we move, basically, from one apartment to another apartment, to another apartment, to a little townhouse, to a house. We live a fairly modest, middle class life.

ZIERLER: Your father is still in the insurance company?

CHOW: My dad is in the insurance company until 1985, where he gets an eye disease and becomes effectively blind. So, then he retires at a relatively young age, in 1985, and then he does not have a job after that.

ZIERLER: Your mom is a homemaker growing up?

CHOW: My mom is basically a homemaker until we're in high school, and then she takes jobs, like a salesperson. Never a career. She does work for a few years. She has jobs. My mom likes working. My mom is a very gregarious kind of person, so for her being out and working and interacting with people as a salesperson, she had a lot of fun doing it, and she liked doing it. My dad is a Trotskyist till the day he dies. He holds out that there's going to be the fourth International Revolution till the day he dies.

ZIERLER: He probably kept this to himself among his colleagues?

CHOW: No -- yeah, his colleagues don't know this, but he --

ZIERLER: Like, he goes to meetings, and that kind of stuff before the internet?

CHOW: No, he doesn't do that anymore. In fact, his citizenship in Canada was held up. The three of us, my sister, and myself -- I was automatically a Canadian citizen at birth. My mother become a Canadian citizen pretty quickly. My dad is held up until, I don't know, the '70s, or late '70s, because of his Communist affiliation. In fact, he has trouble crossing the border in the U.S. He gets held up because he's a known Communist. My dad is like a dangerous Communist. But what he does is that he spends the rest of his life studying Marxist doctrine by these obscure Trotskyist scholars, he translates them from English into Chinese, publishes in some pamphlet in Hong Kong to be distributed to the 12 Trotskyist -- you know, whatever. Like, there's this 4th International of Trotskyists. I think they still exist, this small fringe group that nobody pays attention to. My dad's part of this community, and he's actually held in high esteem by this community, because he's doing this volunteer work where he's translating all these articles, and this is his life's work. He loves it. Every day he's in his study at home. He has reduced vision, but he can blow up letters to the size of the screen, so there will be one letter, and he'll read one letter at a time on this screen, blown up to that size, and he'll translate. He can write, sort of, by putting his face this far from a piece of paper, and he can write. So, he'll translate into Chinese, and he does this. Because it's so slow, he'll do like one article in several months. This is his life's work.

ZIERLER: Now, as a father, was he inculcating you in this ideology?

CHOW: You know, he never really did. He just said he wanted me to have a social conscience. He wanted me to have a sense of social justice and conscience.

ZIERLER: What did you think about his activities growing up? Did you think it was a weird hobby he was into? Did you see this as connected to a bigger purpose? You didn't really think about it that much?

CHOW: I admired my dad for having this passion and drive. I never had one the same way for politics. I actually had one for science. I loved science. But I think that he was a role model in the sense that you hole up in your study, and you just bash away. My dad was tireless. He could just work for hours, and hours, and hours.

ZIERLER: What kind of patience did your mom have for this activity?

CHOW: My mom didn't care at all. She didn't care. She was not an emotionally needy person, so my dad would be doing his thing, and she would do her thing. She thought it was the greatest thing ever.

ZIERLER: Now, growing up, was your identity, like, assimilated Canadian? You were a regular Canadian kid? Did you have an immigrant identity, even though you were born there?

CHOW: That's interesting. I always had an immigrant mentality.

ZIERLER: You're speaking Chinese in the house?

CHOW: Only until I was about 5 or 6.

ZIERLER: Okay. Then you're speaking English back to them, kind of thing?

CHOW: In fact, the teacher said, "Oh, his English is poor." I actually show up in kindergarten without the ability to speak English. I speak only Chinese at home until at 5. I go to public school in Canada, and I'm struggling for two years. So, in first grade, I'm learning English, but I'm speaking broken English, probably, through kindergarten. I guess, I'm a kid, so I pick it up pretty quickly. But even by first grade the teacher said, "Oh, you should speak to him in English at home."

ZIERLER: Is this a diverse school? Not really?

CHOW: No. I mean, there's, you know --

ZIERLER: Are you the Asian kid, or are there more?

CHOW: I think I am the Asian kid. I'll have to check my school picture. No, there was one friend of mine. He was a Japanese boy. I still keep in contact. He lives in Japan now. I think his father was a scholar, or something. He was only in kindergarten. I had my one friend, the Japanese friend, Masa -- Masahiro Onodera -- and then he goes back to Japan. But I had English, Canadian, white friends growing up. Mostly, I had no Asian friends, most of my life. Most of my life, I would say, I had no Asian friends until middle school, where -- there was an Asian Exclusion Act in Canada until Trudeau, so '67, or something like that. So, then, the immigrants start to come. So, there were very few Chinese that were Canadian born, like myself my age. But the younger generation, now you go to Toronto, and it's all Chinese, right? It's probably one of the largest Chinese cities outside of Asia. But it was very different from when I was growing up. But there was a small Chinatown. We would go have Chinese food. On the weekend we'd go down to the Chinese restaurant. So, I felt very much like an outsider my whole life. I always feel like an outsider, even to this day. No matter where I am, I feel like an outsider. In any group, I feel like an outsider.

ZIERLER: Because you're not entirely American, you're not entirely Canadian, you're not entirely Chinese?

CHOW: Exactly. I'm not entirely a physicist, I'm not entirely a biologist.

ZIERLER: Well, you did that one to yourself.

CHOW: I did. I think it's probably because of my outsider feeling.

ZIERLER: So, when do you start to develop, or when do your teachers start to realize that you have this aptitude for the sciences and math?

CHOW: I don't think they ever did. In kindergarten, I decided I wanted to be a scientist, or even before that.

ZIERLER: Before kindergarten?

CHOW: I think so. I know that in 2nd grade, I wrote a little thing. "What do you want to be?" And I wrote, "I want to be a scientist teacher." But I meant scientist. What I did is I said, "How do you spell scientist, teacher?" And she literally said scientist teacher.

ZIERLER: So, what did that mean as a 7-year-old to you? What did it mean to be a scientist?

CHOW: I'm not sure, but I --

ZIERLER: Like tinkering?

CHOW: I would do science as a living. I would read stories about Newton and Einstein. I didn't know that you could get a job at a university. I didn't really understand jobs, even. I just knew that I was going to do science. I didn't even know what science meant. I just knew that I liked reading about science in books. My parents bought me these little science books, and I would just -- I think I still have them. I don't even know if I do. But there was this one book I had called Let's Experiment. I remember I had that as a kid, and it had little experiments that you would do. You know, like baking soda and vinegar, and I would do them at home.

ZIERLER: But in terms of aptitude, you're not stand-out material in primary school, middle school?

CHOW: I guess, I was. I mean, I was the class valedictorian in 8th grade, so I guess I was. But I never thought of myself as the best student. There was always one kid smarter. I always thought there was always one kid smarter than me. Especially in high school.

ZIERLER: One same kid?

CHOW: No, there would always be a kid who's --

ZIERLER: Some other kid.

CHOW: Yeah. I remember when I was in junior high, or maybe middle school, my dad was saying, "Yeah, your sister is better at math than you." So, there was always someone smarter than me. My sister was smarter than me in IQ, definitely. Always did better than me in IQ tests. Always did better than me in chess tournaments. She's two grades behind me. So, she would always outdo me at every stage. Like, I have the smarter sister, but we were different in the sense that she had zero passion for anything. She was just a smart kid who didn't care about anything. She just had no interests.

ZIERLER: Where did her life --

CHOW: She's a physician. My mom bribed her into medical school. I think she said, "I'll pay for a European vacation in college if you go to medical school." So, she went to Europe, and then applied to medical school, and got in. She kind of just coasted through medical school not caring. She became a family doctor, I think. Now she's retired. This year I went to visit her at Christmas, and she said, "Yep, Carson, this is it. I said I was going to retire at 50. I'm 5 years late, but I'm retiring." So, she travels the world. Unfortunately, she can't do it now, but she travels the world. She enjoys her life. She has tons of hobbies.

ZIERLER: She might get pulled into an ER one of these days.

CHOW: Yeah, she hasn't seen patients in a while. She was actually doing counseling. Like, psychological counseling. She was doing sports medicine for a while. She's just an eclectic person, my sister. As an adult, she would be doing skating competitions, and dance, and she'd always be doing something crazy. She'd get into crossword puzzles, or something. So, that's the way she always was. She didn't care about having a career. She didn't want to cure cancer, or anything like that, even though she had the higher IQ. I always think that if I had her IQ, I could have done so much better.

ZIERLER: That's a big combination.

CHOW: Yeah. I had the passion, and she had the IQ. I had the ability to grind. I could grind longer than her. She didn't really care to work that hard, because she was just faster.

ZIERLER: So, toward the end of high school, University of Toronto, is this your spot? You're applying to a lot of places? You wanted to stay close to home?

CHOW: Yeah. My wife, who is a way, way over achiever. She's a super achiever. I was not ever the super achiever. I always had it inside me that I was going to be a scientist, and I was going to do okay. Maybe even do great things. I had this inner conceit, or confidence. Whatever you want to call it. But I don't think I was picked as the kid most likely to succeed ever in life. I was a kid who was known as the kid who was good at math and science. Kind of the nerdier kid. Although, I wasn't the nerdiest kid. Like, I wasn't even the nerdiest -- like, I wasn't even that good at being nerdy. I didn't do Dungeons and Dragons. I didn't do any of that.

ZIERLER: You didn't even excel at being a nerd.

CHOW: No, I was a very gray kind of kid. My daughter thinks I'm the nerdiest person alive. "You must have been the super nerd." No, I wasn't even that good at being nerdy. I was kind of a gray kid. I would still go to occasional parties. I wasn't the total social outcast. I would actually be middle. I was just a normal, gray kid. I would go to parties occasionally. We would play sports. I played sports. I wasn't a super athlete, but I played sports, and I had still played -- well not anymore. I had a lot of hobbies that were non-academic kind of hobbies.

ZIERLER: So, what was the draw to University of Toronto?

CHOW: Well, so the thing was, in Canada, the way that it was, it's not like the U.S. Colleges are not like, you have this grandiose thing where you visit universities, and things. You literally have one form, and you filled out your three top choices, and you mail that in. Then you would be told which one you got.

ZIERLER: So, what were your three?

CHOW: So, I didn't even know what I was going to do, but in the fall of my senior year, we actually got presentations from universities. They would actually come and say, "Oh, this is what we offer." So, these were just Ontario universities. In Ontario, there was University of Toronto, Waterloo, Queens, McMaster, University of Ottawa, and Carlton. So, they all come, and they pitch their programs. So, University of Toronto comes and says, "Oh, we have this thing called Engineering Science." So, there's an engineering school, but there's this actual major called Engineering Science, which is like the super elite engineering. They only take one in whatever it is. The starting class is 200, but the graduating class is 100, because they weed out half of the students. Don't bother applying unless you have a GPA of 4.0, even though we didn't have GPA. So, the equivalent of 4.0 in Canada would be like 90%. I'm like, oh, I'll apply to that. Sounds good.

ZIERLER: You were attracted to the eliteness of it, more than the engineering?

CHOW: Yeah, the challenge. So, the way it would work is that in regular engineering, there'd be electrical engineering, civil engineering, and things like that. But in engineering Science, there'd be options. So, one of the options was the physics option. So, instead of doing a physics degree, which is what I was going to do, but then my dad actually took me aside one day and said, "You know, you should probably be an engineer, because you can make more money. I don't know a single person that's a physicist with a job." So, I'm like, "Well, dad, I don't like engineering."

