

PROJECT: GENETIC ENGINEERING AND SOCIETY HISTORY PROJECT
INTERVIEWEE: DR. PAM MARRONE
INTERVIEWERS: MATTHEW BOOKER, BRAD HERRING
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[Matthew Booker]: --reasons we're in here and what we're doing and then we'll get underway.

[Pam Marrone]: Okay.

[M.B.]: Anything else?

[Brad Herring]: We're good. We're okay.

[M.B.]: Great. And the plan is for this to take something like an hour and a half. It could go two; it could go an hour.

[P.M.]: Okay.

[M.B.]: Great. Should I start? So we're here in the Genetic Engineering and Society History Project. Brad Herring, Matthew Booker, and Dr. Pam Marrone is here today. It's October 26th, 2015. Please tell us your name, your institution, and your roles.

[P.M.]: Pam Marrone, CEO and founder of Marrone Bio Innovations.

[M.B.]: And what does it mean to be CEO and founder in a practical sense?

[P.M.]: Basically I'm responsible for raising money for the company and overseeing the operations of the day to day running of the company.

[M.B.]: And is that what you wanted to be when you were growing up?

[P.M.]: What I—actually I wanted to be an entomologist since I was little like around 8-years-old and my goal in life was to develop products that could control pests sustainably without toxic chemicals, and I actually believed I could do that when I was little. So my whole life was set up to how am I going to create products that can do this? So whether that was in academia or a company it turns out I ended up doing it in a more entrepreneurial way.

[M.B.]: And why was that motivating you as a child?

[P.M.]: So I grew up on a beautiful little mini farm in southern Connecticut of 40 acres. And there were waves of gypsy moth caterpillars that were coming in that would destroy the forest, and I would walk out into the woods and literally the leaves of the forest would be completely denuded by the caterpillars. And you could stand in the woods and there were frass—frass is the layman's term—well, it's a scientific term for insect poop. So that would rain on my head, and I'd look up, and I'd see nothing but skeletons.

And so there was this dogwood tree right by the kitchen window that was being skeletonized by the gypsy moths. And my father wanted to save it, so he went out to the store, and he got a toxic chemical, and he sprayed it. And it killed the caterpillars, but it also killed the bees and the lady beetles and the lacy wings.

And my mother was so furious she dragged me out, and she said look what your father did, and we looked at all the dead bees and such, and she banned him from ever using that. And from that time on they were organic in everything they did. So that had a very strong influence on me, and I decided I was going to find products that could control pests more naturally, sustainably.

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[M.B.]: And you didn't think that these products were already being created by industry or were available?

[P.M.]: Well, my father being an early adopter went to the store to find an alternative and found BT - so Serengesis [*Bacillus thuringiensis*] based product from the local hardware store. And he tried it, and it is a bacterium that controls insects - , caterpillars. And he tried, and he sprayed it, and I said well, Dad what do you think? And he goes well; I don't know if it works, but it's good for the environment and makes your mother happy.

So that stuck in my mind that there's got to be other things besides BT that you could use—that you could discover. And I did a lot of research. I wrote to the USDA. They sent me a grainy black and white brochure about insect—integrated pest management - IPM. Which I didn't know was just being formed as a science at the time when I was little. So that had a huge influence on what I decided to do, and I pursued it without stop the whole—my whole career.

[M.B.]: Okay, so to put some dates on this you start college as an undergrad around?

[P.M.]: '74.

[M.B.]: 1974 and you knew that you wanted to be an entomologist?

[P.M.]: Oh yeah, so I picked a school that had a good entomology department Cornell and went there as an undergraduate entomology major, yes.

[M.B.]: And did you have mentors or people in your world as an undergraduate who were important in maintaining that disciplinary interest or did you simply drive yourself?

[P.M.]: There was a professor Dr. George Eickwort. Unfortunately he died on a bee collecting trip in Brazil. And he took me under his wing, and I actually served as an intern. Actually digging up bee nests on campus—wild bee nests and marking bees and then—with colored paint and then seeing where they flew around. And he was a really really good mentor and helped—really helped me through a lot of things at Cornell. So he got me a real foundation for what I wanted to be in as an entomologist.

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[M.B.]: So you knew you wanted to be an entomologist, you achieved your bachelor's degree in entomology, correct?

[P.M.]: Yup.

[M.B.]: At Cornell. What did you decide to do in terms of going on for further study?

[P.M.]: Well, I knew that if I wanted to develop products and create new products I would have to get a Ph.D., so there was no question that I was going to get a Ph.D., and I decided I wanted to skip the Master's because the fastest route to what I wanted to do was to just go straight. So I—actually, they didn't have—no one else had done it at NC State yet in the entomology department, so I had to actually petition to skip the Master's and I was accepted to do that and then did the Ph.D. in a little over four years.

And then was—and the project I had there was part of a pioneering project that was funded by NSF on the characterization of the soybean agro-eco system. At the time, so this would be '78. At the time no one thought of farming or farms as an agro-eco system. So it was really quite pioneering, and it just so happened my major professor Ron Stinner went to [UC] Berkeley. And Berkeley was the center of IPM. So there was a heavy influence of IPM and alternative IPM and ecologically based IPM among the professors at NC State here when I was there.

So I was actually fortunate to get—and I use the word “indoctrinated” because I was into ecosystem theory, agro-eco systems, and alternative agro-eco systems. And that really then set the foundation—further foundation of what I wanted to do in my life. Which was—so then I went looking—what am I going to do looking for a job?

So I applied lamely for an academic job because I knew that probably wasn't where I wanted to go. And then as companies like now Syngenta or which was Ciba Geigy at the time and Monsanto put—were looking for entomologists. They put ads on the NC State career center and so a bunch of us would go and we'd interview and so I got a job at Monsanto and it was very exciting relative to the other jobs because the other jobs were working with chemicals and this one was—my job as the only Ph.D. entomologist in the company - was to develop a new program looking for ways to control insects without the use of chemicals—toxic chemicals. And so I was an entrepreneur, so I got to do almost whatever I wanted because my boss and none of them knew anything about entomology, so I had free reign.

My first project was to develop an artificial diet for corn rootworm in order for them to be able to screen microorganisms—test microorganisms against corn rootworm and in a very high throughput mechanized way. No one had done this before, so I'd say yeah, this is no problem. And then I started getting into the literature and realized no one has—it was an insurmountable technical challenge and while many people tried to develop a corn rootworm diet no one was able to do it.

So I'm like oh, my God, what am I going to do? So just very methodical science I took a prototype artificial diet developed by the US Department of Agriculture, and the worms would die, the caterpillars—I mean the larvae would die after a certain point. They just wouldn't develop, and they'd poop out. So I said there's something limiting their growth in this diet.

So I took every ingredient in the diet, increased it or decreased it by ten percent, so that's a factorial experiment. Big huge experiment. A lot of painstaking work and then found the ingredients that were inhibiting the growth, reduced those ingredients enough to be able to make the larvae survive and then published the recipe of the diet. Which probably was a mistake from Monsanto's standpoint because the diet became standard in the industry and allowed every company to be able to grow corn rootworms and then screen microbes and then discover new proteins that they could engineer into plants.

And indeed this diet—we then put into a 96 well plate and then the larvae in the plates—or eggs, I developed a method for putting eggs in there that would hatch out and then you could test—and I automated the first ever automated screening system with a robot. Where you could—the robot would deliver really fast and rapid into the 96 well plates, so they were able to then be able to screen thousands of microbes and BT strains against corn rootworm. And that led to the first BT ever for corn rootworm and is now in Monsanto's corn today. So that was my first [major] project at Monsanto.

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[M.B.]: So I'm going to ask you more questions about that because it's fascinating. But I want to ask you if you—you were training to be an entomologist but your program—your actual dissertation sounds a lot like ecology. It sounds like it leads to a comprehensive look. It was the ecosystem—

[P.M.]: Of the bean leaf beetle ego-agro-ecosystem—it was—the population dynamics of the bean leaf beetle in soybeans in North Carolina.

[M.B.]: And so you were forced to think about not just the insect and isolation, but it's habitats, the control mechanism, all sort of things.

[P.M.]: Soil type, temperature, overwintering, yes it was very holistic for sure.

[M.B.]: And similarly it sounds like at Monsanto you were confronted with problems which reached beyond simply looking at the insect in isolation.

[P.M.]: Yes, that's right. Yes. There were—again it required a more holistic view and also collaborating with a lot of other people as well, yeah.

[M.B.]: So that was a habit for you. Was it a habit for people at Monsanto?

