

## Dean Goldschmidt's Interview with Dr. Mary Bunge

April 25, 2008

**PJG:** Maybe we can start by talking about how you became interested in neuroscience and the work that you do. Could you maybe re-trace where it came from?

**MB:** The person who interested me in neuroscience was Richard Bunge. I met him in a laboratory at the University of Wisconsin School of Medicine when I was getting a master's degree with a very well known clinician-scientist, Robert Schilling, who developed the test for pernicious anemia. Every summer he took on medical students, and one summer Richard Bunge was a medical student. This is perhaps a little bit too much to tell you ...

**PJG:** No, please, I love details.

**MB:** He came from a Lutheran pastor's family in rural Wisconsin and he had to pay his way through undergraduate and medical school at the University of Wisconsin, and in order to do that he worked half-time in research and the other half-time he was in medical school. He came upon a very interesting project with a professor there in the anatomy department, Dr. Paul Settlage. Settlage was taking out the cerebral spinal fluid and adding an anesthetic as a means of anesthetizing adult calves, and he noticed that the calves developed a paralysis a few days later and then by three weeks later they seemed to be normal. So Dick came to work in his lab and he said, "Why don't you do this procedure (it's called cerebral spinal fluid barbotage) without the anesthetic and see if we see the paralysis?" And Dick did that and he saw the paralysis without the anesthetic. Then he started to look at the tissue and there was a very thin rim of demyelination around the periphery of the cord, and this was the first demonstration of demyelination. Then, three weeks later, he saw small rings of myelin that had re-appeared and so this was the first demonstration of re-myelination in the adult mammalian spinal cord. By that time, we had met and I was working on gastric juice and I had also taken a course with a very well-known cell biologist, Hans Reese, who was one of the first people in this country to have an electron microscope. We're talking about quite a few years ago, and he was one of the first to recognize that DNA was coiled in chromosomes and it uncoiled during division. So I had taken a course with him and he showed us the electron microscope, and it was love at first sight! I

loved the images in the electron microscope, even though this was one of the first electron microscopes in this country -- we had to hammer the lenses into place. I received a master's degree in medical physiology but then I wanted to get a Ph.D. with Dr. Reese, but what project? Well, by that time I had met Dick and there was so little electron microscopy that had been done — we're talking about the 1950s and first paper on electron microscopy cells was published in 1954 — so we're talking now about the late 1950s. We thought it would be very valuable to look at this material in the spinal cord, the de-myelination phase and the re-myelination phase in the electron microscope, and that became the topic of my dissertation. So he's really the one who introduced me to neuroscience — and it has been a great trip ever since.

**PJG:** So for those who are less familiar with the field, your studies were really at the time of early discovery of a mechanism by which nerve cells can transmit electric information in a way that is substantially accelerated by a cell that is called a Schwann cell in the peripheral nerves (Oligodendrocyte for the central nervous system) and has a capacity for rolling around the axon of nerve cells in such a way that they form a form of isolent with only the nodes being exposed to the outside world and therefore the transmission is extraordinarily accelerated compared to a non-myelinated or non-Schwann covered nerve axon. I can imagine that the advances of electron microscopy at the time provided you with the opportunity to see for the first time the specific structure of these myelinating cells that had the ability to wrap around the axons and isolate them. So can you tell us a little bit about that?

**MB:** Particularly with regard to the Oligodendrocyte it was not known at the time that we started the work, how the Oligodendrocyte formed myelin. It was known from 1954 on how Schwann cells form myelin, but because they are in a different relationship with the axon than the Oligodendrocyte is, it was very puzzling how the Oligodendrocyte could form myelin and that's because the Oligodendrocyte is like an octopus and it sends out as many as 40 limbs, if you will, and each one will be responsible for forming a myelin sheath so the cell body is at a distance from the myelin sheath that its forming, unlike the Schwann cells, so nobody could tell what cell was forming the myelin. So after we looked at re-myelination and we found what the mechanism was, which was not known, it was very controversial up to that point, then we went to the kitten to look at the developmental phase. It was one of these eureka moments because I prepared the tissue for electron microscopy and then put the section in the electron microscope, turned up the beam (that is, turned up the image) so we could see it and there it was. So if I'm

the Oligodendrocyte and my arms are the processes, there are two forming myelin sheaths at the end of each one of my arms and that told the story — we saw what cell type was forming the myelin and that this was happening beyond the cell body and that is why people had not been able to see how the myelin was forming.