ZIERLER: What a capitalist piece of advice for your dad to be giving you.

CHOW: My dad was a practical Asian man first. Trotskyist idealist, second. He ran his family, although, he was not a Tiger Dad at all. They didn't push me at all, which was like major conflict in my family now, because my wife, who is also a Chinese American, grew up very much in the stereotype, and she became the super achiever. She wants her kids to be achievers.

ZIERLER: So, serious Tiger Mom going on?

CHOW: Yeah, although if I say this on tape, I'm dead. Let's just say, she hopes her kids achieve, and I'm more that direction than being slack, but I grew up in a family where my mom is like, "Oh, you know, you're doing well. It's good enough." And my dad is in his Trotskyist -- you know, the Revolution is coming next year. Even though, on the other hand, he's like, "Be an engineer."

ZIERLER: So, in high school, you're definitely more on the physics/math/engineering track, and not the biology/chemistry track?

CHOW: Yeah. I would say in high school, I'm 100% interested in physics, 75% interested in math, and 0% interested in chemistry and biology. I'm more interested in English literature, which I actually flirted with actually becoming an English major, because I actually like to write, and I like to read literature and poetry in high school. But I had no interest in chemistry and biology. To me, that just seemed like stamp collecting. In fact, I didn't even do that well in biology and chemistry. I think I got a good grade, but I didn't do well.

ZIERLER: You didn't push yourself there. And this is public school through high school?

CHOW: Public school my whole life.

ZIERLER: Good quality education, looking back?

CHOW: Oh, yeah.

ZIERLER: Good teachers?

CHOW: Great teachers. We had this one teacher who was -- I think he might have had a PhD or something, but he was a really great teacher. He was like this mythic teacher, because he had this long hair, long beard, and he's kind of like in Birkenstocks. He had the whole cool physicist, math guy going. He played guitar.

ZIERLER: Do you remember his name?

CHOW: Yeah, Steve Kusnir. He was a legend at our school. He was just the coolest guy. He taught us really advanced math. It was great. We had great math teachers. Canada was really great. There was this national math competition -- there was a senior math competition, and a junior math competition. So, all the 10th grade and under would take the junior math competition, and everything 12th grade and under would take the senior math competition. I never did well. My sister did much better than me. But some of my classmates would be ranked in the country. They'd be in the top 25, or something. So, I had some really brilliant classmates. One classmate was brilliant, and unfortunately, he decided it was more important to be cool. So, he got into drugs and I don't know what happened to him. I lost track of him after high school. I hope he -- you know, he was, like, brilliant.

ZIERLER: So, Toronto is your spot? This is it? This is where you're going to --

CHOW: Yeah, so I applied to Toronto Engineering Science, I put, and then maybe I put physics number two, and I put University of Waterloo, number three, which was legendary as a -- you know, has a great reputation as an engineering school. There was something called "systems engineering", which was the equivalent of engineering science at Waterloo. So, I put those three down. That was it. I apply to those three, and I get into Engineering Science.

ZIERLER: Now, the physics is part of the program? It's like a minor in Science Engineering?

CHOW: Yeah. You actually take all the same courses as the physicists do, plus two extra courses per term. So, six courses per term you take.

ZIERLER: That's intense.

CHOW: Really intense. It was unbelievable. I was in shock. I go there, coming from high school, I barely do homework. I'm dying. I'm like barely struggling. I'm barely surviving. I'm struggling. I somehow eek through. I make it. I survive the first year, when half the class -- so, the option is you start Engineering Science, and you get the choice to go to another one after one year if you don't want to do it. So, half the class disappears. Literally, one half of the class.

ZIERLER: Right. Just like they said.

CHOW: Yeah. They decide to do other things. So, they either go into the actual Arts & Science school. So, they do physics, or something, or they'd go do electrical engineering, or civil engineering. So, half the class disappears. I'm a survivor, which is what I've always been like. I always called myself "The Badger." I'll just badger away. I'll just survive. So, even though I'm not the best student, I'm surviving. Then, I start to percolate up the rank. We're ranked from 1 to 200, and then 1 to 100. I think I actually made it to the top 10 one year. I think I managed to creep my way up. I'm in the 50s, I'm in the 40s, I'm in the 30s. I creep my way up. And then by the time I graduate, I --

ZIERLER: Same major? You stay in engineering science?

CHOW: Mhm. Physics option. So, there's only four of us, I think -- three or four of us -- four of us choose physics option. Most of the people choose electrical engineering option, or computer science option. Those are the biggest. Then, four of us choose physics option.

ZIERLER: Now, the physics option, does that mean that the physics classes you're taking are geared specifically toward engineering science?

CHOW: No, they're the physics classes the physicists take.

ZIERLER: Oh, so you're getting a theoretical physics education as well?

CHOW: I'm getting the same physics education as my colleagues in physics. So, what happens is I do two years of engineering science courses. So, there you're taking physics for engineers, kind of thing, which is not that different. The first two years you're just learning thermodynamics, classical mechanics, which is the same physics. Then, I'm also taking electrical engineering classes, I'm taking chemical engineering classes, chemistry classes, no biology. Zero biology. I'm taking all these different kinds of classes. I get one option, which I take English, as my option. Nobody else takes English. They all take something else. So, I'm like trotting over, I hang out with the Arts & Science types, thinking maybe I made a mistake. I kind of like English. I plow through, and then starting in the third year -- we don't call "juniors" in Canada, but the junior or third year, then I'm just taking physics classes with the physicists who went through physics. So, we're taking the same classes: quantum mechanics; statistical mechanics; electrodynamics.

ZIERLER: Do you develop close relationships with any physics professors as an undergraduate?

CHOW: I do, with one particular one I did my senior thesis project. His name was Richard Azuma [00:43:14]. He just passed away recently, in the last ten years. I wrote a little obituary in my blog for him. Great guy. He took me under his wing. He got me a summer fellowship out in the west coast at an accelerator lab.

ZIERLER: Which one?

CHOW: TRIUMF. Are you a physicist, or a historian?

ZIERLER: I'm a historian of physics.

CHOW: Okay. You've got both. So, TRIUMF was a Meson Lab in Western Canada, in Vancouver. So, I got to spend the summer there. So, he was a great mentor. Great guy.

ZIERLER: What was his field? What did he work on?

CHOW: He was a nuclear physicist. He was kind of disappointed I didn't go into nuclear physics. He wanted me to stay at University of Toronto and go into nuclear physics, but I left the country. So, in Engineering Science, when we're in our third year, we start to hear about the legendary fourth year kids, who are getting into Harvard, Stanford, MIT. Suddenly, I'm like -- this is not even like really --

ZIERLER: On your radar?

CHOW: Radar. It kind of is. I remember when I was a kid in the '70s, we did a West Coast trip. We didn't go on very many vacations when I was a kid, but we went on one trip. We went to California, and I thought California is the greatest state. I still, to this day, love California. My whole life, my goal is to move to California. I've never quite achieved it, but... And then I see Berkeley, and I'm like this is it. I want to go to Berkeley.

ZIERLER: Now, on your trek, are Engineering Science kids going into industry, or everyone's headed to graduate school? That's just where everyone's flowing?

CHOW: That's a good question. I don't even know the stats. I think -- this is all made up, but I would guess three quarters go directly into industry, and maybe a quarter go to grad school.

ZIERLER: Now, would that be correlated with the higher achievers and the lower achievers?

CHOW: No, no. There are some really brilliant kids who went into industry.

ZIERLER: Okay. They just want to get right to it and make some money.

CHOW: Yeah. In fact, in the physics option, there were four of us in physics. Victor Bocking, Arif Babul, Peter Jay, and myself. I hope I'm not missing someone. I would say, I was the weakest of the four. Victor, Arif, Peter Jay were super strong students. I don't even know how they ranked. I think Arif ranked maybe higher, but it was close. They were ranked in the top 10. They were really brilliant. Victor is now an executive. He went to IBM for many years, and now he's an executive. I think he was an executive at IBM, but he might be at a different company now. I haven't checked LinkedIn lately, so I don't exactly know. He's had a highly successful career in industry. Arif is a professor at the University of Victoria. He is a very well-known cosmologist. Peter Jay, I lost track of, but I don't think he went to grad school. He was brilliant. They were so much stronger than me in everything. Like, in everything. They were better than me in math, physics, chemistry, everything. I was the weakest student by far.

ZIERLER: So, it sounds like you liked Berkeley before you liked graduate school.

CHOW: I think I knew that Oppenheimer was at Berkeley, or that famous physicists were. Alvarez was at Berkeley. I knew Berkeley was a hotbed of brilliant physicists.

ZIERLER: Yeah, but there are a lot of brilliant physicists in a lot of places.

CHOW: Yeah, of course. I knew Princeton was also a place with brilliant physicists. I knew Stanford, Harvard -- I knew there were brilliant physicists at these places.

ZIERLER: Staying in Canada -- you're thinking beyond Canada at this point?

CHOW: Even as a little kid, I thought, oh, it would be great if I could go to grad school in the United States. I didn't know how I was going to realize this. Like, I just didn't know. I had no plan, but fortunately, Arif --

ZIERLER: So, there's no program in Canada that ranks on the par with the elite physics programs in the United States?

CHOW: As a graduate program?

ZIERLER: Yeah.

CHOW: I would say University of Toronto begs to differ. I think they consider themselves an elite program. Realistically, I think --

ZIERLER: That didn't compel you to stay?

CHOW: I don't think they would even say that we're like Harvard, or Princeton, or Berkeley. But they're a very good department.

ZIERLER: They might say they're the Harvard of Canada.

CHOW: They would say they're the Harvard of the North, yeah. That's what they would say.

ZIERLER: Okay. So, what happened to your big plan to go to Berkeley?

CHOW: Yeah, that's a sad story. So, in third year, I'm finding out that these legendary kids in fourth year were getting into Stanford, and Berkeley, and Princeton. And then Arif, my classmate who is still my very good friend, he's like the most organized kid. He has the mission. He's going to Princeton. Then, one day, I'm talking to him and, I'm like, "Why should I work really hard?" And Arif was like, "Well, if you want to go to grad school, you need good grades. And you have to take this thing called the GRE, and you have to do well on that. And you have to do this." And I'm like, "Oh. That makes a lot of sense." So, that's when I really started to kick it in gear, in third year. My ranking got up. It didn't get up that high, but it got up higher. So, I started working really hard, although I never could get that great of a GRE score. I never could get that great of a -- you know, I was just not that good. Anyway, Berkeley's deadline was October, I think, or something like that. It was earlier than the other schools, and I was too disorganized to apply to Berkeley. So, I didn't get my application out to Berkeley.

ZIERLER: And this is '88, '89?

CHOW: No, this is '85. Well, I graduate '85, so this is like '84 that we're applying. We're applying the fall of '84. So, I applied to something like ten schools. Princeton, I think I applied to, MIT, Stanford, Illinois maybe -- I don't even remember. And Stony Brook. State University of New York at Stony Brook. Stony Brook actually was a hotbed for String Theory -- like, supersymmetry and stuff like that. So, I only get into Stony Brook.

ZIERLER: Of all the schools?

