QUANTUM NANOSCIENCE — Interviews

Noosa Blue Resorts, QLD

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Guifre Vidal (7:05 mins interview -- 0.75 hrs transcription)

Judy: So why are you here? You said that a lot of the other talks aren't really of interest … to your field, right?

Guifre: They might be of interest at some point but I think that, as things stand now, I would rather focus on what I'm interested in.

Judy: I was speaking to somebody else about … I was talking to Hari about how you said that some of it is inaccessible. It's not to complain about you, it's … some people need feedback because he's one of the … he's partially … he's part of the organization of this conference, too, and he said that that's not a good thing if this information is not accessible to everyone here because that's the point of having a conference …

Guifre: But I think that's how it is … from time to time we have conferences where we make people, first, come from different places in the world so that communities can talk from different countries. But also, when you have different … but then when you have this situation, you want to make sure that the speaker makes the extra effort to prepare the material so that it is accessible to people from other communities.

Judy: Right, because he said that he has some sort of rule: a third of your talk is about your specialization, a third of your talk is about accessibility to everybody …

Guifre: Yeah, I think that's a reasonable format to make that people follow, at least, the first ten minutes and then after that … it's not that you would expect to understand everything from their talk but at least you can get the first ten minutes … that would be great.

Judy: So is this the first time that you're at a Quantum Nanoscience conference?

Guifre: I guess so, yes.

Judy: And, so, how is your work a part of this field?

Guifre: During my talk yesterday, I tried to get the attention of people by saying that what I do, essentially, is I'm developing tools to simulate quantum many-body systems and quantum many-body systems is the basic ingredient in Nanoscience so, essentially, what I'm doing can be used as a tool for studying studies …

Judy: So are you a theorist?

Guifre: Yes.

Judy: So what are your goals for coming to the conference?

Guifre: First of all, I wanted to get to know the quantum information community in Australia … I just arrived to Australia last August. I probably spent 2 months, since August, in other places around the world. So I wanted to have a chance to meet all the people from here. Also, it's always interesting to meet people working in slightly different fields. And then, you don't just go to a conference because of the talks, you go to a conference to talk to people there and these are the things that are happening already. During breakfast, you can ask questions to somebody …

Judy: So what do you think the public should know about your work? Do you think your work is significant to the public? Not at this stage?

Guifre: I don't think I've ever thought about that. That has never been my goal. In science, you don't do something that can sell directly … this is not your short-term goal. You just work on things that make sense within the field …

Judy: So that's outside of your concern right now?

Guifre: I guess as you … as part of your career at some point, you would like to start caring about these things because you have some kind of responsibility to the institution that you represent … and I guess I should start caring about that.

Judy: So what's important about your area of specialization? What do you think is important about your work to … you were saying about many-body systems, right? What do you think is important about your work to this conference?

Guifre: I think the idea of many-body systems has an important lack (?) computationally, meaning that there are serious problems … if you want to simulate … you can always build your experiment but it's very important that you are able to check your experimental results with some kind of ? and the theory that you can develop from this system may work in ? situations but then you quickly run into problems if you don't have the theory that you can solve analytically … what you need to do is to use medical techniques and it is here where my work may be relevant because there is a serious lack of medical techniques to analyze quantum many-body problems and it turns out that within the context of quantum information in the last few years we have developed … we are developing these new tools that allow us to simulate quantum many-body systems so that experimentalists can check what they are getting from experiments and can be checked against the theory.

Judy: So how involved are you in Nanoscience?

Guifre: I would say only marginally, in the sense that I haven't made … I think that it's important to keep in touch with what is happening around you in your area of research but it's also important to stay focused on what you want to achieve. At the moment, I need to focus on what I want to achieve and then once you have the ? you can interact with people who may use this.

Judy: So it's not a major factor in your work now?

Guifre: It has not been.

Judy: Okay.

Gerard Milburn (32:47 mins interview -- 4.25 hrs transcription)

Judy: So he’s part of the Physics Department but he’s not part of the Centre? (discussion about Guifre Vidal)

Gerard: No, he’s not part of the Physics Department but he’s not part of the Centre.

Judy: Because I was talking to him earlier and he said that his area of research is kind of on the margins of Nanoscience.

Gerard: That’s correct.

Judy: How involved is your work?

Gerard: Very closely. I have two major research projects: one is in the Centre for Quantum Computer Technology connected with solid-state qubits … so the phosphorus and silicon work that Bob Clark will talk about on Thursday. And the other project, which is my biggest project and getting bigger is in nano electromechanical systems, the sorts of things that Mike Roukes and Keith Schwab were talking about yesterday.

So this year … last year I spent a fair bit of time on this and this year I'll be spending most of my time on this subject. There are a couple of issues that I want to address: one is new ideas on how to read out what are called phonons … excitations … and the other is something that Mike Roukes discussed in his talk, which is how to treat dissipation and decoherence in the systems. They're in a very peculiar regime for a theoretician of having one particular degree of freedom coupled to a few other two-level systems and there's no theory … there are quite a lot of experiments being done on it … very confusing, no one really understands the results … and zero theory so it's a wonderful place to work.

Judy: So are you a theorist?

Gerard: I'm a theorist.

Judy: So what's so significant about this particular conference?

Gerard: From my point of view, it's bringing together a number of slightly different areas. Bringing quantum computing people with the nano electromechanical; bringing quantum chemists together with people working on superconducting devices …

Judy: Like George Christou …

Gerard: Yeah. That's right.

So … at the moment, my current employment contract is as a Federation Fellow and the subject of my fellowship is quantum nanoscience. About three years ago, I identified this as a new area that I'd like to work in … nanotechnology didn't quite cover what I was doing because most of that was not quantum at all. And quantum nanoscience seemed to capture the sorts of things that I wanted to do.

One of the things a Federation Fellow is expected to do is to promote the field and somewhere along the line I got talking to Phil and we decided to have a conference although neither of us quite knows how it got started. But anyway … I've been wracking my brains to figure out how it all got started.

Judy: That's what he said yesterday, right?

Gerard: Yeah. I supposed it's just one of those accidental things. Phil and I have been talking about running a meeting and I probably got an e-mail from the Academy saying please apply for this money for a conference. I think that's probably what happened. I'm sure I could find out if I went back and checked through my e-mail.

Judy: So have you organized other conferences on Quantum Nanoscience?

Gerard: Not on Quantum Nanoscience. I've organized two other conferences besides this … they all … I've been on committees for organizing conferences … lots and lots. But the first one I held was on quantum computing, which was held on Heron Island -- a coral island off the Great Barrier Reef. It's a very small island … the dive capital of the world. If you're a diver, that's the place you need to go. It's a coral quay so you can dive straight off the island onto the reef. It's in the middle of the ocean, a bit of vegetation … a huge ? reef. Visibility is absolutely stunning.

Judy: So you said that was quantum computing?

Gerard: That was quantum computing. That must have been 1996 or something like that … very early on. The other nice thing about Heron Island is that the University of Queensland has a research station there. There's a resort and there's the University of Queensland. So we can put the students up in the research station. We have students and visiting people as well.

Judy: So what are the main themes of this conference?

Gerard: The main themes of this conference are quantum materials … so nano magnets, new kinds of molecular systems, applications of quantum mechanics and biology … that's one main theme … quantum chemistry, if you like. The other main theme is quantum information and the other is nano electromechanical systems.

Judy: So what are the objectives of this conference?

Gerard: My hope is that there will be new science as a result from different sorts of people collaborating. What we heard this morning from John Martinis on new materials for superconducting qubits … maybe there are some very good ideas there that we can take over into our work at the University of New South Wales on phosphorous and silicon qubits.

Maybe people at this conference will never have heard of nano magnets as ways of storing and processing quantum information, so maybe we can get them to think of new ways of doing things there.

Judy: I had heard from somebody who presented at the conference that a lot of the topics are inaccessible because they are so specialized. Part of the reason to bring everyone together is to teach people who are slightly outside of the area about new research and … but there's no … I didn't realize that …

Gerard: I guess that it was probably some of the younger people, but it's good to push people beyond their comfort zone. If you go to a new field, obviously, you're not going to understand anything but the key thing is to stimulate them to think about it.

Judy: I guess they're not interested …

Gerard: They may not be interested. That's fine. You don't expect people to go to every talk, that's for sure.

Judy: So what do you see some of the products or some of the end results of some of this research, as in what will the public see tat they will know is connected to this kind of research?

Gerard: There won't be an immediate pay-off to the public and, I suspect, the pay-off is probably on a time-scale of 5 to 10 years. The most likely one to pay off in the short-term are these nanomechanical systems for ultra-precise sensors. One of the things you can use them for -- which my group didn't get a chance to talk about -- is detecting single molecules.

So it turns out that if you have these little, vibrating silicon cantilevers you can cover them with a biopolymer that only bond to a particular kind of virus or a particular kind of pathogen, but as soon as it sticks it changes the frequency of the cantilever and you can see it … use to use these things as single molecule detectors in biology.

Judy: That's so interesting.

Gerard: It's extraordinary that you can detect a single molecule landing on this little vibrating surface.

Judy: So is that the point of putting something on it …

Gerard: It's called functionalizing. You coat them with a particular kind of chemical, usually it's called a biopolymer … some protein or something like that, that sticks to one and only one kind of molecule and that's the one you're looking for, for whatever reason … maybe it's a pathogen, maybe it's …

Judy: So you're saying it changes the frequency so that you can detect it, so that's almost like the biopolymer adds a weight to it so that it slows it down or something.

Gerard: That's exactly right. Basically, it bends it a little bit and changes its frequency, stretches it.

Judy: So what do you want the general public to know about this conference? I saw that article and I thought it was well written.

Gerard: Which one was that?

Judy: This was in the local newspaper.

Gerard: Oh that. I haven't even read that yet.

Judy: It's well written. It gives a very basic but quite thorough explanation of this conference and nanoscience, in general.

Gerard: The theme of the conference is tat we've acquired the ability to fabricate and manipulate devices and materials now … that's precisely the scale which quantum mechanics is important. What can we do that we could not do while using quantum mechanics rather than trying to fight against it? So that's the basic the theme. New material, new devices while using quantum principles at the atomic scale.

Judy: So when people think of atomic, they think of bombs. They don't understand … and so, this is what I want to convey to the public … a better understanding because yesterday …

Gerard: This is always very difficult …

Judy: Yeah. They hear all these … I interviewed Andrea yesterday and he was saying that people pick up all these buzz words and then they're utilized for some other purpose; they're given some other meaning …

Gerard: Often quite deliberately. Often there is a completely different agenda being used. In nano technology, it is becoming acute. People, for whatever reason, want to … agenda … that's fine but there's a particular organization, I don't know if you've come across it, based in Winnipeg called *Etcetera* -- ETC. It's essentially an anti-globalization organization fighting what they see as the evils of global capitalism and so on. The point is, they use particularly emotional scientific issues to get attention and their biggest success was the genetically modified foods debate. They were very, very much behind that discussion in Europe and they've just picked up on nanotechnology. They're not totally crazy. They do raise some serious issues. My concern is that it's a little bit dishonest at times. Could be said to be misrepresenting … think there's a higher goal they're trying to achieve.

Judy: Some people pick up words without grasping the complete understanding of the word they're using and misusing it.

Gerard: A good example of this is … one of our funding agencies in the United States is the Advanced Research Development A?, at least that was what it was called. They've just changed their name to the DTO, the Disruptive Technologies Office, so I thought that was a bit silly but who cares. Why on earth would they choose a name like that? The public will find it very threatening.

Judy: Just the word 'disruptive'.

Gerard: People don't like the word 'disruptive'.

Judy: But, see, it's used in a different context. You can use one word in different environments and different fields, and it can mean different things.

Gerard: I think it’s too close to destructive. I think that’s the problem

Judy: Dis- is negative.

Gerard: Dis- is negative. You’re absolutely right.

Judy: You understand what the organization was prior to this new name change so you understand what the agenda of this organization is but people just go by the name …

Gerard: … just hear it for the first time they think it’s somewhat threatening. Yeah, I can see it now but …

Judy: So do you want to talk at all about the social and legal implications because you’re talking about these organizations, like *Etcetera* and stuff … ?

Gerard: Sure. I think there are some serious questions that have to be raised about nanotechnology, in general, and people are raising them. And we have to be completely open about what we don't know and what needs to be done so, certainly, we need to bring the public along with us on this issue. It's difficult because you're competing with other people trying to run different agendas, as I just described. And also there's a certain, sort of minimum, level of scientific literacy there that one even needs to have to have an informed debate on some of these things. First of all, there's education … to say what we're doing, why we're doing it, and why we think it's important for you -- for the general public; and secondly to listen: this is what we're doing, why we're doing it, and tell me what you think? … and from that point, we can work together. The worst thing to do is to just ignore anybody's concerns … just to say, "There's nothing to worry about. We know what we're doing. Just ignore … just get on with it." That's a disaster.