**PJG:** Wow.

**MB:** That was one of those eureka moments because it was the first time that I looked at this kitten spinal cord and increased the electron so I could see what was there and there it was. Right there in that one moment, we knew what cell was forming myelin and how the cell was able to do that.

**PJG:** In terms of the quality of the myelin between Schwann cells and the Oligodendrocytes, is there any major difference?

**MB:** There are minor differences in the period, that is the distance between the layers that are seen in the myelin, but they perform the same function and that is...

**PJG:** In between the nodes,

**MB:** The nodes are a little bit different. The nodes are more covered up by the Schwann cell processes in the peripheral nervous system. They tend to be more or less uncovered in the central nervous system. The Schwann cell has basal lamina on it that the Oligodendrocyte does not. So there are some differences but they accomplish the same thing and that is that they are responsible for the saltatory conduction.

**PJG:** Phenomenal. One more scientific question because it is so interesting. To the electrophysiologist's point of view, of course, a Schwann cell is the equivalent of the plastic tube that you put the electronic wires in to isolate them up to the point of connection with receptors or other processors. I am sure that the role of Schwann cells or Oligodendrocytes are substantially more sophisticated than that — that they probably provide the neurons with much more than just isolation from the outside world.

**MB:** Right, they definitely talk to each other and once the Schwann cell or the Oligodendrocyte takes off its territory on the axon, then there are channels, sodium channels and potassium channels that become reorganized to enable that special kind of signaling that goes along the axon, when it's myelinated.

**PJG:** Phenomenal. And tell us, so now you have your Ph.D. and you've got great technology in your pocket, imaging with electron microscopy, plus all of the cell biology that goes with it.

You know, the only thing I want to say is that when I went to work with Tom Pollard at Hopkins, the very first experiment that he taught me to do was an experiment where he was looking at the elongation of actin filaments in the electron microscope where he was using sperm acrosome to be the, essentially, template from which the acting filament would elongate. So I spent a number of Saturdays with him looking at elongation of actin filaments in the electron microscope. I agree with you, it's great technology.

**MB:** He was excellent — I knew him.

**PJG:** So tell me, now you have this and what was the next step for you in your career?

**MB:** The next step was to learn nerve tissue culture and that was the primary interest of Richard Bunge and so we went to New York, we went to Columbia College of Physicians and Surgeons and he learned nerve tissue culture from one of the founders of the field, Margaret Murray, and we wanted to be able to look at the interactions between the Schwann cells or the Oligodendrocytes and the neurons and we thought that was best done in tissue culture so he learned the technique of tissue culture. And then I was studying the tissue cultures that he was creating in the electron microscope and so we saw, for instance, the first synapse formation in tissue culture and we saw, again, myelin formation. There was a woman in Margaret Murray's laboratory who was the first person to achieve myelination in tissue culture and so we looked at the process there, and so that was an exciting time and I was in a cell biology lab, electron microscopy lab, so we were forming a bridge between the tissue culture lab and the cell biology lab.

**PJG:** So, tell us a little bit about synapses. I don't know if many people understand how extraordinary the biology of synapse truly is—that is the opportunity to create circuits in various areas of the nervous system, but in particular, of course, in the brain. I'm discovering technologies at the Bascom Palmer Eye Institute on the ability of the occipital part of the brain to re-learn vision with a very different set of input, instead of being input that comes directly from the retina, an input that would come from a sensory device in the back of the tongue. It is extraordinary how truly plastic and malleable the brain, the nervous system is and that is because of the opportunity to make and break synapses. So tell us, how does it work in the test tube or in a Petri dish? When synapses are formed, are they there to stay or do they get formed and then destroyed spontaneously?