CHOW: Yeah. I get waitlisted at MIT, and I get into Stony Brook. Arif gets into Princeton. He's ready to go to Princeton. So, he's all set. Victor -- oh, actually, Victor did go to grad school. He goes to Toronto, because he gets married right after college. He has a girlfriend all the way through college, his high school sweetheart. He marries her, and he's like, "Well, Sandra doesn't want to go to the U.S." So, even though Victor could have gone to Harvard, or whatever, he decides to go to University of Toronto. He's also a practical person. He does experimental atomic physics, which was not fashionable like it is now. This is pre Bose-Einstein condensation. Pre-quantum -- now, atomic physics is the thing, right? Quantum computing, and all of that. This was like in the '80s. It was not the hippest thing in the world. So, he's doing this, and then he goes to IBM after that. So, he actually got his PhD. I forgot that he went. But he never intended to really be a faculty member. He was like, "I'm going to do a PhD, and then I'll look around. I think about whether I'll be faculty." I think Sandra was saying, "You got to start making money." They had a family. So, he was a practical minded person. Arif heads to Princeton. He's going to be a plasma physicist, he says. There's irony here, because he doesn't become a plasma physicist. I'm headed to Stony Brook, because I'm going to be a string theorist, or whatever.

ZIERLER: How did you fall off the applied track from engineering? I mean, string theory --

CHOW: Well, I never intended to be an engineer. My secret trick was to do engineering science, because I knew that these guys were going to physics grad schools, and then I was going to go to physics grad school and be a theorist. So, that was always my secret trick.

ZIERLER: That's a lot of applied science and math you're learning to go a theoretical route.

CHOW: Yeah, which I had to relearn it all. I realized I should have learned all this stuff when I had the chance.

ZIERLER: So, were you thinking maybe grad school is not -- I mean, if you're getting rejected from everywhere except for Stony Brook, are thinking maybe grad school's not right for me?

CHOW: No, I'm like, "Yeah! I got in somewhere! I'm going to Stony Brook!" I go to Stony Brook.

ZIERLER: So, industry was never even a thought in your mind?

CHOW: No, I didn't even know how to get --

ZIERLER: You had the option to go to some graduate school, you got in someplace, full steam ahead.

CHOW: When I got to university, I said, "This is where I belong." I love the university. I love it. I love English lectures, and Northrop Fry was at University of Toronto, and Margaret Atwood would show up. It was the greatest thing ever.

ZIERLER: You wanted to stay on the quad.

CHOW: I wanted to stay in the university. I hated engineering. I wanted to be -- I don't know if you've been to Toronto and seen University of Toronto. It's this beautiful ivy covered -- but the engineering block looks like 1960s East Germany. The other part is like Oxford. I'm like, "Why am I stuck in East Germany? I want to be at Oxford." I was really upset about that. But I'm in engineering, and I'm like, "Okay, I'm going to finally go to a great U.S. college." I get into Stony Brook, which looks like East Germany again. It's like 1960s --

ZIERLER: Maybe even worse. I don't know how much --

CHOW: Even worse. That is the ugliest university ever. I show up there, and I'm like, "Oh my God, it's awful here." I didn't even visit. I get a phone call from the chairman; I think his name was Ron Fox -- something Fox -- super nice guy. He's like, "You got in! Congratulations!" I'm like, "Wow, I got in!" "Do you want to come visit?" I'm like, "No, I'm coming! It's the only school I got into, so I'm not visiting. I'm going. I don't have time to visit." I show up there, and I'm like, "This is horrible." I'm in Long Island. I had no idea. I grew up in a city. I grew up in Toronto, and suddenly I'm in Long Island.

ZIERLER: Suburb of Suburbs.

CHOW: I'm depressed. I'm really depressed. So, midway through, I apply to MIT again. I said, "MIT --"

ZIERLER: Midway through what? First year?

CHOW: Yeah, at Stony Brook. By fall, I'm like, "I'm not staying here. I'm either going back --" So, I apply to Toronto, and I apply to MIT. I'm leaving. I'm not staying here. I get into MIT as a waiting list again, but I'm like, "I'm coming anyway." I'm just going to fund my way. My mom says, "You know what, we'll just pay for the first year." She had a good friend of hers who said, "You know what, just go to MIT, because they'll find him funding after like a year."

ZIERLER: So, they said you can come but no funding?

CHOW: No funding, right. So, I got in -- actually, the first time I got in the same way. You can get in, but no funding. You have to pay your own tuition. So, I said, "Fine, I'll just go." My mom said, "You know what, we'll pay tuition." Back then, tuition was steep, but wasn't like now. A middle-class family could afford tuition. But then they came through with funding anyway. So, I show up --

ZIERLER: Different world than Stony Brook.

CHOW: Yeah. I get to MIT, and it's great. It's better, but I'm still depressed. I'm really depressed, because I can go, and I can get funding, but have to do experimental particle physics.

ZIERLER: They'll fund you if you do experimental particle physics?

CHOW: Right. So, I show up at MIT, and I go there, and I'm like, "I hate experimental particle physics."

ZIERLER: This is a surprise to you? You're not exposed to this field beforehand?

CHOW: No, I knew I didn't like experiments. I never wanted to do experiments. I only wanted to do theory. I didn't realize that I actually liked math. The irony of my life is that all through my formative years, where I think I like only physics, I actually like math. I don't know this. I don't know I like math until I'm like an assistant professor of math. I like theory, though. I have my head in the clouds. I'm not a practical person, really. I have my head in the clouds. I don't have the talent of my peers, who actually are doing theory, and get in legitimately, to do theory. So, I don't have their talent, but I want to be a theorist. So, I go to MIT. I'm an experimentalist, I get assigned to a lab to go to CERN. They're going to build the UA-1. They're building UA-1, or UA-2. I forget which one, but anyway, I'm in the group. So, I have to pick a group. I pick the group to go to UA-2. Meanwhile, I meet some friends -- I have a friend from Caltech named Tom Luke, who's now on Wall Street. He's not interested in physics that much, but he says, "I'm going to take this plasma physics class." This is the irony, because I don't even know what plasma physics is. My friend Arif had said before, "I want to be a plasma physicist."

ZIERLER: Doesn't work out.

CHOW: I'm like, "What is that?" He decides to be a cosmologist. He goes there, and he's like, "Oh, I don't like plasma physics." He switches to astrophysics. I go to MIT, and the first term there I meet my friend, and we're picking our classes, and we have to take an elective. So, even though I'm in particle physics, I have to take particle physics, and then you have to take an elective outside of your field. So, I take plasma physics. I do great in plasma physics. Who would have known? I didn't even realize this was such an interesting thing. I meet the professor, Abraham Bers, and he likes me because I'm like one of the few kids who actually takes his class seriously. So, I do well.

ZIERLER: What clicked for you with plasma?

CHOW: I don't know. I have no idea what clicks. I have to tell you that the two worst subjects I did were statistical mechanics, and electrodynamics. They were my two worst classes in undergraduate at University of Toronto.

ZIERLER: So, you're as surprised as anyone else?

CHOW: And those are what plasma physics is. Basically, statistical physics and electrodynamics, and I suddenly get it. It clicks in my head. I say to myself that my brain suddenly got better in grad school. I went to Stony Brook, and I did really well in classes. Suddenly, I was like one of the top students. I became known as one of the best students, whereas when I was at University of Toronto, I was known as the worst student. I'm suddenly one of the best students. Suddenly things are clicking. Finally, I understand quantum mechanics, which I had no clue -- I finally understand electrodynamics.

ZIERLER: What do you think this is? Just maturity?

CHOW: My brain just got better. I don't know how to explain it, but my brain just started to get better when I'm 22.

ZIERLER: It wasn't that the professors were better? You don't think it was external like that?

CHOW: I think the professors were better. The classes were smaller; the professors were better; in grad school I got more attention, maybe; I got more time, because I only had to take four classes instead of six.

ZIERLER: Sure. Maybe you were just overloaded as an undergraduate.

CHOW: Yeah, and I got to look at the stuff again. Anyway, my brain worked better. So, I did really well at Stony Brook, and then I go to MIT. I'm taking plasma physics, and I'm doing well. I don't even know what it is about it. I'm just doing well. My brain is working better. The professor, Abraham Bers, says to me, "I have an opening in my group. Do you want to join my group? I can get you funding." I get to be a theorist. He's a theoretical plasma physicist. Hallelujah! I get to leave particle physics, and I become a plasma physicist.

ZIERLER: What is this now, year two, or year three at this point?

CHOW: Year one. I think year one. Second term. I joined a group in the summer, I think. It's all foggy now, but it's pretty close. Anyway, because at University of Toronto, it's not like an American college. There's no recreation kind of thing. MIT, on the other hand, is like a playground. There's like all these sports and stuff, and the beauty about MIT -- I'm so glad I went to MIT and not Princeton, because at Princeton, the graduate students are treated like lepers. They don't get to participate in the undergraduate campus by design. At MIT, there's no distinction. Students are students. So, I get treated like an undergrad. I get to take all the gym classes; I get to take all the art/drawing classes -- whatever. I get to be an undergrad. For the first time in my life, I get to experience undergrad life. I'm like, "Oh my God, this is great." So, I learn to play volleyball; I'm playing tennis, and all the MIT coaches know me. I'm on a first name basis with all the MIT sports coaches. They're like, "Hey, Carson! How's it going?" I'm playing tennis. I'm doing no work. And then the summer comes along, and I have no funding. I don't know what I'm doing, and then I'm going to my advisor, and I'm like, "I have no funding for summer." He's like, "Yeah, you're also not doing any work. So, that's why you have no funding." Second kick in the butt that I needed. So, then I went into gear, and within a few months I started to work. Then my advisor came to my office and he gave me this Russian textbook, and he said, "There's this graph." Plasma physics is like you're basically looking for modes of excitation. It's the dispersion relationship. The dispersion relationship is the Fourier-Laplace transform of the differential equation -- the kinetic equations that govern the dynamics of the particles, and then you get these waves. So, there's all these different types of waves. He's like, "There's this interesting wave here that does not exist in any American textbook." So, you draw k versus omega, right? So, you're in the frequency versus wave number space, and then you draw these waves. There are these acoustic waves, plasma waves, electro-kinetic waves, and there's this extra line that does not exist. He's like, "Figure out what this is. So, it's like a photocopy, or something. It's like a picture. Just one picture in a textbook. So, I track down the reference. It's in Russian. I have to write to some library. This is before the internet. I write a letter. They find this thing, and somehow, I got it translated. I forget how I got it translated, but I managed to find a translation of it. Then, I go through the equations, and I discover that the textbooks have left out an equation -- a wave. There was this wave -- there's a solution in the dispersion relation, and they've ignored this solution.

ZIERLER: So, the Americans made the mistake. The Russian line was correct.

CHOW: Yeah. There was an extra solution. You have this complex, nonlinear equation, and then you have to find all the solutions for omega as a function of k. So, it's easy to just miss a solution, or you consider it not important. So, I found the solution, and I wrote a paper on it. So, within like six months, I had a paper. Although, it took me until 1989 to publish it. But I had the results probably around '88, or something like that. I remember writing that paper, and I would type it out, and then I'd get red lined everywhere by my advisor -- and then I rewrote it like, I don't know -- it took months to write this paper. But actually, I had a paper by '88 or '89. Then I was cruising along. I was publishing, and I was doing pretty well.

ZIERLER: You're staying in plasma physics?