[P.M.]: It was—in those early days it was very team oriented and industry today is still team oriented so yes, we had—we worked together with multidisciplinary teams way back then. So there were chemists, molecular biologists, entomologist, all working together. And so I think that was probably Monsanto was probably breaking the mold in how—because I went and visited other big companies and they would have armies of chemists in one building—synthetic organic chemists but remember Monsanto was going into biology based programs. And then you'd have the biologist three miles—or ten—five miles away in a different building in Monheimer, Monheim Germany where the big headquarters of BASF or Bayer were.

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So Monsanto was very different. And we—there was a big life science center that was being built, and I got to have a free run to build the whole insect facility. And it was designed to be very interdisciplinary, so I think they were ahead of the time.

[M.B.]: So you said that Monsanto was moving into biology. What do you mean by that and why do you say they were moving as a company into biology?

[P.M.]: So Howard Schneiderman was actually an entomologist, and he was another mentor of mine and sponsor at Monsanto. He was the chief science officer at the time. And he was hired by the CEO Mahoney to move the company away from the toxic legacy of parathion and Agent Orange and get into more biological endeavors. And it was right at the forefront of where the first petunia was transformed genetically. And a genetically engineered petunia was created and so they saw that there was an ability to create plants that could be used for insect control and move away from the chemistry.

So they completely cut all of their chemical screening. So I was not allowed to do any screening of new chemistries against insects but instead look for things that could be developed from microorganisms. So yes, biology.

[M.B.]: So this is a significant shift in the kind of work you were doing, right? I mean—or as a graduate student had you explored bio-control or in general or genetic engineering at all?

[P.M.]: No as a graduate student—again it was population dynamics of bean leaf beetle, so I did do one little project which I really liked with the plant oncologist [insect pathologist] there and the insect pathologist here on the part of the whole population dynamics. I found out where the bean leaf beetles were overwintering and when I found them in their overwintering sites a lot of the adults had disease, had fungus diseases and other diseases in them. So the reason for them not surviving during the winter time was a lot of it was because of these pathogens—the insect pathogens. So I really got interested in that area of microbial control of insects and in the back of my mind I was thinking oh, this might be something very interesting.

But I think the training I got here was just—in just the agro-eco system approach and the whole basis for how you run an experiment and just scientific experimentation and solving problems it really meant that I could solve any kind of problem that I had at Monsanto. When they threw that—like the insect—how do you develop a new insect diet? Or how do you test thousands of strains of BT and other microbes against insects? So it's really about problem-solving.

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[M.B.]: So you come into Monsanto. This is 1980?

[P.M.]: 1983.

[M.B.]: '83. You're freshly minted with your Ph.D. And rather quickly though you became an important part of Monsanto's new initiatives. How did that develop? How did you move from simply being a newbie?

[P.M.]: Well, I happened to be the only Ph.D. [entomologist]—well, besides Howard Schneiderman who was the chief science officer with a Ph.D. entomologist I was the only Ph.D. entomologist in the company. So they did look to me for a lot of expertise, and I was—I mean I was directed to find ways to be able to test this new —these new [plants]—like they put BT protein into a petunia or tobacco. And I had to create ways to test them because no one ever figured out ways to test them before. So because of just simply being an entomologist and the expertise I had and the ability to solve problems I was at the—no project could move forward unless my group could find a way to test these things that the molecular biologist created. Or the protein chemist.

So it was interesting being in sort of a mecca of and gatekeeper for whether the projects were going to move ahead or not. So we —I built an insectary in the new life science facility, and we had—my group said we are never going to have an insect colony fail ever when we raised the insects in the insectary year around. Because if the insects failed and you had a gap of when you had to rebuild the population of the insects back up, near a colony that meant that nobody could test anything. Molecular biologists, the chemists, couldn't give anything to test for weeks or months, and that would hobble the research.

So we had set a standard, and I had no idea how to raise insects so brought in the big experts. There's actually a science in insect rearing and how to build an insectary and everything and so then set up a center of excellence so that we never did have a colony that actually collapsed ever. And so the research would go on.

So having that expertise with nobody else having expertise was kind of a really interesting experience that's probably unique. And so I think—I don't think other companies—there would be a lot more entomologists and I'd be just a drop in the bucket.

I also had a mentor in my first supervisor [Dr.] Terry Graham who is now a professor of plant pathology at Ohio State who said you're not meant to be a bench scientist and for whatever reason after a year promoted me to become group leader and said you're destined for management and said you should not be on the bench anymore and you should manage people. That doesn't mean I was a bad scientist, but it meant he thought I had better talent as a manager of people. Which was actually a very important decision and pathway in my career because I have not been in the lab doing experiments since 1985. So I've been in the business of science and the science of business. So that's quite a different move away from being a bench entomologist.

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[M.B.]: So what were the consequences that is to say what did your group achieve in those years you were at Monsanto?

[P.M.]: Quite a lot of things. So the development of the artificial diet for corn rootworm was a major breakthrough. Automating then the high throughput screening the first ever high throughput screening for corn rootworm and other insects was a major accomplishment. And then the discovery of the Cry3Bb protein that's now in Monsanto's corn in combination with Ecogen. A friend of mine at the time who was head of an insect group there [Dr.] Tim Johnson they had a collection of 5,000 BT strains and we had the screening system, so we collaborated together and

discovered that protein.... and Tim Johnson now works for me. He's our vice president of product development. So it's great to have him in the company with that kind of experience from way back.

And so then the discovery of that protein and then all testing all along the way every version of plants cotton, corn, where—of the proteins—various proteins that were being engineered at in the plants, then my group was testing all the versions along the way. So it was really pretty interesting to be on the ground floor of this new technology that is now become very established in agriculture but also still engenders controversy.

[M.B.]: So I have several questions. One would be what else was Monsanto working on at the time or did the company—did the people around you in the company think that they were working on a broad array of possible solutions—ways to move beyond the toxic legacy I think you called it or parathion and chemicals.

[P.M.]: So I was at an interesting time when there were two wings working on agriculture projects. So there was corporate research under Ernie Jaworski and there was my boss's boss Bob Kaufman working on genetic engineering of crops and microbes as well. And the two were very competitive. And they were fighting all the time, and it was very political, and my boss's boss lost, and he left the company and then all of the genetic engineering works consolidated under Ernie Jaworski and the rising star was Robb Fraley who is now chief science—chief technology officer of Monsanto. And so all of the genetic engineering work was consolidated into the corporate [research] sector.

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So, my group—my group had done a lot of different things under Bob Kaufman. So I screened probably over 100,000 different microbes looking for natural products and so we were going to develop natural products as alternatives to synthetic chemicals. We were looking at other kinds of natural proteins and so once that was consolidated under Jaworski's group; everybody had their marching orders that it's going to be solely on genetic engineering and all the natural product stuff was stopped.

And so we screened just for [proteins]—I set up a protein screening system, so we discovered besides the BT for corn rootworm we discovered a cholesterol oxidase for killing boll weevils and a few other things. So then it became very clear that Monsanto was going whole hog into GM. And that's where some of the questions started coming up. As an entomologist, one of the questions I had was, well if you're going to engineer cotton or corn with a single protein—BT protein and you're going to plant it in a monoculture won't insects develop resistance?

So I asked my bosses about that, and no one wanted to really hear about it at the time and said well our goal is profit and so we have to make as much money as possible so we can't think about resistance. So we want to maximize the utilization of this technology, make money. Ah, if insects develop resistance so what.

And I said that is not going to fly. Because I would go out and give a lot of talks and there'd always be someone in the back of the room asking questions. Will the bugs develop resistance? And being an entomologist, I say well, okay.

So I set up in my group experiments to test whether insects—the first experiments whether insects would develop resistance to engineered BT protein and we've proved that it would in a very—not very many generations. And it took me a year to publish that paper. The lawyers, of course, didn't want it published, and it's very controversial. But to Monsanto's credit they—and it went very high up—very very high up in the company probably just under the CEO -- into allowing me to set up what was called a BT Management Working Group, which was to get all of our industry of competitors together to address the issues of insect resistance. And will insects develop resistance to BT—engineered BT?

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And this consortium funded money to different academics and academic labs to see how you could—will insects develop resistance to answer that question and then what would be the strategy to delay or stop development of resistance. And that led to NC State and a number of other institutions starting working on this and we funded as an industry a number of projects that ultimately lead to the current strategy—high dose strategy and refuges that now if you're planting GM corn or cotton with BT you must have non-engineered refuges in your field to delay resistance.