**MB:** We looked at their formation, but we did not follow one particular synapse to see what happened to it. We were thinking at the time that we were looking at the steps of its formation and once formed, then it would remain formed. We were not looking at the turnover synapses. I can't really answer that at this time.

**PJG:** Tell me Mary, after Columbia, you spent some time at Harvard, if I recall, and in England at King's College.

**MB:** We took sabbatical years. And so, at Harvard, it was an exciting time because it was a time when nerve cells were first being dissociated from the tissue and put in a tissue culture and we were looking at the extending tips of axons from nerve cells and they are called "growth cones" and the growth cones are very important during development because they are finding the appropriate areas to get to in the formation of the nervous system and so we were among the first investigators to look at the content of the growth cones in the electron microscope. We would film one particular growing axon and we would, at the time that we knew it was growing, we would preserve it and then we would look at that very same growth cone in the electron microscope. That was rather a monumental feat to find the same growth cone and then to be able to slice it so that we could see it in the electron microscope because it was very thin, so one or two misguided slices and it would be gone. So we were among the first to identify some of the contents of the growth cones, which is so important in path finding.

**PJG:** I love growth cones.

**MB:** They are inspirational structures.

**PJG:** Absolutely. They are the most phenomenal example of entrepreneurial behavior in the entire biology. If something can make it, it's a growth cone.

**MB:** So then our other sabbatical was in England. And there, when we had time to do research around the clock, literally, what we were doing was to look at the way the Schwann cell nucleus was behaving during the formation of myelin and this was in order to more carefully dissect the mechanism of myelination. We were working with cultures which Dick had learned to prepare so well and in thin areas of the culture, one could follow one particular axon and then see the Schwann cell approach the axon and spread along that axon and then begin to rotate itself around the axon to form the myelin sheath and so we examined what was happening for a particular pair, the Schwann cell and the axon, every four hours for 48 – 72 hour periods, so this was "around the clock." We learned how to navigate the tube in London in the middle of the night and this

was very exciting. We did not want to simply turn on a time-lapsed microscope because you had to be there to focus to see exactly where the Schwann cell nucleus was in relation to the myelin sheath that it was forming because we thought there were clues about the way in which the Schwann cell nucleus was rotating, clues about how it was laying down the myelin-- so that was exciting.

**PJG:** Is there a process of lamellipodia?

**MB:** So the Schwann cell approaches the axon, and then it occupies a certain territory, spreads along the axon, for a certain distance, and how it knows what that distance should be, of course, is a mystery, and then it is conversing with the axon, the axon increases in diameter, it's getting a message that it has to be of a certain diameter in order for that Schwann cell to begin to lay down the myelin, so there is a number of interactions between the Schwann cell and the axon and then once the axon has assumed a certain diameter, then the Schwann cell will start to rotate its cytoplasm around the axon and form the myelin.

**PJG:** Phenomenal. Tell me, so along the way, where did your scientific shared life stop and when would the family life start between you and Dick, because of course, there is that relationship that is quite important as well.

**MB:** Yes, and I have been surprised how many people have asked me, "You mean you work with Dick during the day and then you're together the rest of the time? How do you get along so well?" I think the key was mutual respect -- he had certain talents and I had certain talents and they wove together very well. He was just a wonderful scientist, and a very broad and creative thinker and so, in a sense, he was mentoring me throughout our 40-year relationship and scientific collaboration. At the same time I was mentoring him in different ways and so it worked out extremely well. I feel that it was a marriage made in heaven.

**PJG:** That's wonderful.

**MB:** And then we had two sons and I worked at first after the first one was born, half-time. We were at Columbia at that time and Columbia is on 168th Street and we lived on 163<sup>rd</sup> Street so I could walk back and forth very easily. I would be in the lab in the morning and go home in the afternoon and then Dick would come home and then I would go back to the lab sometimes at night. That's the way I handled it, so that I could get a certain amount of work done.