CHOW: Well, then my advisor says, "Oh, you should transition to nonlinear dynamics. At that time, Steve Strogatz was an Assistant Professor at MIT. So, I got to know Steve Strogatz. I took his class, and I became collegial -- friends. We're not like super close friends.

ZIERLER: What was he working on at this time?

CHOW: He was doing his nonlinear coupled oscillators. He was still doing that. Remember, his first book was called Sync, so the work that went into Sync. He was this dynamic young guy, Assistant Professor, and you know, he's great. I would take his class, and I started to learn nonlinear dynamics. At that time, nonlinear waves were kind of big. So, my advisor said, "Oh, there's this plasma system. Everyone linearizes. Why don't you look at it, and when you put nonlinearity into it, let's see what happens."? Then, when I did that, I ran the simulation, and I got these chaotic wave interactions. So, then I did a thesis on spatiotemporal chaos

ZIERLER: That was your dissertation?

CHOW: That was my dissertation, and I wrote some papers on that.

ZIERLER: Do you remember the title of your dissertation?

CHOW: Spatiotemporal Chaos in the Three Wave Interaction. I think that was the title. I have it right over there. I can look it up. I wrote some papers on that.

ZIERLER: What did you see as your contribution with the dissertation? What did you discover?

CHOW: In retrospect, I think it was a pretty weak thesis. What I showed was that there's this nonlinear system, and so in these nonlinear systems, there's a sign. Like, in nonlinear Schrodinger, there's the focusing and defocusing. What I had was a three-wave interaction, which was instead of a nonlinear Schrodinger, which is a cubic interaction, it had a quadratic interaction. But when you have a quadratic interaction, you need three -- it's a vector equation. So, it's three equations of three interacting waves, and they each interact pairwise quadratically. So, wave one would interact with wave two and three, so it would have a term -- wave two times wave three would be contributing it, and wave two would get wave one and wave three, and so forth. So, this three-wave interaction could resolve in two ways. There was one where it would get solitons, and there was one where it'd be scattering. So, it had already been known, I think, at that time, it had a soliton solution. So, solitons were just starting to become big. There was the inverse scattering solution. These Russians were like -- even though it was discovered by Martin Kruskal, and his colleagues at Princeton in the late '60s, early '70s. By the mid '70s, these Russians -- I can't remember his name. He's a very famous Russian mathematician. Started to prove that all these other different systems. So, the way that you did solitons was what they did is they showed this interesting nonlinear transformation that took the Korteveg-de Vries equation, which is this nonlinear dynamical wave equation. You could do this transformation that's called a Lax transformation -- I think that's what it's called. God, it's all foggy now. It's like 30 years. Anyway, you can transform it to a scattering problem. So, it transforms into a Schrodinger equation scattering problem. So, you turn a nonlinear equation that's a boundary valued partial differential equation, you turn it into a linear scattering problem, and then the solutions of the scattering problem, which then can be transformed back into the nonlinear equation. So, in a scattering problem, you could have bound states, or you could have scattered waves. So, if you have bound states, those are solitons. So, what happens is the nonlinearity gets transformed into a potential well, and the depth of the potential well tells you how many solitons you get. So, solitons were just bound states of this potential well, and that's why they persist. So, if you get two solitons that need to go right through each other, it's because they're just two bound states. Then it doesn't matter -- they can never mix. So, what they did is they found the scattering transformation, and what happened was these Russian guys said, "Oh, you don't have to be bound to just this Schrodinger equation's scattering problem. You can have any linear scattering problem. So, they had these -- Zakharov, that's what his name is. Zakharov. So, you could have these two-dimensional scattering problems, and three-dimensional scattering problems. So, then, from there, you can start with the scattering problem, and figure out what is the PDE that it corresponds to, and from that they discovered nonlinear Schrodinger. Other than Korteveg-de Vries, there were all these different ones. The three-wave interaction was one of the nonlinear systems that had solitons. So, then the question was if you took the system, and you put it on a bigger domain, and you added some dissipation to it, and you added some dispersion to it -- so, a soliton system is a purely integrable system. Integrable, meaning you can decompose it into action angle variables, so that in the phase plane, you have these closed surfaces, so there's no possibility of having chaotic orbits. So, what happens is that -- so, three wave interaction is a conservative system. It's a Hamiltonian system. It's an integrable system. But if you add dispersion, and dissipation, it no longer becomes Hamiltonian. So, just like if you take integrable systems, and you add some dissipation, you could break the Hamiltonian structure, and then you can get chaos. Then there's this thing called Hamiltonian chaos, which is that they're non dissipative, but you put dispersion in, so you break it up. So, they're still conserved equations, and then you can have symplectic maps that are -- you know, symplectic form preserving, or some volume preserving map that's still chaotic. Then you could have dissipative chaos. So, at the time, there was Hamiltonian chaos, and dissipative chaos. Those concepts were starting to become widespread.

ZIERLER: And "chaos" means what here? That you can't understand what's going on? That it doesn't --

CHOW: Yeah, chaos is a specific definition. So, chaos just means -- it's a nonlinear system with sensitivity to initial conditions. Any small change will give you a completely different solution. So, it's just that initial conditions diverge exponentially, initially, and then when they hit the boundary of the limit, they start to mix. So, another name for chaos is intrinsic stochasticity, or deterministic stochasticity. So, it's a deterministic system that looks noisy because you have no predictive value, because you need infinite precision of the initial condition to be able to tell what's going to happen.

ZIERLER: And infinite precision is --

CHOW: Impossible. So, for any practical purposes, you'll exhaust the information in the initial condition. Each digit will get lost at each time step. So, that's exponential loss of information. So, a chaotic system is something where you lose information, so you cannot predict what's going to happen. But you can have a chaotic system which is area preserving, or volume preserving, or Hamiltonian. So, a Hamiltonian system is a non-dissipative system. So, energy is conserved. But more technically, there is a symplectic form that is preserved, which is a volume with an orientation. So, the symplectic form is preserved. So, you can have a chaotic map where the area never gets -- you don't have a strange attractor, per se. It's just chaotic, and you can't predict it. It's still volume preserving. Phase space never shrinks. Then you can have a dissipative system, like a Lorenz attractor. That's a famous, strange attractor. The horseshoe map, and things like that. That's where it shrinks down to a strange attractor. So, because it's a dissipative system, even though you start with three dimensions, you have an effective dimension of less than two, or something. It's not quite a line, it's not quite a surface. It's this weird, strange attractor. So, now we have this partial differential equation, which is an integrable system, so it's a Hamiltonian system. Now you add dispersion, and you add dissipation. So, you add some other nonlinearity to it. You break the symmetry of it. What happens? Nobody knew. So, I showed this system becomes chaotic. I didn't actually -- I measured the Lyapunov exponent, but I also showed the autocorrelation is narrow. If you followed a solution, the correlation between the solution now and some other time would decay exponentially. So, another way of saying something's chaotic, is that the correlation function decays exponentially. So, whatever you know about the system now, you get exponentially less information over time, and then eventually, exponentials go away.

ZIERLER: So, what's so weak about this dissertation? That sounds pretty good.

CHOW: I don't know. It just wasn't that great of a result, I don't think. I mean, I showed it's chaotic. It's kind of a demonstration. Later on, real mathematicians would have proved more interesting properties about it. I didn't really prove anything. I did do a nice perturbation calculation, where I showed that if you take the integrable system, and you perturb it, you can kind of estimate some quantities. So, that was one nice thing about it, but it wasn't that deep of a thesis. I think the problem at the time was that the physicists didn't realize how shallow they were. They were entering this field of nonlinear dynamics, and thinking that it was new, whereas it's been around since the early twentieth century and the Russians -- so, the mathematicians were just so far ahead of the physicists in terms of understanding chaotic systems. They were trying to solve these really difficult problems, and they had these (methods) -- whereas physicists were demonstrating new phenomena. So, they were showing new things that the mathematicians didn't really know about, but they weren't really examining it in depth. So, I was just showing there's this new thing without really having a detailed, in depth understanding.

ZIERLER: So, you were part of that process?

CHOW: I think I was part of the process of saying, "Hey, here's something interesting." But I wasn't really studying it with any -- and I didn't even know that you could study it with any depth. I didn't even know what a mathematician did in 1989.

ZIERLER: Who was on your committee?

CHOW: Frances Low was on my committee, Michele Baranger, and I think George Bekefi, who was an Italian plasma physicist.

ZIERLER: So, MIT is a three-person committee?

CHOW: Yeah, and then they passed -- they gave me my PhD. I think they gave it to me with distinction, or something. I actually got a little marker.

ZIERLER: Okay, well they liked it.

CHOW: Yeah, I gave good presentations because of my advisor -- we would have these legendary group meetings.

ZIERLER: Led by who?

CHOW: My advisor. So, every week one of us in the group -- by the time I got to the group, the group had shrunk down to me, and one other grad student named Ken Kupfer, who's still a friend of mine. He's doing biology now. He works in biotech. In the '70s, my advisor's group was giant. That was kind of the heyday of plasma physics in the early '80s, so his group was giant. But by the time it got to the mid '80s, plasma physics was on the wane. People didn't think fusion was going to happen. The joke is that fusion is always fifty years from now. It's *always* 50 years from now. So, funding and fusion were shrinking at the time, and interest in fusion was shrinking at the time. So, by the time it was like me and Ken, and there was Abe, and he had a research scientist that also worked in his group: Abhay Ram. Great guy. So, it was the four of us, and we would have these meetings where every week someone would present, and the job of the other three was to just tear it down, to make you feel like you were the stupidest person on the planet. I remember the first time I went up to the group meeting, I couldn't get past my first slide. They would say, "What's that equation? Where did that come from? Derive it. What does it mean?" And I would be like, "Uh..." Like, right now as I explain to you, nothing went past Abe. He would say, "Wait a minute, is that what you really mean? What was that actually in that equation?" So, by the time I got out of my PhD, I was over-prepared for talks, and I could never be fazed in a talk.

ZIERLER: Uh huh. This was good training.

CHOW: It was great, and to this day, I think that was the greatest gift Abe gave to me. He was a great advisor, but that was great. I try to bring that to my group now, but it's getting pushback. I don't get well-received. So, this being highly aggressive in group meetings is not taken as well now.

ZIERLER: Different time.

CHOW: Yeah. I've been asked to dial it back, so I can't recreate that experience, which for me was the greatest experience of my life. It's considered traumatic in today's times. It was traumatic. I would feel like an idiot, or I would prepare for two weeks. I'd be like, "Okay my time's coming up." And I'd make sure I could derive every equation left and right. So, I could give good talks by the time I gave my defense. I gave a great talk, and during the defense they would grill me, and I was ready. I was good at giving talks.

ZIERLER: So, you defend, and now you're thinking postdoc?

CHOW: Now I'm looking for postdoc, and because I'm in an obscure field --

ZIERLER: It's an obscure field relative to what else is going on then, or it's always been an obscure field?

CHOW: My advisor is a plasma physicist, with great standing in the plasma physics community. He's not known in the nonlinear dynamics community. So, I'm trying to get a postdoc.

ZIERLER: This is a challenge.

CHOW: Just like grad school. Bell Labs? No. Berkeley? No. Princeton? No. Finally, one person takes me. University of Colorado, John Cary, bless his soul. He took me as a postdoc. Just like in grad school, I have one option. As a postdoc, I have one option. My friends are becoming Harvard junior fellows. They're going all over. I'm going to Colorado.