And it's generally worked in most cases except where the farmers in corn —when—why [we] have [resistance] to two of four BT constructs, why have the corn [root]worms developed resistance to them now is because when corn was \$8 the farmers planted wall to wall and back to back corn and didn't rotate. And so the corn rootworm developed resistance. Now it's \$3.80 corn, and so they're planting more refuges and also the seed companies have put what they call refuge in a bag where it's easier for a farmer to have engineered and non-engineered in the same bag instead of planting borders with the nonengineered just to save the susceptible insects.

So Fred Gould here at NC State was instrumental in a number of [ways]—a bit of this work which led to rules, laws at the EPA that mandates the refuge when you're planting genetically engineered corn and cotton and other crops with BT in it.

So we haven't had broad scale resistance for the most part except the corn rootworm. To things like cotton in the delta Southeast and corn for corn—for European corn borer and others. Whereas other countries have had massive failures of BT-engineered because they haven't deployed them so sustainably. They haven't had the rules. So China, Brazil, insects have overcome the BT in the crops.

So interesting that being—I was able to persist and show the logic of it and how they were going to get—they were really going to have a lot of the NGO's and environmental groups coming down crashing on Monsanto's head if they didn't address this BT resistance issue. And so as I said to their credit they did allow me to lead that wing which then led to the current rules.

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[M.B.]: So one of the elements of that story that's interesting is that this was a partnership of university researchers and private companies. Or at least that's the way that it sounds like you sought that.

[P.M.]: Yes.

[M.B.]: Today there's—in recent months and in recent years there's been a lot of criticism by the public including a recent New York Times piece of publicly funded researchers receiving money from private companies. And there seems to be some anxiety about that. Could you—do you think Monsanto might have achieved its goals without partnering with universities?

[P.M.]: No, because the research—if it was just conducted by Monsanto or industry it would be even more suspect. So the fact that we gave money to solve problems so it wasn't to necessarily hawk a product but of course it led—it's led to more durable deployment of BT proteins and genes in plants. Unfortunately, not so with the weed side. Slysotate weeds have become very resistant. A lot of weeds have become resistant to glyphosate. But certainly in cotton and corn, for the most part, it's been durable, so I think that it will always be controversial. Just like in the drug world where drug companies give money to do research on new drugs. There's always a controversy about the independence of the academic professors when there's industry money. But unless state governments are always flush there's always going to be a need for funding from an industry that is given to the universities.

[M.B.]: And it also sounds like this was a genuine problem of interest not just to the companies.

[P.M.]: That's right. It was—everyone wanted to solve this problem so we had the support of the environmental groups, other NGO's and everybody in understanding whether insects would develop resistance. There were people who wanted to stop the advent of GM crops and still today that's true. But they banned it in Europe and so forth. But I think that there was a lot of pragmatists that said this technology is coming so assuming it's coming we better figure it out because BT is actually a resource. It's a real amazing natural resource that should be preserved.

I mean, there's—I screen a lot of microbes, and there's not a lot of things like BT out there. There's other things that we've discovered, but I mean BT and that whole group of BT microbes are quite amazing. And so the last thing you want to do is just deploy it unsustainably and then use it up—it would be just like on a pesticide treadmill. Instead, you're on a genetic treadmill, and then you just dial in every new gene, and you use one up, bugs develop resistance, and then you go to the next one, the next one, and the next one.

So for all of us deploying the technology sustainability was really an important goal. And I think—I don't know whether my boss at Monsanto believed that more idealistic view that I had, but pragmatically they realized that they could actually make more money by having it durable than if you could use [it up]—you could do the math. You know when insects are going to develop resistance in a number of generations. You can figure out how many years you got and it was short. They would develop resistance fairly quickly. So extending the time was actually—it made good business sense as well.

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[M.B.]: So you said a few minutes ago that Monsanto was motivated from the very top by an ideology that they would abandon—that they would leave behind this toxic legacy of their chemical company basis. And move into genetic engineering and other—possibly other tools as well. Do you think that that ideological nature that desire ran into money problems when it comes to this sorts of decisions they made to stop for example the research on the natural products you mentioned? I mean why did they narrow their scope from a series of possible endeavors to just a handful?

[P.M.]: Well, you know when you're in a company there aren't unlimited resources. So the scope and scale of what Monsanto wanted to do they wanted to be the biggest and the first and the leader in this technology, require deployment of all resources and they're just wasn't enough resources even a big company like that to do everything. So they really had to focus on this in a massive scale to beat out competitors. And there were a lot of other companies starting—and academic labs starting to work in this area. And indeed later there were all kinds of patent infringements, lawsuits and all kinds of things because there were a lot of other people discovering things, so Monsanto wanted to dominate this space.

But yes, I was a young group leader, head of the entomology but because I was in a unique position, and I was one of the only women in that level—in that management level I did get a lot of attention in the sense that I had lunch with the CEO which would not usually be typical for someone at my level. And he did say that he wanted to move away from the toxic legacy of Parathion and Agent Orange and he was—he and everyone else in the company were wholly embracing the GM crops because they saw it as a more less toxic technology and so everyone believed that it was better for the world. I mean everyone on down from the top on down but they—at that early stage everyone was so enamored of the technology they didn't actually really look deeply at what the objections would be. Because the technologies are so compelling, how could anyone oppose it? And that was the view at the time.

But when I went out to give speeches there was always someone at the back of the room who would ask all these different questions. But what about this? But what about that? What about this? And I brought a lot of those questions back, but they were not—it was like oh that was a bunch of [academics]—the technology's so compelling no one could be against this technology.

[00:30:14] And so that was because it's an ag company that deals with farmers it wasn't a consumer company that dealt with consumers. And consumers do things differently than farmers do and consumers don't always listen to facts and science. They do things based on their opinions, beliefs, and values. And Monsanto obviously has learned that.

[M.B.]: So these voices at the back of the room asking these questions these are questions about the social consequences of the technology or what kinds of questions might they have asked?

[P.M.]: Social, health, resistance, consolidation of or escaping you know this technology escaping and genes jumping from one species to another contaminating organic crops. Will bugs develop resistance? Corporate power. I mean all kinds of questions and a lot I couldn't answer because they were questions that hadn't been answered at the time. But I did bring—I would often bring those questions back and so it was a very interesting—very very interesting time back then.

[M.B.]: So these are not questions about whether the technology will work on its scientific or technological merits. These are questions about what happens if it does work?

[P.M.]: That's right. Everyone assumed it was going to work. And I always did. I mean it was obvious it was going to work, and I think everyone realized that it was going to come so then what are we going to do about it? And then as I said there were always—there was always someone asking about it. And still, today since they're still being banned in Europe. And yet in the United States and elsewhere Brazil I mean it's heavily adopted.

But you have this anti-GMO froth here in the United States that continues, and I mean eventually, I think that you'll see labeling. They label in Europe, and it's a nonentity because it's so ubiquitous that people—the consumer just forgets about the label. So and there's many other situations like that, like prop 65. We have prop 65 where you have to post that chemicals on premise may cause cancer. Well, it could be chlorine bleach. I mean there's so many chemicals that are used commonly that might fit in that category it's so ubiquitous that everybody sees every restaurant with that sign and nobody even thinks about it anymore. I mean, so that's probably what will happen with the GMO labeled crops too because it's in everything except organic.

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[M.B.]: So a couple more questions about Monsanto. You were there for seven years?

[P.M.]: Seven years, yeah.

[M.B.]: Seven years. And you've already mentioned some of the turnover and the disputes within the institution and so on. Do you know what happened to some of those people who were in that world you were in? Have they dispersed from Monsanto across multiple institutions, companies or are they still with the company?

[P.M.]: It's a mix.

[M.B.]: The people who came in with you?

[P.M.]: Yeah, so the entomologists who I hired are still there after many many years, which is remarkable. Entomologists seem to last and adapt I guess. My old boss as I said, my immediate boss is a professor plant pathology at Ohio State. His boss Bob Kaufman became an entrepreneur and runs a little synthesis—chemical synthesis program company in St. Louis. He's a synthetic chemist in St. Louis. I just saw Maude Hinchee. She's working—has now left Monsanto - and is now working in a bio stimulant company.

But some of the core people are still here. David Fishoff and Fred Perlack so those were my cohorts. The molecular biology people who were my counterparts are still at the company and of course Robb Fraley was a rising star, and he became CTO. So a lot of the core group is still at Monsanto on the science side.

On the management side total turnover. So that's the way Monsanto is. There's a lot of turnover on the management side, but on the science side, they've been pretty stable on that. So some

have come and gone, and you can find ex-Monsanto people everywhere in industry particularly on the commercial side. Less so on the science side.