And in my experience, there's an enormous appetite amongst the general public to learn what it is we're doing. I've given many public lectures on quantum computing over the years and people come.

Judy: People want the outreach. They want you to go out and offer this instead of them doing the work to find out.

Gerard: Mostly, but if you make the slightest effort there will be a response. There will always be some people who want to get on with drinking beer and watching cricket, but you don't have to make much of an … well, you actually have to make the effort. It's actually very hard to communicate in lay terms what it is you're doing …

Judy: That's what my role is.

Gerard: It's very hard and I sympathize with you because I have written two non-technical books myself and they were the hardest tings I've ever written. I call them 'non-technical' … I would have … most people call these things 'popular' but in my case 'non-technical' is a more accurate description of this style. They didn't do too badly, not too badly at all.

Judy: I actually agree with everything you've said. I'm in a good role to be doing this because I worked for Philip for about 4 years and I have basic understanding and I've taken some science courses, genetics … I was working part-time, for about 3 years, at a place … a centre on the UBC campus: the Centre for Applied Ethics. I have a lot of understanding about how the public perceives this, I have a little bit of scientific background, and I know how to write, and I know how to talk to people, so just the combination …

Gerard: Well, when Philip suggested this I thought it was a brilliant idea. This is exactly what we wanted. I trust Philip. I hadn't actually realized that there was going to be this guy, Julian Cribbs, sort of beavering away in the background sending out press releases.

Judy: I don't quite understand why this guy is not here because he should be.

Gerard: It's quite puzzling. He didn't want to come, actually, as far as I can tell.

Judy: He said to me over e-mail … I'll forward you his e-mail …

Gerard: He never raised this with me and the Academy never raised this with me …

Judy: It's so odd …

Gerard: So it never occurred to me to ask him to come. I just assumed that if the Academy was employing him to come to the conference, he would come if he wanted to.

Judy: He said that it wasn't in the budget. That's what he said to me. But I don't quite understand what …

Gerard: I don't know what budget he's referring to. The Academy must have some budget for publicity for these sorts of things. Perhaps this is what he was referring to.

Judy: He asked me … I offered to help him … and then he asked me to, actually, work for him … I'm not actually working for him, but he wants me to give him whatever information I collect and I don't quite know …

Gerard: First of all, I didn't know he was involved until quite late. I got a phone call while I was on the beach here in Noosa just before Christmas … this was the first I heard about it.

Judy: So did the Australian Academy of Science organize his involvement in this?

Gerard: Yes. That's correct.

Judy: So on their website I noticed that the conference is posted …

Gerard: Is it?

Judy: Yep.

Gerard: I didn't even check that. I just assumed …

Judy: I checked a bunch of different sites. Philip gave me some great background reading and anything I didn't understand, just did some web searches, and any buzzwords, like 'Australian Academy of Science' … I just checked.

Gerard: The Australian Academy of Science is funding it and the Australian Academy of Technology and Engineering. There are the two scientific, technical-based academies.

Judy: So what's going on with this Supreme Court … ?

Gerard: Yeah, that's a good … that's a really good exercise … I'm sort of involved because of my role with PiTP. We had one very interesting meeting with them in Ottawa, which I flew all the way from Australia for, for one day and flew back again. I just had no time for anything more.

It was very interesting. They were remarkably well informed. I was particularly impressed by the Chief Justice. She's obviously a sharp person. Very sharp.

So we discussed a wide range of issues and in preparing for the meeting I learned a hell of a lot, reading up on the background of the toxicology of nanomaterials and so on. Since then, I've become more involved in Australia as well. I'm the Academy's representative and on the Australian government's advisory on nanotechnology. I think there's a meeting next week in Melbourne …

Judy: I noticed when Philip put up the Advisory Board for PiTP … I think that's what it was, the Advisory Board … the President of UBC is on that list. Is the President of the University of Queensland involved in … or Vice-Chancellor … ?

Gerard: Our Deputy Vice-Chancellor of Research is well aware of what we're doing with PiTP. Philip and I have spoken to … well, I've certainly spoken to him at length about PiTP. And I wish he would be just a little *more* supportive, but of course he's …

Judy: Do you mean financially or … ?

Gerard: Yes, yes. That's correct. He has been extremely supportive of the Physics that I do and the Centre for Quantum Computing, but when it comes to international links for some reason he's a bit … I'm not sure why. I'm sure that will change. I just have to find the best way to …

Judy: Approach him on that …

Gerard: That's correct.

Judy: Because international links are very important.

Gerard: That's absolutely, especially for Australia. We're miles from everywhere, so we just can't survive without being totally connected to all the major activity that we do.

Judy: And PiTP is a great connection.

Gerard: It's fabulous.

Judy: The Pacific and also …

Gerard: Well I'm happy to expand it beyond the collaboration of what Philip and I have because there's a little bit of string theory done in Australia and I've done a bit a nuclear physics, a fair bit of astronomy and astrophysics … but all of this is being … PiTP … but the idea is to start with what we've got and what we do well, which is condensed matter physics and quantum information and then build on it from there. So PiTP is the central ground of my strategy.

One of my roles … I'm the Chair for the National Committee of Physics which, basically, doesn't do anything but one thing it's trying to do is to get a National Institute for Theoretical Physics running in Australia. Canada has two world-class centres for theoretical physics; Australia has none and it's extremely difficult to get anybody to take it seriously. There's plenty of money for biotechnology or nanomaterials or whatever if you want just a centre to do world-class theoretical physics, people just yawn, just walk away. They say, "What's the return? What are we going to get?" I have to explain to them …

Judy: See, I don't understand because it's the basis, right?

Gerard: I know. I tell them that it won't have an impact on the next quarter or the next year, but it will totally transform technologies 10-20 years from now. Then they just walk away.

Judy: So a lot of people don't understand … so you're looking for funding for are part of the science community, but they don't understand the significance of theorists, right?

Gerard: I think that's right. But … we'll keep working on it. The other Institute in Canada that we have a close association with is the Perimeter Institute oh Theoretical Physics in Waterloo. It's a private institution set up by … who's the CEO of *Research in Motion*. They're the Blackberry's communicators? That's his company.

As he explained it to me, he feels that Western society is threatened from within by the silliness of some activities, like the amount of money we spend on sport, the amount of money we spend on rock music, golfing tournaments … he said, "Why can't we spend a lot of money on something really important like theoretical physics?" And when I mention this to people in Australia, they just laugh: "Why would anybody spend money on theoretical physics? What a waste of money." Mike ? sees it very differently because his background is in engineering. He knows that basic sciences, like theoretical physics, could change economies.

Judy: I was thinking the same thing yesterday. When something came up on the news and I thought, "Why are they spending money on this?" In South Africa they're trying to fund black people to learn how to play golf or compete with white golfers and I thought: sure, it would be nice but that's very insignificant to real poverty; we're not just talking about caddy's … they were saying, "A lot of blacks are caddy's. We want them to be golfers, too." They missed the point, right?

Gerard: They missed the point, entirely.

Judy: And that's the whole thing about theoretical physics, how significant it is. A lot of people are missing the point … and, I know, the kind of salaries that basketball players make, right?

Gerard: Yeah, yeah. Basketball players, golfers, swimmers … Australia always has had a sporting culture so the real heroes of the society are sports heroes.

Judy: It's like that in north America, too.

Gerard: Largely the same. It's slowly changing. Now, at least there's the Prime Minister's Prize for Science which receives a lot of publicity. So each year there's this big splash … recipients that have been ignored for the last 50 years.

Judy: So maybe if I write some articles … when this information gets out and more people are understanding of the topic and realize the significance, that's one step toward your goals.

Gerard: Absolutely. Science communication is absolutely vital. In having an informed debate, it has to be first informed so these are things we're hoping you'll do for us is critical.

Yosef Imry (13:63 mins interview -- 2.00 hrs transcription)

Judy: I'm going to writing some articles for Gerard and Philip … there are some ethical and legal concerns of this research, so … you're from the Weizmann Institute … what's so significant about this conference to you?

Yosef: The title of the conference is about the subject that I love. I think I've been one of the first to think about nanophysics or mesoscopic physics as it is called from the point of view that the bridges between microscopic world with quantum mechanics dictates when happens in the macroscopic world, which is mostly classical physics. Regardless of the fact that all this may result in applications, etc. in quantum computing -- which I am not a practitioner of -- I am very interested in the fundamental question of how the laws of physics change between microscopic and macroscopic.

Judy: That's a very interesting that you explained that.

Yosef: That's enough to preoccupy someone like me for 20 years, which is what happened.

Judy: So are you a theorist?

Yosef: I'm a theorist.

Judy: You do work on solid-state qubits, too?

Yosef: I can work on solid-state qubits but I am not particularly active in the application, which may or may not materialize into quantum computing. To me, the interest is the basic physics, not whether it will be applied to this or that.

Let me say, at the same time, there is absolutely no doubt in my mind that there will be a lot of applications to this sort of physics, and most of them are things that we don't even think about yet.

Judy: So what is your goal of attending this conference?

Yosef: My goal is just to present what I want to present and to get current on what other people are doing.

Judy: Have you presented yet … no.

Yosef: No. It will happen tomorrow.

Judy: So what do you want the general public to know about quantum nanoscience?

Yosef: I think the general public might have heard somewhat about the wonderful rules and problems of quantum mechanics. Quantum mechanics is a fantastic discipline … it gives possibilities that did not exist before and at the other end it's very much against our daily intuition. So we as physicists got used to it and, in some sense, we are already used to crazy things that can happen and do happen. But, still, the fact that you can as a theoretician predict something which is totally counter-intuitive, totally against everything that we believe in our common day-to-day experience, experience based on macroscopic life-sized objects … but when you go into the small scales, scales that you cannot even see with a microscope, new rules prevail and these rules are very exciting to us because now people have been able … today, there have been lectures demonstrating such things … not the first ones, there were many before … but it's more and more becoming clear that one can, in the lab, visualize quantum phenomenon. I think the general public might be quite interested in that because sooner or later, maybe the general public will be able to see these quantum phenomena for themselves.

Judy: What is so important about your area of specialization?

Yosef: It's not so important. It's important as any other area. It's very important to me because that's what I'm doing and I'm very excited. I think it's pretty interesting. It addresses new questions of science that people did not think about 25 years ago, or 30 years ago. Most people didn't even consider that there was a legitimate question to be asked there. Nevertheless, there are such questions. They are very exciting. We may be going to … small piece of another lecture which … what enables us to do this is the model technology which was developed by engineers over many years of making tings smaller and smaller.

Judy: So how have you seen the progress? You've seen a lot of changes and … do you think it's going in the right direction … this research?

Yosef: Sure. It's doing better than what I expected. In science, you have the things that you can more or less expect or hope that will happen based on experience. And then, the most wonderful thing in science is here, and then there is a new breakthrough. And the new breakthrough happens because somebody somewhere had a new idea. If you knew a great, great idea that happened and I suspect occurred 23 years ago in Switzerland, a person called … ? … a big something called a scaling tunneling microscope -- STM. This is a small instrument that really made a quantum jump in our ability to go into the micro world. Nobody expected that to happen. And that was just a little bonus in condition to the regular advancement of science … there are these leaps and these leaps do not happen that often. When they happen it's great. There was this one and based on it there have been a few other developments, and that has made the field much more exciting that, I must say, I expected myself.

Judy: Where do you see … what research institutes in the world do you see as making, not necessarily the most advancements, but doing the most important work in this area? Are there just a few or are there a lot of … ?

Yosef: I think that the three leading institutions in the world are, more or less (1) Delft University in the Netherlands; (2) a laboratory in France … Saclay; and with all due modesty (3) the laboratory in my institution (Weizmann) … which I don't belong to because I'm a theoretician, but I initiated. That lab is a couple of real experimentalists and it's doing very competitive, very innovative work.

In addition, there are a few very excellent places in the U.S. and in Japan. As far as North America, it's case tat I'm afraid the U.S. lost it's position of leadership probably due to insufficient funding and management which was not done in the right way, but still there are a lot. The great universities -- Stanford, Harvard, MIT -- are doing very well, but with all due caution I must say labs in Europe are doing even better. And the Japanese are also advancing very well.

Judy: And how do you see organizations like PiTP and the University of Queensland research centre … how do you see them in this role?

Yosef: PiTP plays a very important role in internationalizing the research, not only in this field … PiTP is much more general than this … but quantum condensed matter, a sub-field of which this nanoscience is very important. I'm familiar mostly with. The other important areas of PiTP research is complex systems, string theory are also very important. PiTP plays a very important role in making this happen on an international scale, making people from different countries meet, work together, transfer information

Judy: Right, that's very important.

