Round Table Talk:
Peter Goddard with Hitoshi Murayama and Hirosi Ooguri

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How the Newton Institute Got Off the Ground

Ooguri: Thank you for joining us for this conversation today.

Goddard: It's my pleasure.

Ooguri: You were the Deputy Director of the Newton Institute which is now one of the leading institutes in mathematical science in the world and you have been responsible in starting that institute, including the designing and the construction of the building.

Goddard: With other people, yes.

Ooguri: You were also the Director of the Institute for Advanced Study and led the expansion of programs. You guided the institute through financially turbulent periods. So, I think we have a lot to learn from your experience. The areas you have worked on are also quite relevant for this institute. In fact, tomorrow, you're going to give a colloquium about the interdisciplinary research between mathematics and physics—that would be another subject that we would like to talk about today.

Murayama: I'd love to hear about the story of how the Newton Institute got off the ground—how you actually had a vision for the institute and how you tried to bring people in.

Goddard: Well, I think that in the middle of 1980s, I and many of my colleagues in the UK, and particularly in Cambridge, realized that the country didn't have such institutes. We realized that there was a growth in such institutes because the Institute for Advanced Study had been playing a particular role worldwide for many years and that had inspired various people to start other institutes. For example, Hirzebruch's Institute in Bonn is one famous example, and the IHES (Institut des Hautes Études Scientifiques) near Paris is another that was inspired by the IAS.

Ooguri: And there is RIMS (Research Institute for Mathematical Sciences in Kyoto).

Goddard: So, often people who had been at the IAS had seen there were

things that they could emulate in their own countries—they didn't usually make replicas. In the United States the MSRI (Mathematical Sciences Research Institute) in Berkeley and ITP (Institute for Theoretical Physics), now the Kavli ITP, in Santa Barbara were started. I think many of us found that we were spending our sabbaticals and our vacations in these institutes because they were very good places to go to intersect with lots of people and to be in a research intensive environment. But there really wasn't any such institute in the United Kingdom. We thought that it was excellent that we should go and help run a program in Santa Barbara or take part in the workshop in Oberwolfach (The Mathematisches Forschungsinstitut Oberwolfach), or what have you, but it's important to have a two-way flow and to be able to bring people to the UK and, of course, to Cambridge. Some people had already started thinking about this in London. Michael Green was involved, but they hadn't managed to get off the ground. And we saw an opportunity in Cambridge because, at that particular moment, we could see that there might be resources available in the colleges rather than in the university, in Trinity College and Saint John's College, and that it might be possible then to convince the UK research councils to match the resources that Cambridge was finding for itself, to make an international institute there. Then we had to decide what the appropriate scope of the institute, and what the appropriate model of operation of the institute should be. We felt that the scope should be very broad and this would help get broad support, but also many of us thought that the interesting areas were perhaps preferentially where there were crossovers between disciplines or between sub-disciplines. Then you had a greater added value from an institute because you could bring together people, who would not normally have the time to get together in universities, from different disciplines. I think one of the reasons that institutes have grown in importance—and it was one of the founding principles of the institute in Princeton even back in the 1930s, that the modern university, and I think this is true all over the world, is now a busy place. It's a place in which the academics are expected to be entrepreneurial, not a place in which they're expected to sit in their offices and have the detachment to think about fundamental questions. They don't, in general, have the time to interact with their colleagues in the next department. They're more likely to interact with colleagues from other disciplines when they're in other places, when they don't have to go to meetings—I think that has been one of the reasons for the growth of institutes like ours worldwide. We saw all those reasons as good reasons. The idea was that if we had a broad institute, it would gain perhaps more support from a wider range of colleagues and, secondly, that it would have the opportunity then to operate in cross disciplinary areas: not that the things that happened in the Newton Institute had to be cross disciplinary, but in each program, in comparing one with another, one looks at what is the added value of having this happen in this institution.

Murayama: Who initiated this discussion? Was it Michael Atiyah or you or...?

Goddard: Well, there were a number of people who initiated it. Peter Landshoff, Martin Rees, and others.

Murayama: Oh, Martin Rees?

Goddard: Yes, Martin Rees was involved all the way through, and Peter Landshoff played an important role along with me. We did most of the donkeywork, as they say. Then there were very skilled mathematicians, John Coates and...

Ooguri: Is that because of the British tradition that theoretical physicists are regarded as part of the mathematics department?

Goddard: It was partly that, because the initial push for this came from the Faculty of Mathematics which included the Department of Applied Mathematics and Theoretical Physics.

Ooguri: It included many of the leading theoretical physicists like yourself and Martin Rees.

Goddard: Yes. Then we got support from other Faculties as well. The dominant push came from inside the Faculty of Mathematics. I was a professor of theoretical physics in the Faculty of Mathematics.