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[M.B.]: So you have mentioned that you were the highest ranking woman at Monsanto. The first—

[P.M.]: Not at Monsanto but in R&D at the time.

[M.B.]: In R&D. I beg your pardon. What was it like to be a woman in science in the 1970s at NC State and then in the corporate world but as a scientist at Monsanto?

[P.M.]: Well at NC State there was this agro-eco system grant from soybean agro-business NSF [the National Science Foundation] so on that grant there were a lot of women, so we had more women than men than our cohort. So I didn't even know that that was unusual in graduate school although I did get turned down when applying for graduate school by other professors like at Michigan State and other places where the professor of entomology said I don't want women because the women just drop out and have children. And I said well that's not me. I'm very career driven. He said I don't care. I don't want women. So I mean right up front.

So, fortunately, there was this embracing of women at NC State at the time. And so we had a lot of women. But then at Monsanto, this was just a sign of the times. It was before the—you know the sexual harassment laws, were not passed until 1991 around that time. And I came to Monsanto in 1983, so it was just a different time.

And so it was—Monsanto was trying very hard to increase the women in the ranks. But the attention was almost to the point of absurdity because they would want us to go to charm school and do all—we had so much attention on us that I kind of lost control over my career in what I wanted to do because there was so much attention on moving women up.

And so when I got a call from Novol Nordisk, this Danish company I'd never heard of, and they said we are going—we want to deploy our fermentation technology and we want to screen microbes for looking for natural products. I was like oh my God, oh my God. This is exactly what I want to do.

So I left Monsanto because there was something more in line with what I wanted to do for my life. But I knew that if I stayed at Monsanto I would probably be very successful but I would have had to move around to a lot of different jobs that left the natural product and the entomology, and I made the decision that I would rather do what I was destined to do and loved to do rather than go up the corporate ladder.

[00:36:33]

[M.B.]: So two things. So first what year did you move over and secondly what do you mean by a natural product?

[P.M.]: Okay. So I was hired in 1990 by Novo Nordisk to set up a company, which we called Entotech in Davis, and we were screening microorganisms for natural products. So that means just like

penicillin comes from a mold you're—more than 50 percent of your drugs come from natural sources. You've got digitalis from a plant, and you've got—actually aspirin was originally from willow bark. And then you've got your antibiotics from microbes.

+ So same concept we're looking for microbes that would produce substances that would kill pests. And I had done that at Monsanto in the early [days]—before we went whole hog into genetic engineering, we were screening microbes at Monsanto, and I fell in love with that part. And all that stuff just stayed iced at Monsanto. They never developed it.

But then Novo when they said we want you to screen microbes, so I set up testing mechanisms and automated—building on what I'd done at Monsanto but different. And the next version 2.0 and screened another 50,000 microbes looking for the substances and we had natural product chemistry that identified the by-products of the microbes that could kill pests, and that was great fun. They sold us to our largest competitor after five years when they got into some trouble with their core businesses, and they needed to get back to their core, and they diversified too much. They hired McKinsey for a million bucks and then McKinsey said you've diversified too much go back to your core of industrial enzymes and insulin.

So we were sold, and incidentally they spun out their industrial side is Novozymes years later and then bought their way back into biologicals and now are huge into biologicals. But that gap of ten years they were not in it and I said why did you get out? They said it was too hard. It was too early. The market wasn't ready, so we let others like you do all the hard work on the ground and then we just buy our way back in. I said gee, thanks. So but anyway I did that for five years, so they sold us and then I started up Agra-Quest, which is a venture capital back doing the same thing.

[M.B.]: So would you make a distinction—would you clarify a distinction for me which is when I think of genetically modified corn and BT the *Bacillus thuringiensis* in corn what is the distinction between that and the kind of microbial work you're describing. Are they both forms of genetic engineering?

[P.M.]: Well, it's whether you're using recombinant DNA or not. So putting a BT protein into a plant is using recombinant techniques. Whereas what I'm doing, it's—we are in a way taking—well, we're taking something from nature and then we select it so we will ferment it in a vat and then you'll constantly select the microbe to make—have it make more and more and more cells and more and more and more of the substance the insecticidal substances so you're selecting, but you're doing it in a non-recombinant way, so I don't know if it's more genetic modification versus genetic engineering but because we're not using recombinant DNA we're not putting genes from one species into another. It's not controversial because you're just improving what is already in nature and using only natural fermentation techniques to change and modify the microbes. So it's much less controversial.

So I've stayed away from genetic engineering recombinant DNA, and what I'm doing—because it's too controversial, the consumers won't accept it, and the regulatory system is not set up for really evaluating it in an efficient manner. It would take too long. So we have a very streamlined method for getting these natural type of microbes through the EPA. In fact, I helped actually get the system—I started a trade group that helped—went to Washington and helped in another

consortium get the current rules on the books that makes it faster for our types of products. And so it's just a lot easier.

No small company could afford to do genetic engineering of microbes or plants to the level that the big companies can do. And no one's really tackled genetically engineered microbes unless they're—it's used for producing a pesticidal protein that's then purified and sold independent of the engineered organism. So there's no [living] genetically engineered organisms on [the market]—for pest control currently. Just simply because it's too controversial.

[00:41:03]

[M.B.]: So you've just made I think a very clear description of the ways that biology, chemistry, and genetics are all interrelated as a practical set of tools. But I wonder do you think that publics—broad publics understand these distinctions? And if as you say GMO's are more controversial than other forms of biotech if I can use biotech as a broad category. Why do you think that is?

[P.M.]: Because you are moving genes around from one organism to another, so moving a bacterium into a plant. So moving a bacterium [I protein] into a plant or in the case of—it could be any other kind of protein—there's some kind of other protein—fish protein into a plant or into some food product or something. It's not considered natural.

So we're in an era where everyone wants something natural. And there's no definition of natural and we know that nature produces very toxic substances. So but that's what the consumer wants. So if you talk to any consumer care company, they're getting rid of all these inert ingredients and non-natural substances. Talk to food companies. They have—they're focusing on all these natural preservatives. So this is where the consumer is going - in addition to cage-free eggs, and McDonald's is going cage-free. No antibiotics in the meat at Chipotle.

Now everybody is falling in line on that. The consumer is driving this and whether it's scientifically valid or not it doesn't matter because the—it may matter to some, but the consumer doesn't care. It's what's driving so the consumer companies who are in a consumer business are following what the consumer wants because that's their business and they could lose overnight millions and millions of dollars if the consumer—if they went against what the consumer wanted.

And so times have changed, and so the manipulation of genes with foreign DNA is seen very differently than just something that's natural or you're moving around like traditional breeding moving around genes in the same plant in the same species. Or a wild tomato in a modern tomato. It's just very distinct.

Now in terms of my stuff, we're working on microbes. I found that the consumers recognize immediately the difference between good bugs and bad bugs, which I find interesting but they do. So, for example, everybody eats yogurt and cheese, and people know that there's good probiotics and microbes in their yogurt that helps them and well you have Activia and all this stuff. So it's become quite known, and then everybody knows that there's salmonella and E-coli and bad bugs, so they've been able to distinguish.

When I talk to [consumers]—I was sitting on a plane, I'll tell them what they do, and they immediately get it. And so that surprised me in not having to really explain too much. They get what we're doing and everybody universally it's nice because wherever I go I'm the good guy and they say well, that's great what you're doing. We want this. And oh, by the way, can your products be used in organic production? Yes, they can. Our products are all organically certified. So our products cross both.

So we have a product that's used—it goes on corn in the glyphosate spray so it's used in the tank with the herbicide and at the same time it's glyphosate, and it increases the yield of corn or soybeans. And it's just put on top of everything else they're using and goes right in that spray, so it's used on corn—GM corn. And it's for yield enhancement. But then we have other products that are replacing chemicals in strawberries and are used in conventional systems because bugs—insects have developed resistance or the buyer doesn't want residues. The European buyer doesn't want any chemical residues. So they use our product in conventional programs because chemicals are not the sole answer and our products are used in organic production because they're certified, and they have fewer tools, and so they need tools. So I bridge all three.

Our products are used integrated with GM crops, integrated with chemicals and alone on organics. So I have a unique position where I sit in seeing all the controversy about all these different systems and the debate and controversy and conversations going on about what is the best system for how our food is produced and how we're going to feed the world. And it's interesting because I'd say the GM crop people have won the conversation on we need GM to feed the world.

