Capturing the Past
Inspiring the Future

Sir Michael Brady

Interviewed by

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At

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Welcome to the Archives of Information Technology. It's the 26th of November 2019, and we are in Oxford, at Perspectum's offices. I am Elisabetta Mori, an interviewer with Archives of IT. Today I'll be talking to Professor Sir Michael Brady. Sir Michael is Emeritus Professor of Oncological Imaging at the University of Oxford, having retired in 2010 as Professor of Information Engineering. He is co-Director of the Oxford Cancer Imaging Centre. He is distinguished for his work in artificial intelligence, and for his outstanding contributions to developing computer-based post-processing for a variety of medical images, and applying his work to a wide range of medical problems, particularly breast, liver and colorectal cancer. He combines his work in oncology with a range of entrepreneurial activities. He was Deputy Chairman of Oxford Instruments, and also a founder of successful start-ups such as Guidance, Mirada Medical, Optellum, Perspectum Diagnostics, ScreenPoint Medical, and Volpara Solutions among others. Sir Michael was elected Fellow of the Royal Society, Fellow of the Royal Academy of Engineers, Fellow of the Institution of Engineering and Technology, Fellow of the Institute of Physics, Fellow of the Academy of Medical Sciences, and Fellow of the American Association of Artificial Intelligence, and also he is Membre Étranger de l'Académie des Sciences. In 2000, he was awarded the IET Faraday Medal and the IEEE Third Millennium Medal for the UK. In 2005 the Royal Institution awarded Professor Sir Michael the Henry Dale Prize for 'outstanding work on a biological topic by means of an original multidisciplinary approach'. In 2010 he was awarded the Whittle Medal of the Royal Academy of Engineering. In addition to this numerous academic fellowships and prizes he received a knighthood in 2004 for services to engineering.
[02:19]
Welcome Mike. When were you born?

Hi. I was born in Prescot, which is a small, a small town in Lancashire between Liverpool and St Helens, and I was born on the 30th of April 1945.

What was your family life like?

I remember it being, two things really. One, very happy, and, quite poor. We, my parents were, my parents were both really quite poor. My father had not been able to go to university because of the Depression. My mother was an orphan. There were

religious problems in my family. And, the upshot of this was that we were a very close-knit family with my, my parents and my two sisters.

What do you mean for religious problems?

So, my father had been brought up as a Roman Catholic, and my mother had been brought up as a Protestant. When, just before they were going to get married, my father went off to join the RAF in the Second World War. My mother stayed back and was under enormous pressure to convert to be a Roman Catholic. Very difficult relationship with my father's mother. And when my father came back he really kind of pretty much finished with religion after what he had seen in the Second World War. My mother wanted to be, revert to Protestantism, although in truth, neither of them were particularly devout. And, my father converted to Protestantism, which is where I was baptised. And so my, my father's parents and all of his brothers and sisters did not speak to us again.

[04:20]
Who were the important influences on you in your early life?

Well, dominant influences were my father and my mother, and, and my friends. I, obviously I was very close to both my parents and to my sisters, they were the only family I knew. And then, at school, largely through playing sport, I, I had a very wide circle of friends at school, in music, in science, and in playing sport for the school.

[05:04]
Which schools, colleges and universities did you attend?

So, after a, a typical local primary school, in those days you did a scholarship, which I passed to go to Prescot Grammar School, which was a boys-only school in those days. And I was at Prescot Grammar School from 1956 to 1963. And I managed to get good enough A Levels to get to university. In those days there were relatively few kids who would go to university; the norm was that you went to work when you had finished school. But I went to university, and was the first person in my family ever to do that. And, it changed me, completely.

What subjects did you most enjoy?

At school I always loved, I always loved science, and it was mathematics and physics. I always found chemistry a little bit like cookery, I found it, the lack of quantitative chemistry in those days, although I realise now that that's not the case, but, I found it too descriptive, not very interesting. But maths and physics I just adored, and when I went to university I hesitated between maths, physics, engineering, but in the end I, in the end I, I did mathematics.

Where did you go to university?

I went to Manchester University. I was, in fact I was accepted at about four universities, and I went to Manchester University for the, for the profound and rational reason that there was about, there were four of us went out one night for a few beers, and they were all going to Manchester University, and so it seemed to me like that was a pretty good reason to go there. So I went to Manchester mostly because my mates went there.

Was there any particular event that shaped you during your education?

The most extraordinary thing that happened to me was, in my, my first year in Manchester I went to a series of lectures by an émigré Jewish mathematician by the name of Professor Bernhard Neumann, who was already a Fellow of the Royal Society. And, he absolutely captivated me. And, when it came time… But then he moved to Australia, him and… His wife was a professor in Hull, he was a professor in Manchester; they were both offered chairs at the Australian National University. And so when I, when I was finishing my degree, and was scheduled to get a First Class Honours degree, I decided that I would like to do a PhD, and if I was going to do a PhD with anybody it was going to be with Bernhard. So, that's why I went to Australia.

[08:12]

And in 1967, you didn't just go to Australia, but you also married your wife, Naomi Friedlander.

Yeah, well that was the most important thing that happened to me at Manchester University, was, I met Naomi. I was playing… To be honest, in my first year I was a bit, I really was a bit off, off the tiles. I was playing a lot of rugby, I was on the university 1st XV at rugby, I was doing mathematics, I was dating a hell of a lot of girls, but I was drinking, you know, really at Olympic qualifying standard. And then, I realised if I carried on over the, over the summer vacation, I realised if I carried on like that, I was, I was probably going to shorten my life. So, amazingly, the week before my second year at university I met Naomi, and, we started discussions. It might sound like arguments, but they were always discussions. And we developed a, a friendship and a love that, you know, 55 years later burns just as brightly as it did then.

What did she study?

She did pharmacy. And so, it was pretty easy when I, when we went to Australia, I won a Commonwealth Scholarship to go to Australia, and it was fine because Naomi could come out and she could work as a pharmacist. And so she got a job in Australia, in fact she opened a pharmacy for a guy. She started up a pharmacy, she became the manager. And, and I was a student doing mathematics for a PhD.

[09:55]
What are your memories of Australia?

Well let's see. The memories of my first three years, or two and a half years of married life, we, we just had a ball. We did a lot of, we travelled a lot throughout Australia. I played, I played football for the Australian National University, and we played in a professional league. We played a lot of squash. We partied a hell of a lot. But I also did, you know, really, really, we had a, it was a world class research laboratory doing mathematics, and, ideas were just flying around, seminars, and, they set a standard of doing mathematics that was just, fantastic.

[10:48]
How important was travelling and working outside the UK to your career progression?

[pause] To my personal, my personal progression, I think it was extremely important, in the sense that I had, I had only ever lived in the north of England, which is, you know, is, is not the wealthiest part of the world. It's cold and grey. Going to university was an extraordinary shock to me to first experience middle-class life. And I really loved it. But then, to go and live in a country where it was hot and sunny, where there was completely different vegetation, it was a very different, relaxed lifestyle. And my wife, Naomi, is from Cape Town, so she was used to that. And so, I really began to understand what it is to live in a different culture. And the ANU, Australian National University, in those days had huge numbers of students that were from outside Australia, from Africa, from South America, from the United States, from China, from Vietnam. It was also the years of the Vietnam War, and so… Two of my friends in Australia were killed in Vietnam. And, so, it was a kind of, an awakening of the world beyond the UK. But I also increasingly, as the years went on, I felt that Australia was more and more parochial, I really felt as though real life was carrying on in Europe and the United States, and so when I finished my PhD I just wanted to come back, either to North America or to the United – or to Europe.