Yosef: In science, it turns out that transferring information is very important. In the old days, Newton use to write to his friends and foes … who did this and that first … but writing letters is long ago … it became, not obsolete, but old fashioned because things are much faster. We have telephones, facsimile, e-mail, and it's much better to meet than …

Judy: It's much easier to fly …

Yosef: You are I are meeting now -- 4 eyes, eye-to-eye -- and we discuss … especially in science …

Judy: With collaborations, learning about each other's areas …

Yosef: We have to use a piece of paper and write something on a table … a piece of paper or blackboard … so that's why PiTP conferences and extremely useful. I have participated in a few of them and they have all have been very useful for my work.

Hari Manoharan (35:39 mins interview -- 4:00 hrs transcription)

Judy: What do you see as significant about this particular conference?

Hari: I would say that this is the first conference that I've been to that would explicitly combine quantum mechanics and nanoscience. Some very good have been invited, experts in the field and pretty good talks so far.

Judy: So what are your goals in coming to this conference? The usual … to meet people, to share ideas … ?

Hari: Yeah, to talk to some potential collaborators, some existing collaborators. Here, also, we're doing some work that's moved from basic physics to this area of quantum information, quantum computation so … the main things is that … I was invited to the conference but it happened to coincide with when we got some nice results that actually pertain to quantum information so this is a great place to show off of these results and talk about them, get some feedback from people.

Judy: So is this the first quantum nanoscience conference that you've gone to?

Hari: Well, certainly … probably the first one that's called "The Frontiers of Quantum Nanoscience." I've been to conferences on quantum information, quantum computation, and stuff like spins.

Judy: Do you think that some of the leading people in the field are at this?

Hari: I think so.

Judy: What do you think the public should know about this conference?

Hari: It really combines some contemporary areas of research, but what they need to know is the starting point: so there's quantum mechanics, which itself is an old field … it seems like we're learning more and more about quantum mechanics everyday … well, in terms of the history of physics, quantum mechanics is relatively new, since 1900s. Somehow, it's last few decades there have been surprising experiments, groundbreaking experiments that have allowed us to wrap our minds around quantum mechanics, more than we have before, and maybe bring it a little bit more out of abstract but at the same time, it illustrates how hard it is to understand. Things like experimental demonstration of quantum teleportation -- sounds like science fiction, but it's a real experiment that you can do in the lab. It's based on the fundamental of quantum mechanics … but yet you can only do this in the lab and you try to understand it highlights some of our conceptual difficulties in understanding this … some of the bizarre stuff that happens in physics, quantum mechanics … and, so …

Just understanding quantum mechanics … it's sometimes written up in the press as impossible to fathom or …

Judy: It seems like that in many ways …

Hari: But in reality, a lot of us as physicists, we also have a hard time conceptualizing things that seem non-intuitive and, I would say speaking for myself … you step back sometimes and you think, “Wow. This is really strange.”

Now you intersect this pursuit with this new field, nanoscience or nanotechnology … nanoscience and nanotechnology is a little bit poorly defined, maybe it’s defined in terms of size or length-scale … fundamental laws of physics, right? Almost more on the technological side … and with it come all these new tools, methods for accessing matter smaller and smaller length-scales … as it turns out, quantum information, which is a new pursuit that came out with quantum mechanics and quantum computation, they’re finding maybe the implementation … maybe some of the tools … that are being developed in nanoscience because at a fundamental level quantum mechanics tells us how individual particles behave and it’s only in the last couple of decades that there’s been almost a theme in experimental research that accesses one quanta of stuff. So paring down all the physics to one of something, and then understanding that and then coupling it to a second one, third one … now with new tools and with new understanding, we’ve been able to piece a lot of this together … and it turns out that there’s some potentially revolutionary new technologies that could come out …

Judy: So that’s why you think the public should care?

Hari: That’s definitely why it’s relevant to the public.

The other thing to know is that there’s also the reason it’s relevant that people need to be doing this research, purely, on scientific grounds. It’s pushing the boundaries of our knowledge, helping us to understand nature in ways … we didn’t have this knowledge before.

Judy: Access to it …

Hari: Right. So just expanding the boundaries, the frontiers of human knowledge … that goes hand-in-hand with any technology we develop and, just by itself, does motivates most of us … and new technologies are very promising.

Judy: So it affects people in a way that they understand their life, what goes on around them, but also the potential, the possibilities of the results of modern research.

Hari: That's right.

Judy: Are you a theorist or experimentalist?

Hari: I'm an experimentalist.

Judy: Do you want to say anything about the legal implications, the social-legal implications?

Hari: Of … ?

Judy: Of quantum nanoscience or … what's your area of specialization?

Hari: Well, my area is manipulating matter at the smallest possible … which means at the level of single atoms or even smaller … electrons and parts of electrons. We work at the lowest rung of materials.

Judy: You were showing electrons in your … you called it a video.

Hari: I was showing pictures of electrons … one way of classifying this is ‘top-down *versus* bottom-up’. If you look at a Pentium chip, a microprocessor … it starts with a big, relatively huge, wafer of silicon and it’s processed over and over again … smaller and smaller features are put on this wafer, eventually getting down to length-scales of 100 nm or below … so, actually, current technology has gotten to this field … length-scale nanotechnology.

We call this top-down technology because it starts big and you end up with something small … transistors with features, length-scales of 100 nm or less. So it stops there and to go further down is turning out to be a big, fundamental limit, limited by fundamental physics because the way most electronics behaves, we call ‘classical’. It doesn’t use, it tries to avoid quantum mechanics … scaling down another factor would … that’s where we begin to … limitations given by quantum mechanics. So instead of working along this same progression, what we’ve done is leapfrogged to the bottom, so to speak, and work our way up. So if you go down to the smallest constituent -- materials such as single atoms, electrons -- so we went to that level and we’re try to build up from there … build up structures, assemble atoms, put them together, study them … materials that we make, we’re often surprised by the physics we see, we can try to make devices … test for information, do some kind of computation … so the thing to understand is we’ve gone so far down that the biggest thing we can make … you compare it to the smallest thing … top-down, there’s still a big gulf between them … we haven’t met and, actually, that’s where a lot of excitement is because maybe in that gulf lie our future technologies -- quantum computers or quantum transistors, new ways of communicating, quantum encryption or … all this stuff … maybe stuff we haven’t even thought of yet.

Judy: Have any of your experiments resulted in any substantive applications or produced any kinds of technologies that the public would be familiar with?

Hari: I would say … experiments in my lab … what we're doing with atomic manipulation has mainly resulted in fundamental discoveries. However, it may be surprising to most people to know that a few of those fundamental discoveries -- fundamental quantum mechanics discoveries -- have become patents. For example, doing something practical and transferring information … I would say that they haven't directly affected the public yet in terms of a working device …

Judy: Larger scale …

Hari: Right, larger scale … but the patents have gone into contracts with in the U.S., definitely, so they have been … and certainly they do deal with technologies that … technologies, computations for the future.

… I would say that, related to what's going on in this conference, it's not as if everything is 'pie in the sky' 30, 40, 50 years out. A closely related component of quantum information is called quantum encryption and that's a vibrant technology … it has really been blossoming in the last decade. For example, the phone company is investing in this technology and you can go out and buy some pieces of hardware and … that can transmit photons that will enable communications, quantum encrypt … so it's been demonstrated in the lab … satellite transmissions …

Judy: Like wireless stuff …

Hari: Exactly. So this is real technology … a lot of people are interested in its promise and the power it brings for making a kind of communication that nobody could eavesdrop on … as you know, this is surveillance … justified or not justified …

Judy: Well, there's a lot of this in the news right now in the United States, right, with Bush?

Hari: So a lot of governments are interested in this technology because they're worried about it, right?

Judy: Is this how you're involved in … you had to go to Ottawa, right?

Hari: PiTP or Supreme Court?

Judy: Supreme Court.

Hari: My involvement in that …

Judy: … is through PiTP?

Hari: Is probably through PiTP and also because I have some existing collaborations with some of the people … like Philip … and he had heard me talk and … wanted to get some people together who could talk at a basic level to the public or to the Supreme Court Justice and explain some of the ramifications … I never answered your questions about legal stuff …

Judy: Right.

Hari: I talked about general impact on the public but … so legal stuff …

Judy: You're talked about security …

Hari: First thing I would think of is 'patent', private law … intellectual property … the Supreme Court is very concerned about this.

Judy: You were also saying about eavesdropping …

Hari: Eavesdropping … yeah.

Judy: So what's going on with that anyways? You only had to go to the Supreme Court once?

Hari: Right. We had one meeting but there were some e-mail meetings and drafting some materials that went to the Supreme Court … so we had one meeting and met few of the Supreme Justices and the Chief Justice … a Sub-Committee was formed, which I'm on with … and our next mission is to have a bigger conference where we combine scientists with people in the legal profession.

So the Supreme Court … actually, it's quite interesting … the Supreme Court was taking quite an active role in educating themselves … and this is one component of that … trying to look into the future, looking at what can come out of this, just looking at what is going on in this field …

Judy: You can at a basic level but it's very hard to predict, right?

Hari: That's right. So at least they have some background information on what is real from the scientists, possibly legal implications …

Judy: It's interesting how seriously they're taking this, right?

Hari: Right.

Judy: How do you see the momentum of quantum nanoscience? Do you see greater interest, greater developments in the future? How long have you been involved in this area?

Hari: I would say, in many ways, since …

Judy: Or kept an eye on what's going on … ?

Hari: Since starting with research as an undergraduate, somehow connected, but progressively more … maybe in the last 5 … 8 years, doing these really small-scale manipulations.

As far as momentum goes, I would say that this … I could give you one example for … so when I went to school … high school … atoms were still abstract so in my lifetime tools were invented to see the atoms and manipulate them and so in my lifetime, we've gone from that abstract concept to doing this in the lab and seeing atoms … which is mind-blowing to me. And the same with quantum mechanics … quantum mechanics is very abstract, it's really very hard to understand. Now we've got these textbook pictures of what quantum mechanics look like, things you've read about … almost see them, touch them … these abstract concepts. So …

I talked at lunch to many people today … if they looked back in just the last few years, what has … the momentum …

Judy: The changes …

Hari: So it all bodes very well for … discoveries in the next decade, at least.

Judy: And I think that when people work on their area of research and they're not sure what's going on in other areas close to theirs, they come to this conference and they see all these discoveries -- like yours -- and then people are really surprised at the …

Hari: Right. A few people have said to me, "I had no idea you could do this at this level of manipulation, get this kind of resolution" and so forth, and I see these kinds of talks in a slightly different field but still related to quantum mechanics … and it's amazing, the control and the measurements that we have of nature and, actually, going after some technology …

Judy: It seems so much more accessible.

Hari: Right. In Australia, there's this big effort that's technology-driven to build computers … it's technology-driven but here's a lot of basic science that's come along the way … in the U.S., we operate a little differently … we don't have a big effort to say, "We're going to build a quantum computer" … that's not really as cohesive an effort, which stands in contrast to how things are operating here.

The conference was nice in that it brought together these different approaches.

Judy: So you're saying it's very competitive in the U.S. … different organizations working on …?

Hari: Well, it's more … in a way it's … I don't know if competitive is the best word … it's more of a 'distributed' network that's not very correlated and there's smaller groups … not as cohesive groups … going after one big challenge. Maybe that's compound by … we have a lot more funding agencies that distribute funding for doing research *versus* here, for example.

Part of it is, maybe, cultural, too. There is more hierarchy in Asian countries in the way research is done.

Judy: But do you think people in the United States, say working on a similar project, want to talk to each other about their discoveries or …

Hari: Definitely. Yes. It's critical to have …

Judy: Really. That's why I said competition because I didn't think that …

Hari: I don't think that's a problem, in fact, I think it's critical to progress, having conferences and talking so … it's not competitive in that sense. Just a different

Judy: My mistake …

Michelle Simmons (14:50 mins interview -- 2:00 hrs transcription)

Judy: So what's so significant about this conference to you? Is this the first quantum nanoscience conference that you've been to?

Michelle: It is, yeah. I guess the number one significance other than overseas speakers coming over here … there are really good speakers, and I guess in Australia it's good to get a lot of really good speakers to go to one conference … and I guess a lot of it is related to quantum computation …

Judy: So are you an experimentalist?

Michelle: Yes.

Judy: Asking people what they is basic to understanding where they take this information, what they do with it … because people that are doing theory aren't going to have end-products in the near future, right?

What do you think the public should know about this conference? You don't see it at that level? You're seeing it mainly for the scientific community? For physicists?

Michelle: I think primarily … the talks are quite specialized.

There was a nanotechnology conference last year in Perth, and there they asked a lot of ethical questions … but also their topics are very broad so that's …

Judy: So I'm supposed to educate the public … what's important about you and the others at this conference are working on. Why should the public be interested in this? Not specifically about your research because people … I mean, the general public wouldn't understand it, right?