And that makes the organic people really mad because then you'll hear everyone saying that organic can't feed the world. But that's not actually true. There's a new Grist article out that says that does a long analysis of that. There are systems where definitely organic might be the preferred system. And I believe there's a big tent to where all of these can coexist. So it's not either or. It's all of them have a place in agriculture because there's a constituency who will continue to buy organic food. It's a juggernaut. 70 percent of Americans buy organic food at some—every week. Some more than others, obviously. But it continues to grow.

So and I know—I sat on the board of an organic farming research foundation and those are the best farmers on that board that I know. And they will out yield any conventional farmer. So it's not true that you have to sacrifice yields for organic production. You can if you want to and focus on quality, but you don't have to.

So there's a lot of mythology on both sides. There's a lot of froth on the anti-GMO people talking about health and safety, and these are going to kill you. Which is not true. And then there's a lot of people on the traditional ag side who will take pot shots at organic. And that's not true. So as I said, I sit here in and having to coexist with all of these which is a very interesting position to be in.

[00:47:02]

[M.B.]: And you just have mentioned now your most recent endeavors. How long—so you left Monsanto we talked about that. You moved into Novo Nordisk. You left that company.

[P.M.]: Yeah, that was sold. Yeah and then I started Agra-Quest. Yup.

[M.B.]: And how long were you at Agra-Quest and how did you get to your current company?

[P.M.]: So I was at Agra-Quest for 11 years and a CEO for ten, and I was developing—screening natural products, screened another 25,000 microbes or so, looking for natural products to kill pests. We developed a line of fungicides and one insecticide. And I was a venture capital back, so I had to raise as an entomologist I had to raise the money. And I raised \$60 million in venture capital from investors. And got the company to a filing for IPO, on NASDAQ, [for] a listing on NASDAQ right at the end of the tech boom which was in 2001.

Unfortunately, my timing was off. I filed for the offering on September 3rd, 2000—I mean sorry, yeah, no it was August 3rd, 2001. August 3rd, 2001. I was actually flying to the world trade center. The lawyers for our deal for the IPO were in the south tower and the bankers Merrill Lynch were right across the street. And the hotel that I was staying in was demolished. I was flying there September—supposed to fly there September 12th to practice the road show. That didn't happen, and I was faced with—had built up the company to 80-90 employees and ready to get more money and pop the company and then had to face where I was not going to be able to do the offering and what was I going to do?

So I traveled around to meet customers, and I had to clear my mind. Because I felt terribly selfish that I was thinking about the company and the future of the company and oh, my God I'm going to—when people died. So I had to put it into perspective.

So anyway I talked to my customers, and they all recommended that I don't do a major downsizing because it would look like the company was unstable. And because I'm competing with giant companies. So I don't—just keep the company together and that's what I did, and I ended up seeking new money rather than downsizing. And took money from investors who unfortunately did a takeover of the company and it wiped out my founder's stocks.

So I had—when Monsanto—so six years [later]—I left in 2006. I had a difference of opinion with the direction of the company. They wanted to sell the company. I wanted to continue developing new products. And they sold it successfully in 2012 for quite a lot of money--\$425 million to Bayer. But unfortunately for me and all the founding investors and my friends and family got zero because they wiped out the equity—they diluted the stock out.

So that was a painful experience, which I figured I would make up on the next company. And that's another story but hopefully, I will. But being an entrepreneur is fraught with a lot of difficulties and especially in a regulated [industry]—it's not a software company or social media company where you can develop in two years and flip and get into a unicorn valuation of multi-billion dollars. We have to slog it out with regulatory approvals and adoption with farmers and all these gatekeepers who don't want—who say stuff about your products and it's not an easy business. But—and it's very competitive. There's a lot of companies in it.

So I left in 2006 and started up this one Marrone Bio Innovations and raised another \$70 million in venture capital and did take it public in 2013. And got money to be able to continue to develop the products. Unfortunately, we had a situation where some of our people on the sales side did some

transactions that they did not declare to the auditors which have lead to restatement of our — restating of our financials, which was a huge deal if you're a public company.

So little did I know again as a CEO founder that there might be some lightning strike that would happen that would divert my plans from the true goal which is getting these products into the market and changing agriculture for the better.

[00:51:15]

[M.B.]: So you've described yet another acquired skill set you know in your career when you moved from this clear sense of being an entomologist from a child—as a child into scientific work at university where you broadened your sense of what an entomologist might be by looking at all of the kind of context. And then into managing people as a group leader and now raising money, running companies, dealing with takeovers and so on. What do you think is next?

[P.M.]: What's next? That's a very good question. Right since our stock dropped 85 percent after when we first announced the investigation. My goal is to get—actually the name of the company is named after my father. And to get his good name back. And to build value for shareholders. That's my job as a CEO of a public company. And continue to develop products and get them adopted and ramp up sales. So to have the value of our great technology be realized in the marketplace and that's where we're at.

What's next? I don't know. I think that I always say that I'm far—I'm getting too old and too—work too hard and still the 70 hour weeks and stuff, to do another start-up. But I really don't know at this point what's next. What's very interesting is right now there's an explosion of new technology coming into ag. Silicon Valley has woken up to ag, and so there's a lot of new startups and lots of Silicone Valley and other money going into ag tech.

Now that most of it's going into—not businesses like ours... although a lot of it's going into companies with lower barriers of entry like bio-stimulants where you don't need EPA regulation for the products. But there's a lot going into precision farming, sensors, big data and drones and food to consumer delivery and new foods and all kinds of things. So it's a really exciting time to be in food and ag. And a stodgy old industry is being woken up by Silicon Valley, and I think it's very exciting.

[00:53:29]

So there's—I see for the next innovative thing to be matched with what we do would be the marriage of ag tech with our types of products and how you would use [them]—for example I met an entrepreneur from Silicon Valley who has developed a video technology—micro video technology, to actually put it out in the field and you can actually watch aphids real time and what they're doing in the field.

Another one has developed sensors, for—well, actually some imaging technology for—so when you spray a field of pests their heat signature changes so they can actually do imaging and see the difference in the heat signature and get images of it. Oh, that's really cool.

So our products are really hard to work with in the sense that they don't—you can spray them and they—the bugs don't knock down immediately and fall off. So they have these unique modes of action where they're slow kill, and these microbes and microbe compounds from the microbes do—are very unique, and so they have more slow kill, and you have to educate the farmer on how they use it. Wouldn't it be really cool to have some of that imaging technology to marry with our products?

So I see the next frontier is to marry what we're doing with modern—the really modern ag tech and involve some of these Silicon Valley type stuff. And they have a different way of doing business. It's called innovation at speed. And I've been highly criticized for this in my industry. However, Silicon Valley gets it right away.

So what this means is okay, if you're an early adopter of technology let's say you want to get the next version of iPhone. You wait in the line at the Apple store that goes down three blocks to get the next version, okay? You're an early adopter. So you want it. And you're going to beta test. You're going to be the beta test for Apple because of that first version—that version of that phone coming out it has a lot of bugs in it. So you then complain to Apple, and they find out all the things that are wrong with that particular phone model and the software of that phone model. And then they come up with the next version, the next version and you get your download for your new version, okay?

[00:55:40]

We do that with our products because we can go out to the market. It costs us \$3 to \$6 million in three to four years to get a bio product to the bio – [US market compared to a chemical] side to the market where it's ten million—ten years and \$250 million for a chemical. So we can get to the market with the beta version. So we can get our first version.

We don't—our products aren't toxic. We know they work well enough when we launch them, so there's pretty low risk. And we put it out with a very tight set of beta customers—testing customers. Early adopter farmers who are—yeah, I'd love to try this new technology, and they tell us what they like and don't like about our product. And then that goes back into our R&D, and they have version 2.0.

Oh, my God this—you would think this was heresy in ag and that I have been criticized for all the companies I've started up of putting products out too soon. And I don't put products out too soon. I'm using my customers to develop—help develop the products in this manner. It's just a different business model.

And so yes, we could spend another \$10-\$20 million and then five years later launch it big and perfectly. But then I would have no revenue and that would be very difficult to survive because I have to show the investors that I'm getting product out there. And so not everybody is comfortable with that model.

So I've had to find scientists who have a more entrepreneurial bent that doesn't need to have everything perfect before we launch a product. Good enough. Perfect is the enemy of good. And so—but that's probably where I made the most mistakes in hiring. Is - there's always good

scientists and then—how do you find ones that are more nimble and entrepreneurial than the ones who want to research something to death and not get it out the door? That I would say I still haven't figured—I still am not good at figuring that one out. Yeah.

[00:57:27]

[M.B.]: So the analogy you use drew between people who want the brand new iPhone and a farmer who is an early adopter, and she is just anxious to get your technology is an interesting one because it paints farmers as consumers. And this is not a typical frame in the United States. At least outside of the agricultural world. We tend to think of farmers as producers, not as consumers.