[12:46]
And so, what did you do after your PhD?

So, I decided that, although I had had good fun, I just didn't want to work in pure mathematics. I had been working in group theory for my PhD, and it was very intellectually satisfying, but I realised that what I really wanted to do was something that was applied. So the first thought was to get into applied mathematics, but, you know, that's, that's pretty different from computing – pretty different from pure mathematics. And then I had the thought, you know, gee, I wonder what it would be like to work in computing. Because computers were just becoming available, and ANU had one computer. And…

Do you remember what the computer was?

It was an ICL… Ah, now you've got me. 1900 I think. It was around that vintage. I guess it would have been a 1900. It was definitely ICL. And it was, it was a pain in the neck to program. I just wrote, you know, simple ALGOL programs, just to find out what it was like. But you weren't allowed to go and see the computer, you just posted a card deck through the wall and you got back a sheet of paper the following day telling you that, you know, your program was crap and you had made a bug, and stuff like that. So… But I decided I would apply to jobs in computing. So I wrote 66 applications from Australia, just all over the United States, Canada, and the UK. And of course, I, 50 of them didn't reply. You know, I basically said, 'Look, I've done a PhD in maths. I quite fancy getting involved in computing. Do you have any suitable jobs?' And, as I say, 50 out of 66 didn't bother replying. But actually, amazingly, I was offered six jobs. Because, I think, in those days there was such a shortage of people who wanted to do computing, and such a shortage of people who could do any mathematics in computing, that, I got picked up, and was offered a bunch jobs in industry, and a bunch of jobs in universities, and in the end of the ones, I accepted to go to the University of Essex.

[15:09]
And it was 1970.

Yup.

And, what are your memories of the University of Essex?

Well, the university, I mean what I remember most about being at the University of Essex, those was ten years between 1970 and 1980, I guess were, three things. On, on a personal front, Naomi and I had our two wonderful daughters, Sharon and Carol. Second of all, I, professionally I started off working, you know, as a pure mathematician coming into computing, I started working on, Turing machines, recursive function theory, and the like, and I even wrote a book called *The Theory of Computer Science*. Because it struck me that the, the kids who were doing computing science in those days were people, were by and large people who weren't very good, or weren't very confident, at mathematics, and so, the theoretical foundations of

computing seemed them to be a completely alien subject, as opposed to programming and, and so forth. And I wanted to write a book that regarded Turing machines as a kind of, very abstract kind of computer, recursive function theory, and in particular Lisp, as a, the lambda calculus, as being a, a programming language, and so the equivalence of all the methods, all the models of computation, was equivalent to building a compiler for example from the lambda calculus on to Turing machines. And, right up, you know, about that time Dana Scott came out with his model of the lambda calculus, and so that meant that there was this, formal mathematical foundations. And so what I wanted to do was to communicate the idea that there was programming with a kind of, programming with a programming approach, to providing a basis for the theory of computer science, and to show that it was absolutely rooted in the fundaments of mathematics through Dana Scott's work. So I wrote this book. And that's the second thing I remember. But the third thing I remember, which, actually I guess is the reason for this interview, was, I realised that what I had found myself doing in computing, in theoretical foundations of computing science, weren't that much different from pure mathematics. And, that really wasn't what I was seeking. And so I was still looking around for an application. And I came across AI, and in particular came across image analysis, and it was like a kind of, burst of thunder. I mean I just thought, wow, this is what I'm going to do for the rest of my life.

[18:16]

And so, about five years in, you know, when I had, you know, house, wife, kids, car, you know, so I couldn't move or anything like that, I had a sabbatical of a year, and in that sabbatical year I wrote a book, the one I told you about, and then I applied to what was the EPSRC for, to pay my travel to visit what seemed to me to be the twin Meccas of AI, which was MIT and Stanford. And I asked for travel and accommodation for two months, and to my astonishment they wrote back and said they would give me travel but they would like me to go for three months, and would I also go to Carnegie Mellon, and, various other places as well, SRI International. And, that was how I first went to MIT, and met these wonderful people like Patrick Winston and David Marr.

[19:24]

What brought you to the MIT AI Lab in 1980?

So, I first went in 1975, as part of this three-month trip funded by the British, EPSRC. And, the administrator of the lab, Karen Prendergast, fixed up for me to have accommodation very close to the lab so I could spend… At the time my wife was staying with her parents, which was in Upstate New York, and my two daughters. So I was pretty much by myself. And so I just, I like, worked sixteen hours a day for the month that I was at MIT. And I struck up a bunch of friendships with an English guy named David Marr, a South African (my wife is South African), Berthold Horn, and, most of all, with Patrick Winston who was the director of the lab. And I just really loved being there. I got to meet, you know, my heroes, Marvin Minsky, Seymour Papert. But just to be at the AI Lab, around, surrounded by these various people, with these brilliant young students, like Gerry Sussman, you know, Carl Hewitt, it was just, it was just like, every day was Christmas. And, I just couldn't get enough of it. But I also developed kind of, social, friendships, with Patrick and Berthold particularly, and with David. And, so they asked me to come back in 1976, and I couldn't do that because my wife's father died. But I went back in 1977, for about three, four weeks. And then, they asked me to go for the whole summer in 1978. So we went for about two and a half months. And at the end of that time Patrick asked me if I would like to go to the lab and be the Associate Director. And, and so I, you know, at that point… So then we had to… I went again in 1979, but you know, at that point it was a question of getting a visa. Which turned out to be easy in the end, because my wife's mother still lived in New York City, and had American citizenship. So it was easy. And… But by that stage I had also been, you know, promoted to a senior lectureship, and they were trying to keep me around Essex. And, I guess, the people, my colleagues in Essex just could not believe that I would give up a tenured, senior position, you know, at the age of, 35, 34 actually at the time, to go to an untenured research position in the States. Naomi was just absolutely supportive, even though she had to go back to university, in Massachusetts, to get another, yet another degree. My kids were very supportive, despite the fact that it meant they had to leave their friends behind. And so we went off on this American venture.

[22:55]

What are your memories of those years in the US?