Ooguri: I have a question regarding the scope of the institute. You mentioned several mathematics institutions existed before your institute. But there are different kinds. For example, places such as IAS and IHES have their own strength in the faculty. They have leading scholars in the area, and they are the attractions. On the other hand, the places like MSRI have only a very lean faculty, basically just the director, and the strength of their program attracts people. You chose the MSRI mode.

Goddard: Yes.

Ooguri: What has led to that kind of choice?

Goddard: There was a discussion among those people who were forming the institute—and this is at

the end of the 1980s. [We started thinking in about '88.] There were a number of points if you look at the taxonomy, if you like, of these institutes, their various structural aspects. And this is an important one. Do you have a permanent faculty or do you not have a permanent faculty? There are arguments each way. One of the issues for an institute in particular is, "how do you gain a body of support for it?" How do you have a group of people who care about it? One way, of course, is to have leading academics be faculty members. I think this is true of ITP in Santa Barbara, and so on. The other issue you have there if you have a permanent faculty is that you could make some wrong appointments. Now, in fact, if you take something like the Institute for Advanced Study, I think it has a remarkable record of not making wrong appointments.

Ooguri: You can't afford to make mistake at places like this.

Taking Risks to Do Things That Change How People Think

Goddard: Well, I think the problem is —the way I would say is and when I was director at the institute I would try to explain to trustees is the following. Even if we make a mistake, we're making them extremely rarely, and it is more important that people do groundbreaking work. What one has to try to get across is that we are not trying to do quality control here. We're not trying to be in a risk-free environment. What is important is that we do things that change how people think, that we change the nature of the subject, that we make break throughs, if the choice is between doing that and doing very good research that doesn't really change anything.

Ooguri: That's a difficult decision, right? You have to take risks to do that.

Goddard: Yes, you have to explain to people that that is the whole point. That it is much preferable to have an institution in which there might be one or two people who are not as great as you might like, though I don't think this is true of the institute, but even if it were true, that would be better, because alongside that there are people like Edward Witten, Pierre Deligne, and so on, who are completely reconfiguring how we understand whole areas of intellectual activity. You should be more concerned about that than you have nobody who falls below a certain standard. The analogy I used to take, it probably works in Japan as well, is—if you want to take the driving test, you go to the driving school, presumably.

Murayama: In Japan, yes.

Goddard: Then all you're concerned with is passing the test.

Murayama: Right. There is a minimum threshold. Other than that, you don't care.

Goddard: There's a very precise thing that you want. You don't care...

Murayama: You don't care whether you take 100—yes, that's right.

Goddard: You don't want to get a perfect score. That's not really relevant.

Murayama: That's not necessary.

Goddard: You don't go home and boast to your spouse or your parents that you have a perfect score. You don't go there to have your life changed. You might expect when you go to a university, perhaps at 18, that your life will be changed and that it will be a formative experience. But that's not the purpose of the driving school. The purpose of the driving school is to have a very quality controlled result and if you looked at choosing between driving schools, you'd just select the one that had the highest passed rates, whereas—this is the complete antithesis of this—we're not trying to produce people who can drive cars. We're trying to change the way people think, and so it doesn't matter if there are one or two bad results.

Ooguri: I recognize that. "I shouldn't make a mistake" alone is not a good way to approach this recruitment.

Goddard: You shouldn't if you got very few appointments. Then if you make a mistake, that's a real problem. But I don't think it's possible to have an attitude that you're trying to avoid risks and still really, really do dramatic things.

Ooguri: But in the case of the Newton Institute, you decided not to go that way, but rather...

Goddard: Yes. There were a number of reasons but I think the fundamental one was really related to the sort of model of programmatic activity that we decided on, which was based on, let's say, particularly Santa Barbara. We decided that a permanent faculty wasn't necessary for this model of operation. It would be quite expensive. It would also arouse jealousy in the sense that in Cambridge, by and large, nearly everybody is teaching. If we were to try to create positions in the university, which were completely free of teaching like this, or even if ones which would in some sense be seen as privileged in this institution, this would arouse some opposition. I think one of the considerations we have to have—I don't know whether this applies very much in Japan; it applies much less in the United States I think than in the UK—is that

there is a danger when you try to make such an institute other people, outside Cambridge, would be jealous because it's in Cambridge, and inside Cambridge people might be jealous because it was being given such special terms.

Ooguri: I think, you can argue in both ways. In the case of Santa Barbara, there could be people who are jealous, but most of the faculty members who are not at ITP would recognize that this is an excellent tool to recruit people like Joe Polchinski and Lars Bildsten.

Goddard: Of course, they had some good people like Jim Hartle, John Cardy and Bob Sugar and so on, before, but I think it must be true that the standing of Santa Barbara as a graduate school in physics has changed enormously.

Ooguri: For the university as a whole, they benefited by having this, so probably most of the people recognize the value there.

Goddard: Yes. But, at Cambridge, it is more difficult to get that to be recognized, I think, because there are already so many good things happening.

Ooguri: So they might argue, "We don't need that because we are at Cambridge and we are already excellent."