Yet as you noted here and as many of us now understand farmers are dependent on a whole series of inputs which they purchase. And which they use to further their production. Just like in any other industry in that sense. Do you think that this vision of farmer as a consumer is going to be more familiar to people in the public? Do you think—are there any problems with the analogy that we've just drawn? Are there any ways that farmers are not consumers in a typical sense?

[P.M.]: Well, you know I haven't considered them the way you said. Farmers are consumers. The way I see farmers is farmers are innovators. And so there are some like in any industry who are—I think there's a curve of them and in any industry there's—you've got your early adopters, you've got your mainstream and you've got your mainstream farmers and mainstream people and then you've got your late adopters with any technology and I see that curve with farmers just like in any other.

But right now you're right, in that there's a whole set of new technologies being marketed to farmers. And the farmer is the consumer and trying to wade their way through do I need this drone? Do I need this precision tool? Do I need this big data for this company? And right now you've got all these different sensors of different kinds that don't talk to each other so which technology is better than another?

So there's a lot of—and the weakness of Silicon Valley companies is that they haven't actually been on a farm or haven't grown up on a farm. So they need to bridge the practical with the technology.

But yeah, in that sense a farmer is a consumer. They buy a lot of stuff. And so they sort through like the consumer of buying the iPhone just like there's—the early consumer, early adopter there's the farmer early adopter.

So it is a good analogy I would say. Yeah. But I've known some of the most innovative farmers are—they're amazing. And what they do with our products. They will find things about our products before sometimes we do. Especially organic growers. They're the most innovative because they don't have all the crutches of the chemical pesticides to farm with.

[1:00:05]

[M.B.]: So for a while, it seems like the major technological—the greater technology in farming was the seed. It seems like Monsanto was sort of packing into the seed and other companies were packing into the seed. A whole series of technologies. Pesticide, herbicide and so forth. These were

inherent inside the seed. Or could be coated onto the seed to enhance its productivity. How is that kind of model of seeds technology the kind of one place shopping it's all there in the seed different from the way, for example, your technology might be deployed?

[01:00:41]

[P.M.]: Depends on which crops you're talking about. So Monsanto's focused on the big crops corn and soybeans as most big companies are. Whereas most biologicals have been adopted in specialty crops where there are different drivers. So there are human health concerns, there are residues for export, there's resistance, worker safety and so those are different drivers than corn and soybean where it's yield, yield, yield. So why is Monsanto going into biological and why have they invested \$3 hundred million in a joint venture with Novozymes? Because there's a diminishing return on getting yield enhancements through traits.

And so everybody knows that there aren't a huge pipeline of big new fabulous traits out there, so you have to package something else with chemicals and traits. And that would be biologicals. You can find microbes, and they're rather common of [such as] bacillus that increases yield by a certain percentage and then you can put it as a seed coat or a microbe that kills nematodes. And Syngenta and Bayer have done that with microbes that combined with chemicals are put on the seed for seed treatment and then with these are traited seeds, so you have a package. So that's where for the large crops everyone is going.

And so it's all about yield production and so—and also some [on] quality. I mean sometimes quality like increased test weight or size but it's yield. Whereas the drivers and especially the crops of fruits, nuts, vegetables and flowers is quite different. And that's where the growth historically has been in biologicals. But today the biggest sales of biologicals are actually on the seed. And to the tune of hundreds of millions because that's where the big acres are.

[M.B.]: So this is another way for a non-expert like me to think about consumers and producers. Because it sounds like the audience if you will—the consumer for the traditional Monsanto—it's now become traditional Monsanto method. Is the ultimate consumer. The person who purchases the corn or the cotton or what not. That is, it feels like you're saying there's a larger group of consumers. In this case, farmers who have a choice to add or not add biologicals.

[P.M.]: That's right.

[M.B.]: In these specialty crops and that it's much more free flowing much more fluid and the story is not yet written.

[P.M.]: Right. Right. Now on large-acre crops—like there's two companies that control the corn seed. So they're going to determine what microbes go on the seed and where new technology is coming in is that you're going to be able to match the best microbe with the best crop variety. So there'll be microbes that are tailored for individual varieties, and so you're going to get more—what we're seeing on the farm is much more customization based on data.

So just like—so with the new CRISPR technology coming out there you're gene editing where I'm hearing that Pioneer will be able to make very easily a variety that's grown on 200,000 acres of corn for a specialty grain for somebody—some buyer. And indeed that's in the works.

So you're going to see —instead of varieties being—these big companies being able to just working on the massive tens of millions of acres they're going to be able to more customize to different customers. I think in all of society we're seeing consumer customization. Same things are happening on the farm. And each farm is different. So you know they think it's going to be one size fits all but the farmer will tell you that this part of the field is very different from this part.

So the big data there's a lot more to do on big data. It's not so simple. And microbes change over time and you start characterizing microbes at the start of the season it's very different at the end of the season and so forth. And in season.

So there's a lot of complexity there, but everybody's racing to simplify that technology—that complexity and there are going to be interesting companies and coming out that are going to be providing tools to farmers and farmers will win because they're going to be more efficient, more innovative and have more transparency and data to do what they're doing.

[01:04:57]

[M.B.]: So one of the questions that have come up repeatedly in conversations about genetic engineering in agricultural biotechnology in agriculture is the who benefits question. And this is particularly fraught when it comes to thinking of farmers outside of the United States. Or even outside of the main commercial crops.

So here I'm thinking of the—will the technologies that are now being increasingly available to US farmers will those also benefit farmers in Sub-Saharan Africa or the huge numbers of subsistence farmers still in places like India? How might these technologies play into the stories there?

[P.M.]: Well they'll eventually come there. I think—let me look at Brazil and India. They just—I think they just approved Bt Brinjal they call it. It's aubergine or eggplant BT - engineering into that. And so I think—and I think they already have BT cotton so I mean it's coming. It's been more mixed in Africa but because the FAO came out and said and it is I believe this is true - that while GM is a powerful technology for Africa, the farmers can also—small scale farmers, can also do quite well with organic systems. And get as good or higher yield. And more tailored to their local site. And there's a lot of interesting things going on in India and China and Africa. The application of ag tech to production small-scale farming and of course Gates Foundation has been involved in that. So I don't think you have to say you have to have GM everywhere. There are other production systems like organic that can work in those, but it's on more of a small scale farming type diversified operation.

So but we're—where there's big farms, and you turn into corporate—like in China where the government is moving people of the farm en masse and making this huge big corporate farms, of course, that's a place where GM crops are going to fit very well. But this whole area is fraught with a lot of debate. And I try to stay out of this debate.

But what I do counter is—so if someone on the organic side says GM is all bad I will explain to them that's not the case. And then someone on the traditional conventional side will say there's no science in organic I will argue and say excuse me, but I actually know that's not true. So I do tend to say that there is a big tent for all of these systems and they—there's a place for all of them.

But if you think that you're going to win the argument with the consumer based on facts and science forget it because just think of the pink slime situation. Or cage-free eggs or antibiotics in meat or any of those things. And why do people buy organic food? If you want to snow people with the facts, they're going to say a mom who's new—who has a new baby is going to say, I'm hedging my bets. I don't want all those pesticides. They may have an effect. I don't care if you're going to tell me all these residues are fine and they're regulated by the government. I'm going to hedge my bets and say I'm going to buy organic now.

And that's where it starts. And that's very hard for hard scientists to really understand. But that is the way—that's the way it works. It's a purchasing power through values rather than scientific fact. And I think Monsanto now realizes that and it took a long time for them to realize that with their GM technology.

[01:08:37]

[M.B.]: So if you had—if you could tell us your greatest fears for the future of technology in agriculture generally or genetic engineering in particular. What do you think those are? What are your greatest concerns about that? About the future?

[P.M.]: You know my biggest concern is sustainability of the—whatever system we're talking about. So when you look at what happened with glyphosate-resistant weeds. So weeds developed resistance... so then the next technology is to develop crops that have engineered for resistance to dicamba and 2-4D. There's a problem with that because those two compounds are not as really as safe as glyphosate. So a lot of people adopt whole hog, adopted and really loved glyphosate tolerance – [the safety of] Roundup Ready because of the fact that—I mean there's controversy about glyphosate now. WHO coming out and everything. But generally, people saw that you could reduce the amount of toxic chemicals with GM technology. Like cotton you got rid of all these sprays of toxic chemicals organo-phosphates and carbamates and in one fell swoop with would be BT cotton and with Roundup Ready you got rid of more toxic herbicides [pesticides].