They were very… The things I remember most is, what a phenomenal place the AI Lab was. It was… But what struck me, and really informed the work we did when I came back to Oxford, was, the sheer brilliance and power of the PhD students. And I realised that, the PhD students were really the engine of all that was innovative and great at MIT. Sure, there were some terrific postdocs. And the faculty of course were, superb. But the tenure system, which was pretty brutal, I mean there was about one academic in nine or ten who was given tenure, really made it such that, the academic staff did not work closely in teams with each other on the grounds that your success is my failure. So, the graduate students were just kind of immune to all of that, and they just were brilliant. So the first thing I remember, the PhD students. The second thing I remember were, a number of young PhD students, John Hollerbach, Tomás Lozano-Pérez, Matt Mason, Eric Grimson. And we kind of put together this kind of, hubris of, we were going to start off a robotics laboratory. Berthold Horn had done a terrific job in starting, but we really wanted to breathe new life into this thing. And so we sat down on a regular basis and read loads of papers, and argued about those papers. And then we put together a reader, which was my first book for MIT Press. And then, we realised that, there wasn't a conference, so I organised the first conference. And had to organise our first conference, we had to raise some money. So, I went and spent a hell of a lot of time cultivating a guy called Charles Smith, who was running the, who was the, the administrator for the System Development Foundation. And they made a huge grant of around five million dollars, which, you know, given that this was now, 35 years ago, 38 years ago, was a prodigious amount of money. And, so we, we organised a conference, which to this day, the international conference on Robotics Research, International Symposium. We realised there wasn't a journal, and so, I persuade Lou Paul to help me, and so we started a journal. [26:07]

So now we have a journal, we have a conference, we have a reader, and we started doing loads and loads of research. And, Tomás and Matt, John Holler, and Eric, and then other students like Demetri Terzopoulos, started writing superb theses, and then it really kicked off. What Berthold had always done before, but it really kicked off into, and amplified very substantially, what was happening in robotics at MIT. I mean basically, I had my own research group, which, I attracted a bunch of graduate students to come and work with me. Margaret Fleck, and, Phil Agre, Demetri Terzopoulos. And, I also had a couple of postdocs, one of whom, Jean Ponce, came

over from a friend of mine, one of my closest friends now, Olivier Faugeras, who is in INRIA in Sophia Antipolis. He had a couple of PhD students. And in those days one of the ways you could get a French student to excuse them from doing military service was, you could get them into a major research lab. And so, Marciella Derch went to CMU, and Jean Ponce came to MIT. And Jean and I worked very closely, wrote a bunch of papers together. And at the same time there was a kind of, a bit of a, a scruffy physicist came by my office as well to talk to me about some of the work that David Marr had done, and very unfortunately my first year in MIT David Marr had died of leukaemia. And, so this, this English kid, Alan Yuriel, came to see me, and I got him a postdoc position, and he and I worked together on a bunch of things, on a whole bunch of papers. And then Alan went off, after I left MIT he went off to California, and then, he is now a senior professor at Johns Hopkins. And Jean Ponce is at the École Normale Supérieure in Paris.

[28:41]

So, we had a terrific group doing vision, but at the same time we were also doing image-guided control of robotics, and that was these other people like John Hollerbach, who were doing tactile work, and design of hands, design of, touch sensing. Matt Mason was doing work on planning, and so was Tomás Lozano-Pérez, both collision avoidance, path planning. Matt Mason was working on what became one of the most interesting ideas developed in the theory of mechanical assemblies. And I also attracted one graduate student named John Canny, who was an Australian kid, who did his MSc with me, and did perhaps one of the most widely cited feature detectors, the, Canny edge detector. And then John went to work with, he realised he really wanted to work in theoretical stuff, and he went and worked with Tomás, and won one of the best thesis prizes at MIT, and then went off to, and still is, full professor at Berkeley. So they were a terrific bunch. And it was, scientifically it was just a great time. The, the AI Lab was, Patrick was an inspired director of course. He very very sadly died this year, earlier this year, but he was a wonderful, wonderful human being, you know, one of the, one of the best mentors I've ever had in my life.

[30:26]

But at the same time, while all that was happening, my wife realised that she didn't want to, she didn't really want to live in the United States. She felt much more comfortable in Europe. And our kids were coming to the time, the age of fourteen and twelve, where, if we stayed on much longer, the education systems of Europe and

the United States diverge, and so Naomi was really very very keen, by about 1983, 4, 1984 I guess, she was very keen that we explore the possibility of coming back to, back to Europe. And since at that time we only spoke English, that really meant back to the UK. And, I thought she was nuts. And so we had this, I was having, you know, I was at the greatest place on Earth for doing AI. I wanted to stay. I loved Boston. And Naomi wanted to come back to the UK. I thought of it was the Third World. And, you know, we… And it was just a, kind of unresolved. It wasn't something we argued about, but it was always there as an issue. It was always the elephant in the room.

[31:41]

And then, an astonishing thing happened. In 1983, I was sitting in my office at MIT and I was asked by the industrial liaison organisation, Industrial Liaison Office, sorry, at MIT, to, would I, would I meet a bunch of businessmen from the UK? And they said they were from the Department of Trade and Industry. And I thought, oh Christ. You know, a bunch of administrators, you know, on a boondoggle. You know, what am I going to do with these guys? So, with no enthusiasm I said, yeah, I'd meet these guys. So anyway, there were three people showed up to my office. And we started talking. And, they were asking about the AI Lab, and then they were asking me about me, and why I had moved to the AI Lab. And, and why didn't I go back to the UK? And, you know, as far as I was concerned, they were a bunch of administrators. So, you know, I just told them straight out, you know, nothing there that would attract me back to the UK. And I noticed that two of the administrators were talking, and one of them was saying nothing. Anyway, it turns out, the guy who was saying nothing was the, was Kenneth Baker, who was the Minister for Science and Technology. [laughs] And I hadn't realised. So he then fessed up and told me. And I was embarrassed as hell. So he laughed. And we laughed about, I met Kenneth several times after that, and he, he always laughed about this. So, he said, 'What would it take to attract you back to the UK?' And I said, 'You would need to have a chair, it would have to have a small number of positions, like three or four. Faculty positions you can hire. I'd need to get a dowry, I'd want to see a research grant to get me going; after that I would figure on getting my own money.' And bugger me, nine months later I got a phone call from the University of Oxford asking me to go visit for a chair, whose existence I didn't know of. So, I went over to Oxford to be interviewed for a chair that I never applied for. [laughs]

[34:07]
And so you moved to Oxford in August 1985, correct? And, when you arrived to Oxford, you established the Robotics Laboratory.

Yes.

Would you to talk about the laboratory?

Yeah. So, by this stage there were three things, and I've mentioned them. First is, I had been working in applications of computing, and I felt very comfortable with that. So I wanted to be a member of an engineering department rather than a computer science department. In those days the computer science department in Oxford was very very different from what it is now. It was a fantastic department. It is now but it was a fantastic department then. And it was led by Sir Tony Hoare, who was just, you know, one of the world's greatest theoretical, theoreticians in computing. And that was fine, but that was the computing that I had set my face against, and why I had got into AI, and why I had gone to MIT. So, I wanted my chair to be in engineering science. I wanted to declare that we were going to do practical stuff. And, I had this idea I wanted to do robotics, and in particular I wanted to do mobile robotics. Because we hadn't had room at MIT. But that seemed to me to be, could do image-guided servoing, that would be, that would be fantastic. Bring all these problems of robotics together. And, the second thing, though, was, I wanted to build a research lab, and surprise surprise, after my experience at MIT, I wanted to build my lab around PhD students. And the third thing I wanted was, I wanted to make sure that the faculty that we hired collaborated. And so I insisted that in the letter of appointment to new faculty members, that the sentence be inserted, at reappointment, which is the equivalent of tenure, at reappointment, credit will be given for having collaborated with colleagues. And if you set the criteria for success, that determines the behaviour you get. So by saying I wanted that we would value collaborations, all the young faculty that we hired all collaborated with each other.
[36:40]
So we had great graduate students, we had a great young faculty. And what I did was, I wanted to hire some of the smartest young people I could find, and so, we recruited

Andrew Blake, who is now FRS, Andrew Zisserman, who is FRS, Hugh Durrant-Whyte, who is FRS, Alison Noble, who is FRS, Lionel Tarassenko, who is FREng, et cetera. They were just a phenomenal bunch of guys and girls. The lab we built, we set up seminars, reading groups. We encouraged all kinds of interdisciplinary action across the thing. And, Andrew led image analysis, the two Andrews led image analysis. Hugh Durrant-Whyte led control with Ron Daniel. And I wanted to build synthesising projects, so we started working on mobile robots. And mobile robots in those days, we, I was very fortunate to hire a couple of really good postdocs, Huosheng Hu, who is now at Essex, and Jan Grothusen, who became the CEO of Guidance. And in those days, to get EPSRC funding in robotics, you needed to have a company that would collaborate with you, and that's what brought me in contact with GEC.