Michelle: I don't know. I think that … I guess a lot of people are using electronic devices -- camcorders, tvs, games -- everything is getting faster and for that to get faster, the technology has to be improving all the time. So the area I'm working is, an experimentalist, is to get the technology to improve … the conference is about quantum nanoscience, I guess we're at the point now where the devices we're making … to use electronically, is getting to the point where it's crossing over to quantum and it's happening now, so … and the devices being made is actually in the quantum regime but are still being used for commercial devices.

Judy: Right. In your talk yesterday … you were talking about using silicon … everybody knows about Silicon Valley and the use of silicon … what's so significant about silicon?

Michelle: Many things, but I guess the most important thing is that you can control the way it conducts electricity and you can control it very, very accurately. They discovered that back in the 50s and since that time a lot of effort and money has gone into how well they can do that … that's really all transistors are and transistors are what make up every electronic device. So for 50 years, they've been using one material, understanding it … all its properties, how it reacts if you put it in sunlight, if you drop it in water what's going to happen to it … and even now, as they make devices smaller and small, material properties change … if they change, can we actually use those changes and still have devices getting smaller, can computers still be faster and …

Judy: And can you still use silicon?

Michelle: Well, that's the big question. The big question at the moment from people out there … they say electronics industry is … hitting a brick wall … but I think silicon is coming to the end of its life and so they're starting to look for other things … different materials. This material which we've been looking at for 50 years is suddenly not going to be good enough when we go very small, all of its properties change, we're not going to be able to use it. And the question is at the moment is – is that true or not? So, I guess, the research that we do is …

Judy: … questioning that …

Michelle: Yeah, answering that question and … I guess, probably, about 10 years ago they were saying, "We've got to go elsewhere." So all this other research started in other materials and some people still believe that silicon can still go a further 10, 20 years before it …

Judy: That's not much longer, though.

Michelle: It's not, it's not. And the reason why, though, is the next 10 to 20 years it keeps … have you heard of Moore's Law?

Judy: Yeah. Exponentially, right?

Michelle: Yeah. It's only 10-15 years before we get to the level of single atoms and then you get beyond the material problems so you have to come up with some way of having many electron systems where you're controlling, essentially … not the amplitude where the atom is, but the phase of … quantum computation comes in. You get away from magnitude and go to phase.

Judy: So what alternatives are there? For silicon?

Michelle: I guess organic systems is one thing that people are looking at and it really comes down to the fact that they are now looking at molecules that have lots of bonding states and they're using the bonding states rather than the single atoms to control … it's really getting … fundamental chemistry. There are people using DNA to interconnect between two circuits and DNA is also very, very thin and self-replicates and … the idea would be to make circuits build …

Judy: It's very exciting, isn't it?

Michelle: Yeah, it is.

Judy: I mean, I can see it from the way you're talking about it but also, just by these changes. People on the outside don't know what's going on at this conference and they don't understand that what affects them starts at this level, you know?

Michelle: Yeah. I think … in Australia, they do pretty well in terms of … they publicize a lot of scientific results as they come through. If you look in the newspapers, there's a high proportion of reports about scientific … medical or scientific … I think it's higher here than in most countries.

Judy: Oh really.

Michelle: Yeah. So the Australian public … they did a poll and someone asked them, "Are you interested in Science?" Something like 70% answered, "Yes."

Judy: Oh. Interesting.

Michelle: … which is quite high … and in other countries, I think it was more like, between 30 and 50%.

Judy: So some of the work that you've done, what results have you seen that the public would know about?

Michelle: From what I've personally done? They wouldn't know …

Judy: What about in your group or in your field …?

Michelle: In the field, I guess … certainly Australia … they've been made aware of this quest to build a quantum computer and the idea that if you build one it can be much faster for certain problems … I think, to some degree, people will be aware that we're manipulating single atoms … there's been quite a lot of press coverage on that, but the implications of what that all means and really understanding it is still missing … people working on quantum computation … if you could do it, that would be great … such a difficult problem, people working on it … if you could make one what would it do?

Judy: Right.

Michelle: There's also that question. There are a lot of questions out there.

Judy: So you're happy with how the conference is going so far?

Michelle: Oh yeah.

Judy: People you've seen, bring this group together … ?

Michelle: Oh yeah. Fantastic.

Judy: So how have you seen the growth of quantum nanoscience or nanoscience in the last 10 years?

Michelle: I guess … it's been quite a dramatic change I think. If you looked … like 100 years ago, people were working in particular subject areas but they've actually crossed over a lot of areas … you could call someone a physicist, but he was really doing a lot of chemistry … and then it kind of really spread out … a physicist was really a physicist, a chemist was really a chemist, and they didn't really talk to each other. I would say that in the last 10 years, because everything is getting to the same size scale (indicates with her fingers a very small size), everyone is working at same size scale, they now … not having to talk to each other but they're finding that they actually understand more about what each other does.

Judy: More interdisciplinary, more collaboration … ?

Michelle: Yeah, but it's kind of naturally happened. To some degree, people are trying to force it but …

Judy: It's just the shared area …

Michelle: Well, for me … for me it's interesting. We're an experimental group and we've worked very strongly with the theoretical group … when we first started 5 years ago, we use to have meetings and we would literally sit there and we would tell them about our experimental problems and they would tell us about their theoretical problems and …

Judy: There's no connection?

Michelle: Yeah. And we'd go away thinking, "Why are we having these meetings? … What are we getting out of them?" But, ultimately, we knew that we both had problems that we couldn't solve and it was because we didn't understand each other. It took 3 years before we got to a point where we could actually communicate.

Judy: What changed that?

Michelle: This is fascinating. It was a person. It was a person that was a chemist. He moved to the physics department. He was sitting in the Physics Department and he was talking in his language to them, and they were talking in their language to him … I guess, out of frustration, he said, "I can do this, this and this … and I think this relates to you by this …" and he, basically, being in a different environment … and then they talked to him and people around him started to understand him a bit then that communicated … in the Physics theory group and they communicated to the experimentalists and … it really opened the door.

Judy: That's fantastic. That's amazing … 'cause that's just a fluke, too, that that happened?

Michelle: Well … actually, no, not really a fluke because we had been trying all the time to hire in chemists …

I did a double degree physics and chemistry. When I would go from the Chemistry labs to the Physics labs, and they found out that I was doing a double degree … there's a hierarchy … there's a psychological barrier that you have to get through … so when you advertise a position and you try to get a chemist to come … I guess it takes particular pairing …

Judy: I've always seen interdisciplinary as beneficial … in the past, what I've seen at UBC is that they like you to specialize in one thing -- they don't like you to do double degrees -- but I think that helps connect different areas, right?

Michelle: It does, yeah.

Judy: So you're happy with the conference … you've been really busy meeting with people … so you think you've more than met your objective with the conference?

Michelle: I think everybody comes with pre-conceptions … one reason I like about presenting … is that you get to tell people what you're doing, which is great … and then, for me, if just one person comes and talks to you afterwards, then tat has made it worthwhile.

It's more than met any expectations I had.

Judy: Fantastic. So how involved are you with PiTP?

Michelle: At the moment, not. I have this proposal that they're obviously trying to get through to get more funding … they're looking to collaborate with groups across the world … and they've contacted me through Gerard, probably about 6 months ago … and I've been watching that group and, I guess, they've been watching what we've been doing and I hope, in the future, that will grow. In terms of … theoretically, a lot of the stuff we're doing, I'm sure … it's a good opportunity, collaboration.

Fei Zhou (9:21 mins interview -- 0.75 hrs transcription)

Judy: So have you been happy with the conference so far?

Fei: Very much so. I think this is one of the most interesting conferences.

Judy: Really. Why?

Fei: The location is interesting, first of all. Second of all, having all these experts … coming together and talking about things we're all interested in … that's very good.

Judy: So since grad school, have you seen a lot of advances in the field? Is nanoscience a big part of your research?

Fei: It has completely changed. There have been a lot of revolutions … if you compare it with 5 years ago … it has changed very rapidly.

Judy: Have you met some people that you haven't met before that you wanted to talk to?

Fei: Yeah, sure.

Judy: So my role is to write articles for the public in various journals, like a basic scientific journal.

(gap in recording)

Fei: … with the technology that was never available before. Cooling technology can bring the temperature all the way down to 10 nanocaron (?), 20 nanocaron (?) and this offers great opportunities. I think that nobody would have dreamed of doing this kind of thing 10 years ago or 15 years ago. And now there are … hundreds of groups able to do that. It's suddenly a great opportunity in this field.

The other thing is, what people are doing here, they are exploring very, very fundamental aspects of quantum theories for matter and the impact of this research is not only our understanding of atoms, but also the impact definitely goes beyond the physical system it can have a whole … this is a very unique field … there are very few fields can have, by starting those systems, but people can learn something not only the systems themselves, but something more fundamental. This is one of it. It can really have an impact on nuclear physics, elementary particle physics, string theory, cosmology. This is what I think. I think the impact of research can go far beyond the subject itself.

Judy: So what is so important about your area of specialization?

Fei: Let me summarize, for you, in a few sentences. One thing is we … I think a physicist … if you start with elementary building blocks, and you understand each building block, but the way you put them together … just like you build a house … you have bricks but when you put them together you get all different architectures … and this is one of the similar issues here. When you put them together, what are you going to end up with? What are you going to build on top of it? What kind of matter are you going to end up with? These are very fundamental questions. Technology-wise, there are a lot of applications of this kind of research … this is one of the themes of this conference … quantum information … one of the motivations to start … apart from the motivation to understand the basic aspects of this ? systems is by understanding this ? systems … we are actually able to use resources, these quantum state resources … resources can be used to process information and store information and this is not completely far-fetched because people already know how to make atom entanglement using optical lattices … becoming standard technology now. At least about 10 groups are able to do that.

Judy: So that's part of the importance for the public to understand that, too … you're saying standard technology is based on a lot of this research.

Fei: That's right, that's right. The fundamental science, just like the history … contribute to the technology. In this case, the process information in quantum … will process exponentially faster than the classical way. Most of the research has a fundamental value … in this case, by understanding ? physics itself, one can understand something beyond this domain itself. The other thing is the application. That's very important. It's important that the scientific society can make contributions to the whole society.

Judy: Well, I think that society … a lot of their functions are based on the laptop, right? People need laptops, cell phones, PDAs, and all this is based on the scientific research.

Fei: To transform the basic knowledge into science and technology. I don't think that anyone can say that we skip this state and go into that …

Judy: No, no … because you have to test everything, too, right?

Fei: That's right. Everything has to be done in the lab before anything is sent to the manufacturer.

What we're doing is at the very beginning stage, baby stage. It's very promising in the sense that …

Judy: Because you're a theorist, right?

Fei: I'm a theorist but I'm also saying this technology experimentalists are using and they are just starting to explore all the new systems and that's very exciting because there's a lot more ahead of us … compared with other fields which have been started for 20, 30 years and people think that they more-or-less understand everything and we understand more-or-less the applications. Probably it's the time for us to leave/lead (?) those areas to industry and research and further transform scientific results … I think it takes a few decades to reach the stage where we can say, "Wow. That's probably more-or-less what we want to do." Let's move ahead and leave this chunk of knowledge to people who …

Judy: Right. So it's at a very early stage …

Fei: That’s right. This is why this is called *Frontiers* … *Frontiers of Nanoscience* is really, really new stuff in different fields.

It’s quite amazing. These people … this conference has people working in solid-state systems, superconductor, semiconductor, people work with QED … this special … quantum optics … very, very different systems. People here actually belong to different fields.

Judy: I know. Somebody here said … somebody who is just on the margins of working in quantum nanoscience … said to me that a lot of these talks are inaccessible for him and I hadn’t realized just how diverse these areas are until he said that to me.

George Sawatsky (23:29 mins interview -- 3:25 hrs transcription)

Judy: I was looking at designer molecules and designer quantum materials. How is nanoscience involved in the reduction/creation of these molecules?

George: I guess nanoscience itself … molecular science and molecules … even macromolecules … have been around for many, many years and people have been doing research on them for many, many years but the interest is actually now in using them in a completely different context than one ordinarily did at that time … so really using them as functional elements and devices and tings of that kind, and that has really increased the activity and the interest in making some designer molecules, like these magnetic molecules, which there really was no interest in before … or, actually, even if one could make them what would you do with them? So I think that has really changed an awful lot, the field of macro, molecular, synthetic, organic, and organometallic chemistry.

In the materials, the same thing is happening now. So the thing I was talking about is in nanostructuring things … you can get materials, properties … to exhibit properties, which you simply wouldn't get in any other way. That is starting to catch on now so people are really trying to concentrate on designer materials. Of course, that designer aspect of it really doesn't work because, generally, one is dealing with this many-body problem which one can't solve anyways so whatever theory one has done is very approximate … and that means that you will still be meeting up with lots of surprises … things won't work the way you expected them to, but maybe they'll work in a different way, which is exciting.