But now as resistance has developed, and you're going back to more of a pesticide treadmill with more toxic chemicals or would I say, less —more higher risk. Then one would say that are you then developing—are you going to be on a genetic treadmill just like you are with the pesticides? Put it out in the market. Resistance happens, use it up, go to the next thing. And farmers always assume that there's another technology coming around the corner. And I personally believe that we should be deploying any technology in a sustainable, durable manner and that includes GM crops.

So it pains me to think that you're going to put out the next generation of BT crops somewhere in Brazil and they're going to use it in that two years you've got—it's gone, and you're just going to use it and then it's done. Or we're going to use up —we're going to—dicamba and tolerant crops

and 2-4D crops will have a limited life cycle. Just maximize them and then go on to something else. That is not really how I think durable, sustainable systems should be.

But it is the way it is when you're in a company, and you need to maximize your return on an investment for your shareholders. But there are alternatives. I really think that every new technology that comes out there should be like the BT cotton where we did the refuge that there should be a part of that deployment of that technology that thinks about its sustainability. And that's really—everyone agrees that I think the conversation is now that everyone agrees -- that you need a multiple—multiplicity of technologies. But and that they should be deployed sustainably. We can't do what we've done in the past. We just can't pollute the ground and deploy things the way we have in the past. Pollute water and air and so forth. So I think everyone knows that the systems have to be more sustainable. But where the debate is - what does that sustainable system entail?

[01:11:57]

[M.B.]: Okay, then how about the corollary which is what is your greatest hope—or what is a great hope for you about agricultural technology at large or genetic engineering in particular?

[P.M.]: I do see that a bunch of new entrepreneurs who are not in ag and who do come from Silicon Valley with innovation at speed in models borrowed from Silicon Valley coming into agriculture in a chaotic way now but that will shake it out. That there will be disruption and I really—I'm an entrepreneur. I really like to see that. There will be someone who is the Uber of ag disrupting some portion. There will be—that disruptive technology that changes agriculture fundamentally and shakes up a stodgy conservative system where you have to follow exactly through a certain distribution channel and so forth and how things are done and even the way the land grant system interacts with farmers in a very traditional way. That's all going to change.

And so I think it's a most exciting time to be in agriculture and it's the most exciting time to be an entrepreneur and the most exciting time to be an entomologist or a plant pathologist or a social scientist because we are at the forefront of a revolution in ag. You've got a huge—you've got—the average age of farmers is what? 56,57,58? And so this generation's—that generation is retiring. [Or maybe even older than that.]

But and the new generation, the sons and daughters, are then bringing this new technology and then you've got \$12-\$14 billion in the last year of venture capital and investment going into ag tech. So it's quite a tsunami that's very very very exciting and so the next 10 to 20 years is going to see change like we've never seen it before. And I'm so excited to be at the end of my career—the tail end of my career although I still have a lot of things I could do watching this happen. I mean I've waited a long time.

And the same thing with my technology—the biologicals are being mainstreamed. We're at the tipping point with that, and I've worked my whole career for that, so that gives me a lot of satisfaction.

[M.B.]: So there's a really interesting tension between your desire for sustainability and your entomologist's hat.

[P.M.]: There's no question.

[M.B.]: You warned about resistance. And your desire for sustainability and your entrepreneur hat where you look forward to this change, and I'm especially thinking about this in the context of agriculture. Because the history of American agriculture especially the 20th century is such a striving force for stability, consistency for putting a floor under prices, for slowing the rather sudden drop-offs in the number of farmers, farm loss in the 20s and 30s and the 50s. So there's this desire in the 20th century for stability, and I wonder if there are elements of this desire for change that work better in the 21st century in the United States? Do you think in other words our agricultural system is ripe for these kinds of fresh starts that you're describing?

[01:15:12]

[P.M.]: Yes, because we live in a digital world now and so you can measure and blueprint and digitize everything. So the ability to have data has changed everything. So I mean the time that you're talking about historically you didn't have data to manage a farm. But now—you had data but it was pencil and paper, and you walked the farm. But now when you have the advent of the digital tools it really changes that game.

So I don't think it'll disrupt farming to the sense that farming is unstable but it will—those—I hear it in the Midwest now. We're at \$3.80 per bushel corn. Whereas just a few years ago it was \$8, so there's a lot of older farmers who are traditional farmers who are good farmers, but they can't make it with \$3.80 corn, so they're just going to say okay, I'm going to sell my farm.

And so there will—there is a shakeout, and there will be—continue to be a shakeout and why is California typically survived, big ag in California survived especially crops when we've never had subsidies to speak of. And the subsidies have gone to corn and soybeans. And specialty crops haven't gotten subsidies to speak of. They have some other incentives now, but they hadn't in the farm bill. Because California farmers are darn innovative. They've always been—and then you've got them competing with cheaper Mexicans and Mexico farming, and labor was much cheaper, and everything but California farmers seem to manage to always survive.

But farms have gotten bigger. So what you have big farms what will always be successful and little—you've got a lot of little farms now. A lot of young people starting organic farms—local farms and farm to table and community supported agricultural boxes that consumers subscribe to. All kinds of stuff going on at the local organic level of small farms. That's a very robust healthy ecosystem now. And then at the big consolidation of farmers where—who's getting squeezed now are the middle size farms. That's where the big—the family farmers are losing, and that's where some angst is. But it's really hard—it's really going to—this trend is just really going to be hard to stop. Especially because there is this renaissance of small local urban farming going on that's quite exciting.

[M.B.]: I have a few—a couple of concluding questions to ask you but before I do that I wanted to ask Brad if he had any questions he wanted to ask.

[B.H.]: I don't. I had one, and then you followed it up, or you actually answered it. I—maybe what's the bug in your—is this the beetle that you studied or is this significant in any way?

[P.M.]: No, but as an entomologist and passion about what I do I do wear insects. I have insect earrings. I have an insect bracelet, and I do have—but this I got from China. And it's a squash beetle, but I have a number of these with different insects in it. And I always wear an insect—I always wear insect jewelry on myself. It's kind of a trademark.

[01:18:30]

[B.H.]: And these are—that's a pest insect?

[P.M.]: This is. This is a pest. This is a squash beetle. I'm assuming it's a Chinese squash beetle because I bought it in China from a street vendor. I bought a whole bunch of them, and I wear different ones, and I had to laugh -- I was at a—leave it to a party of entomologists. UC Davis entomology party and I walk in, and I had another one on, and this entomologist comes up and goes “oh my God. You have a necklace that has a soapberry beetle”. And I went oh, for God sakes. It was like, you're kidding me. And he said I've never seen a soapberry beetle in the United States. Soapberry bug, excuse me. Bug, not beetle. And he was so excited it was the talk of the whole party because I had a Chinese soap [berry bug]—and it was an introduced pest -- from—it came in on some nursery stock on soapberry trees and then came into the US and he was studying it...his research project was the population dynamics of the introduced soapberry bug. Too funny.

[B.H.]: Maybe I'll ask one more. So you mentioned at the very beginning your father sprayed and that had a big impact on your life early on. What else as you've moved throughout your career has played an important—has played probably—any really important role in really motivating you and keeping you—because you do seem driven. Obviously with your record of your career. What is it that keeps you going?

[P.M.]: What is that keeps me going is.... the—everyone thinks that I'm one of those serial entrepreneurs that just likes starting up companies and then moving on. No, I only moved on from each company because I wasn't finished with what I needed to do. I have to see these products adopted. And so the science of discovery part is exciting. Really coming up with new things. But that's relatively easy to discover a microbe in my book. To discover a microbe that has a biological activity and can kill a pest, it's much harder to get it developed and then adopted.

And so I still have a lot of ideas about how better to get our product adopted and how to get these new technologies adopted. Listening to farmers and going out to—what keeps me going and what influences me most is talking to farmers and customers about their needs and what they want to know about these type of products and how they would deploy them. And I do truly believe that a product like what we have—a number of our products are completely safe to bees and humans and other non-targets—the more probably more politically correct would be say “low risk”. Because you're not supposed to use the “safe” terminology but “low risk”. So why not see that biologicals could be the base of the entire crop production system and pest management system. And then you only dial in the other chemicals when needed.

So you turn the whole system on its end. And I think that certainly can be done with the kinds of discoveries we've had. And I believe that our company has discovered some things and that no

one else has that are really truly earth shattering. We haven't proved them yet. We still have a ways to go to prove in the marketplace. The commercial success of them but we're at the early stages of that. But I mean we have the ideal too—ideal insecticides. They're broad spectrum, but they don't harm other organisms. They're non-polluting and yet they kill a broad range of pests. Same with our nematicide, our fungicide and then I'm working on a very interesting herbicide.