[38:23]
Can you make some examples of the applications you developed?

So, we, the, the thing we did most of all in the Robotics Lab in those days was the, was the mobile robots. And I was working together with GEC Electrical Products, and they had built, they had built electro-mechanical devices with a rotating infrared scanner that could figure out where, it knew where it was, and there were barcode reflecting, retro reflecting targets around the environment, so it could figure out where it was. It just didn't know where anything else was. And so what we did was, we built ultrasound, infrared rain sensors, vision sensors, and a kind of distributed computer architecture based around transputers, to do a whole series of hierarchical control from, making sense of the environment. It was at the time when Rod Brooks was developing his subsumption architectures at MIT, and we were developing a kind of alternative, but, you know, very closely related. And with models of the environment, understanding various strategies for navigating around obstacles, either by re-planning a path or by slaloming around an object. And the stuff that we did, both the, the device that was, that was built, which was a transputer running a, a bunch of software for doing signal processing, which we called a locally intelligent control agent, or LICA, we, we licensed to what was going to be GEC Electrical Products, but effectively became Guidance. And then also, a lot of the software that we developed also went to Guidance.

[40:27]

So, let's talk a little bit about Guidance. It's a company that you founded in 1991.

Yeah. So, that was a kind of bizarre story. We finished our, we finished our first research grant in 1991, and we went to… It had been hugely successful, both in terms of the research that we had done, the graduate students that we had graduated, and the transfer of our technology to industry. So EPSRC made it very clear that they would welcome a follow-on grant proposal. So on the final review I talked to the guys we had worked with, Malcolm Roberts, and John Potter, and Russ Miles from GEC, and said, 'Hey, are you guys up for a follow-on project?' And they said, 'Well we would be, except that GEC have just shut down Electrical Products – robots, automatic robots, robot vehicles.' So I said, 'Well that's a bit of a bummer.' And they said, 'Yeah, yeah.' So, I said, 'So what are you going to do about it?' And they said, 'Well, I guess we'll go off and build control systems for steel plants and stuff.' And I said, 'Jesus, that sounds boring.' And they said, 'Yeah, it really does.' So I said, 'Well why don't you…' I said, 'You know, excuse me, if you want to, if you want to build mobile robots, why don't you just start a company?' So they laughed at me as though I was some stupid academic. And that was it. And then about three weeks later I got a phone call saying, 'We've been thinking about your offer.' And I said, 'What offer?' So they said about forming the company. And so, between Christmas and New Year we met up in my office in Oxford, and we planned what we would do to start this company, Guidance. And so Guidance started in 1991, and to be honest, it was a bit of a lifestyle company during the 1990s, you know, we, we made stuff, we sold the product that we did to FMC Corp in the United States. But the company didn't really grow that much, there were only about ten, fifteen people by 2000. And then, there was a bit of a scare with, whether or not FMC were going to continue to buy at the same rate. In the end they did, in fact they doubled it, but there was a big scare.

[43:05]

And we realised that we needed to diversify. And so, we started, first of all a marine division for dealing with putting sensing technology on supply vessels going to offshore oil rigs and gas platforms. And second of all, we were approached by Securicor, who later became G4S, to develop tags for offenders, on the grounds that

we knew how to build a mixture of mechatronics, devices and smart software. And so we were building some kind of AI software that went into the, data logging, and the control of people, trying to draw inferences about when somebody was perhaps skipping off, taking off their tag, and stuff like that. And so, the company then grew, from 2000 to, there were about 120 people working for it by 2010. We then sold the monitoring division to G4S, we carried on with the other two. And then, in 2017 we sold the automation part to Matthews, and then in 2018 we sold the… No, '16 and '17, sorry. 2017 we sold the marine division. And, yeah so that was Guidance. And so Guidance is no more.

And this was your first start-up?

It was my first start-up, yeah. And, and it was a pretty interesting experience. And so, it really got me in the mindset about what to do and what not to do by the time it came around to the time of doing my second one, which was in 1999.

[45:13]
Let's go a little bit back. So in 1994/5, and also 1996/7, you were a Professeur Invité at INRIA, France.

Mm.

What do you remember of that experience? Can you tell us a bit?

Yeah. So, the… OK, so, the background is, in 1989 I did my tour of duty as Head of Engineering Science, which is a five-year tour of duty. In fact most people did ten, but I was damned if I was going to do that. So I did my five years as head of department. And then when I… And during that five years, and it was pretty hard to keep research going then, because we had about, 75 academic staff, we had 1,000 people in the department, and I was on God knows how many university committees, so it was bloody hard to keep the research going, but during that time I had time to reflect, and one of the things that struck me was that I, I had by this stage been, by 1990 I had been in the, in Oxford for five years, and we had built the mobile robots, we had done a lot of work in computer vision, I had done a lot of work funded by

industry, by the Defence department, but also on research grants from Europe and EPSRC. And, I reflected on the fact that my, my wife's mother, the wonderful Irene Friedlander, had died of breast cancer, and her tumour was probably two centimetres across. And the more I thought about it, the more I, the more I learnt about breast cancer, the more I was just appalled that a tumour had been able to that size without being detected. And it was about that time that the screening programme started up in the UK. So I was kind of, I was curious, why they had missed this tumour. So I went up to talk to the people in radiology up at the John Radcliffe Hospital, and then I went to Addenbrooke's, and I went to St George's, and I went to the Institute of Cancer Research, just to try and find out what was known about early detection of cancer. And I was appalled by the lack of decision support for radiologists. And so, by 1991 I had determined that my future was going to be in breast cancer, from being cancer. And I attracted a fantastic young PhD student named Ralph Highnam, and I explained to him what we had in mind, and that became the work that led into Volpara, and we can talk about that separately.