Goddard: Some people would argue that.

Ooguri: So it sounds like it was a political decision.

Goddard: It was partly a political decision, yes, and it was partly financial. But it was a challenge to get the resources together anyway. And to get these resources as well, and with these political considerations, we decided at least to put the issue off.

Ooguri: It is functioning very well because it's located right next to the math department and within this mathematics complex.

The Institute Constructed outside the Traditional Univ. Area: The Faculty of Math Moved There

Goddard: It is now, yes. We had to make a decision at some point as to whether we would try to get a building in the middle of Cambridge. In that case it would be a preexisting building. We already thought that it was very important to design this building so as to encourage interaction, and if we had the existing building, it would almost certainly be impossible to do that very well, because it's very expensive to rip apart an existing building and to reconfigure it inside.

Ooguri: Was it why you decided to move outside of this traditional Cambridge University area?

Goddard: That was probably the major consideration. The second one was that the buildings of the faculty of the two departments (theoretical physics and applied mathematics, and pure mathematics) were overcrowded, so that we were inhibited in doing new things or even having very many visitors in comfort because every space was already over-occupied.

Ooguri: I remember your previous location at Silver Street.

Goddard: Yes.

Ooguri: That was some kind of a factory or something like that.

Goddard: You're very discerning. It was a book factory! It was the building in which the University Press actually printed the books.

Ooguri: So then, it's interesting that the institute was constructed outside and the math department followed it and moved to that location.

Goddard: What we perceived was that if we put it in the center, the departments might have to move anyway, at some point, and that probably we should force the issue. Then fortuitously, my college, St. John's College, had a field of seven acres available. It had been reserved for the expansion of one of the colleges that was further out, Girton College, to come more into Cambridge. It had been kept empty for a few decades actually when it might have been developed. It was earmarked for college or university purposes so that when we talked inside the college about whether the college had any land that might help with this process, the Bursar of the college, Chris Johnson, mentioned this particular site. We saw that actually the whole of the faculty would fit in this site.

Ooguri: So, you already had the vision of eventually building this mathematics complex there.

Goddard: We thought it would probably take more years. But as soon as the institute was opened and I was there running it day to day for Michael Atiyah, we felt that one mile from the old faculty buildings was a real disadvantage. People would not just pop over to go to the talks, and then they wouldn't feel so supportive or get so much value from it. In some sense actually a mile is a very bad distance because somebody will make a special effort to go to London but they don't necessarily make a special effort to go a mile. So we decided that, very soon after we opened the Newton Institute, that we should seek to move the faculty next to the...

Ooguri: And you succeeded in doing that.

Goddard: Yes. Then we had to raise

money. So, Peter Landshoff and I, with help from people like Martin Rees, set about raising the money funding those buildings.

Murayama: It's a doubly expensive proposal to do that, right? You started a new institute and at the same time were working to move the mathematics faculty.

Goddard: But we had already started the institute. So the fundraising then was for these new buildings.

Murayama: I see.

The Institute's Building Designed to Promote Highly Interactive Activities

Ooguri: Now, since we are talking about buildings, I want to ask you this. When I first went to the institute, I immediately fell in love with the building. It really worked like a dream. You have the central interaction area and you come out and you're in the middle of discussion. But if you want to focus on your research, you can just retire to your office. It's very well thought out, and it works very well.

Goddard: Thank you.

Ooguri: It has been subsequently emulated by many institutions, including this one. What was the process of coming up with this kind of design?

Goddard: We wrote a brief for architects. We listed all the things we felt we needed, what were important to try to achieve. And, in particular, we explained that we needed to encourage interaction. I should say there was one prior aspect to this. You said that there are different sorts of institutes in which different things happen and you distinguished whether there was faculty or not, but along with that also goes whether you're bringing people there to interact or whether you're bringing people there to do their own thing. At the institute in Princeton, basically people do their own thing though some schools are more interactive than others. Natural Sciences is more interactive perhaps than, say, Historical Studies, and Social Science is a bit more interactive perhaps than Historical Studies. It just depends on the style of the particular school, but the institute can accommodate those differences of style. If you go into IHES, it's more like IAS, in terms of people sitting in their offices. But we decided—so it was a choice—that we should have activities going on at the Newton Institute that would be highly interactive. There would be programs and we would specifically tell people that you're not meant to come here and write your book or your paper. You're coming here to discuss. As you say, you must have the opportunity to go to your private room and work out your calculations if you want, but there will be a tendency to interact. We put all of these into the brief...

Ooguri: So, that probably also has to do with the focus on interdisciplinarity that was already there from the beginning of the idea of the institute.