ZIERLER: Yeah, but there's good stuff that's happening in Boulder.

CHOW: Yeah. At least I survived. I'm still in survival mode. You have to understand, even though I'm doing better relatively, I'm not doing well relative to my MIT colleagues who, a lot of them are going on directly into professorships. In chemical engineering, and electrical engineering, they don't do postdocs. A lot of them are becoming Assistant Professors. One of my friends, Stephen Hsu (who was at Berkeley) is a Harvard Junior Fellow. Another, Terence Hwa goes to the Institute for Advanced Study. He's the star in stat mech. Other friends, right? They're doing well. Better than me. I'm always the laggard.

ZIERLER: Boulder's a nice place to be.

CHOW: I'm in Boulder, I go to Boulder, and I'm like, "Wow, this is nirvana. Boulder is beautiful." I love Boulder. It's great.

ZIERLER: Right. If you can't get all the way to California, Boulder's a nice stop on the way.

CHOW: It's the furthest west I ever got. I'm in Boulder, and I'm like -- but I have to do plasma physics, which I kind of lost interest in. Actually, no. John Cary hires me to do particle accelerator physics.

ZIERLER: What is he doing at this time?

CHOW: John Cary is a very prominent plasma physicist. A dynamicist. He's a very famous dynamicist. He was a fellow of the American Physical Society in his 30s. He had this very famous paper with Robert Littlejohn, where they worked out Hamiltonian Dynamics, and KAM theory -- Kolmogrov-Arnold-Moser Theory -- they worked it out. They had great results. He was this brilliant physicist, applied mathematician. He wants to do particle accelerator physics. At the time, the way particle accelerators are designed is they're designed to be as linear as possible. So, there's an aperture problem, that if you're linear and you get out near the edges, you get into this edge effect. So, that's why the beams can't be that dense. So, he has an idea to say, "Hey, why don't we make an accelerator integrable, because then we know its orbits are all confined." So, instead of trying to be as linear as possible, where it can be understood very well as just matrix multiplication, we're going to make it as nonlinear as possible. Now, we're going to bring in nonlinear dynamics technology. So, I'm hired to do this. I know nothing. I don't know anything. I have a thesis, I'm inventing stuff, I do simulations -- I didn't really learn anything. So, I show up there and I don't know what I'm doing. But John Cary is like a really kind advisor. He just lets me do whatever I want. So, while I'm there, I go to the Applied Math Department, because two of the people that were the top soliton people in the world, Harvey Segur and Mark Ablowitz, are on the faculty at University of Colorado in the Applied Math Department.

ZIERLER: Did you know this before you got to Boulder?

CHOW: It's a good coincidence. I kind of knew, but I didn't really know. I knew the names, but I didn't really know they were there.

ZIERLER: Are you drawn to the Math Department because you have this lingering feeling at MIT that you need to know more math?

CHOW: No, I'm still not thinking that I need to know math, but I know solitons. I wanted to continue in solitons but I'm not able to. But these guys are soliton guys. So, meanwhile, I'm doing my day job with John Cary, where I'm learning accelerator dynamics, not really interested. This was like maps, and Hamiltonian chaos. In retrospect, it was super interesting stuff. I was just too boneheaded to know at the time. I'm thinking PDEs are the cool thing, whereas this is like maps and ODEs. Even though there's no such thing as a cool thing. They're all cool. So, I'm going to the Applied Math Department, and hanging out with Mark, and Harvey, and Harvey and I hit it off, and we actually have a joint project. We write papers together. Meanwhile, I didn't even include John Cary in this. I didn't even let him know I'm doing this. So, I'm the world's worst postdoc. I don't let my postdocs have the freedom he gave me. So, here I am: the world's worst postdoc. We finally publish one paper, I think.

ZIERLER: But you're giving John what he needs. Right?

CHOW: Sort of. I mean, I'm a terrible postdoc. What I did do for him is at the time he's getting into C++, and object-oriented code. He's really a mathematician, but he likes to code, or at least he's getting into coding. So, I introduce C++ to his group. He's writing code in C, and I bring C++. He sent me out to Stanford to go to go to SLAC to meet some guys out there doing accelerator design. They're like, "Oh, we're coding in C++." At the time, to do graphical interface, you had to write it yourself. There was this program called Motif. It was a language called Motif, which is how you made the nice frames in X windows, if you remember from UNIX days. So, they said, "There's this new way you can write objects in Motif, and we're doing C++ in Motif. You should do that, too." So, I brought that technology back. So, I wrote this code to do, and we did do some stuff. I have to say, he gave me so much freedom. He was the greatest advisor, and he was a super nice guy. He didn't bother me. He let me do my stuff. He gave me resources. He didn't complain that I was a terrible postdoc. I could have been so much more productive for him, and I wasn't. He even wrote me a pretty nice recommendation letter. So, I'm in Colorado, and again, here I am, reaching the end of my time in Colorado. I'm not stellar in the field. What I realized, which is what I tell my postdocs and students now, is make sure that you work in the area where your advisor has got a reputation. So, here I am, coming out of Colorado. I'm not stellar in the field where my advisor has a reputation. I'm not interested in doing particle accelerator design. I never really get to choose what I get to work on, because I've never been in a situation where I've been in that position. I'm always the bottom of the heap, kind of guy. So, I'm just a survivor guy. So, I'm desperate, coming to the end of my postdoc. I have nothing lined up. I'm interviewing on Wall Street, not even doing that well, because I don't have the stellar grades, and I'm not that smart. So, I'm not even doing that well on Wall Street interviews. I don't even make the cut to go to McKinsey, because I'm not smart enough. So, you know, I'm struggling. I call Ken up on the phone. Ken went to France to do plasma physics postdoc, and now he said, "Oh, I'm at University of Texas, doing a postdoc in biostatistics, or genomics." This was right when the Human Genome Project was starting in the early '90s.

ZIERLER: And there's a lot of money being poured in, too.

CHOW: At that time, it wasn't much yet. It was early '90s, so it was just starting. But he was early. So, he said, "Oh, I got this NSF postdoc," -- or fellowship, or something -- "where they're going to train physicists to do genomics. You're too late for this, Carson, as usual. But you know what? I saw this ad while I was walking down the hall, for a guy at the University of Michigan advertising for a physicist to do epidemiology research. Why don't you call him up?" Or he knows about this, or something. Anyway, so I call that guy up, and he says, "Oh, that position is taken, but I saw an ad for a guy at Boston University looking for a physicist." So, I call that guy up. Now, that guy is named James J. Collins, who you might know, who's going to win a Nobel Prize someday. This is before Jim Collins is Jim Collins. Jim Collins is not even on the faculty at BU. He's a Research Assistant Professor, which is soft money, at Boston University. He's fresh out of his Rhodes Scholar from Oxford. So, he's like five or three years younger than me. He's younger than me. He's this guy who's starting a new lab. He wants to bring nonlinear dynamics to biomedical engineering. That's Jim's thing at that time. He's not even doing the stuff he is now. This is pre all that stuff. He's doing posture control.

ZIERLER: What is posture control?

CHOW: So, elderly people have a problem with balance. One of the reasons that elderly people die is they break their hip. It's because they fall. So, what he's doing is he's trying to come up with ways to help people diagnose people that have balance issues, and also probably some kind of therapy for this. So, what he invented was -- what he did is you put people on a pressure platform, and it moves around, and you can measure the center pressure. What he did was he imported random walk analysis, and nonlinear dynamics to this, and he started to analyze this thing using nonlinear dynamics tools. So, this is very novel. He's starting to do this, and he needs a physicist.

ZIERLER: So, he's on soft money, but he has enough money for a postdoc.

CHOW: Right, because this is Jim. Even though nobody knows who Jim is, he's still Jim. He's good at getting grants; he's brilliant; he has ideas. He's Jim. He's the same Jim as he is now. He's just young. He's 30, or he's 28, or whatever.

ZIERLER: Right, so what's his affiliation at BU?

CHOW: He's a Research Assistant Professor in the Neuromuscular Research Center at Boston University. It's a soft money position. I call him on the phone, he's about to hire some guy, and I call him up, and I talk my way into the job. Jim and I just hit it off. I manage to convince him I'm buddies with Steve Strogatz. He knows Strogatz. I tell him all the stuff I know. At this point, I actually know a lot of stuff, although not in depth, because I've been in so many fields. I can code, I know nonlinear dynamics stuff, you know, whatever. So, he hires me. So, I get in my car, and I drive to Boston.

ZIERLER: You're single at this point, still?

CHOW: Yes. Single. Not even a girlfriend. Just really single. I get in my car, and I drive to Boston. Now, when I left Boston, I had two parking tickets that I never paid, because I never thought I'd come back to Massachusetts. They were waiting for me. I couldn't register my car until I paid my parking tickets. I remember that. They were like, "You can register, but here's $140 in tickets." So, I paid that, and now I'm back in Boston.

ZIERLER: Do you realize now that, uh oh, I don't know any biology. This is a problem. Or no?

CHOW: I've never had that, because I've never known anything. This is the thing that people don't understand about me. I change fields like I change underwear, and I'm never afraid, because I've always been in this situation. I never know anything. I always just learn on the fly, and just make do. I never really think of myself as being the expert in anything, so it doesn't matter to me that I don't know anything. I'm comfortable not knowing anything. I think that's my greatest strength. I'm comfortable not knowing anything, and just doing it. So, I just show up. It doesn't matter. The thing is --

ZIERLER: Is Jim dealing with patients? Is he really right there?

CHOW: Yeah, yeah. Well, subjects. He's doing experiments where we measure them, and stuff like that. So, the thing is -- you know, he says, "Oh, I have this posture control thing." So, I'm telling my friend Terry Hwa this idea, and he says, "Oh, why don't you model it as a polymer." He doesn't remember this. He's like, "Oh, that was a great idea that you model it as a polymer." I'm like, "It's your idea." Anyway, so, I worked it out. I worked out the statistical mechanics of it, kind of, before I got there. I already worked out the theory for his posture control.

ZIERLER: You mean like what? On a drive cross-country, you worked it out?

CHOW: No, I took the job in something like the spring, or something, and I showed up at the end of summer, or something. In that time, I worked it out. I worked out the theory. So, when I show up at Jim's doorstep, I give him notes. Like, "Hey, I worked out a theory." So, we're writing a paper the first month. So, Jim thinks I'm the greatest postdoc that ever lived. For the first time in my life, I'm ahead of the curve. This is when my fortunes start to change. So, we're at BU, and it's going well. Then, Jim comes up with this idea to work on stochastic resonance, and we write this Nature paper. It's actually based on one of my failed results. I actually showed him a result where I get this thing, and I'm like, "Oh, I don't know what to do with it." Jim spins it into a Nature paper. And then things are going great. But -- then there's political intrigue again, because Jim and the director of the center, this guy named -- oh my God, what's his name? Carlo, something. Anyway, this guy and Jim have this power struggle, because Jim is starting to become prominent, and he's starting to overshadow. This guy, Carlo DeLuca -- he believes I'm his postdoc. Jim thinks I'm his postdoc. But I'm not working with Carlo.

ZIERLER: Why would Carlo think this?