[48:12]

So then, as I came to the end of my time as head of department, I knew I didn't want to be a vice-chancellor, or a head of an Oxford college or anything like that. And I applied for a senior research fellowship from the EPSRC, which gave me five years with no teaching and no administration. So I went from one extreme of being a head of department to another where I was just doing research. And… But I was determined that after five years being in Oxford, and then handing over to my successor, David Clarke, in engineering, I was determined that I wasn't going to stick around Oxford. You know, the last thing I wanted was, 'Oh Mike, you know, engineering science is not like it was when you were head.' I thought, screw that. You know, I just wanted to be able to work. And so, I cooked up the idea, wouldn't it be nice if we, Naomi and I could go somewhere else in Europe, and maybe learn a second language. You know, if we were really serious and committed to Europe, which I am, I would love to learn a second language. Naomi was a little intimidated by that, but she was, as always she was supportive and game to do it. And, it really meant France, because I had done French at O Level and I had done pretty well in French at O Level. And so, I started looking around. And the most obvious places for me to go were Toulouse with Georges Evalt, and Grenoble. But in the end, the stuff that most attracted me was the work of Nicholas Ayache and his group, was in

those days called EPIDAURE, at INRIA in Sophia Antipolis near Antibes. I curiously had been the *reporter de thèse* of, that's the, the reporter of the thesis, of Nick. I had examined his PhD. And so I knew Nicholas pretty well, and I knew a bunch of other people, Jean-Daniel Boissonnat, Eve Costa-Maniere, Olivier Faugeras. I knew a bunch of people. And I thought, wouldn't it good… So I applied to Nicholas to go, and he got some funding from the French government to enable me to go. So we went out for '94/5, and, that's how I worked at, that's how I started working at INRIA. And it turns out, my wife fell in love with the south of France. I told you she's from Cape Town. And so, the mountains falling into the Mediterranean with the bougainvillea and hibiscus and the, and the birds, and the smells, and the sunshine. And she was just in heaven. And so, she fell into doing French. And so when we came back, in August of '95, she quit her job as a pharmacist and did a French degree. And, so we then went again for her year abroad, so we went back in '96/7, and then we bought an apartment. And then I sold a company and we bought a house. So… And I, to this day I have very very close relationships with Nicholas, Xavia Pennec, Olivier, Jean-Daniel, et cetera. So, you know, they're very, and some of my deepest friends in this world.

[51:56]
So, can we go back to your relationship with Ralph Highnam?

Yes.

You supervised his thesis, and then you co-founded with him Mirada Solutions.

Mm.

Subsequently also Volpara Health Technologies.

Mm.

So can you describe him?

Sure. So, Ralph was and is, quiet, tall, smart as hell, hard as nails, kind beyond belief. And he wandered into my office in, 1991. He had done a master's in computing, in Oxford, and he wanted to think about doing a PhD. And at the time I had been reflecting on Irene Friedlander's death from breast cancer, and the need for better image analysis. And by that stage I had learnt enough about mammography, and I had looked at enough mammograms, to know that this was going to be a pretty tough nut to crack from an image analysis standpoint. And I had concluded that the only way… Look, if you're going to put something into a clinic, you can't just have something that works on 30 examples and you write a paper. If you're going to put something into a hospital, and you're going to have people use it, it's got to work 99.99 per cent of the time, and it's got to get things right. It's got to be rock solid, and it's got to be built bulletproof. And I knew that. So, I wanted to know how you could make mammography bulletproof. And the problem fundamentally is that, when you look at an image of a woman's breast in a mammogram, the image you get is determined by two things. One… And, and think black and white photographs, right? The photograph that you took is in part dependent on the scene, and in part to do with the various settings that you choose. Like for example, the exposure time, the f-stop number, the film speed. Various things like that. Now of course, if you're doing photography, and I'm a mad keen photographer, but if you do photography, you exploit those possibilities, you know, to give an extremely pleasing image. When you are dealing with mammography, you've got the inverse problem. You've got this choice of parameters of the exposure time, of the tube voltage, of the tube current. And, what you're really interested in is not that. You don't care about that. What you care about are the contents of the woman's breast. And so you've got to separate out these two things, which are confounded. And I figured that the only way, this is way before the years of machine learning, I figured that the only way that I knew that you could do that would be to model the flow of X-rays, the fluence to give it its proper title, of X-rays through the woman's breast to expose the, the image.

[55:47]

So Ralph walked into my office, and I said, 'Listen, I've got this thing. I have a dream. And my dream is that we could build a physics model of the formation of a mammogram, and we could use it to make a quantitative model of the breast. But,' I said, 'I don't know whether we can do it. It's a lot of… It's pretty high risk.' And he just said, 'It's exactly the kind of thing I want.' So the two of us worked for three

years. We bust our arse to… And amazingly, we came up with a model that gives, from a mammogram, a representation of the dense tissue in the breast, measured in centimetres. It was the first time anybody had ever made a quantitative model. And we were pretty pleased with it. But I couldn't get it funded by the EPSRC, it was, it was far too adventurous for that, although, when we put up a second version of the grant they did fund it. But it was obviously a bit too advanced for some of the referees. But then we wrote up a book. And then, we started a company, Mirada Solutions. In fact Mirada Solutions had two pieces of technology, one was our mammography stuff, and the other was image registration. And, actually what happened was, it was at the time, 200, when we started the company, that a new hybrid imager, a so-called PET/CT… PET is a medical imaging method that gives information about metabolism within the body. Unlike MRI which gives soft tissue contrast, and function, CT gives information about dense tissue, for example, bones. But PET, a PET and CT hybrid machine came available, and what they needed were software that would fuse these two images together. And we had such software like that. And so we had these two technologies inside Mirada Solutions, but it was pretty clear that the world wanted fusion. And so we, reluctantly, it was a real heartbreak, we put the mammography stuff on the back burner. That eventually became Volpara. But in the meantime, Mirada Solutions went with PET/CT image fusion and MR-CT, PET-MR, and so forth. So that was, 2000. And then we sold that company in 2003.

[58:33]
So, let's go back to the Kadir–Brady saliency detector. So that was, the first was 2001?

Yes. So, one of the things that I have worked on a lot in image analysis has been feature detection. We know that the, much of the retina and the first many layers of visual cortex extract features of various kinds, and, both in terms of intensities but also in terms of motion. And so there had been over the years various ways in which you could try to understand that. It was originally what I had worked on when I first went to work with David Marr at MIT, was on feature detection. He was developing what he called primal sketch. I was working in motion, I was working in texture analysis. And then, one of the things that we have known from perceptual psychology for many years has been that, if you draw a shape, you can take a small number of

points on the bounding contour of that shape, and if those points are chosen appropriately, recognition – and you just draw straight lines between successive points – it turns out that your ability to recognise an object is as fast as if you had the original curved outline of shapes, where if you have a cat, you could just give about ten points and, [clicks fingers], you would get a recognition of cat almost as fast as you would if you get a silhouette of a cat. But you can't just place those points at random. And typically where they are is, they're at points of high curvature, for example the tips of the ears, tips of the nose, the ends of the paws, the end of the tail, where the tail meets the butt, and so forth. And, we knew, therefore, that not all points carry the same amount of information. And that raises the whole issue, when you come on to look at texture, of what constitutes a point which is, carries maximum information, and how can you even think about that? Well there's a pretty interesting way of thinking about information which is to think about entropy. And entropy has been one of the fundamental components of the theory of information.
[1:01:19]
And so what Timor and I did was, we had begun to ask the question, how could you combine the notion of entropy, local entropy, with another extremely important idea, that's in imaging signal analysis, which is scale-space, that you could look at things at different spatial and temporal scales. And we worked together to try to figure out how you might choose. Well then you can have features given at each of these spatial scales. In the case of an image, we have entropy to give us a notion of local information content. Now the question is, that's a hell of a lot of information. Not all scales are treated equally either. We figured out, what are the important points, what are the important scales? And that led us to this notion of saliency, and that's what Timor and I produced, and it's had an enormous number of, hits. [laughs] Not that I give a damn about that kind of stuff.