**PJG:** And then, after your sabbaticals at Columbia, you came to Miami.

**MB:** Then we had 19 years in St. Louis.

**PJG:** That's right, you were in St. Louis first.

**MB:** Then we were in the Department of Anatomy and Neurobiology at Washington University School of Medicine in St. Louis, and that was a very exceptional time at Washington University. It was one of the outstanding departments organized by Max Collin and it was really a great honor to be there for that period of time. It was wonderful place for neuroscience.

**PJG:** In general, in science I think, Wash U was just extraordinary with not only the cell biology, but the neurosciences and the biochemistry were also incredible. It was an exciting time, period.

**MB:** And a particular strength was the collaboration between the basic scientists and the clinical scientists — again, I think mutual respect for each other. There were a lot of exciting collaborations that went on at that time.

**PJG:** How was it fostered — rather rare at the time?

**MB:** It must have involved the people who went there. People who went to St. Louis, I think, were very serious about science. There is no ocean, there are no mountains, and also I feel strongly about the value of, they're called "Midwestern values." I don't know if you are familiar with those or not?

**PJG:** Very much so.

**MB:** But I think the Midwestern values ... a lot of the investigators in St. Louis were from the Midwest and I mean, Dick was a wonderful example of Midwestern values -- no airs, no nonsense, everybody has something to offer and so I think in part because of the Midwestern values that worked, but there must have been some very special people there who were able to start the ball rolling for the collaborations between the clinic and the lab.

**PJG:** Tell us about the transition between St. Louis and Miami.

**MB:** In St. Louis we had done a great deal of work looking at the interactions between Schwann cells and neurons from peripheral nerves and our interest in myelination was appropriate to multiple sclerosis. So for years we were interested in that particular clinical challenge. We had always been interested in bringing our basic science knowledge to clinical challenges and so we knew a lot about Schwann cells and we knew that they would be valuable in enhancing regeneration in the central nervous system. By that time, by 1980, it was known that peripheral nerve was an especially good environment to engender regeneration in the central nervous system. So when the call came for Dick to look at the directorship of The Miami

Project, we visited and we thought, first of all, they really need us here, it was very young at that time and we're talking about 1988. Also, because the kind of work that we wanted to do does take a village, we thought, "Here is an opportunity for us to assemble a team that would be appropriate for extending our work in spinal cord injury." So, we viewed coming here as a wonderful opportunity for us to enter the spinal cord injury field more seriously than we had been in before. And also, there was funding available. NIH, as you know, likes to invest in projects that they know are going to be productive, and we were getting into a much riskier kind of research and so the funding here was very valuable in order for us to get going in this more expansive type of project that we wanted to pursue.

**PJG:** And so, The Miami Project was about five years old at that point...

**MB:** It was three years old.

**PJG:** And the Buoniconti Fund had just been created and Nick Buoniconti was organizing substantial philanthropy around The Project, which, by the way is an amazing phenomenon on its own.

**MB:** They have worked tirelessly -- in fact Nick always says jokingly, "People know what I'm after when they see me coming," so the family has been absolutely outstanding in keeping funds rolling in.

**PJG:** And tell me, so at that point, how many scientists of your caliber were already working in The Project?

**MB:** There were just a very few working in The Project.

**PJG:** Like two or three?

**MB:** I think so. It might be three or four. It was a handful — no more than a handful.

**PJG:** And what is it that you could do at that point that you were really aiming for when you came with Dick? Was it the opportunity to extend your *in vitro* work to the *in vivo* arena?