Goddard: Yes, exactly, to bring together people who weren't normally talking to one another. We wrote down a whole series of considerations about this and then we selected with the help of the central university authorities, a number of architectural firms—maybe four. We got these firms together for a day and we showed them the existing departments. We talked about what was happening there that we wanted to happen in a new place, what was not happening well there, and we spent the whole day talking to them about the issues. We gave them a formal document as well. Then we asked them to come back in a month, and each to make a presentation for an hour or two to us about how they would tackle what we were after. The firm that won came with a model and the model was conceptually very like the institute that you came to. It had a central mezzanine floor and it emphasized the fact that you would know what was going on in the building. One way I think about this is that people's experience of buildings has a characteristic timescale that depends on what you're doing there. If you come to be a student in the mathematics complex in Cambridge, your experience there is on a timescale of 2, 3, and 4 years. If you're a faculty member, it's ten years. Now, if you're coming to this institute, the timescale is 2 to 3 months. And that effects how your experience of the building should be. For example, if you're coming somewhere for 2 or 3 years, you can spend time learning how to get around the building.

Ooguri: It should be more intuitive if you only have a short time.

Goddard: Yes, exactly. It should be immediate. If somebody takes you on ten-minute tour of the building, you will already know it. That goes along with the interactivity because you can see everything that's happening in that building once somebody shows you around and takes you to your office. You've already seen where the coffee is, you can see into the two

seminar rooms, you can see where the library is. Now, the mathematics faculty buildings are built next door—they're built more on a three-year timescale, and you'll take some time to learn all the nooks and crannies. It's not so transparent. It's also the case that at Newton Institute, if you go to your office, there's basically only one way you can do that, and that way involves going through the central area, whereas in the faculty buildings, you can get to your office in one of a number of ways.

Ooguri: Sometimes you may want to do that.

Goddard: You can either walk through the main concourse and advertise your presence ... you know, like in Italy, they have this practice in the evening in the cities of walking through the streets, families walk through the streets in Florence or in Siena, and advertise their presence to see people and so the Newton Institute makes you do that. I don't know if I already told you the story about Vladimir Arnold. He was a very lively character. He was a member of the first program and after a while, he stopped me and he said, "You know this building is terrible for my health." I said "What's wrong? Nobody is complaining." He said, "Well, you see, I come in here, I have a cup of coffee and then after an hour, I need to go to the men's room. So I go out of my door, I go to the men's room, and immediately somebody stops me and then I manage to get past them and then somebody else talks to me and eventually there is going to be some terrible problem."

Ooguri: Yes. My experience was like that, and it was very intuitive and so it would naturally be in the middle of a discussion when I go out of the office. Also, I like some of the playful elements of the building such as having a small blackboard in the elevator. I remember when I was there, somebody wrote, "I found a remarkable proof of the Fermat's Last Theorem, but the elevator ride is too short to write it." And, of course, it was soon afterwards that the proof was actually announced at the Newton Institute.

Goddard: Only one year afterward. Somebody wrote that very early.

Ooguri: So the remarkable proof was almost there.

Goddard: Yes.

One Should Have an Idea of Timescale for an Academic Institute

Ooguri: You were the deputy director of the institute. For how many years?

Goddard: For three years, formally. For one year before that I was doing it in practice. So, I was really looking after it for two years before it opened and then two years after. I decided after a year of its operating, it would actually be good to leave after two years and let somebody else continue. If you start something like that, your experience may be different, but mine was that it's probably good for the person who starts it not to continue too long because it's like you have a parental relationship and it's good to let go.

Ooguri: At some point, you have to let go of your kids.

Goddard: Yes, I think so. Since I had been dealing with all the practicalities, many of the things started as a file on my desk in my academic office, and now there was the whole building, and so on, and I just felt it would actually be good to step away. I actually planned then to go on sabbatical to IHES.

Ooguri: Just to be intentionally away from the institute.

Goddard: Yes, for the next year. But then my colleagues in my college elected me master of the college so that thwarted my ambition to get away.

Ooguri: So, what's your view of the institute now? Has it turned out in exactly the way you anticipated it would be, or were there any surprises?

Goddard: I went back there for the 20th anniversary. We had a short meeting and they asked me to give a talk, so I surveyed what had happened, and I felt very content about the model. At the start, I thought that you should have an idea of timescale for the institute—at least that particular institute, and Peter Landshoff and I and the others felt confident that what this model of the Santa Barbara and MSRI type of interactions, which had really become much more prevalent in the previous 20 years, I would say, would be a very good model for the next 20 years—50 years, perhaps, who knows? But at least 20 years. Let's think that this place would exist for 20 years and it should function well for that period, and after that one could revise one's view, and so you acquire permanent fixtures, etc., thinking about that timescale. And so, after 20 years was a good point to review it since it had reached that point and I think now they still think a 20 years' horizon is a good horizon and are striving to get more endowment. I think it's approaching £10 million. It really needs at least £20 million together with grant income, too. But I think it's made valuable contributions. So, I'm pleased that it worked.

As Governments Are More and More Dirigiste, Private Grants Are Very Important

Ooguri: You mentioned the raising of funds and you did that while in Cambridge in building this mathematical science complex in particular and then subsequently, you moved to the Institute for Advanced Study and I imagine you have been heavily involved in that. It seems to me that this kind of private philanthropy in helping basic science is very much in the Anglo-Saxon or British-American tradition.