[1:02:18]
Then let's talk about commercialising research in medical imaging.

Yeah, sure.

And let's go back to your entrepreneurial activities too. So you said, 'There is nothing like the thrill of watching the fruit of your research being used by doctors to

cure people.' So this brings us to the topic of science and its commercial exploitation. What are your views on this relationship?

So, let me be absolutely clear. I have always been a great fan of basic research. I always will be. But, I would make a personal statement that, although people talk about the, and quite correctly, the thrill of doing research, the thrill of scientific discovery, and I've, I've had my successes in that, and it's very very thrilling, it's very thrilling to see your name on the book cover, the first time you do that, but it's a personal statement about me. It's not the only thrill that you can have in science. And for me, having done a PhD in pure mathematics, then worked in the theory of computer science, and then worked in AI, and worked predominantly, writing research papers, when I came to work in breast cancer, and then in medical image fusion, which we did for Mirada Solutions, I happened to be in a clinic where we had been installing stuff, and I happened to see a clinician pull up the software based on the maths that we had done in determining what he was going to do for the next step of patient care. And I realised that I personally got a buzz from that which I had never ever had before in science. Now, that's a personal statement, but I don't believe that that is a second-class, makes me a second-class citizen, because I transfer stuff. [1:04:32]
So in fact, what I have come to realise over the past 20 years, 25 years, has been that, while you strive to build systems that work 99.99 per cent of the time, if they don't, if they break, it's not usually because, you know, we're crap programmers. In fact, given that most software… All software sold commercially in medical imagining has to be built in quality standards, it's got to get regulatory clearance. You know, it's not that the programming is bad; it's because you have a limited understanding of the problem that you're trying to work on, whether it's segmenting out the liver, whether it's detecting hepatocellular carcinoma, whether it's finding whether or not this particular breast tumour is benign or malignant, whether this particular colorectal cancer is responding or not responding to therapy. You can build programs and you can build mathematics to try and help you do that, but actually, if you start to have things which consistently fail, it's because of your lack of understanding. So what you find is that in order to set the bar so high, you really have to have an extremely deep understanding of the medical context. But at the same time, if you find things don't work, that poses problems. And so you get this two-way between an application

that really works and the underlying science. And to me, there has always been this symbiosis between the absolute practical, cutting-edge application in medicine, and the underlying science, and that is where I have found my greatest thrills. It's not for everybody. But actually, the more I talk to young people, and communicate this passion, the more that some of them become imbued with that same spirit, which is how we've grown the company. So I've now got about 500 people working for me.

[1:06:58]
So in 2003 you sold Mirada.

Yup.

But now Mirada exists again.

Yup.

So, two questions in one. So, who chose the name Mirada, and why? And, what happened in 2009, 2010?

Right.

So, when Mirada Medical…

Became again.

Yes.

So, we actually brought together two little companies to form, to form what became Mirada Solutions. And when we brought them together, I was chairman of the company, and we had about, fifteen employees, something like that, and I wanted a name for the company. And I set down a competition for which the prize was a bottle of champagne. And, the competition had, that, the name had to sound attractive, even beautiful, but because the primary market for innovations in healthcare is the United States, and because one third of the population of the United States is Spanish-

speaking, the word had to sound beautiful, not just in English but in Spanish. And so I set this competition, and we had some really stupid names. I won't even go through them. And I was despairing. But the day before the competition closed one of our guys, who had done a PhD in our lab, Miguel Mulet Parada, who is from Madrid, came and said, 'Mirada.' And, for people who don't speak Spanish, a *mirada* is a glance. So that for example, a radiologist might take a quick look, a *mirada rápida*. Or, if you see somebody beautiful, you might take a *mirada expresiva*. And so, I just love the name Mirada. Although half the people in America call it Miranda, but that's their problem. So, that's how it got the name Mirada. And what we did was, it was all based around, medical image fusion. At the time PET/CT machines, hybrid machines, had just been produced by a small company in Knoxville, Tennessee called CTI Solutions, and they work collaboratively with Siemens. Siemens provided the CT, and CTI provided the PET, and the cyclotron, and the radiochemistry that went with it.

[1:09:41]

And, in 2002, November 2002, together with one of our business development guys, Chris Behrenbruch, we tried to do a workstation deal to sell to CTI Solutions, and they listened. We were supposed to talk to them for about fifteen minutes, but in fact they brought their entire board, and we, Chris and I spent an hour and a half. It was like, it was like your worst interview. It was like, you know, a DPhil viva, a PhD viva gone wrong. Jesus, these guys really put us through it. Anyway, we finished, and I went for a beer with Chris, said, 'What the hell was that all about?' Anyway, didn't think anything more about it, and about three weeks later I got a phone call from a guy named Greg Brophy, who was the legal counsel, and he said, 'Dr Brady, I'm afraid, I have bad news and good news.' I thought, shit. You know, we were running out of money. He said, 'The bad news is, we're not going to give you a workstation deal. Good news is, we want to buy your company.' So they did. So in 2003 CTI acquired Mirada Solutions. And, and then, in 2005 we became… And then we became CTI Mirada. And then in 2005 Siemens Molecular Imaging acquired the whole of CTI for a billion dollars. And, they, Siemens really pumped a lot of money into the bits of Mirada's portfolio that they were interested in, but the rest, the so-called third party business, they were letting wither on the vine. For, for Siemens, it was a question of empowering the competitors. So, we, the guy who was running our product at the time, the third party bit of our product at the time, was a guy named

Hugh Bettesworth, and he, together with Mark Evans, who had been the finance director, Chris Behrenbruch, who had been the CEO at the end, and myself, did a management buyout of what is, effectively we raised money to buy out of Siemens the third party business. And so we had got the third party business, the source code, the customer list and so forth. And that was Mirada Medical, and that's how Mirada Medical… So Mirada Medical has now got, 70 people, it's working a lot in radiation therapy, and is using AI, particularly machine learning, to do radiation therapy planning avoiding organs at risk. So you know, you know, if you're doing head and neck tumours, which are particularly hard, you don't fry somebody's throat or their carotid artery. You know, so, those are known as organs at risk. So there's a lot of AI gone into Mirada Solutions and then Mirada Medical, and, so forth.

[1:12:58]
What about ScreenPoint?

So, in… I was working in breast cancer with Ralph, and one of the people who kind of understood what Ralph and I were doing was a guy, Professor Nico Karssemeijer, from Radboud University in Nijmegen in the Netherlands. And so, I met, I met Nico at a conference in 1998, and we just got on like a house on fire. I really, really, I really liked, I was really very fond of Nico, and to this day he's a very close friend. So, when we started Volpara in 2009, 2008… well 2009, Nico was one of the co-founders. And then in 2014 I met him, and, he came over to see me, and he said, 'Hey Mike, I've been thinking about what's been done in computer-aided detection of breast cancer,' which is a type of application machine learning to breast cancer. And he said, 'You know, the way it's being done at the moment is just plain wrong. We need to rethink it, and I think I know how to do it.' So we sat down and we talked about it for a day, and in the end he said, 'Will you help me form a company?' And I said, 'Sure.' So, we started ScreenPoint, and that's in, we're based in Nijmegen, and we have about 32 people working for the company, and then a year ago, year and a half ago, Siemens made a major strategic investment in, in ScreenPoint.