**MB:** Yes, we knew so much about Schwann cells that we could prepare very large numbers that would be transplanted and also Dick had two additional goals. One was to study the human spinal cord lesion because not very much had been published about exactly what the lesion was like and we have to know that in order to model that. Then he wanted to find out the rules regulating the proliferation of human Schwann cells. They have different rules than rat Schwann cells so he started a program to look at how we could achieve proliferation to generate large numbers of human Schwann cells in culture and that was accomplished. So we know that we

can get, over a period of a few weeks, millions and millions of human Schwann cells for transplantation because the idea was to be able to transplant Schwann cells autologously. Dick had published in 1975 his vision because this was a time when glia were first being isolated and could be purified in culture and so this time he proposed that glia could be used to repair the central nervous system. So that had been his working hypothesis for quite a long time. So when we came here, he was able to more closely identify what had to be done in order to reach that goal. So now we have the technology and as you know, we are now preparing the GMP Facility here, and so the idea was to take a piece of peripheral nerve from the spinal cord injured person, and then remove the Schwann cells and then grow them in a culture and add substances that would enable their proliferation to very large numbers so that they could then be transplanted into the spinal cord injury site in the same person and then we don't have to worry about immune rejection.

**PJG:** Phenomenal. You said that an early goal was also to understand specifically what type of wound was created at the site of an injured spinal cord. Was there any surprise in what you found?

**MB:** I think that one surprise was the nature of the injury in central cord syndrome and also the differences depending upon whether the cord had been penetrated or not — that is whether the cord was hit, but the surface had not been penetrated, versus a gunshot wound, and of course there is much more connective tissue that enters the lesion when the spinal cord is penetrated.

**PJG:** We all know that there are axons that run from bottom to top and from top to bottom.

**MB:** Forty-four tracks in the spinal cord.

**PJG:** So there are really, probably, a multitude of responses that were identified in the process of looking at the cord?

**MB:** Because of all the events that are occurring in the tissue after injury, that is why my specialty became the development of combination strategies for treating the spinal cord after injury. That has been my major work since the early 1990s and that is, we found advantages for transplanting Schwann cells in that nerve cells regenerated axons onto a Schwann cell bridge and this was a completely transected spinal cord, we made a complete gap in the spinal cord and then we would place a bridge of Schwann cells into that gap and we found that nerve cells on either side of the gap extended axons onto the Schwann cell bridge and then the Schwann cells myelinated those fibers even though they were from central neurons, not from their usual

peripheral neurons, but the fiber stopped at the end of the bridge, and also we did not see a good response from supra spinal neurons, that is neurons that are at the brain stem of the brain and we needed their response for improving the locomotion that had been modified after the spinal cord injury. So then we thought, “What else can we add to Schwann cells to improve the regenerator response?” and that has been the subject of my research ever since that time.

**PJG:** Then you had a major breakthrough?

**MB:** And then one of the combination strategies that we tried was to elevate a second messenger molecule in the cell, cyclic AMP, along with implanting Schwann cells into the site of injury. We saw a good result in that we saw many more neurofibers that were growing onto the Schwann cell bridge and also that were leaving the bridge, and we saw a response from neurons above the spinal cord and then we saw up to a 70 percent improvement in locomotion. The rats’ hind limbs are paralyzed by the injury that we induce and that paralysis was partly reversed by this strategy.

**PJG:** And that is really extraordinary. I remember my Uncle Yves, who plays the violin ...

**MB:** My father was a violinist.

**PJG:** ... and one day, he was a nuclear physicist, so he played the violin as a hobby and one day he was doing plumbing work, which he should never have done, and actually damaged the nerve that innervates the hand. What I recall is that as a violinist, it took him about six months to a year to really recover some degree of sensitivity in his fingers in such a way that he could tell when he was actually pressing the chords adequately on his violin. Is it that slow in the biological models?

**MB:** In general, nerve fibers will grow about one millimeter a day. So if the nerve is damaged at the elbow, one will be able to calculate that it is quite a long time before they will extend out to the fingers.

**PJG:** So, it is research that requires a lot of patience, Mary?

**MB:** Yes.

**PJG:** That’s wonderful.

**MB:** The experiments we do are very laborious, they are very time consuming, and we generally wait three to four months, and it would be wonderful to wait for six or 12 months to see what has happened, but we can’t wait — we have to know what’s happening before that period of time.