So my goal would be to get an organic herbicide that can transform organic farming because the single biggest cost of organic production is weed control. And every farmer surveyed [says] number one [need is] weed control. And why so many conventional growers don't transition to organic weed control. It's too hard. So you have to still hand hoe and these other ridiculous things like flaming and vinegar. So coming up with new tools for organic farming that would transition many more acres is a personal goal. And we—and it happens that we found some very interesting technology to do that. So the products just keep going. And developing products and transforming production systems is what keeps me going.

[M.B.]: Well here's the second to the last question. This effort—this archive is an attempt to capture critical voices in the history of genetic engineering and agriculture. And in biotechnology in agriculture. And we wonder who else you think we should talk to?

[P.M.]: Let's see.

[M.B.]: And they might be opponents as well as.

[P.M.]: You should talk to Robb Fraley

[M.B.]: Why should we talk to Robb?

[P.M.]: Well, because he's a key figure. I mean he's been chief technology officer at Monsanto forever. And he was there in the early days as my boss for a time—a short time when I was there. And I think Monsanto is the way Monsanto is, is because of Robb Fraley. The cultured DNA of Monsanto is because of Robb Fraley as chief science officer, chief technology officer. And he's probably one of the most influential people in—certainly in who Monsanto is but in the how Monsanto has deployed GM crops. So I think that would be one. If you could get him to get off his script in being 100 percent pro-GM and see. That would be tough, though. But he would be one.

I noticed you're talking to Mary-Dell Chilton. She's a pioneer. Let's see who else? Oh, have you talked to Chuck Benbrook? You have to talk to Chuck Benbrook. So Chuck Benbrook is the one who writes about how GM crops don't increase yield to the level that everybody says. And he worked—he was hired by Consumer's Union for a while to do a detailed scientific analysis on this yield question of do GM crops increase yield? And to come up with all the—a real analytical view of it. And he's very controversial and very opinionated, but he also was—works for the organic center in debunking—every time someone comes up with a myth about organic food he debunks it scientifically. And so I love reading his stuff on the organic center's website because he used science to do that. But because of that, he's very polarizing, but it would be really good too—he's not like me where I have to sell products to everybody and bridge all of these worlds. He's more okay, I'm in this vein and so he'll—and he will give you the view—well he does bridge it. He knows

a lot about—because he's done that analysis of GM crops but he also then works in the organic industry, so he'd be a really good one.

[01:01:25:52]

[M.B.]: Okay, well here's the last question. What question should I have asked that I didn't ask today? Is there a topic that you think we should have asked you about with your experience and your skills and your knowledge that we did not touch on?

[P.M.]: Well, you've covered a lot of ground. So I'm trying to think is there anything. You know what we didn't talk about too much was the—we did a little bit but the consumer influence on the food channel and their drive to sustainability and the metrics they're imposing on farmers.

So one of the things I'm seeing more and more is Unilever, Wal-Mart, Costco, Sysco the big food distributors whatever part of big food you are because of the consumer pressure on them they are then dictating to what the farmer has to do and they're—there's this—I know some farmers who have to comply with four different sustainability metrics from different food companies. So there's an area where what is the definition of sustainability?

There's an entity called Field to Market that is trying to define that. It's very controversial because there's a lot of voices at the table. And when you have a chemical company that doesn't want to see sustainable as reduced pesticide and then GM is part of sustainable. Is it or isn't it? And then you have all those other voices at the table.

So but there's no question that the companies that are consumer companies that sell directly to consumers are calling the shots when it comes to farmers. So I don't know if you saw, but a shareholder group has been after Monsanto. I'm sorry, after McDonald's, they're called—there's Toxic Taters and then there's the Bard College and the nuns group of shareholders and who think that the french fries, that McDonald's french fries they haven't done in potato production to reduce chemicals in potatoes.

So there's just an example and then of course at the whole animal welfare side where big food is on—and other consumer companies. It's also in shampoos, and other household products are under a tremendous amount of pressure from the consumer. So with today's social media, times have changed. There's a nanosecond between a consumer and a company now because they can put something on a blog or somewhere and it travels around so quickly.

So times have changed, and one of the things we didn't talk about but is a big area is the whole use of social media and how that is making a consumer-directed farmer and farmers adopting—I know a lot of farmers who are—they have their own Facebook pages and their own Twitter feeds and everything. Because they're connecting directly to consumers to draw in more customers. So there's a lot of things changing and that whole sustainability [focus], big food imposing things on farmers and then the impact of the consumer directly to farmers. We could spend a whole number two hours on.

[B.H.]: Well, who will have the biggest impact on the future of farming? Will it be the consumers or will it be the scientists?

[P.M.: Consumers—it will always—the consumer rules. And the consumer—

[B.H.]: Are you worried about that?

[01:29:21]

[P.M.]: No. I'm not because I mean there are some cases where—well like in the pink slime situation where—or the one in California where we had the—here's a good example. So comes up there's a consumer driven ballot initiative to give chickens enough space. So UC Davis comes out—in egg laying hens. So UC Davis comes out with this study that says - debunks this whole thing and says you don't have to give chickens this much space. It's not scientifically correct. They published a study. Consumers yawn and I told my husband who is not a scientist about the UC Davis study and he says, I don't care what they say. Chickens should have more space. I'm voting for it. I'm going like oh, my God. Voila!. Here you go in my own household when he's living with a scientist. He doesn't care. He did not care to listen to the scientist. Chickens should have more space.

So yes, that is—that consumer view is fraught with all kinds of things if you're a scientist. But live with it. I mean that's how consumers make decisions. It's through values, passion, beliefs, ideas. That is not going to change. So the challenge for scientists is understanding that and then connecting with that. So I have an easier time because I have a company that develops natural products that are safe and environmentally responsible. So I have an easier time connecting to consumers. But those companies like Monsanto they have a harder time. But it can be done.

[B.H.]: So it seems like facts and values are in agreement in your company but maybe not so much in some others, and that's where the—

[P.M.]: That's right. It's harder for a big chemical company. Harder for a GM company to connect with the consumer in that regard. Not impossible but it is certainly—it certainly is harder.

[B.H.]: I mean I think from a human side chickens should have more space. But maybe from the scientific, it's not proven but still it just feels right.

[P.M.]: It does. It does.

[M.B.]: It feels right now, but I think what's so interesting is that values and facts align, but that changes over time.

[P.M.]: It does change. It does change.

[M.B.]: So whether people think chickens need more space in 2015 that may not be how they felt in 1915. Or in 1965. And what counts as more space?

[P.M.]: Well, that's the question. How much space is good? Because there'll be someone—someone will tell you from the scientific community that free range is horrible and they get—or cage free is horrible because they'll be pecking at each other and they get more diseases and so forth and so forth. So but again the consumer says I like the idea of cage free or more space.

[01:32:04]

[M.B.]: So that leads to I'm afraid one more follow-up. And that is some people have pointed out that while we discuss and describe agriculture as an industry and it is an industry for all of the reasons you've described today. It is also some argue different from all other industries. It is fundamental. We could do without an iPhone they argue, but we cannot do without food. And that food is somehow different from all other kinds of industry and should we treat it differently. And this shows up in lots of ways. It shows up in the values points you've made earlier. The idea of the family farm for example. What do you make of that? Do you think that agriculture is simply going to be different from other kinds of industries? Is it true that it's really distinct in this way?

[P.M.]: I do think that agriculture is different because you need food obviously for human survival and with the population growth that we're having. We have—it's a fundamental human need and each—like the US—it would be devastating if there was a lack of food security and someone came in and tainted—you know put a bad microbe in your food or something and used bio-warfare for wrecking the food supply or something.

So yes, it is different than other industries. And it has—while there's a lot of corporate—big farms and everything it has been the purview and there's still are a lot of farm families, so that is a different again a different dynamic than other industries, where you still have so many family run farms. But you—but it does come down to food security. So that sense and also our—the health of our population and “food for health” is a big deal. We have obesity, diabetes and all these other diseases related to how people eat.

So that also the health of the population is so connected to the food, that does change it fundamentally from any other industry. And we haven't connected enough—our food and our health, and that is happening now. I see, these—like UC Davis has a food for health center and everything, but it's ridiculous that we haven't connected food and health much bigger than we have. How people eat determines so many concerns, how much diabetes and all these things and it's just now coming into its own.

[M.B.]: Thank you, Dr. Pam Marrone, for sitting with us today.

[P.M.]: Thank you. It's been a pleasure.