[1:14:52]
So, we talked about Mirada, we talked about ScreenPoint. Can we talk about Matakina, that now is Volpara Solutions?

Yes. So, Ralph and I met up, and, in 2008, at a conference in Tucson, Arizona, breast cancer conference. And we started listening to some of the talks, and we realised that whilst in 2000, 2001, the stuff that we had done, the world really wasn't ready for it, they didn't understand what the hell we had done, actually, the more we started looking at breast cancer, the breast density, it became clear that the amount of dense tissue in a woman's breasts five, four/five years after the menopause, is probably the best single risk factor for whether that woman's going to develop breast cancer. And we had *the* technology to quantify breast density. So, in Tucson we sat down, and, over an evening with, let me say conservatively two or three beers, but it was actually a lot more than that, we sketched out what we wanted to do to form a company. By this stage Ralph had met in Oxford a New Zealander, Sue Bibby, and they had gone back to New Zealand where she is a doctor. So Ralph was living in Wellington in New Zealand, and I was still in Oxford, and it's entirely appropriate we should meet in Tucson, which is about halfway. And, we… And so we figured out, we were going to start this company. And so the question then was, what shall we call it? Well we had already called a company Mirada. So… And that was Spanish. And now we were in New Zealand, so wouldn't it be great if we came up with a Maori name. And wouldn't it be nice if we came up with a Maori name that meant something along the lines of Mirada. So, the word is *matakina*. And so, we called the company Matakina. But our first product, which was about breast density, was, coming up with volumetric parameters, 3D parameters of the amount of breast tissue. Well, volumetric parameters is a real bloody mouthful. So, how do you shorten it? Well you call it Volpara. And so, our product became Volpara. So, sadly, sadly Elisabetta, it's got nothing to do with the wine areas of Italy, but, no, indeed there is wonderful grapes from Volpara in Italy. But we were, we had this volumetric parameterisation and we were selling breast density. And, in the end people knew our product, but they didn't know what the hell Matakina was, and they couldn't remember Matakina. But they could remember Volpara, because that was the name of our product. So a little bit like Hoover in the 1930s, we changed the name of the company. You know, that's what people knew. So we became Volpara Health Technologies. And then, we've kind of progressed the company to now, we do a lot of AI for breast positioning, for, understanding image quality, automatic measuring of image quality, automatic measurements of how well positioned the breast is, so

whether or not you're going to get the right information that you need for detecting both breast density and breast cancer. For figuring out, again using AI, what the performance of a, a technologist, which is what we call a radiographer in the UK, and radiologist, and whether we could do automatic assessment of the quality of a mammography machine, and separate out these various things. And so that has become our enterprise product. And now we're in 2,100 sites in the United States alone, and we're in about 38 countries in software. So that's been a pretty good story.

[1:19:37]
What brought you to found Perspectum Diagnostics in 2012?

So, I had retired, because I was 65 and therefore a geriatric. And, I had every intention of just leaving the university. You know, I had spent quite a bit of time, I had spent 25 years in Oxford. So, I was just ready to walk away. And, I figured, what would I like to do next? And I had had such a buzz with, you know, Guidance, and Mirada, both Solutions and Medical, and Volpara. And, I figured I could take on one more company. And I didn't know which, but I was kind of, just chewing on it. And, a friend of mine, Stefan Neubauer, who is Professor of Cardiology in Oxford, called me and said, 'Hey Mike, could I get you to come and give us a run-over about, we think we've got some interesting technology.' So, Stefan and Professor Matt Robson, who's a medical physicist, invited me to go, but they said, 'Well the only problem is, it's a Sunday, because, the guy we want you to meet is also an on-duty clinician and the only time he can get off is Sunday morning.' So, I don't give a damn. So I went along on the Sunday morning. And here are two senior professors, Stefan and Matt, and they were sitting back, and there was this, very personable British Indian guy, Rajarshi Branerjee, standing at the podium. So, Rajarshi Banerjee is called Banjo to all his friends. And so, Banjo proceeded to talk to me about the work he had done for his PhD, which was about applying quantitative MRI to the liver, and how you could use this to assess the development of fatty liver disease, which is a downstream consequence of obesity, which is when the hepatocytes, the cells inside the liver, take on far too much bad stuff and particularly fat and become, the fat creates a toxic environment. And so you get inflammation, you get fibrosis building up within the liver, and if left unchecked that can lead to ballooning of the cells and they basically give up the ghost, and that's called staoto, which just meant

fat. Steatohepatitis as opposed to viral hepatitis from Hep B or Hep C. So stayatohepatitis, and in particular the non-alcoholic form, NASH, is one of the greatest healthcare burdens in the world at the moment. So for example, there are about, 20 million people in the United States with NASH. There's five million in the UK. People who have got fatty liver disease who are on their way towards NASH, there are about 40 million in the United States, and there's about, sixteen million in the UK alone. And that number's growing, if you look at childhood obesity. And with it is coming diabetes.

[1:22:45]

So anyway, they were telling me all these stories, and then they were, 'What are you going to do?' If you're an engineer… I told you, I've been an engineer, I've been doing mathematics. I believe in numbers. I believe in quantitative stuff, that's the basis for my breast cancer stuff. It's the basis for what we were doing in image fusion for Mirada. So, the moment that Banjo started telling me they were doing quantitative MR of the liver, I really began to take notice. And, so, when we finished, I said, 'This is really neat technology.' They said, 'Do you think it's got the legs to be a company?' And I said, 'Yeah, but why don't you just, you know, just license it. You're three, you know, you've got two academics, and you've got one guy who's a, you know, a consultant physician. What the hell do you want to give up your jobs for? License the technology and get on with your life.' They said, 'No no no, we want to form a company, and we'd like you to be involved.' And I said, you know, 'Bullshit you want to form a company,' you know. 'You want grey hairs? You know, I'll show you grey hairs, right?' And he says, 'No no no. We want to form a company.' So, I just… So, in the end, I said I would take them seriously if one of them would give up their job and go full-time. And Banjo said, 'Me.' And so, he has been the CEO; I've been the Chairman; and Matt and Stefan, the co-founders, Matt's now the CTO, Chief Technology Officer, here. And we've now got this company that's rooted in MRI physics, image analysis, software engineering. And you know what's really nice? We have 200 people working for the company. We've got branches now in San Francisco, Dallas, Singapore, main office here in Oxford. But, of those 200 people, 55 per cent are women, and nearly, 98 per cent of our employees are graduates. 30 per cent of our employees have got PhDs, of whom 60 per cent are women. And, we have people from 29 countries with 25 first languages. So, it's a

fantastic place to be. I love, really love working with and for Perspectum. And I love what we do. And, yeah, it's been a gas.

Sounds amazing.

[laughs]

[1:25:26]
And, you are also the co-founder and Chairman of Optellum.