CHOW: So, Carlo suddenly gets upset. So, he fires me, sort of midway through. Oh, I have to pick sides. He's like, "You have to work on one of my problems." I choose Jim. So, I get fired midway through, but prior to being fired, I meet Nancy Kopell, who is another MacArthur Fellow. My lucky life continues. So, while I'm at Boston University, Philip Morrison, the famous physicist, is having a -- MIT is having a Celebrate Philip Morrison. Either 50th anniversary of him being on the faculty -- anyway, there's a celebration for Philip Morrison, and I go there to sit in on this symposium. One of the professors giving a talk is Nancy Kopell, who's talking about oscillations, and the lamprey, and modeling it with differential equations. I'm like, wow! And then she's talking about how we're going to apply this to the brain. She's like, "We're doing neuroscience." I'm like, "Neuroscience? How is this possible? There's a mathematician working on the brain?" So, the next week, I show up at her doorstep. I'm like, "Hi, I'm Carson Chow. I'm Jim Collins's postdoc. I think you gave the greatest talk ever." And then Nancy says, "Oh, I have this weekly group meeting. Why don't you come to this meeting?" So, I go there, and --

ZIERLER: What's your status at this point? You're fired? You're not fired?

CHOW: I'm still working. This is slightly before the political intrigue, but Carlo is already pissed off at me, so I'm kind of working on a problem with Carlo already. But Carlo is kind of angry at me. So, I'm going to Nancy's group, and then I start to do a project with Nancy, and we start to get results.

ZIERLER: What's the project?

CHOW: It's on synchronization with neurons. So, when do they synchronize? That time in the early '90s was about when the neurons synchronize. So, I'm working with Nancy, and there's an Assistant Professor named John White, who is now the chairman of the Biomedical Engineering at BU now -- a good friend of mine. He and I, and some other grad students start working on this project together, and I become an integral part of this group. Then, Nancy gets this really big grant with Jim. So, Jim, Nancy, and a bunch of other guys get this giant BU, NSF grant. It's called the GIG - Group Infrastructure Grant. The idea is to combine theorists and mathematicians with biologists. It's the early '90s, and math in biology is starting to become a thing. So, I become the first postdoc. So, right when the funding comes through, I get fired. So, Carlo's like, "Hehehe. You're fired." And I cross the street, and I get an office in Nancy's. Jim and Nancy had already saved my life. So, I'm saved, and now I become Nancy's postdoc, and then my stock starts to rise. I'm finally working in the field where my advisor is strong, although I do miss out on one thing. While I'm at BU, Tim Gardner is Jim Collins's graduate student, and Tim, me, and Jim start working on the genetic toggle switch. Charles Cantor has this idea to make a genetic toggle switch, if you remember that back in the late '90s. So, I'm actually in the project. Then, I move to Nancy's lab, I start doing neuroscience, and I kind of get dropped. That's when Jim becomes Jim, because that blows up, and he moves into genetics.

ZIERLER: Does he stick around, or he moves on?

CHOW: Well, what happens is because Jim becomes so important to Boston University, he becomes -- I don't even think he becomes Assistant Professor. I think he becomes full Professor at Boston University directly. Anyway, he becomes a real faculty member at Boston University quite shortly after I leave. Then, he starts to become the Jim we know now, which is like publishing in Nature and Science every week, and coming up with brilliant ideas, and attracting brilliant people, and having a great laugh. So, he's just doing great work. Then he moves -- he's at MIT now. He only moved to MIT like five or seven years ago. He was at BU for a long time as a professor, running a giant lab, getting lots of grants. You know, Howard Hughes, and MacArthur, and all that stuff. So, he's doing that. Tim and I, and Jim and I -- I was almost there. I wrote this blog post once of me missing everything -- like, missing every trend. I was in Boulder, and I was one of the first people on the internet, because John Cary was very farsighted. I had a friend who worked at Yahoo. He was an employee in the teens at Yahoo, and I missed the internet. I could have gone to Silicon Valley and missed that. I could have gone into synthetic biology, because I was there at the start, and I missed that. I missed every trend. I was at University of Pittsburgh kind of when Jeff Hinton was not famous yet, and when Neural Networks weren't famous. I was there, and I missed that. So, I've missed everything, which is fine. I've managed to do way better than I should have in my life. My career has gone way better than it should have, by any stretch of the imagination. I've defeated death so many times. I'm like the miracle person. So, I'm working with Nancy, and I'm publishing stuff.

ZIERLER: And then you get to tenure track?

CHOW: Then I get a tenure track at University of Pittsburgh. So, Nancy's colleague, Bard Ermentrout, brings me to Pittsburgh. Then, I also get a big NSF grant -- NIH grant. K01 Award. So, I have a big grant. So, I show up at Pittsburgh as a star. For the first time in my life, I'm a star. I show up at Pittsburgh, and they love me. The Dean loves me. I'm getting stuff done.

ZIERLER: Star in what world? How are you being defined these days? Because you come from the math department.

CHOW: I'm called a Math Biologist at this point, where I don't really identify as being a mathematician yet. I'm really not mathematical yet. But I show up in the math department. I'm an Assistant Professor of Math. I'm teaching math classes, and I actually am a pretty good teacher. Unfortunately, this is before whatever that rating thing is -- that Rate My Prof thing -- my comments aren't there. I was rated -- I remember one time when one of the senior professors was going through my tenure case, and he's looking at my ratings. He's like, "I've never seen ratings like this before." I started the Pittsburgh Integration Bee, which goes on to this day, where there's a little competition. I'm doing so well at this point.

ZIERLER: You're having a good time, too.

CHOW: I'm having a great time. I'm like on top of things; the administration loves me; I'm getting stuff done; I get into inflammation research; I get these grants. My wife is at Hopkins. I wasn't married to her.

ZIERLER: When did you meet?

CHOW: I actually met her at MIT, although we weren't a couple until 2000.

ZIERLER: What's her field?

CHOW: She's an ophthalmologist. So, she's number one, and she was an MIT undergraduate. She goes to University of California - San Francisco -- UCSF. She becomes an ophthalmologist. She's whatever. She's plowing through her career.

ZIERLER: When are you getting married?

CHOW: We get married in 2005. So, we start becoming a couple in 2000. I'm in Pittsburgh, and she's in Baltimore. We aren't even thinking this through. My wife doesn't plan, because she's always been -- unlike me, she's always been the first choice. So, she's got the pick. I never got to choose. But she doesn't plan, ever. She still to this day doesn't plan. You know, we're not really thinking this through, but then I'm at Pittsburgh. John Rinzel, who's a famous math-biologist, used to be here. He used to be literally sitting in this chair. He was the chief of this branch when it was called the Mathematical Research Branch. Somewhere in the early '90s -- so, this branch predates the Diabetes Institute. It was the National Institute of Health. Back in the '50s, there was a very forward-thinking Director of NIH -- this was right when the ENIAC was built. He said, "I bet computers and biology are going to be important. Let's start this thing called the Mathematical Research Branch." So, in this branch, the NCBI -- you know, the software tool Blast, and all that stuff -- the ideas came out of a postdoc, David Lipman, who was a postdoc here. Compartmental modeling for that kind of pharmaceutical modeling -- a lot of those ideas came out of here. After Hodgkin and Huxley, Wilfrid Rall -- computational neuroscience, a lot of it started in this lab. So, John Rinzel was a computational neuroscientist. He was here. He was chief. At this heyday in the '70s, it was a big great. Bard Ermentrout was a postdoc here. So, I knew John Rinzel through Bard Ermentrout. Then, Rinzel left to go to NYU, to be a professor, because when this thing -- at some point, one of the scientific directors of NIDDK said, "I have this branch here that's not doing any research on diabetes. It's a neuroscience branch, so I'm going to shrink it. So, when he shrinks it, Rinzel goes. It becomes just Artie Sherman, and one other person. So, just two people. Then, that scientific director leaves, and another one comes in and says, "I'm going to rebuild it, but it's going to be, now, a molecular biology modeling kind of lab, computational biology..." Rinzel says, "No, you should make it a mathematical physiology branch." Meaning, not do molecule level, but do, say, organ level. It doesn't have to be neuroscience, but it can be physiology. Let's model the human organism level. He says, "And I know a guy who you can bring. Carson Chow, who is at University of Pittsburgh, who needs to move to the D.C. area." So, I apply for the job, and I get the job, miraculously, because I didn't even try that hard at the interview. In fact, I think I gave a terrible interview.

ZIERLER: Where were you on the tenure clock?

CHOW: I was tenured already.

ZIERLER: You were?

CHOW: Yeah. I was on the fast-track at Pitt. I was probably going to go out for full professor within a year or two. I was doing really well at Pitt.

ZIERLER: So, did you come here with tenure, or you had to start over?

CHOW: No, I came here without tenure.

ZIERLER: Wow. That's a big risk, there.

CHOW: Yeah, well, you know, I wasn't even thinking that, because I was like, "I can get tenure once. I can get it again." Little did I know, it was kind of hit or miss. So, I show up here in 2004. I leave Pitt, I come here, I get married to my wife eventually in 2005, I live in Baltimore --

ZIERLER: How far away are you moving from physics at this point? I mean, intellectually, and day-to-day. Is it still with you, or are you really like -- this is definitely in the past for you?

CHOW: I'm still a physicist in the style of my work.

ZIERLER: What does that mean?

CHOW: I do back of the envelope calculations where assumptions come in off the fly, where I don't quantify. I don't make everything precise, but I do pen and paper kind of calculations, and computational simulations. It's kind of like approximations that are uncontrolled, is how you would say it in math. So, I do lots of these kinds of calculations, and I'm pretty good at it. I'm actually pretty good at what I do. I'm doing computational neuroscience kind of things, modeling the immune system, the inflammatory response system, which is highly pertinent, now, to COVID-19. So, some of those models actually apply directly. I'm doing this kind of work, but I finally take the label of mathematician when I'm in Pittsburgh. When I was with my colleague Bill Troy -- he was a faculty member -- and we're at this function -- you know, one of these faculty social functions. We're talking to the economists, or whatever, and he introduced us as mathematicians. That's the first time in my life I've been called a mathematician. And I'm thinking to myself, "I like that. I like being called a mathematician." The fact that my colleague, who is a really good mathematician, is calling me a mathematician? I'm like, "This is the greatest day ever." It really was one of the best days of my life. From then on, I've identified myself as an applied mathematician. With the general public, I call myself a mathematician. With a pure mathematician, I qualify as an applied mathematician, which I do consider myself. And my style starts to change. I try to be more rigorous in what I do. I'm still not super rigorous. I'm not doing theorem, proof, theorem proof. But theorems are creeping in -- you know, theorem-like things where I actually prove things. I start to find the value of being a mathematician in biology is more than being a physicist in biology.

ZIERLER: Why?

CHOW: I think that physics, at the time, was dominated by Pierre-Gilles de Gennes, the famous Nobel Laureate on disordered systems. The de Gennes style is super intuitive calculation. The thing is, to do calculations like de Gennes, you need to be de Gennes. He makes these assumptions, and then he says, "Oh, let's assume that the molecules are separated. Let's assume that the polymers reptate. They move like this. Let's calculate the diffusion constant --" And at the end he gets some exponent which matches the data, right? He happened to make six assumptions and approximations that just so happen to be correct because he's de Gennes. Now, if you do this, and you're not de Gennes, you can get an answer, too, but you have no idea if you're right or wrong. If you're lucky you're right.

ZIERLER: You wouldn't know.