**PJG:** Wonderful. One day, when we look back at this work and realize that it was instrumental to really helping patients with spinal cord injuries and obviously the way that response will take place in the case of spinal cord injury, will be a multi-modality approach where there is going to be some early protection of the spinal cord.

**MB:** Yes.

**PJG:** There's going to be early stimulation with Schwann cells and other cyclic AMP to provoke the re-growth of the tissue across the lesion and we will think about this wonderful work that you have done over so many years to create that opportunity, beyond the shadow of a doubt, because whenever humans have decided to accomplish something they have always succeeded even if it takes some time. What do you think, if that can be accomplished, would be the impossible frontier ... what would be the next frontier? I would say that if I think back to the time when I became familiar with the nervous system, its anatomy, its biochemistry, its biology, and its physiology, if I think back, spinal cord injury came across as the toughest frontier in the field.

**MB:** Hopeless.

**PJG:** Everything compared to that, perhaps short of repairing a substantial stroke, would be less daunting. What do you think would be the next frontier for the neuroscientist of the end of the 21<sup>th</sup> century when all of us are watching this from another viewpoint?

**MB:** How do we think? How does the brain operate? That seems to me a very challenging frontier.

**PJG:** That's true. I think that the modulation of the formation of synapse could be of tremendous help. There is so much suffering that comes, for example, from what we engulf into our definition of psychiatric illnesses, or drug abuse and other substantial challenges for humanity, and maybe at the end, it is all going to be resolved by the glia and the way the glia can recapitulate pathways that are more consistent with health and wellness. Do you think that is possible — that one day we will achieve that level of understanding of the brain and the neuro system?

**MB:** Nothing is impossible. I believe that.

**PJG:** I agree with you. And tell me -- I have been fascinated by The Miami Project because it is an outstanding example of how the creation of a research organization that has grown almost as an isolated axon in the nervous system or an isolated pillar in an environment with an intrinsic

mechanism of funding which was really totally unique in the creation of that wonderful center -- do you think it is a model for dealing with difficult disease and illnesses in the medical field?

**MB:** I think it is very important to bring together people who have different expertise and if they are all focused on the same problem, but all have different ways of approaching, solving that problem, I think the synergy is very important. Think about the Manhattan Project for example. That was what Barth Green had in mind when he envisioned The Miami Project. He thought if we can bring people together, as they did in the Manhattan Project, then we can advance more quickly.

**PJG:** Do you think Barth was also influenced by the success of Ed Norton, with the Bascom Palmer Eye Institute, in the creation of The Miami Project?

**MB:** I really can't answer that. I don't know.

**PJG:** OK. I'll ask him. He's a smart guy and I am sure he noticed that that was very successful. Of course, in every one of these substantial medical challenges, there is a very important emotional component — it can be very heartbreaking to see a young child or an adult, for that matter, severed from the opportunity to move legs or arms and even breathing.

**MB:** Absolutely.

**PJG:** How much of that emotion was actually a source of energy for you to make a difference and to get to the goals that you had defined with Dick?

**MB:** I think there is a balance. Obviously we were highly motivated to make a difference, but on the other hand, if one gets too involved emotionally, then that might be counterproductive, but clearly, since I was a young child, I have been very interested in making a difference doing something that would make the world better. I think that certainly has been part of our success.

**PJG:** Did you develop that spontaneously or did you have parents and other role models that guided you in that direction?