Judy: Right … are you a theorist?

George: I do a lot of theory … my research group is 50% theory, 50% experimental. But the theory we do is directly related to the kind of experiments …

Judy: Experiments that you're doing … right. Okay.

What do you think is significant about this conference?

George: I thought it was … it's really interesting to get together such a wide diverse group of people with, obviously, very, very high levels of expertise in both … the materials aspects of things, the theoretical, the abstract theoretical, the more down-to-earth applied theoretical, the computational … quantum computing theoretical work … information theory … Vidal's stuff, for example, the chemists … and out of all that … and talks which are given at a level which are understandable by a wide group of people also, so the talks are very good.

When people go to a conference like this which is so broad, they generally will fix up their talks to match the public or …

Judy: The audience?

George: … the audience that they're talking to and I think they're doing a very good job of doing it … that makes it possible, then, to actually understand each other and actually, perhaps, create some collaborations and some … a lot of people were continually saying as to how … many people … as to how they have really learned an awful lot from this meeting and a lot of stuff that could be very useful next … research program.

Judy: So did you have research goals when you came to this conference? Or goals for projects…?

George: Certainly … and goals that have to do with these new materials that we are interested in and in hoping to find people to actually go ahead and do some other kinds of measurements, like transport properties and things like that … we generally don't do. But, also, the theoretical people to see where there is of something that might be of interest … Soucheng Zhang gave this talk in which he wanted to have a material which a particular band-structure … it had to be ferromagnetic, it had to be an insulator, and it had to have bands which are overlapping in a particular way … and, just coincidentally … so I thought about that and I found several possible … it's very difficult to find a material like that, but there are actually some possibilities now with nanotechnology … like you could perhaps make materials that could do that.

Judy: I think conferences like these are wonderful to bring people together and help each other, like this is what has happened with you and Soucheng.

So I'm the intermediary between scientists and educating the public. What do you think the public should know about nanoscience and/or what is happening at the conference? What is significant about this to the public?

George: That's a big more difficult, I guess, because virtually everything that is being talked about at this meeting is really quite far-removed, as yet, from an application. One may find an application here and there but it will probably be more serendipity than anything else. So, at this stage, one is setting out a completely new way of doing science which involves this large diversity of people that interact, each with their own specialties, that are willing to listen to each other and interact and that, I think, is the only way nanoscience will become to a stage where it will be useful for applications.

I think that's an important thing for the public to realize that the very abstract theoretical physicist and mathematician is interacting with a synthetic organic chemist … that's quite extraordinary and I can hardly imagine that not being fruitful.

And the quantum computing aspect of if, of course, is a fascinating thing and I think that the public should know about the possibilities as to what might, in principle, be able with quantum computing. But also about the absolutely phenomenal challenges that one has in order to get there and it will all be, in the end … it'll be nanoscience and nanotechnology we will need in order to get there but we're nowhere near to having something which is even close to working.

Judy: There are so many possibilities but far off …

George: There are so many challenges because there's this decoherence … the big problem then to … one now suddenly realizes that there's all kinds of imperfections in the material choices, and so on and so forth.

Judy: So it's at an early stage now and there's so much to explore still.

George: But one is meeting so conceptually … I think quite a number of people thought that this might not be too difficult a problem but one is meeting up with the real materials challenges, which are horrendous. They require a purity and a perfection which is way, way beyond what …

Judy: I was talking to Michelle Simmons yesterday about silicon and the life of it.

George: Right. There are severe challenges there also with phosphorous and silicon … I can hardly imagine that idea will ever work simply because of the materials challenges, which is how you ever make it in a way which is controllable … and without interactions in between the phosphorous … or controllable interactions, so they have to be far apart so they don't interact in the first place. It's a real difficult problem.

Somebody else mentioned about the dielectric that one uses in these electronic devices … that those are usually what one uses … very bad materials because one is usually isn't worried about that for ordinary transistors or devices and that, now, is turning out to be a real big challenge … one thing he has learned, John Martinis … so he wants to go to single crystals but I showed him how careful you have to be with single crystals because it depends on what particular surface and what particular interface you're going to make. People, generally, don't realize that so …

Judy: It's so important that these different people come together and help point out possible downfalls.

George: It's a different way of operation than … I've been involved with material science activities for a long time and material science centres now in the last 10 years have been trying to make material scientists out of people. In other words, take a physicist, a chemist, a theoretician, and so on and try and get them all to become experts, or at least know something about all of these different areas, and then each one will then be a materials scientist. The difficulty with that is that they won't be very good -- they'll be 'jack of all trades, master of none.' And what's being done here is really quite different from that, right?

Judy: Because you specialize …

George: You keep your specialty, you're at the top of your field, you're suppose to stay at the top of your field, and then try to link things together … which is a much more intellectual way of operating.

Judy: What about someone like Michelle Simmons who has a background in both chemistry and physics?

George: Sure. I think that her background … there are people that have backgrounds that are on borderlines of fields … it depends on where you are. Sometimes a physical chemist in one university would be a physicist in a different university anyway, so there are areas of research and expertise that actually overlap an awful lot.

She is … as a semiconductor, physicist, a chemist … but a physical chemist or an inorganic chemist … those tings can be very close together. So, that's fine. To be a synthetic organic chemist and at the same time be a device-oriented physicist … that's a real challenge so I don't think that's possible to do, to have both of those at a very high level in one person.

Judy: That's good to clarify that. So are you involved in the Supreme Court …

George: Yes. I will go there and see what happens.

Judy: Oh, so you haven't been to Ottawa yet for any meetings?

George: No. I wasn't able to go to that first meeting, so Jeff Young replaced me.

Judy: What are the social and legal implications? What do you see as problematic with nanoscience?

George: There are several things. First of all, there is the unknown. There's always the unknown, so if you're dealing with new materials, with new molecules, and so on and so forth, which haven't been properly tested for toxicity … things of that kind … one always worries about that and one should. However, I would say that one of the most important … unless we go into the problem of the nanobugs and things of this kind … actually making devices which are invisible and which could infringe on your privacy and things of this kind … those are, of course, important issues. The difficulty right now is that people that don't know anything about it or the technological challenges in doing things like that are simply frightened and one has to do something about that. So that's an ethics challenge in itself, is to make sure that there is enough trust within the public that we can go ahead and carry on with the research in the nanotechnology.

So these bugs are a problem … drug delivery … those are the kinds of things which one, of course, has to worry about.

Other … we've been surrounded by nanoscale objects and particles, and so on, forever. All the aerosols and things like that which we know are dangerous … that's why we're stopping a lot of them … or paints. Now one uses titanium dioxide particles … but they've always been used in paints … nanoparticles with titanium dioxide. We've been surrounded by nanoparticles and things … the buckyball and the carbon-nano tube is not something that wasn't around before. As a matter of fact, the buckyball is sort of 10% of the product of the soot from a burning candle and that has always been around. So it's not new and these things have not really created a huge problem. It's when we start … just like in biology and in genetic engineering and things like that … if you start manipulating something then you have the chance of producing something which you don't actually know what it's properties are going to be. That again goes back to this problem of not really being able to predict properties to any reasonable degree of accuracy. What we can do is when we really

Boris Spivak (23:77 mins interview -- 0.75 hrs transcription)

Judy: Are you happy with the conference so far?

Boris: Sure. I think it's a good conference.

Judy: Why do you think it's a good conference?

Boris: Good people, interesting subjects.

Judy: Have you been to a quantum nanoscience conference before?

Boris: Sure. A lot of times.

Judy: How do you see the progress in research that's happened in quantum nanoscience in … how long have you been interested in this area?

Boris: Infinity …

Judy: Okay. So you've seen a lot of changes?

Boris: There's a constant progress in the field.

Judy: Right. But has it increased?

Boris: Speed? There's a more or less constant speed. It's a healthy situation … it's developing.

Judy: But it's a fairly new field, right?

Boris: It's new work, it's not new field. I mean, it's very difficult to say … I think it depends how you define it, but I don't think that it's a new field. You know, ancient Greeks new something … it's an integral part of condensed matter. You know physics … some things are new, some things were known but developed …

Judy: But the micro-level of the research and the manipulation of the nanoscience …

Boris: Again, there are a lot of new things but to say that … again, also from which point of view … from a theoretical point of view? It's just a continuation of knowledge, which was known. There are some new fields. From a technological point view, sure there is constant progress

Judy: Are you a theoretician?

Boris: Yeah, I'm a theoretician. There is constant progress …

Judy: So what's significant about this conference compared to some of the other ones that you've been to?

Boris: I think the collection of people.

Judy: And what's so great about this group of people?

Boris: They're the best people in the field, so it's nice to bring them together. It's very simple … everything.

Judy: So did you have any goals, objectives when you came to this conference?

Boris: No, not really. I wanted to talk to people, discuss things, to update, consideration … as I said, there's constant progress so I just want to know what is going on … to exchange opinion, to discuss things. It's very typical for …

Judy: For conferences … yeah, for people to gather and share ideas.

So, as an intermediary for the public what do you think the public should know about this … because they have a distant connection to this, they have a connection to the end-product which is technology … which is far down the road from a lot of theories, right?

Boris: I think that in very general sense, if anything can be done about it -- which I am not sure -- I think the public should be informed that science is important, that interaction has its own value which cannot be measures in other currency … so it's, by itself, a value … and also that clever people can do clever things … and eventually this good idea to have a lot of them around. That's what I think.

Judy: Clever people or clever ideas?

Boris: I think clever people. It's a good idea to have clever people around, which I think is a simple idea, which doesn't get to the public.

Judy: Why should the public care about nanoscience?

Boris: I think the public should care … nanoscience is one of the aspects … astrophysics is also important, so scientists should decide which particular area to go but the general public should respect this … part of this is education but another part of this is … it has its own value.

Judy: But you don’t think your research is more important than just an esthetic value? Because you said about … this has a great value to people’s lives.

Boris: No, no, I mean that … more important than what? Look, I have a lot of friends who are architects … (Boris talks about architecture, beauty, esthetics, etc.) … it’s extremely important, the public should respect it, understand that something is going on, there are new laws of nature discovered which is once forever, so …

Judy: Okay. What is your area of specialization?

Boris: Condensed matter, solid-state theory.

Judy: And how to you apply that to quantum nanoscience?

Boris: You could say that it’s a part of theory, it’s just an integer part of theory. You’re interested in everything and particularly interested in what happens at a small scale. Theory is a subject which is universal, it covers everything. This is also a subject to be addressed … if you know theory in general …

Judy: It’s just looking at all the possibilities, right?

So, do you see any social and legal implications to your research at this level?

Boris: Mine? No, because I’m a theorist. I’m sure that experimenters do, but theory … it’s a very long from theory to something else. It may be that it has some little material, social implications but it is so far. You go from theory to experiment, to development, to applications … I never encounter this.

Judy: That's separate from you?

Boris: Look, I sometimes discuss things but it's not really … not like in biology … everyday they meet the … they encounter this question.

Philip Stamp (49:08 mins interview -- 7.00 hrs transcription)

Judy: What do you see as the significance of this particular conference?

Philip: It has both an intellectual significance and a science-politics significance. The intellectual significance is that quantum nanoscience is a very new field so people talk about nanoscience all the time … and nanotechnology. Basically, nanoscience and nanotechnology is making things smaller … much smaller. Now that's very important because the reduction of size of …

(break -- Philip received a phone call)

To finish answering that question … so this is what I like to call classical nanoscience. Not just making all these things a lot smaller, but essentially doing the same things with them … like little Lego blocks, you put them together and you make bigger things in the same way that people have been making houses out of bricks for a long time, they make very much smaller things and that's very important because if you can make them small then, first of all, they can be packed into a very tiny volume and, second, they tend to use a lot less power. And so that's why you've got a laptop here which is capable of doing …. a laptop can do about 2 billion operations per second and it can store 80 giga bytes of stuff which is … if you looked at a computer in the 50s, you would have needed the whole of downtown Toronto to store that information. And … in fact, more; you would have needed all of Toronto. Every single building would have been packed full of memory elements. And you can extrapolate that to the future let's … you can say, let's suppose that nothing dramatic happened … we just continue in this way … what will it be like in 2050? We just keep on reducing things in the same way as before? This is called Moore's Law … the size of components, electrical components and computers, just get smaller by a factor of 2 every 1½ years. Doesn't sound like much but if you just keeping halving it then … and if you did that then the entire computing power of the world right now will be in 2050 would be contained inside a sugar lump.

Judy: That's what you were saying in your …

Philip: That's right, but that's an incredible change because now people process and send information around like nobody's business … in a way that was completely unimaginable before. That's why we have that global village. But it's all built on exactly the same principles as before, its just smaller and faster. That's all.