Goddard: Yes, in recent decades, the last century or so, it's been particularly American. If you look back over the centuries, there was a long, strong tradition in the UK. That's how Oxford and Cambridge in particular had got their resources and the extent of independence that they have, through the resources that people gave to the colleges. That has become eroded as the sole method of finance.

Ooguri: In the UK, you say.

Goddard: In the UK, it has, from about the beginning of the 20th century, as a result of a combination of the expansion and the diversification of higher education, which meant that you needed university laboratories, in particular. It was getting more expensive to teach and do research in universities because until the middle of the 19th century, people were doing the traditional curriculum or they were studying mathematics or classics. These were not expensive things. But from the middle of the 19th century, you needed laboratory facilities, the Cavendish laboratory and so on, for research. On the graduate level, you needed more and more resources and that combined also with the First World War meant there was crisis in Cambridge and Oxford at that point. And the government started giving money to the universities initially through university commissioners which separated the government from the process in the sense that the giving of money was not meant to be an instrument of government policy with government influencing the university. That arrangement was eroded from the 70s and 80s in particular into the situation now that the government certainly takes the view that it gives money to universities in order that they should do things the government would like.

Ooguri: Are there incentives?

Goddard: Yes. From about 1990, in particular, a big emphasis started on wealth creation as an objective rather than saying that we just let universities do what they want, and they should be an independent force in society. And so, that change has meant that government financing tends to come with strings. Also because government, at least in the UK, and I think in the United States, has become more short term in its perspective. It's more responsive to public opinion. It's more concerned with getting reelected and that means that it's looking for results on a timescale of two or three years because otherwise you can't influence the next election. All of those features influenced us when we needed new buildings and so on. We decided that we needed to raise the money for Cambridge because you just couldn't rely on the government coming up with funds.

Ooguri: Yes. It's a very interesting trend. It goes both ways. There was an article in the New York Times recently about danger of relying too much on private philanthropies, but on the other hand there are benefits of private philanthropies such as—well, I'm in a private university in the US and Berkeley is almost like a private university.

Murayama: Yes, only 10% public funds these days.

Ooguri: We do recognize, for example, that if there are new breakthroughs, sometimes we cannot wait for the government funding to follow. If you have private funding at your discretion, you can pick low-hanging fruit, which may not be easy to do if you wait for government to react. I guess it goes both ways. The Kavli IPMU is sort of unusual in Japan in that we have been successful in getting private fundings.

Murayama: Right. You wanted to, for example, start a workshop on a wall-crossing formula and then immediately, I could allocate some funds to get the workshop started, and that would produce lot of activities afterwards.

Ooguri: That's what's pretty amazing. It was a workshop that I proposed to Hitoshi because I wrote some paper with Masahito Yamazaki who is now a postdoc at the Institute for Advanced Study and that was starting a new field, so we wanted to have a workshop quickly. I talked to Hitoshi and he immediately granted funding and then the workshop was put together within 3 months or so. Usually, those kinds of workshops take a year to prepare but, thankfully, we had the funding, we had a very talented and dedicated team of international office and so we were able to have this workshop and that was very, very helpful for my research as well as many other researchers at the IPMU. And so those kinds of things make a big difference.

Murayama: Right. Flexibility is very important indeed, yes.
Goddard: Yes. So I certainly came to the conclusion that private grants would be very important because governments, everywhere, I think, are more and more dirigiste. They're more and more trying to set agendas and these agendas are often short term. There's this other aspect that goes along with that, *managerialism*—the idea that you can address issues by managerial action: suppose, hypothetically, you have decided that the UK was weak in functional analysis, I don't know that it is, then you put in a few million for a few years and then you can turn it around. But it doesn't happen like that. That isn't the way that you build up strengths academically. You may make some short term effect but the idea that by managerial action, you can make, on a timescale of 2 or 3 years, important developments in academia, I think is just wrong. But, the bureaucrats have to believe in that because that's their raison d'être.