CHOW: You don't know, right? If you're still within physics, you can do the experiment. The problem with biology is you often can't do the experiment controlled enough. There are just too many unknowns. So, I think that when physicists start to try to -- it was during Max Delbrück's time, and they were working out the laws of genetics, that was when being a physicist was super useful. He worked out, look, here's the Null hypothesis, the Poisson distribution, here's what you would expect if mutations were Lamarckian, here's the distribution. He calculates, and he does the experiment. Okay, Max Delbrück was a God, right? He was brilliant beyond belief. But when you're going to, like, modeling diabetes -- now, NIDDK, you've probably interviewed some great physicists over there. Bill Eaton, Attila Szabo, Robert Best... Smart guys, right? They're doing great work. They're working at the molecular level, mostly, and that's where I say you need to take into account of Hamiltonian, quantum mechanics, h-bar -- constraints that are physics. Physics is highly constrained, so that when you do approximations, you kind of don't need to know if they're right or wrong, because the constraints kind of force them to always be right. If you know it's going to be a Hamiltonian system, and you know this symmetry, you only have so many actions, or Lagrangians you can try, and then you can work something out. So, you don't need to prove that they're right, because you're given the structure already. You're given a scaffolding. Now, when you start to get the disordered system, like de Gennes, now you're on thin ground, because there's no physical constraint. There's still no Hamiltonian for water. When you're modeling a liquid, the Navier-Stokes is an empirical equation that works, but there's no fundamental theory behind why it works. We still don't even know if Navier-Stokes is well-posed. Terry Tao, the famous mathematician, may prove it one day, whether or not it's a well-posed thing. We don't know whether a solution will always exist, or whether it'll blow up. We don't know whether or not the discreetness at the fundamental level matters. We don't know lots of things about fluids, especially when you get the non-Newtonian fluids, and you get the gels, and you get the polymers... Physics starts to blend with what's called soft condensed matter. De Gennes invents the field of soft condensed matter. I think that a lot of physicists were soft condensed matter physicists coming into biology in the '90s, rather than the particle physicists coming into biology in the '40s, or '30s, during the Delbrück era. Then, Wally Gilbert -- they're bringing rigor to biology at a time where rigor was useful. Now, the soft condensed matter physicists are coming into biology bringing de Gennes style calculations at a time where if you're not de Gennes it's hard to know if you're right.

ZIERLER: Yeah. So, this all gets back to why mathematics is --

CHOW: I think that math is useful because you make your assumptions explicit, and then you work out the consequences of those assumptions. So, you say that if you believe this, then this is true. I think that the strongest contribution you can make as a mathematician in biology is to say, if you as a biologist believe in this, then this is the consequence. If you believe the R0 for this disease is 1.3, then this is how many people are going to be infected in a year. If you believe it's 2.3, this is how many people are going to be -- these are the assumptions, this is the consequence. You make the decision whether the assumptions make sense, or we empirically test. Or, at least, we find a set where the experiments can tell us what the assumptions are. Then we can work out the consequences. So, that amount of rigor, I think, is important for biology. That's why I think mathematics has more use in biology today than physics, even though my good friend, Keir Neuman, who you talked to, may disagree. But from my point of view, when I became more mathematical, I think I became more useful.

ZIERLER: Useful how? Clinically?

CHOW: Yeah, in the sense of the results that I had had more utility.

ZIERLER: But utility how?

CHOW: In helping the experimentalists in moving the field forward. But I think a lot of models the physicists come up with in biology don't really move the field forward. It's more like a diffusion. I have a model, and I do a little twist in the model. We don't really know if it helps advance the field. I think theoretical neuroscience is at a stage now, where there's lots of interesting results, and we don't really know whether it's advancing the field.

ZIERLER: So, biological modeling -- in the matrix of where you fit in with the bigger picture, who are your clients? Who are the people who are coming to you, and who are the people that you are going to, in terms of everybody exchanging information, and trying to figure out problems?

CHOW: Yeah, that's a great question. The people coming to me could be anyone. I collaborate with Dan Larson, who does single molecule imaging. He's looking at gene transcription at the mechanistic level. I collaborate with Bruno Averbeck, who's a neuroscientist. He's also a physicist. Well, he's very mathematical.

ZIERLER: He's here?

CHOW: He's here, yeah. He's at NIMH. Bruno Averbeck.

ZIERLER: I've got to get him.

CHOW: Yeah. Actually, I don't think he's technically a physicist. His degree might be in biology, but he's very much a physicist. He's very quantitative. He's very mathematical. He's working on models of cognition and decision making, and how optimal are we in terms of the ideal observer. So, he's at the very high cognitive level. I collaborate with people who are interested in autism. I collaborate with Kevin Hall, who is also a physicist. Do you know Kevin Hall in the office next to me? He's in the news a lot, because his work is on obesity and metabolism. So, he and I came up with some simplified models of how you gain weight when you eat. That actually may be the work that has the most impact of anything I do -- that pretty simple mathematics where we came up with a way to quantify, if you eat x amount of calories every day, this is how much you're expected to weigh. It's pretty useful.

ZIERLER: You've been in so many academic institutions. I wonder if you could compare how collaboration works here as opposed to other places.

CHOW: It's hard for me to say, because I'm so atypical, and I'm also -- forming collaborations for me has never been a problem. It always just sort of happens. It's just the way I hire people I've never put out an ad for a job to hire a postdoc or anything. I've never systematically done anything in my career. So, it's hard to really say. I mean, the way my collaborations happen -- when I was here, I got here in 2004, and I started collaborating with Kevin. We were working on obesity, and then I met a physician here, who is Anne Sumner, who works in diabetes and glucose levels. I started collaborating with her because she said she needed a statistician to talk with. So, I knew zero statistics. I come here. The most useful quantitative person to a biologist is a statistician, so I'm suddenly, "Oh, yeah. I'm a statistician." So, I start to learn statistics. Vipul Periwal comes along. He introduces me to Bayesian inference. He's like, "Oh, you're doing stats the wrong way. Bayesian is the way to do it." So, I learned Bayesian inference from Vipul. Then, I meet Stoney Simons, who is a biochemist. He's working on steroid gene transcription, so we come up with a model to model that. From that work, I meet Dan Larson, who is interested in the same problem, but he has a different tool. So, still understanding how an agonist induces transcription. So, in Stoney's case it's steroids, but any hormone can induce transcription. So, Dan's interested in that prep, too. So, I start to interact with Dan. Then, I meet people at NCI through Stoney and Dan. Gordon Hager -- so, I can talk to these people.

ZIERLER: So, you see yourself as -- I mean, you're really all over the place.

CHOW: I'm all over the place. I have no theme. I have no agenda. By design, I'm the opposite of my dad.

ZIERLER: The fact that you're at NIH, where applying for grants is not as much of an issue, does that --

CHOW: Frees me totally.

ZIERLER: It does free you. Right.

CHOW: Total advantage for me.

ZIERLER: So, for some self-reflection, what are the pros and cons of being all over the place, versus being hyper focused on one thing, both for your field, and for your service to the health science community?

CHOW: I would say that there's almost no pros in being like me, in being all over the place,

ZIERLER: Except, I mean, to state the obvious, that you're so useful to so many people.

CHOW: Eh, maybe. But maybe I would be more useful in aggregate if I focused on one thing, because I could get deeper. I'm not deep. I'm a very shallow person, tragically. I've always wanted to be a deep person, but I have a very shallow understanding of the various many things. I rely on my experimental collaborators a lot. In some instances, that's good, because we don't have very much friction. I trust them completely, in the experiments they do, and what they tell me in terms of the biology. Whatever they tell me, I just take as gospel truth. So, it frees me in that sense.

ZIERLER: Right. And that's because of the caliber of the people you're working with.

CHOW: Yeah, and also that I know I'm not an expert. So, the fact that I don't think I'm an expert is freeing in that sense. And they trust me, for the most part, in the computations that I do. So, in that sense, my collaborations work really well.

ZIERLER: How much have you relied on advances in computational power over the years?

CHOW: I've relied a ton on advances in computational power.

ZIERLER: Are there things really concrete that you can do now that you couldn't do five, ten, fifteen years ago?

CHOW: Yeah. So, right now, I'm fitting a bunch of these gene models to Dan's data. In fact, I'm fitting it to Rafael Casellas's data, who is in NIAMS, a small institute, which I never remember what it is. He's a fantastic molecular biology geneticist. So, what I have is a kinetic model. So, it's saying, what are the states -- so, what Dan does is he visualizes transcription in real time. He has a prep where he can see the molecules being created, and then being ejected from the gene. So, you can actually get the time course. One of the things that Dan and his colleagues have discovered is that transcription is stochastic, and it's bursty. It happens in these bursts. It's not this steady thing. It's very random. So, a random process can then be modeled by a random -- essentially a Markov process. A random process. So, then the question is, what random process? So, there's no prior knowledge to that, because you're just measuring -- you kind of only have pieces of information. You don't have access to the states. You can only see, oh, this is when the GFP is glowing, and this is when it's not. So, you know when transcription is happening, and when it's not, and you can measure the end products, but you don't know what's happening in between. So, what we do is we create a bunch of these kinetic models where you have these transitions that are totally unknown, with rates that are totally unknown, such that they will transcribe at certain amounts, and not transcribe at other times. And then it'll produce product, and we can compare those to the data, and then we can try to fit them all. We don't know how many states we should model, so we try lots of different states. It takes a long time to fit these models, because we don't know where the parameter regimes are, so I'm doing a Monte Carlo, which is the cheapest way to search, which is just randomly search, and see whether you're doing it. So, that takes a ton of computational time, because I'm just searching, and grinding, and grinding through models. Now, Rafael Casellas is now doing what Dan's doing, but he's doing it on the entire genome. So, now, instead of one gene, I'm trying to fit 15,000 genes with these kinetic models. So, I'm completely reliant on (the NIH supercomputer) Biowulf, and I have to say that the Biowulf staff at NIH is just top notch. They're just so good. Our computational facilities here are great. So, I'm blessed with the fact that I have the freedom to interact with the greatest scientists in the world, practically. We have first-class scientists, and first-class computing facilities. So, things are great in terms of a research environment.

ZIERLER: Now, on this theme of you being all over the place, I think, despite being all over the place, being trained as a physicist, are there fundamental concepts, or laws of physics that just stay with you all the time, no matter what project you're working on? There is probably a ton of physics that you've forgotten, but there are probably a few key things that you remember, and that stay with you. What are they?

CHOW: Yeah, absolutely. I think the thing that most stays with me, and probably all physicists, is that any system you have, there is a simpler system that describes what you want. Biologists don't really buy into this. They think all the details matter -- depending on which biologists, right? Especially if they're working on some detailed system, it's really hard to tell someone that their system is not important for the disease they're working on. The analogy I say is, supposing your car doesn't work, and then you figure out the horn doesn't work. So, then there's a guy who studies horn dynamics his whole career. He's trying to figure out if he can fix the horn, maybe the car will work. Then, there's a guy who does car lock dynamics, and the guy that does gas pedal dynamics. And really, the model of the car not working -- and you've got to understand, there's a thing called the internal combustion engine, and maybe you need a drive train, and you've got to get the spark plugs timed, or whatever. But there's a simple model of what's wrong, and it's not the horn.

ZIERLER: So, in this metaphor, what's actually the whole car?