Judy: And a lot of people don't remember what laptops looked like 10 years ago.

Philip: Well, they didn't exist.

Judy: Right … or like cell phones or cordless phones. They were huge.

Philip: Right, but a phone is very unsophisticated. The thing they use to have 15 years ago, all it could do was relay your voice messages which have very low information per second … so it's really simple, but a cell phone now is basically a miniature computer

Judy: And we've got the PDAs which are the same thing.

Philip: And this is nothing compared to what they send into orbit. A communications satellite now is capable of relaying hundreds of millions of conversations at one time whereas when I was a kid you had to book a Trans-Atlantic call a day in advance and they could only do a few thousand at any one time. Now, not only could everybody in the world be phoning each other all at once now with no problems, the computer traffic … every time you send a file, you're sending … you send a file … these things now work at 100 megabytes per second. One hundred megabytes is the equivalent of several months of phone conversation, all at once.

Judy: Everything is speeded up and miniaturized, right?

Philip: But otherwise, it's exactly the same principles. Quantum nanoscience, in that respect, is utterly different because it works according to the rules of quantum mechanics which are totally different and so it's not … the fact that it's small is important because of the exact same reason as before because we can put a huge amount into a small space. It because it works according to the rules of quantum mechanics and that's crucial … so intellectually, that's what this conference is all about. The actual applications are very far in the future … so intellectually that's what's important Now the science-politics, that's completely different. That's all to do with the construction of this large supercentre involving, basically … it's called the Centre for Quantum Structures and Devices and is supposed to involve Australia, Stanford, Tokyo, and various other people. It's been built on the structure laid out by PiTP. PiTP is already an international institute and the much larger thing has been built on top of that, so this is really a conference in which this whole idea of these international networks set up by PiTP has been brought alive … and that's what allows this … it's the structure of PiTP that's allowing these research collaborations in this new field to get going and PiTP has been doing that for lots of different research fields in the last couple of years. Here there's something extra which is the possibility of something much larger … the centre being put together, so that's the background of science politics.

Judy: And how does the University of Queensland fit in?

Philip: It's one of the Australian partners.

Judy: So what are the goals of this conference? Is this the first time PiTP -- the nanoscience part of PiTP – has met up?

Philip: No, there's been other conferences in various areas of nanoscience run by PiTP. There's … actually, every year we have one on magnetic molecules so … George Christou is very much involved in that, Walter Hardy and George Sawatsky, various other people …

Judy: So what's different about this particular conference?

Philip: Magnetic molecules is a much smaller-scale thing, it's very focused on one area. And there are people that do magnetic molecules here. It's part of quantum nanoscience.

Judy: So this is a broader …

Philip: Yeah. And different people in quantum nanoscience are working in different 'points of attack', if you like, developing different things. A field doesn't just do one thing at a time … trying to do all sort of things and …

Judy: So is this informative to the group?

Philip: Yeah. It's very important to have a conference like this because different people working on different areas of investigation in quantum nanoscience get to hear what everybody else is doing, it gives them ideas, in some cases collaborations get started … you know all sorts of things that wouldn't have happened otherwise get going.

So you say, "What's supposed to come out of this conference?" I imagine lots of different, interesting ideas will come out of it and also research collaborations will be generated. And, as I said, it's kind of cementing the role of Australia in all of this.

Judy: What do you want the general public to know about this? And what do you want the scientific community to know about this?

Philip: Right. Well, the general public probably knows very little about quantum mechanics. They've heard about nanoscience and nanoscience has generated all sorts of scares because people talk about nanobots and all sorts of nasty things going into human body invisibly, they talk about eavesdropping going on by objects that you can't even see, and so on so there's all sorts of nasty possibilities that people have imagined. You can't just dismiss them. Certainly, in the future it will be possible to have listening devices that are extremely small. Everyone should worry about that, but that's really got nothing to do with this conference which is looking at a new scientific idea. So any technology that comes out of this … who knows what that will be … is many, many years down the line. We probably won't see it. So, the challenge of all this is really scientific … it's understanding how quantum mechanics can lead to extraordinary behaviour, involving many different things working together, even on our own scale which involves some very strange philosophical paradoxes as well, some of them which we don't know the answers to. So I would say that for the scientists here, the excitement is in that; but for the general public I would say that this is really looking at something with very important scientific implications, but also very interesting philosophical ones because it's really taking quantum mechanics, which is a description of nature which makes no sense from the common sense point of view, and it's pushing it up into the microscopic realm that we live in so it's very, very interesting from that point of view.

Judy: So for scientists outside of this group here today, what do you want them to know about this conference?

Philip: Well, there will be scientists whose interests are quite direct and, ultimately, they can study stuff coming out of here by looking at the conference webpage where the talks will be there for them to look at … and also papers that people write … but I guess people who aren't here, scientists, will think, "Oh. That's interesting … the whole idea of a quantum nanoscience … it's organizing different activities under one heading and the implications that there's some set of methods, or ideas or vision that is animating everybody which they hadn't thought about before.

Judy: How did the UBC Physics Department feel about the start-up of PiTP?

Philip: The Physics Department at UBC didn't really have too much to do PiTP. It was set-up by UBC, not by the Physics Department. In fact, it was set-up by the Administration of UBC. It had an impact on the Physics Department in that it meant the hiring of a whole bunch of theorists at UBC … probably most people think that's a good thing, particularly since the theorists they hired aren't very good. In the long run, of course, it can only benefit the Physics Department because there's this huge amount of activity that has all of a sudden focusing on UBC so there's an enormous number of interesting visitors, very well known physicists …

Judy: I just wanted to know how the Physics Department was affected because it [PiTP] is in the Physics Building.

Philip: Right now we have these small temporary corners, but ultimately there will be a building for PiTP. It's an independent institute, basically.

Judy: So what's important about magnetic spin qubits and solid state qubits?

Philip: Well, magnetic qubits are one kind of solid-state qubit. You've also got superconducting qubits, there's atom traps and cavities … lots of different design for qubits. And each of them has their advantages and disadvantages … People working in each field are trying to get over the problems and occasionally they have amazing ideas which change that we look at that possibility …

Judy: So what are the applications for your research …?

Philip: Let me just answer that question first. So spin qubits, the advantages that … they don't involve moving electrons around causes dissipation of heat, which is a bad thing. The biggest problem right now in your laptop is the heat it generates. All these operations that generate heat … if you tried to make it work too fast, it would melt. If you move spins around, they don't have to generate heat at all. So that's a good thing. Then, the other interesting advantage is that you can make spin qubits very, very small. You can make them the size of an atom or even the size of a nucleus … that's extremely small. And not only is it very small, but every atom is the same. Any hydrogen atom here is the same as any hydrogen atom in the universe. That's terribly important because when you make these devices, you want them all to be the same; you want everything to be exactly the way it's supposed to be. The problem is that when you make something out of larger components like superconducting squid cubits … I mean, these things have to be made using nanofabrication methods and no two one of them are alike. They're all slightly different from each other and they're also … they all have bits of junk in them … you can never make the process perfect. But a molecule is made by chemistry, it's made by quantum mechanics -- every molecule is the same. If I took a molecule sugar here, it's exactly the same as a molecule of sugar anywhere else in the universe. So, if you make a spin qubit out of a magnetic molecule then you have (1) reliable fabrication, because they're all the same and they're all perfect; and (2) you have spins, which don't generate electric currents which means no heat generated. So even if it's not a quantum qubit thing, it's still much better. And then there are other advantages of having spins for qubits, but … the thing about superconducting qubits is because they're a lot bigger, it's a lot easier to see what they're doing and that's why the first qubit functioning systems have been made with superconductors or with atom/ion traps which are also very easy to see what they're doing. These spin magnetic molecules and so forth, they're so small that we can't actually see what they're doing there. Within a few years we will be able to … I don't think it will be

Judy: The other question was … the applications of your research.

Philip: My research? I'm a theorist so … theorists tend to be a long way from applications. The way it works is that the theorists try to do general stuff … creative or imaginative ideas … things they want to do and an experimental physicist tries to turn these ideas into something real.

Judy: So who's working with your ideas?

Philip: Lots of people. One of the things I do is I try to understand what causes decoherence, which is something that tends to ruin … lots of experimentalists have checked that out. I guess Morello here and Christou has been involved in that and there's a whole bunch of people in France and …

Judy: And what are the applications to some of the theories that experimentalists have …

Philip: Ah. Typically what the experimentalists do … they play a number of roles. They could be checking out the theory which helps because once you understand how things work then you can go on to design better things or they do something which they find more exciting which is that they discover new things which they were not expecting before … and that happens also. And it's the job of theorists to clean-up afterward.

Judy: So what has been created from some of your theories? Because there are all these presentations about people's research, whether it's their theories or their actual experiments.

Philip: I think that work that I did in the 90s on the dynamics of spin qubits and how that's controlled by all sorts of things -- nuclear spins and photons and so forth -- was really important in helping experimentalists in knowing what experiments to do and to then … it's really opened up the experimental field because people knew what to look for, using the theory, and found it. The whole business of the way nuclear spins control the way … spin qubits, most experimentalists fund that completely bizarre when we proposed the theory but now that's been completely established and, if you like, that's the starting point for new designs. So now instead of being … these nuclear spins , people think we can use them and make a new design which involves nuclear spins. In fact, the idea of making a quantum computer from nuclear spins is now a serious idea. People have thought of putting the quantum information into nuclear spins … electronic spins and let the nuclear spins do their little dance and then afterwards taking them out again. Maybe that will happen? So, I guess, the theory of all that, initially, it was most experimentalists found that they couldn't believe that it was true but now it's an essential tool.

Judy: So what are some of the …

(interruption)

Judy: What else do you want me to ask you?
What's important about your area of specialization?

Philip: Let's think … well, for me what's important about it is these questions of raising quantum mechanics up and doing it on big objects kind of raise deep problems, philosophical problems about how it's possible for a field like quantum mechanics to work at our scale because, after all, it makes no sense at all to imagine entanglement at our scale. No one has ever been able to figure out an answer to that, so if you can't figure out an answer with pure thought the next best thing is to try and push it around and see what happens so you apply quantum mechanics on a large scale and you work out how systems should behave, you see if they do and then … it's like you're given a puzzle and you mess around with it until something happens and you hope that you'll get some insight. And at the same time, by doing this you're actually, in the end, creating new technologies and so forth … but that's not for me … of course, if I asked for money from somebody I'll tell them how wonderful the applications are; that's because that's what you're supposed to say. But it's the intellectual depth that is interesting, for me.

Another question that I was asked by the TV people was, "What about the social implications of nanoscience?"

Again, social implications of present nanoscience are going to be huge, even though it's just the same thing but smaller, and you can discern several problems. There's a problem of invasion of privacy, the fact that this could give organizations the capability of spying on almost anybody …

Judy: [President] Bush?

Philip: In the future, one can imagine, in principle, miniscule cameras which are invisible to the eye which are transmitting information to somewhere. You can imagine a room full of them and nobody would know.

Judy: Do you want to talk about the Supreme Court issues?

Philip: Not particularly.

… privacy and so forth. And then there's health … people see nanotechnology as either the 'good genie' or the 'bad genie'. Here, they can imagine unbelievable advances in healthcare because you can imagine eliminating a cancer, for example, in the most direct way by sending in nanoprobes which attack only those cancer cells. They go in and they pinpoint them and they take them out. And that such things have actually been demonstrated in research labs that you can target individual cancerous cells with, essentially … this is with nanodrug delivery, basically, and one can imagine getting rid of genetic defects in the same way. It's extraordinary what one can imagine. One can imagine growing neural networks, networks of neurons on nanocircuitry, thereby providing direct interface between neural tissue -- the brain -- and some electronic gizmo. This is the *Star Trek* … the Borg sort of idea. A competent machine in a living organism. The ideas are there and the beginnings of the actual devices … although we're a long way off from doing that … people get worried because they see that on the one hand this could be incredibly beneficial to humans … I mean, it could completely change everything, really, but on the other hand it could be misused very badly. Someone misusing that could do untold damage.

So that's the healthcare side of the … so we've covered the privacy and the healthcare, and I guess people like to worry about things like security and so on. They worry that if these things got in the hands of … of course, nowadays everyone likes to worry about terrorism. If you actually think about it … it's hard to distinguish terrorism on the part of individuals from terrorism on the part of organizations. And who's to say whether a government organization is good or bad. And so people worry a lot about how organizations or individuals can misuse all this in many different ways: biological nanoscience, spying, all sort of things. There's obviously a lot to worry about and that's just classical nanoscience. And we know so little about quantum

Judy: I can't remember what I was going to ask you … something about microcircuitry … about being able to foresee the utilities of some of the research …

Philip: Well, part of the problem is the media always wants to know what you see and when you try to answer that question it's very hard because … I think the best way to put it is this: fundamental new technology changes all the rules, so everything else starts to be modified by that technology so in order to understand what use the new technology is, you have to remember that if something is really, really different then society itself will start to modify in response to that technology and so … if you asked the question, "What use is this?" The implication is "What use is it to me now? What use is it to society as it is now." But really important technology will change a society and society will change under the influence of this technology. I can easily imagine someone looking at the first compression engine and saying, "What use is this?" But of course the answer is, "None at all." But you put it in a car, then you build roads, and you have gas stations everywhere, and lo and behold the whole of society has evolved in response to this compression engine and everybody drives around in cars.