Progress of Science Is Far More Exciting Than We Could Have Anticipated

Goddard: Then the other aspect that accompanies this is the audit culture—the idea that you have to be able to justify to the taxpayer that you have spent the money on what it was intended to be spent on. The problem with that is that it implies that, at the time you get the money, you should know what is going to be spent on, but we don't know what we're going to do. I remember just after I left the UK and went to Princeton, I was asked to report on somebody who had held a senior fellowship from one of the research councils in the UK. This gives money for five years to a senior professor to do research. What I was asked to do was to report on what this person had done. I was sent all of the details of the papers he had written and so on. And I remember that the first question was, "Has he done what he said he was going to do?"—and I said, "No," of course.
Ooguri: What was the issue?
Goddard: Of course, what he said he was going to do was interesting but as you would have hoped, he has done things that were far more interesting. I think this is something in which the bureaucratic arrangements that fund science in many countries consistently fail to be able to grasp.
Ooguri: Open-ended research ...
Goddard: Yes. The way I would put it to incoming members of institute was that if you know what you're going to do and how you're going to do it and when you're going to do it by, it is not going to be truly original research. We are finding out things we couldn't imagine. The excitement is that we may have fertile imaginations, but what happens is far more miraculous than we could have anticipated. If you look at the great writers of science fiction, Jules Verne and H. G. Wells, they were writing these marvelous stories at the end of the 19th, and the beginning of the 20th century. And if you think of what actually happened in science compared to what they wrote about, it's far more exciting.
Ooguri: Right. The progress of science surpassed their imagination. So, you cannot plan those fundamental researches ahead, especially the goal of the research.
Goddard: Right. If you look at the development of string theory at any stage, it was never what people would···
Ooguri: On the other hand, there are lots of unintended applications of the results that you obtained by wandering through this process.
Goddard: Yes. It even goes for practical results, I mean, if you think about one of the things that has changed, more than anything else, the way we live our lives, or many of us live our lives, and it's made more commercial possibilities available than anything else, is the worldwide web, and that was not the result of some R&D department in some company sitting down and thinking: we have the Internet now; how can we make this a commercial possibility or how can we make it more useful! It was the result of scientific challenges.

Relationship between Mathematics and Fundamental Physics

Ooguri: I also wanted to ask you about your view on interdisciplinary research between mathematics and physics. I guess in the UK, the division between physics and mathematics is somewhat different from that in the continental mathematics. Has that influenced your view on the interdisciplinary activities? In the UK, the interaction between physics and mathematics is tighter in the sense that some of the physicists are even regarded as mathematicians.
Goddard: I think always the boundary is artificial and determined by the local culture. It has been a tradition in the UK that you can approach physics in various ways, particularly in Cambridge. You can trace it back into the history of the organization of the university which was, say, different in Cambridge from Oxford and other places. In Cambridge, the dominant subject from the 18th century onwards was not actually classics but mathematics. The first honours

examinations in Cambridge were in mathematics.

Ooguri: Is that for all students you mean?

Goddard: Yes. From the 18th century onwards, they developed special examinations in mathematics, and so if you wished to obtain the highest honours, you would have to take mathematics. That was true up until about 1820 when classics became available as a first honours subject to study alongside mathematics. It meant that people like William Wordsworth, the poet, studied mathematics. He didn't do very well, even though he came to Cambridge with a scholarship in mathematics. But then it meant that great figures in the later part of the 19th century came out of mathematics and went into the Cavendish; from James Clerk Maxwell onwards. Then even people like Maynard Keynes, the economist, started off in mathematics at the very beginning of the 20th century. That tradition was always there in the background. Now you have to dig down to find it but it has influenced the way that things have grown up.

Ooguri: That's very interesting.

Goddard: That's a Cambridge phenomenon but within the mathematics framework, then, people split off in various ways. I think the main thing that has changed over time, viewed internationally, is that the relationship between mathematics and fundamental physics has changed just enormously, clearly.

Ooguri: What's your view? How has it changed?

Goddard: I think if in the 1960s, there were very few people who knew very much mathematics of the sort that is now taken for granted in your seminar, for example.

In Early 70s, Marriage between Mathematics and Physics Ended in Divorce?

Ooguri: Right. Well, I guess I remember there was an article written by Freeman Dyson. That was written probably in early 70s...

Goddard: *Missed opportunities*?

Ooguri: Yes, *Missed Opportunities*, where he says, "the marriage between mathematics and physics, which was so enormously fruitful in past centuries, has recently ended in divorce."

Murayama: Yes, that's right. Did it elaborate on what the cause of the divorce was?

Ooguri: It was partly because elementary particle physics was chaotic. That was before the standard model of particle physics was established and the gauge theory became the main stream.

Murayama: That's interesting.

Goddard: It was odd timing because I would say that the time when ...

Ooguri: It was just about the time when gauge theory actually started to fly.

Goddard: Well, the triumph of gauge theory came along with Gerard 't Hooft in the 70s, 71 or 72. Then it went on from there to the building of the standard model, but the dominant influences that really, I think, started changing things here were the work in the mid-1970s of Michael Atiyah and others, and then the sort of growing influence of Edward Witten. I think that that really changed how people perceived what is regarded as a reasonable amount of mathematics for a physicist to learn. For example, when I was a graduate student, the initial problem that I studied was the singularities of the scattering matrix in the complex plane. It was thought that there was a reasonable grasp of the singularities and their discontinuities in the physical region, but attempts within the context of perturbation theory to get a handle on complex singularities had been limited and so it was suggested that I should think about singularities outside the physical region and complex singularities. There was work on this using homological techniques and so on, but very few people knew about it and when you spoke about it, you really had to, in some sense, translate all of that.

Ooguri: That was not a standard language?