**MB:** I had four heroines when I was growing up and one was Sonja Henie, but I realized that I would not be following in her footsteps, and then another was Anna Pavlova, who is one of the greatest ballerinas of all time. I love ballet and I was a good dancer, but again I was not going to go in that direction. I grew up in a very small town in Connecticut, but it had a good library and when I used to go there as a young girl, there were some books about Marie Curie and I don't know why I found stirring pitch blend so romantic, but she was very inspirational. The other person was Eleanor Roosevelt and she came to a neighboring town when I was in Girl Scouts

and I was the Girl Scout chosen to escort her to the stage. So I met Eleanor Roosevelt and I thought she was a very extraordinary person and doing wonderful things so she was inspirational. Then we lived in the woods and there was a small stream, this is in the autobiography, and so I used to, at quite a young age, go out on a row boat and I saw the tadpoles and frogs and became very interested in nature. I also designed and made all my own clothes so I thought of fashion design. I thought there is one thing that I cannot do on my own is to learn about science and that is why I decided to learn science, but there were these women who were outstanding in whatever they were doing -- skating or ballet dancing, or helping people in general, as Eleanor Roosevelt did, so I think I took a lot of inspiration from them.

**PJG:** It is notoriously, incredibly complex, for women to successfully develop a career in the academic world. As you know, a lot of men have a preconceived opinion about what women can achieve, which in my view is a dreadful mistake. But we are not here to talk about my views, we're here to talk about you. What allowed you to become, obviously, one of the most successful women scientists in the world — what allowed you to not be blocked and tackled by the environment? What gave you the force of carrying on?

**MB:** I think sincere interest in wanting to make a difference, focusing. When I was a graduate student, I was in the laboratory of Hans Reese, as I mentioned, and he was gender-blind. There were a number of women in the lab — I did not think of myself as a woman going into science, I was thinking of myself as a developing scientist, period. I think if I had focused on being a woman in science, how will I do as a woman in science and so on, I would not have done as well. I think it is focusing on what your interest is and I was interested in being a good scientist, period. I didn't think about the pitfalls and perhaps a little bit stupidly, but on the other hand being very positive and focused, I think, is what made the difference with a sincere interest, at the same time, in being as good as I could be.

**PJG:** You know it's interesting, because if I recall the way I developed my scientific interest, there were really three women and one man, which is a bit unusual I guess. Marie Curie, I share your enthusiasm for her work and her inspiration and her character—she was unbelievably inspirational and her ability to, of course, in the atomic, physical field to make extraordinary discoveries, is just at the level of discoveries of an Albert Einstein and all of the folks who are put into a very small group of scientific pioneers of all times. Another one that fascinated me

was Barbara McClintock because I loved her very quiet way of making extraordinary discoveries. Her work in genetics was ...

**MB:** She was certainly a good example of being focused — she did not even have a telephone, and when you think about all the people who are carrying around phones all the time ... She was very devoted and very focused.

**PJG:** Totally, and she also was not too worried about what others would think about her work by the way,

**MB:** That's another important aspect.

**PJG:** She was just doing what she thought was right, absolutely careless of what others may think. The third one was my grandmother, who learned English nursing and human anatomy at the same time while nursing at the front lines during the first World War and I thought she was a pretty amazing lady and then my Uncle Yves who was a nuclear physicist and I thought it was very interesting. He was telling me about matter, anti-matter and that one day I would meet somebody who would be my anti-matter and we would both disappear. I thought that was quite interesting, but I can feel for you. I think that among the greatest scientists of all times have been extraordinary women and I cannot tell you how proud and humbled I am for having you on our faculty.

**MB:** Thank you very much

**PJG:** And for having you carrying the flame of an extraordinary couple and a remarkable page in the history of science, in the scientific field of the nervous system.

**MB:** Well, I am honored to be here and this has been a wonderful situation for me. I have been able to do the work that I wanted to do.

**PJG:** We hope to keep you for a long, long time.

**MB:** I hope so too.

**PJG:** I wouldn't be surprised if you have a few more major discoveries in your back pocket.

**MB:** Well, we'll see — it's about time for the younger generation to take over, but I'm not ready to give up yet.

**PJG:** Thank you for everything you have done for us.

**MB:** Well, thank you.

**PJG:** And for science and for the patients with paralysis and all of the neuroscientists in the world who are learning from your work.

**MB:** Thank you.