Judy: And hasn't society already evolved around something basic like laptops, right?

Philip: Yeah, exactly. So science has already started to evolve under the influence of crude nano, really microscience … it's not really nanoscience, it's microscience.

(interruption)

So it's a very interesting thing about how really important technologies are never invented to answer some need of society. That never happens. So this whole way that journalists look at it and saying that new technologies are invented in order to do something for society is completely wrong. They're never invented to do something for society. What happens is that society evolves in such a way that these things become useful.

Judy: Exactly.

Philip: And it takes a while because it takes some imagination to see that a compression engine can lead to the replacement of the horse with cars … and later on, the propeller plane … so there's misunderstanding by politicians and the general public about how technology works, where it comes from and that in which it's useful. It's not at all the way … the standard picture is wrong.

Judy: Just from what you've told me in this interview, there's tonnes of stuff for me to write on. Don't you think?

Philip: Sure. So what you're dealing with now is the non-quantum mechanical.

Judy: I found an article on BBC on nanoscience and nanotechnology, which I'm going to read …

Philip: But it will be classical. There will be no quantum there. See that's the key: 99.99% of stuff that you find out there on the web or in reports or whatever … it's all classical nanoscience, not quantum.

Judy: So by adding quantum mechanics to nanoscience, how does it change?

Philip: It changes everything. It's a whole new world and we're just beginning to explore it. It's really not very easy to say where it's going.

Judy: How did this joint research come about, combining them?

Philip: Combining Quantum Mechanics and nanoscience? We're had quantum mechanics since 1926 and quantum mechanics is this incredible theory which is basically capable of explaining everything that it touches. It's like a magic wand. It's really a magic wand because we don't understand it. But up to now, people have been using quantum mechanics to understand what goes on around them in the universe. So everything from the very small to the very large … from chemistry to biology to … it's stuff that is all around us already. But it's only recently that people have really said, "Now hang on a second. We don't have to be so passive with all of this … looking at the universe and understanding all these things that we never understood before quantum mechanics … and that's amazing -- the change in our understanding of the world around us since quantum mechanics is unbelievable. Before quantum mechanics, almost nothing in this room you could have understood properly.

Judy: At what level are you talking about?

Philip: Well, I mean why is the wall white? What does it mean to be white? What about this structure? Why is living tissue the way it is? What is it that makes us? At a stroke, quantum mechanics suddenly made chemistry an open book. At a stroke, quantum mechanics allows us to understand … it didn't take long … to understand the whole idea of genes, the genetic code, all of this depends on quantum mechanics.

Judy: Oh, I didn't realize that.

Philip: The stars, how they work …

Judy: You mean the interactions, the functions …?

Philip: Everything.

Judy: Right.

Philip: Before quantum mechanics, we had these crude mechanical/electrical models of how things worked. They didn't really tell you very much about anything. It was very crude. You could build a steam engine with them because they were just pieces of metal and hot water and so on, but if someone said to you, "But why is a metal shiny?" You had no idea.

Only the real crude things about matter that we understand, it was mostly a hit-and-miss thing, messing around with experimenting whereas now essentially any question you could imagine about anything that you see, in principle, can be answered by quantum mechanics.

Judy: And how is this application to nanoscience going to …

Philip: So my point is that until now, we have been more-or-less passively understanding this incredible kaleidoscope -- which is the universe around us, including ourselves – using quantum mechanics, but eventually you say, "Hold on for a second. We don't have to be passive. We can change things. Now that we understand quantum mechanics, we can build new things in which the quantum effects come out in a really bizarre way. And the moment that you start thinking about that you realize that you can make things … or you can imagine universes which are totally different from the one we're in. You can imagine matter behaving in ways which nobody had seen but, according to quantum mechanics, ought to happen. Roughly 20 years ago now that people started saying "Hang on. Supposing we try to process information but we process them using things obeying quantum mechanics …" And then you realize that it can be processed completely differently. And, in fact, it didn't take long for people to realize that you could process information, not one at a time, but in these superpositions and somehow … the idea of computation, not one computation at a time being done but an incredibly large number. All of this hinges on the fact that in quantum mechanics the system is not in one state; it can be in many different states at the same time … which makes no sense. It violates common sense completely, but in fact that's the way it is we just don't see it most of the time because … the reason is called decoherence. So, basically, it's like opening doors to worlds that are so different from anything else that we see around us that it's a major effort to even imagine them and that's actually, what theoretical physics is all about. That's why theory is absolutely essential because just by messing around with experiments, you're never going to go through those doors. It's purely intellectual voyage into these new worlds, if you like. And then the experimentalists will follow and see if they can make these … and that's what's happening.

Judy: It's so interesting, but people don't know this level, right? People just know that there's this science that they can't grasp. See I understand all this but I'm not good at the math, right? And so people just see it as a science with math and I can't do it [math] so it would be too hard to understand.

Philip: Well, I think there are two reasons why the general public finds it hard to follow, and I'm talking about intelligent people in the general public … because, frankly, most people just don't care. It involves too much thought.

One is, as you say, mathematics. The reason why we use mathematics is that the structure [of quantum nanoscience], in actually in some sense deeply mathematical. Greek philosophers like Pythagoras and Plato were the first who really understood that somehow the structure of the world is deeply mathematical and mathematics is a way of … is a language for discussing this structure … which is very close to that structure, whereas ordinary words are very, very bad at discussing them. You have to go into these lengthy explanations which in math you can describe in two seconds. So that's the reason math is used and if you're not use to it then it's hard to follow.

The second reason why it's hard for the general public to understand this is because some of it is very, very strange and it is very different from anything in ordinary life and, obviously, it's hard to understand that's why it takes so long to train a physicist. I mean, they have to learn these new concepts and ideas.

I find that when I teach Arts students about this stuff, sometimes they grasp it quite quickly but it's only because they're prepared to be open-minded.

Judy: Exactly. That’s what I found when I was doing my genetics course. There was a brief quiz which I failed, and it was something that I should have understood very easily but I wasn’t opening my mind and once I did I got an *A* in the class.

Philip: I remember once, many years ago when I was living in France, I was a postdoc and I was asked by the ski station to do these *Spectacle de Science* every weekend at this centre which had 1800 rooms -- it was this massive ski hotel. So they had a team of 16 people putting on entertainment for the guests, working full-time and they would bring in on Saturday night … they would bring in a professional magician and then I would go in. In the minds of the hotel, magic and science are pretty much the same.

So I put on these shows which involved lasers, liquid nitrogen and superconductors and all sorts of stuff and it was always very amusing to me that the kids found this very interesting and they would be really curious, but their parents would often sit there saying, “I don’t believe this. It’s a trick. It can’t be possible.” Basically, their minds have just gone solid and they weren’t prepared to accept what was right in front of their very eyes. They thought it must have been some sort of trick, like a magician.

Judy: I realize that I can’t of genetics in the way I understand history. I’ve got to think more like a mathematician, more like a scientist. It’s totally different. You have to be open-minded to understand that difference, right?

Philip: Well, I thought that ? summed it up very well. He pointed out that the structure of the electromagnetic field, for example, gravity … it seemed very strange in some ways but it was not a lot we could do about it. It's just the way nature is and either you allow your mind to grasp it on its own terms or you don't understand it. Then he came to quantum mechanics and said, "Well, frankly, nobody really understands quantum mechanics. It doesn't make sense to us, but that's our fault.

The universe was no made so that we could understand it. We're very lucky that we can understand much of it at all.

Judy: It's true.

Philip: And we're just a miniscule part of it.

Andrea Morello (16:28 mins interview -- 1.50 hrs transcription)

Judy: What do you think is significant about this conference … this group of people coming together?

Andrea: What I think is significant and exciting about the conference is that it is both focused and broad. So there are people touching very diverse aspects of quantum nanoscience but really they are all interesting for each other. I've been hearing talks and if I look at the program I will be expecting to hear talks about very diverse aspects of quantum mechanics at the nanometer scale.

Judy: And they're not …

Andrea: But somehow I feel like I can learn something from each one of them, not something really far away that you listen to for general scientific culture but it really may mean something to my own research despite being very different in the details. It is very well put together.

Judy: So what are your goals from the conference? Do you want to meet people, collaborate, and perhaps …

Andrea: Yeah. That's the main reason why you go to a conference.

Judy: And get ideas for your own research, right?

Andrea: Yeah, I get ideas for own research and, what is also happening, is my research is giving ideas to others. I have a lot of people coming up to me and asking me details and trying to find out whether I could meet something to them, so …

Judy: So I'm the intermediary between the scientists and the public because Philip wants people outside to … everyone has heard of nanoscience, but a lot of people aren't interested in science, a lot of people are too lazy to try to make the effort to try to figure out what this group is working on … so what do you want the public to know about your research? What is so significant about your research for the public?

Andrea: I think for the general public, the main significance for my research would be that we have a system where we can make a very precise and reliable test of our knowledge of quantum mechanics in nanometer-scale systems. It is a system that, at the moment, is not big. Not foreseeable applications in the near future. But it's a benchmark for testing the basic theory.

Judy: So you're a theorist?

Andrea: No, I'm an experimentalist but I'm very close to the theoretical work. For example, why I collaborate a lot with Philip.

Judy: He said that you are very good at theory.

Andrea: I really see myself as an experimentalist in the first place, but the experiments that I do are the most … they are the closest to the exact check of the theoretical predictions. See, you will hear lots of talks that are about systems which have possibly more immediate applications and they see phenomena … even larger scales than the molecules I work on … but all of them will tell you the sources of decoherence -- which is the biggest problem in quantum nanoscience -- is basically unknown. They have some vague ideas about defects in substrates and two-level systems that should be there but they don't really know what they are and how they got there in the first place, and so on. Whereas the physics I do is about systems where you know exactly what is what. They are chemical compounds, stoichometric … you know the structure, you know the position of every single particle, the coupling between all of them … so you can really test …

Judy: Everything is precise, right?

Andrea: Yes. So it's a very, very basic level because the theory is not complete, as we know it. That's something that the public should appreciate … that's probably the most difficult message to convey to the public. People … either they don't believe in physics or … people have this spiritual approach and there's some extra force that rules all of us or they think that physics is all that's in the books, that's all there is. We are really working on a level, which is challenging your knowledge and your trust everyday. So the kind of work I do is really pushing this to the extremes, of doing experiments that everyday clash with our theoretical understanding of quantum mechanics at the nanometer scale.

Judy: So what's the next step after your experiments?

Andrea: Well, the next step would be to use the thing we learn from this to design and engineer systems that, given this knowledge which has been checked, they can perform much better hopefully.

Judy: So what can you tell me about magnetic spin qubits? Is that your specialization?

Andrea: Yes, that's my specialization. So, magnetic spin qubits, at the present moment, are not the most advanced proposal for qubits for quantum computation. But, I think, there's a huge potential. From the one side, there is the very deep theoretical understanding that we can get my matching theory and experiment -- that's pretty much the work I'm doing with Philip -- and on the other side, the chemists are coming day after day with many new ways to put them together, to manipulate them on surfaces in a way which is ultimately very exciting because it does not necessarily involve a lot of nanofabrication -- which is expensive and complicated and involves big machines, and chip-by-chip you have to make them -- it just exploits basically spontaneous chemical phenomena, if you want. In the end, the hope is that … it's already happening in some of the systems we work on … you hope that these magnetic qubits would go where you want by themselves by chemical affinity, if you want.

Judy: So what are some results from your type of research on magnetic spin qubits?

Andrea: Well, the main results of my research, so far, is to pin-point very clearly what are the gaps in the theory as we know it now. Do you want me to scientifically precise in my … ?

Judy: No. What I'm saying is … so whoever is taking your work to the next level, what kinds of results have they come up with?

Andrea: So, basically, my work is at the frontiers so far so nobody has taken it t any further level yet. So in that sense, me and … also some other collaborators … we have pushed the experimental understanding of magnetic qubits to as far as we know it now.

Judy: So this is a new frontier?

Andrea: Yeah. Yes, yes.

And the thing is that, in a way, we got a negative result. So we have shown the gaps, what needs to be understood and so I really think that now the big work to be done is in the theory to fill those gaps

Judy: So what's so important about your research?