Goddard: It was not a standard language at all. In fact, it was slightly suspect. At various times, people have worked things out in one language and then translated them into another. There's argument about to what extent this is true in Newton. He wrote everything in classical geometry, the geometry of the Greeks—Apollonius and so on—and didn't write it using calculus. But, that's how he had worked things out. He suppressed the calculus because what people spoke was classical geometry.

Then, Dirac at some point says that he used geometry in his work. And there's an argument there about exactly how did he use geometry. He used geometry to think about space and time, to think about with the relativistic equations, and so on. Did he also use it in the context of the Hilbert space? Probably it was the former rather than the latter. Anyway, he does say at some point that he thought geometrically but translated that into algebra because that's what ...

Ooguri: That's what people understand.

Goddard: ...understand. These

processes go on at various points but, now...

Ooguri: Now, we don't have to hide.

Goddard: No, we don't have to. It is no longer terribly suspect. So what do you think about the relationship of mathematics and physics?

Ooguri: Clearly, it has been very, very productive in both ways. I think that, as you've said, modern mathematics has very much strengthened our understanding of gauge theory and string theory and other areas for fundamental physics, but I think the insight from physics has also influenced mathematics in a positive way and provided them, for example, conjectures to prove or a new way to think about geometry. Especially the quantum nature of geometry is something that the mathematician, of course, didn't know about but now very much in the common trend in the forefront of mathematics, especially in the area of geometry and representation theory. So it has been very, very beneficial for both I think. It's quite natural that, whenever we try to understand more and more fundamental laws of nature, which is one of the things we are doing at this institute, the existing mathematics is often not useful. Newton had to invent calculus, Maxwell had to use the partial differential equations, and Einstein had to use Riemannian geometry.

Goddard: But that existed already.

Ooguri: It existed already, but at that time it was quite modern mathematics. It is very natural that when we try to push the boundary of human knowledge in that way, there is no guarantee that the existing mathematics could be useful. So, interactions between physicists and mathematicians can be useful for both. For mathematicians, it's going to give them a new problem to work on and open new areas and also connect the different areas of mathematics.

Now Mathematics and Physics Have Areas Developing Simultaneously

Goddard: You have areas developing in mathematics and in physics now simultaneously. In some sense, it seems fortuitous that they are developing at the same time. For example, the theory of infinite dimensional Lie algebras and how that related to ideas in physics and vertex operators and so on. These developments happened in parallel, but they started completely independently of one another in a completely unrelated way, but at the same time. I always find it fascinating to wonder whether those things are really accidents, or there is something you don't understand. What would have been true in the 70s and perhaps the 80s is that people who were interested in the more mathematical questions would be prepared to use it in talking about physics but people interested in more phenomenological questions would not, tending to create a certain gulf. But, now, that seems to have eroded because many of the people who —like you, Hitoshi, who are also interested in phenomenological questions and are also very prepared to talk in ways that relate to mathematics. So things really have changed in that sense, I think.

Ooguri: I think for people, like Hitoshi, who built a model of elementary particle which you hope to actually test experimentally—maybe I'm putting words into your mouth—but it seems that the ideas and the mathematics that come out from this kind of development have been useful in building models that you had not thought about before, like large extra dimensions and ...

Murayama: Going back in history, for example, when Gell-Mann came up with the quark model then that's the first time people started using bigger group than *SU(2)*. That was the first time, right? People complained about group theory fever. Apparently that was the people who would not be able to catch up with this level of group theory. And then language was felt to be left out, but that actually turned out to be the right language, not just for the quark flavor symmetry, but also for the gauge symmetry, and so forth. Without that, I don't think particle physics would have existed the way we know now.

Goddard: That's true, but I think also the other side of that. I think, somewhere in the 1950s, when Gell-Mann realized that having introduced strangeness and so on, you needed a bigger group than *SU(2)*, some people started talking about *SU(2)* × *SU(2)*, and so on. They didn't know of this to be compact Lie groups. They didn't immediately go and ask—they didn't know who to ask, I guess. Gell-Mann, at one point, said that he sat there trying to work it out himself. I think he gave up when he got seven generators.

Murayama: So, it could have been like G_2.

Goddard: So, it's amazing when you think back to that. Now, you only have to say something and you go and look at Borel's work or whatever on the classification, the spaces and so on. We immediately plug in to the mathematical literature.

Ooguri: Yes. So we got remarried.

Goddard: No, I think the divorce didn't ...

Ooguri: ...didn't happen?
Goddard: No, I think it was a trial separation.
Ooguri: It was kind of a probation for a while, then.
Goddard: I think that, of course, is a very good argument for your institute. I mean this is now not just some esoteric or small group interest. It's part of the culture that's generally accepted by people of various inclinations. Whether they want to think about very theoretical problems or whether they want to really understand the latest results from the LHC, everybody has more of a common culture.
Murayama: How do you think we can protect this kind of area which doesn't have an immediate impact on the society?