CHOW: For example, if you're interested in obesity, and you want to answer the simple question, is the cause of the obesity epidemic that people eat too much, or is there such a thing called low metabolism, or is there a virus that's infecting people, or what is it? The fundamental question you can ask is -- one thing that's really hard to tell is how much people eat. It's really hard to measure how much you ate, unless I follow you every day. Even if you try to record, even if you're a trained professional and try to record, you always under report. Everyone always under reports what they eat. So, it's very hard to link how much you eat. There's also this idea that there's low metabolism, right? There are always these stories about, oh, Joe can eat whatever he wants, and he never gains weight, and I eat one grape and I gain four pounds. Are these things true? How do you figure that out? So, if you had a model of if I knew how much you eat, and how much you will weigh, then I could help answer this question.

ZIERLER: So, you're kind of like a traveling circus, in a sense.

CHOW: I am a traveling circus.

ZIERLER: You have your modeling, and you can model whatever it is that your colleagues need you to model. That's the idea.

CHOW: Yes. I am the traveling circus. Now, most people are not like me. They specialize in things. Even theorists.

ZIERLER: What about colleagues in your field? Are other people that are into biological modeling not like you?

CHOW: Yeah, most are more focused.

ZIERLER: So, what would be a focused thing that you conceivably could do?

CHOW: Say they do computational neuroscience, or they do, you know, how does the brain process information? And they would focus on that. They would focus in one area, or if you're interested in -- like, Nancy's very focused on rhythms in the brain, and how they relate to pathology. So, she just does more and more in depth about that. So, she knows a ton about how rhythms in the brain affect your cognitive function. I'm all over the place. I don't think very many people will work on obesity, diabetes, cognitive neuroscience, memory, gene transcription -- it's ridiculous, the topics I work on. And it's not a good way to do your career. Even if you have a high h-index, your h-index in a subject is low.

ZIERLER: That's the Hirsch index.

CHOW: Is it Hirsch? It's the citation index.

ZIERLER: Yeah, yeah. Hirsch.

CHOW: It's named after Hirsch, okay. Yeah. I have a pretty good h-index, but in any given field, it's not high. So, I have no reputation anywhere.

ZIERLER: Uh huh. Breadth, not depth.

CHOW: Yeah. It's not a good way to be. To succeed as a scientist, it's much better to be deep than broad.

ZIERLER: Except, again, if you're being useful to a lot of other people who are being deep.

CHOW: Yeah. I have a utility, I guess.

ZIERLER: There you go. Junior Ortiz, I remember as a kid, Junior Ortiz was the ultimate utility player, meaning that he recorded in baseball -- he played every single position, including pitcher, on the field. He wasn't a superstar in any one of them, but I was just amazed at the concept.

CHOW: Yeah. I'm a Junior Ortiz, I think. That is me. I don't think it's a good way to design a career. It just so happens that I'm like that, but I had such a weird trajectory, and it's my personality.

ZIERLER: It seems like a great place for this personality, for your style, to be at a place like NIH.

CHOW: I think at NIH, my style probably works. It'd be much harder in the real world, because then I'd have to write grants, and I'd have to be more focused.

ZIERLER: So, this has been very unique, because I've never talked to anybody like you that has this traveling circus kind of career trajectory. So, it's usually at this point where I ask the big questions about fundamental mysteries of things that have been with you for the past 30 years, and that are still mysterious. But I can't ask those kinds of questions to you, because you don't have the narrative where you can draw on -- I was working on this 30 years ago, and I'll be working on it for --

CHOW: Correct. Although, there are problems that I've been working on for 15 years that do exist.

ZIERLER: Uh huh. So, for my last questions I'll ask, given your style and the way that your career has progressed, what are the things for the remainder of your career that you're really excited about in terms of contributions, in terms of discoveries, in terms of advancing human health? What are the things that are most exciting to you, where you feel like you're part of a larger process that's on the cusp of really putting together something big, and really moving the needle?

CHOW: Yeah. So, I think there are probably two areas where I think things are going. One is something that I've not talked about really. I think that my fellow, Shashaank Vattikuti, has come up with a scheme to quantitatively assess cognitive illnesses that could really change the field.

ZIERLER: The whole array of cognitive illnesses?

CHOW: Yeah. It's a new way to think about cognitive function in illnesses. One of the byproducts of the Human Genome Project is that we've now done GWAS - genome-wide association studies -- on lots of different phenotypes. Of course, mental illness is one of the things that people did, and still do. One of the things we're figuring out is genetically, bipolar disorder, severe depression -- not just feeling bad, but real depression, and schizophrenia are almost genetically identical. The difference between these diseases is some manifestation in a person that's not really at the molecular level. There are some molecular deficits in these people, but they get manifested in various different ways. The symptoms are all over the place. Whereas, autism is not as genetically related to schizophrenia. It seems to be something different. ADHD is also something different. So, at a genetic level, we're already starting to segment these illnesses. But now, let's say you're in the schizophrenia, manic depressive family. The treatment may not be the same, even though the disorder is the same. Or, the treatment might be the same. We still don't really know. So, it would be nice to be able to quantify where are you in this spectrum, other than through symptoms. One of the problems with the way symptoms diagnose illnesses, using the DSM-5 -- the Diagnostic Statistical Manual -- is that a lot of the symptoms overlap, so if you have one disease, you can't have the other one as well, because you've already put your -- you know, you kind of put all your eggs in one basket. So, you can't be autistic and schizophrenic at the same time, because there are overlapping symptoms. But how do you know that there isn't a person who's autistically schizophrenic? There could be this thing, whereas, diagnostically, the symptoms aren't enough.

ZIERLER: To determine that there are two things going on?

CHOW: Right. So, the tool that Shashaank and I are trying to develop is that we know that we've been developing -- this is something that I have been working on for 20 years. I have a very simple cortical circuit model that's somewhat faithful to the physiology. It has excitatory neurons, and inhibitory neurons, and they're connected in a way that's very biophysical. This model that I've been showing over the years can dynamically reproduce experiments in monkeys doing very simple tasks. So, when monkeys have these observational tasks, experimentalists, like Bruno, have measured their neural responses. They've found that their neurons behave in very characteristic ways. So, I have a little circuit that can reproduce those characteristic, dynamical patters given the expected inputs. We have a model of how the sensory input gets to the circuit, and then the circuit does its little dynamics, and it reproduces what, you know. We have a suite of these tasks that this model can explain simultaneously. It can do working memory; it can do this thing called binocular rivalry, which is a very interesting illusion. If I give you very diverse images to the different eyes, you don't see a blending of the two, but it alternates between the two. So, I have a circuit that when you give it this kind of ambiguous stimulus, will alternate, and there are lots of highly constrained phenomena that are associated with it. So, it doesn't just randomly alternate. It has to randomly alternate in a specific way. So, the model can do this. And when you perturb it, it has to be perturbed in the same way. So, what this does is that this -- they've also found that performance on these simple tasks is correlated with your pathology. So, autistics will perform slightly different from schizophrenics. So, our idea is that from the performance on the task, we can then invert the performance and get parameters of the model. The model is now -- the way people do cognitive tests now, or whatever, they'll get parameters, in terms of a cognitive test, that are abstract, and they'll do some kind of factor analysis to try to separate out the effects. But what we're seeing is that we can have a person do this simple task, and fit it to the model, where the model has the excitatory connection strength, the inhibitory connection strength -- it's now reduced to parameters where you could possibly target with a drug, or some other intervention. So, the idea is then to take people, give them this battery of simple tasks, simple psychophysical tests, get the set of parameters, and then classify them based on the parameters, and also, if we can perturb the parameters, can we then perturb the pathology -- like, treat the pathology. So, this is a mission that I'm kind of doing --

ZIERLER: Treat the pathology to cure these diseases?

CHOW: Cure the pathology, yeah. Because now we know what the target is. Right now, the way you do drug targeting is you just sort of try lots of things and see what works. Oh, this person looks kind of like this one, and this worked on this patient. You know, there's no underlying theory. So, this is the mission that could take decades to get done. And because I'm not in the neuroscience institute, I'm not getting any support, institutionally, to do this. But that's something that I would like to do.

ZIERLER: So, that's one. You said there were two.

CHOW: The second one is we're running out of drug targets. Most drugs now target GPCRs -- G protein coupled receptors -- and some nuclear receptors. But most drugs target some receptor that's known already.

ZIERLER: You mean, drugs across the board?

CHOW: Yeah, all drugs. Pharmaceuticals. You know, there are antibiotics, which are slightly different, but a lot of drugs that treat illnesses. Like, mental illness drugs are like dopamine receptor agonists, or antagonists, or at least they affect the dopamine system. They either block something -- but we don't really know how to target transcription directly. So, the receptors will then affect transcription. Ultimately, if you want some drug to work, you're going to have to change the state of the biology, which is to change the state of the molecules underlying the biology. At some point, if you accept that you're a reductionist, and you've got to accept that molecules are the underlying cause of everything, so you've got to affect molecules at some level.

ZIERLER: Now, this is you talking as a physicist?

CHOW: As a physicist, and a biochemist, say. But if I'm accepting, kind of, the mechanistic world view, then you're going to have to target at the molecular level, genetically.

ZIERLER: As a theoretical proposition, this is how you're accepting it, or in an applied sense?

CHOW: Both. Both, right? Drugs are targeting at the molecular level, and just from a teleological, if I'm using the word correctly, like from a philosophical sense, that you're going to have to target at the genetic, molecular level. Any intervention you do, if it's going to block a hormone, or it's going to cause some cytokine to change, you're going to affect some process, right? You're going to cause your heart rate to increase. You're going to affect channels in the heart cells. You're targeting at the molecular level, whether you like it or not. Now, you can electro-stimulate, but even electro-stimulation is affecting, at least, at the cellular level. So, you're affecting at the cellular, or sub-cellular level. Now, you have something like obesity, or diabetes, that's at the organism level, how do you bridge those scales? That's the challenge. So, targeting gene transcription, if we could understand the mechanisms of gene transcription -- what's causing genes to transcribe -- that entails lots of things, because it's a big network of them. So, you've got to understand the network, but also at the mechanism level of just actually changing one gene, then you have to understand how it percolates to the rest of the system.

ZIERLER: So, gaining understanding here, the end product is better drugs?

CHOW: Yeah. Better control. Better understanding of everything. If we understood transcription better, we have a better underlying mechanistic understanding of the biological process, we would have a better understanding. Right now, we have no idea why if two people are infected by the same virus, SARS-CoV-2, one person gets this intense immune response, goes septic, and dies, and the other person doesn't get any symptoms at all. They've even found genetically identical twins have different immune responses.

ZIERLER: To the same exposure, same virus.

CHOW: We don't know why. We have no idea why. Somehow, it's the state of the system. Now, there is a genetic component, and there's a non-genetic component. We don't know how to tease it out. We don't really understand the immune system very well. Now, I have some great colleagues over in infectious diseases, Tony Fauci's branch, that are doing great work. But even they would be the first to admit there's a lot to understand. And I think understanding transcription is fundamental. So, I think the work I'm doing with Dan and Rafael could possibly lead to a better mechanistic understanding of gene transcription and could open up a new way of viewing biology. So, I see those two things as being continued well beyond me.

ZIERLER: So, it might be a traveling circus, but it could be one that produces, ultimately, some pretty fantastic results.

CHOW: I could be lucky. One thing is, if you're a traveling circus, you visit a lot of places. You could be a hit somewhere.

ZIERLER: Right. Well, Dr. Chow, this has been an absolute delight. Thank you so much for spending the time with me.

CHOW: Thank you for spending the time talking to me.

ZIERLER: Okay, great.