Andrea: The importance is that we can get to a much for precise and deeper understanding of the theory of quantum mechanics at the nanometer scale.

Judy: And what are the social implications to your area of research? Too early to tell?

Andrea: Yeah. The social implications are … I think, to be really practical … the biggest social implication would be that, when given this knowledge that we're building up now, we will be able to build new devices that do things that are not possible now. Social implication of the internet, of mobile phones …

Judy: Right. It's hard to tell …

Andrea: For that part of the world that is really interested in understanding the world outside of us is to … ultimately, the fundamental side of this research is to really understand the transition between quantum and classical physics. That's probably one of the biggest question marks of this century, if you want. That's one ting for which we have some hand-waiving arguments, if you want, but we don't have a real established theory for how come you never saw any quantum phenomena in your life, whereas, people like me and my colleagues work in the lab everyday looking for that phenomena. We do find them and we know that they rule world, at the microscopic level. But we don't have an explanation for you, to explain to you exactly why you have never seen it. I can give you good-enough explanation, if you will, which would probably be satisfactory to some extent, but we don't have a complete explanation for that. And, for example, if you think of it, there is a lot of talk going on nowadays about parallel universes … you may have heard that. Even last summer in Vancouver there was a theatre play -- at least one, probably more than one -- the movie came out about that … these concepts are actually being thrown at the public. When I was flying here to Noosa … to Australia … the lady sitting next to me on the airplane … we start chatting and she asked me, "What do you do? … Oh, Quantum Physics …" She started telling me that she had been reading books and that she had been to workshops, people explaining all the spiritual sides of quantum physics, and then at that moment I feel it is my mission to explain to that lady … "Look. It's not quite as spiritual as they told you. it's not 'my cup of tea' to realize why people explain to you Quantum Mechanics in those terms." There are some people that do it in a purely exploitational way and want to rip money out of you. I've seen that: people with no concrete scientific knowledge, but with a certain interest toward that and also with a certain attitude towards deeper understanding, they can be so easily mislead. With big words … it's just some buzz words … "quantum mechanics," parallel universes," "superconductivity" … a friend of mine, an artist, a very brilliant person, but with kind of spiritual attitude toward … and

Judy: Well, this is why I'm helping Philip with this.

Andrea: But it's amazing to see how this scientific depth can be abused by people … who abuse the beautiful words.

Judy: Misuse them …

George Christou (26:06 mins interview -- 2.75 hrs transcription)

(discussion with George about the
Chemistry Department at Gainesville, FL)

Judy: So you're happy with how the conference turned out?

George: Yeah, yeah. I loved it. I didn't know what to expect in many ways. The truth is, these kinds of physics conferences don't usually have chemists … not because they've got anything against us … I don't think they necessarily realize the …

Judy: The value?

George: The value, and that we're actually doing things that overlap with them. Now that we're getting into really small things -- nanoscience -- and people like me … not all chemists … but people like me, synthetic chemists, people that make molecules … we've always been, basically, working with nanoscale things. We just called them molecules; we just never called them nanoparticles. So as they've become more and more interested in smaller and smaller things, to make devices that are smaller or to do whatever … we've naturally sort of met and so I kind of got interested in the physics of what I do and it's nice to see that them appreciate that what we do may not be exactly the same kind of style or the same kind of materials, but we're also able to do things that impact, that overlap the general area of quantum nanoscience. It's basically molecular quantum nanoscience and … nevertheless, having said that how there is a natural sort of fit, it was still the case that this is a physics conference and physicists speak a different language from chemists. They're much more mathematical, for one thing, and it was always a question in my mind as to how a chemist's talk would go down, and I was pleased that it seemed to go down well. They seemed open-minded enough to appreciate something new or a different way of looking at things than they're use to … but they will give you the feedback. Philip has always seemed to bring chemists into things he's organized, and I've always reciprocated because I had him come to meetings that we had, beginning with the famous London meetings … I don't know if he mentioned those … we had some great times.

Judy: I've heard your name many times.

George: Oh, okay. I think Philip is broadminded, scientifically speaking, I think he can appreciate things that are interesting and worth doing in different areas of science.

Judy: I think that's so important, especially if you're running a centre like PiTP. Not only to make it international but to cover a broader area for collaborations, for new discoveries, and

George: Absolutely. Sure, sure. You know, people talk about interdisciplinary research, people from different areas collaborating … it happens, it happens in almost … sort of, sometimes an accidental way. It's certainly true that chemists and physicists don't often go to the same kinds of conferences, so you ask yourself that if they're going to collaborate when are they going to meet? They can meet accidentally or if a chemist knows a physicist that can help, or *vice versa*, they can always …

Judy: This is so much better when you create the environment.

George: Exactly. You're putting people in the same place, they're eating lunch together, they're sitting in lectures together, they're drinking beer together … they start here listening to what each other is doing, and that's important because it's tough to keep up with our own literature, let alone read other people's literature.

Judy: Especially, like you were saying, when the language is a little bit different and when you can come together and actually come to a point and actually communicate with each other …

George: Exactly. And ask questions. I'm not familiar with 'that language', whatever it may be. Just tell me in English. So it's really useful, it's really stimulating.

Judy: I think what Philip is doing is amazing because it's interdisciplinary. Personally, I think interdisciplinary has so much value, it offers so much … opportunities for everybody, but it's rarely done. And if you don't create the environment, if you just talk-the-talk and don't actually follow through with any kind of arrangement like this, it's never going to happen.

George: That's right.

Judy: So you're happy with the conference, you've met some …

George: I enjoyed it immensely. I saw talks that I would never see … here … otherwise. I'm not saying that they were relevant to what I'm doing; they were just interesting talks.

Judy: They can make you think about things, right?

George: Yeah, right. That's part of the fun. I learned a lot of things here. Not everything was relevant to what I'm doing. A lot of the stuff I'll never actually, perhaps, use or …

Judy: Or explore any further …

George: … or explore any further, but it was still very, very interesting to hear about it and learn about it and to see the sort of people doing that work.

Judy: It was nice that he put you on the panel, too.

George: Yeah. I actually ended up enjoying that. Again, I thought that they were going to talk about their quantum nanoscience in a more, kind of, specialist way but it turned out to be fine. In the end I sort of diverted the thing a bit by going into the more societal impact. I really thought that was something important …

Judy: It should be addressed. Yeah.

George: Philip was actually going to ask a question about that, but I didn't realize that so I kind of sneaked it in. When he was taking about challenges, he meant scientific challenges and I, kind of, wanted to bring that out into the open. A lot of concerns that we chemists have about the public's perception of us … chemistry as I said … were you at the discussion panel? What I said, I think, is true. Chemists have a really bad reputation …

Judy: So you're talking about educating the public about chemists …

George: Yeah. You ask any person in the street what's a chemical, and they're going to have a negative response to that.

Judy: People don't understand.

George: Even though chemicals are in everything from aspirin to sun tan lotion to whatever. Perceptions are …

Judy: That's my role for … that's what Philip and Gerard have asked me to do, to educate the public.

George: Right. I thought that Discussion Panel … that discussion was really very, very good. In fact, I was enjoying being on the panel. I wish we had another hour.

Judy: I thought it was going to be a two-hour panel.

George: What I wanted to bring up, which we didn't have time for, of course, is the fact that most of the things that we're investigating now are really to develop new technologies and so on … and what's going to happen … and it always happens … nanoscience will lead to the development of things that will form the basis of devices that will be militarized.

Judy: Yep.

George: They're always militarized, any new technologies … and what I would have liked to have heard is … and we're arguing about what nanoscience is and what quantum nanoscience is and it's effect on society, and so on. I think it should have been brought up … where will this lead in terms of military applications and are will we all fine with that. A lot of us accept it. It's just the nature of things. But that would have been a nice topic for the discussion.

And you know he's put together this panel of scientists for the Supreme Court meeting in Ottawa?

Judy: Yes. And you're part of that, too?

George: I'm part of that and I haven't read any of the documents he sent me and I don't know exactly what this committee is charged with doing. I know we're going to meet and discuss with the legal people, but I'm sure it's not to discuss the nitty-gritty of science. It's going to be these other things and, clearly, it's going to be a whole-day discussion … not that the Supreme Court is going to say anything about the military applications …

Judy: But doesn't it always … from my understanding of how science works, whatever is discovered is for the military, initially, and then later on a lot of these 'inventions' or whatever, discoveries, become accessible to the public.

George: That's certainly true for a lot of things.

Judy: Not everything, of course.

George: I don't think that we're funded by the military … a lot of us … and I don't think that what we're doing is with the military mind … clearly, the military are very good at recognizing and developing things because they have their own … I'm not saying it's any different now than it's been forever. I'm just saying that's another aspect of nanoscience that nanoscience can impact, and nanotechnology, will impact our life in way different ways and we don't want to leave but military applications.

Judy: I think that's really good that you brought it up …

George: I didn't bring it up.

Judy: I know, I mean bringing it up with me in this interview because I'm also sharing a lot of what I'm discussing with people with Philip and I've told him about ways we can improve future conferences and I think everybody should make comments to him, even things like this … because I said to him that next time we have a conference, maybe have a separate room for interviews because I had to pack up at 10 (a.m.), right? And just doing things, like, maybe scheduling ahead of time when to talk to people instead of trying to squeeze it all in especially when people want to attend all the sessions, or most of the sessions and don't … it's really hard to fit an interview in at the last minute … people have other things planned … whatever. Little things like what you, what I say … and help to create the next … that's a very important topic to bring up at the next panel discussion and … various ways it can impact society.

George: Actually, I have to say, one of the reasons why I wanted to bring it up is that I wanted to get a feel for my own information as to how many people want to sit down and talk about this.

Judy: Right, absolutely. That's another reason to bring it up … not just to discuss it, but informing people of other views or what is going on because some people might know more than others.

George: Well, the quantum computation research is clearly … clearly has military applications in the sense that it's going to impact cryptography and that's the common thing you talk about … quantum computers are going to put current cryptography out of business. I was thinking more of other types of devices based on nanomaterials. I've never done that kind of research, myself. None of anything I've ever made has involved any toxins or lasers.

Judy: It's so interesting to be included in this.

We were talking about people misusing these words, catch phrases or whatever. People pick up on things and want to sound knowledgeable but misuse a lot of this.

George: (discuss Prince Charles interest in nanoscience)

I think there are a lot of worries in peoples' minds about what's going to happen and they've faced this before from science that has killed or maimed or whatever . And this is the latest one … Why should they trust us now when we've let them down so many times before? There was a time when they said DDT was harmless, that thalidomide was harmless … they use to give it to pregnant women. And then the dioxins and … those are the ones that caught a lot of the headlines … asbestos … there's another one we use to use all the time … you can't blame them. They're just naturally worried and we should be sensitive to those worries. And not disregard them because we think "we're the scientists" …

Judy: And that's part of the Supreme Court's meeting … ?

George: I hope so … I actually don't know what we're going to cover in that meeting …

Judy: Philip writes well, so it's really easy to comprehend Physics … if I can say that about Physics.

George: Going back to the conference, I they thought that expanding it to let a couple of chemists through the door is considered by them to be a success then they'll continue doing that … I don't know.

Judy: Do you think people in different fields … ?

George: In chemistry?

Judy: Biology, microbiology, or … ?

George: Yeah. I got the impression yesterday that a lot of people … at least some people in the audience, didn't really want the biologists … that it's separate from what they're interested in … they didn't even want the bio stuff to be part of the …

Judy: But even in Philip's … the background readings, he says it's a combination of physics, chemistry and biology.

George: Of course. And its impact on biology will be immense.

Judy: Of course … genetics or medical … drug delivery or …

George: Drug delivery. That's right.

I think that as often happens, in fact, the science fiction writers and the novelists pick up on these new things before …

Judy: And they make it into a fiction …

George: Yeah. You stop someone on the street and you ask what have you heard about nanoscience. You'd likely hear about Michael Creighton's book or in Britain about the scare mongering of people in *Prince of Glass* … and that's what they hear. I don't see scientists on television discussion nanoscience … very much … well, I have seen some. Maybe we do need better PR, as I said in the discussion. Scientists are notorious for not having good public relations. You know the oil companies and big business, in general, they have professional staff of people whose job it is to sell what these companies are doing in a media-friendly, public-friendly way and we don't seem to have that.

Judy: And I think that's where I'll be coming in. (discuss about PR)

I really like people and talking to people and I really think need to know what is going on because right now they're being it's misinformed, whether they want to believe these fictional writers or … and not much else is coming out except in scientific journals which speak this jargon that most people can't access, right?

George: Yeah, we're too insular in many ways and … to be fair, whose going to pay for a team of lobbyists in Washington and other places and professional staff … most scientists have trouble getting enough money to do their own research without having all these other aspects.

Bottom line, is that I really enjoyed myself … I know they're going to have them regularly. I would be happy to back.