Basic Science Has a Valuable Cultural Impact Though Not Having an Immediate Practical One

Goddard: It doesn't have an immediate practical impact in terms of producing what might be a cure for some disease but it obviously does have a valuable cultural impact. I am conscious of it talking to my friends who are not academics. They now know more about what is happening in basic science. It's very much more than it would have been 30 years ago. Look at the interest in the discovery of the Higgs, it is absolutely enormous compared with, say, what arguably had more importance in conceptual terms, the discovery of the W and the Z. I mean, we'd all have had a collective mental breakdown if they hadn't been there. I think that was partly because we were decades waiting for this event, the discovery of the Higgs.
Murayama: Yes, that's right. So, a historic event.
Goddard: I think also that places like CERN and the people concerned with funding them in the various countries had realized that they had to do more in explaining to the taxpayers and others what was going on. So they couldn't just let this be the press office putting out some press release. It had to be a whole process of getting people to understand what was about to happen. That all feeds in to, I think, the position of institutes like ours in the public perception, in that they're much more likely to understand what we are about. The attitude that existed many years ago, 50 years ago or 80 years ago, was that you really needed to have ivory towers. If you look at the history of the institute in Princeton, I think in the early decades, people in the institute felt that there wasn't anything wrong with practical applications but this was not what happened here and in order to make sure this was an environment in which people stayed pure, so to speak, you had to have an ivory tower with polished walls and people couldn't come in.

Now the attitude is everywhere, I think, different. That is to say, it is important to protect the academic environment in that we need to give space to people and not ask them all the time to produce a practical result tomorrow. But that is completely compatible with our explaining what we do to people outside, inviting them in, giving them talks, and discussing what we do with them, because we don't have to isolate ourselves into some monastic community that has no contact with the outside world. It's actually good for us and it's good for the outside world to have this contact.
Murayama: But that's in the UK, right? The science café—that was actually a British invention?
Goddard: Yes. But it has to go along with explaining to people that it's important that opportunity is given to people to do things where you don't know what the outcome is going to be, where you can't imagine that outcome. That is what will change our understanding of the universe and will change in the end the practical aspects of lives. But there's no easy prescription for this, I think. But I think it is incumbent on all of us who feel any ability or any inclination to do it to engage in that. So at the institute in Princeton, I'm sure Robbert (Dijkgraaf, Director) will continue this even more, putting increasing effort into our publications and our public dissemination of research. In fact, compared to the institute I went to in '74, which was a marvelous place, but there wasn't very much of this going on, now it's going on all the time. It's not the case that at the institute you can't go and be quiet, you can't go into a room, you can't walk in the woods and have those peaceful and inspiring experiences. But at the same time, the institute is interacting more or less continuously with the outside world.
Murayama: That's an important point. Maybe the last question I would like to ask. Now that you oversaw the founding of a new institution in the Newton Institute and oversaw the progress of the Institute for Advanced Study in Princeton, you gained some insight on what should not be done to run a truly tremendous academic institute. I'd like to hear your lessons about that. Maybe you never fell in any pitfalls?

A Truly Academic Institute Should Stay Focused within a Defined Mission

Goddard: No, I've been there. Probably, there've been lots of pitfalls but I think that, along with what I just said, it's possible to have these interactions with the outside world but still to make sure that priority is given to having an environment where science can happen. I see here that you made great efforts, very successful efforts, to make sure that the bureaucracy that surrounds any institution doesn't intrude because it can have a major impact particularly on people coming for a few months somewhere. I think the other aspect is that in funding, when seeking support—this is in the American and UK context—you have to be very careful about sticking to the mission because one thing that happens, when you try to raise money is that you have objectives and then somebody comes along and offers money which is only partly for what you want. Maybe it isn't really even for what you want, but you want to make your fundraising target and so you accept money to do things which weren't your main objective. These may be very good things to do. But, in the end, I think in an institution like this, there are only a limited number of things that you can do. There may be excellent things that people suggest, but they aren't part of what the institute is for, and I think then one has to say, "Well, let's try and find someone else for you to do that."

Murayama: That's important.

Goddard: I think it is important to have a defined mission and not just do everything that's good.

Ooguri: Yes. There can be opportunity cost.

Goddard: Yes. Now, I think somebody can come along and say, "Well, I'll pay for your time," but they can't pay for your time, and you can't be duplicated. I mean, everything that happens in the end impinges on the administration. It impinges on the director. It impinges on the institute. I think it's very important to be broad but to stay focused within that mission but not to do arbitrary things.

Murayama: That's a profound advice I would say. Thank you.

Ooguri: Thank you very much.

Goddard: Thank you for the discussion and I'm really, really impressed with this place. It's a great development, I think, for Tokyo, for Japan, and for the world, actually. Each of these institutes makes a statement about what is important, and so together, the network is really saying something about what the important ideals are. Thank you.

Murayama, Ooguri: Thank you, Peter.