Yeah. So I was…. By this stage, I began to get a bit of a reputation didn't I for, you know, you want to form a company, go call Mike Brady, right? So… Especially my graduate students. So, I had a graduate student who right from day one, a guy named Vaclav Potesil, who was from the Czech Republic, and had come to us via Cambridge, he went into the doctoral training centre. And Vaclav clearly wanted to do a, he wanted, clearly wanted to do a, form a company. He did a brilliant DPhil. We published a bunch of papers together, but then he wanted to do a company. So I said, 'Look Vaclav, you know, for Christ's sake, you don't know anything about this. Do me a favour. Go find a small company, learn about whether you really want to do it, and if you do, come back, and we'll have a conversation.' So he said, 'Yeah, OK.' So I said… So anyway, it turns out, he went and worked for a company in Zurich. So I said, 'What the hell are you going to work for a company in Zurich for?' So it turns out, he's a bloody rock climber, and he wanted to climb in the Alps, right? [laughs] So, that's fine. Whatever, right, whatever turns you on. So, anyway, about two years doing this, and then he came back and said, 'I really do want to form a company.' His thesis had been supervised, he had been partly funded by Siemens, who you remember, Siemens Molecular Imaging had acquired Mirada. Because they had acquired CTI who had acquired Mirada. So, the guy who had co-supervised Vaclav was Timor Kadir, of Kadir–Brady. So, Timor and I sat down, working with Vaclav, and in particular working on the idea of applying AI to lung cancer, and in particular for finding nodules which occur within the lungs. Quite often it was accidental finding, because you might be X-raying somebody's ribs for a broken rib, you might be looking at the heart with CT, you might be looking at the spine for a slipped disc. And nevertheless, you get this, if it's a CT image you will get a picture of the lungs.

And so within the lungs you quite often get these little nodules. And, a very small number of these nodules are malignant. But, the question then is, what's the, what's the AI and decision support problem? Well, quite a number of, but very very small percentage, are actually malignant. And yet, people rule, radiologists rule them as being indeterminate, and they call somebody back for a CT. As a result of which there are, right now around the world about, between ten and twelve million unnecessary CTs done per year with all the radiation burden that implies.
[1:28:32]
So I started talking with Timor and Vaclav about, we should set about building a company. And of course they say, 'Well will you be the chairman?' And of course, I said yes. You know, I'm a tart with a heart. So I said yes. So… So that's how we started. So we started Optellum, and we've got about, 20-odd people working for Optellum.

[1:29:02]
So, at this stage of your career, how did you overcome obstacles along your way? And what lessons did you learn?

[pause] So… [pause] I don't know whether it was an obstacle. One thing I learnt when I first started working in cancer is that, the only thing that matters in research is the identification of a problem that you care about. And it's the problem that matters. And departments in universities get in the way. Departments are a completely artificial administrative construct that can make your life difficult by erecting silos. So why has that not been a problem in Oxford? Well it's not because people a smarter, because they're not. It's because of the colleges. Because the colleges are cross-disciplinary. So every day, if you're in a college, you end up talking to the fellow in history, or the fellow in English. So, actually you know what, departments become irrelevant. People ask you what you are working on. They don't ask you what department you're in. And I find that unbelievably liberating. And when I think back to when I was in Essex, I could have really worked closely with people in electrical engineering, but they were different departments, and it was kind of hermetically sealed within departments. That's crazy. So it was not really an obstacle for me, but I could see how it would be an obstacle for a hell of a lot of people.
[1:30:58]

What have I learnt? I have learnt that, the most important thing in an academic's life is that you create people. We don't produce research, we produce people. That's our main product. Even if we work with industry, we produce people. It doesn't matter whether it's undergraduates, master's, or PhD students. That's what we produce. Somebody asked me, what am I proud of? My academic career. 115 PhDs. I'd like it to be 120 when I retire because I've got five at the moment. That's what I care about. And as I never tire of saying, in, just before his death, Sir Humphry Davy was asked, what was his greatest scientific discovery? And he said, 'Michael Faraday.' It is so right. I could list you all my PhDs, and to this day if you ask me to tell you, to give you a ten-minute talk on any single one of those theses, [clicks fingers], I'd do it like that. That's who I care for.

[1:32:20]
In 2004 you went to Buckingham Palace to receive a knighthood from Her royal Majesty the Queen. What are your memories of that day?

Cost me a bloody fortune. So, you are allowed to take three people, and I have a wife and two daughters. And, I don't know whether the same is true for blokes, because I've ever given a damn about, you know, what I look… You know, the extent to which I am neat is a triumph of my wife, because, you know, I'm basically a slob. But my wife knows we're going to Buckingham Palace, and so she had to have a new dress, a new coat, new shoes, new handbag to match the coat and the shoes. And my daughters say, 'Well you know, gosh, if that's setting the bar, that high, we've got to have new dresses and shoes and coat. And it cost me a bloody fortune. So anyway, that's joking aside, I don't begrudge it for one minute. But we thought we'd make a bit of a deal of it. So we went down, we stayed overnight at the Royal Society, in two bedrooms. And had bed and breakfast. And so we could go out into the centre of London, and we took one of Naomi's uncles, one of, a really lovely guy, Marcus Sarler, and his wife Andrea, and we took them for dinner. And then the following day we could just come out of our, come out of the Royal Society, and just walk down The Mall, into Buckingham Palace. And of course, they don't give you anything to eat. You know, they're pretty poor at the, Royal, at, you know, the Palace, they don't have that much money. So, they don't give you anything, not even a cup of coffee. So, afterwards of course, what you do, you go to the Ritz. Well, there's only the three

of us, so we go to the Ritz for lunch, and that wasn't cheap. But we thought, you know, it would be really lovely to meet up with my grandkids by that stage, because I had two grandkids by then, and… And my, my sons-in-law. So we went out for dinner as well. So, yeah, it wasn't the cheapest day of my life. But joking apart, joking apart, what do I think of it? Actually, it was seeing how much it meant to, Naomi, and to my friends, and to my mum. And that's probably the strongest feeling I have about being told, well apart from disbelief, was, telling my mother. Yeah.

[1:35:05]
Recent news tell that you are going to help the world's first artificial intelligence university to open in Abu Dhabi.

Mhm.

So, can you tell us a little bit?

Yeah. You know, by now you may have got the impression that I kind of fall into things. You know, I kind of, find things that are pretty interesting, and I just, can't stop myself saying yes. So, this time in November in 2018 I got a phone call from one of my former PhD students, a kid from Beijing named Ling Shao, and, he said, 'Hey Mike, I've been made, about a year ago I've been made director of a research laboratory in Abu Dhabi,' which is one of the most, the wealthiest of the seven Emirates in the UAE. And he said, 'I've been made the director of this Inception Institute of AI, and, I've got about 75 people already, and, you know, I'm kind of, I've never done this before, and I know you've run labs and companies. Would you be on my advisory board, come over for a couple of days a year and talk to me? Just help me.' So I said, 'Yeah, of course.' And so I flew out to Abu Dhabi, and what I realised was that there were two groups. There was the Inception Institute of AI that was doing some really lovely stuff, mostly in speech recognition, natural language understanding, and image analysis, mostly based in machine learning but not only. And then, second of all, there was a big data company, which was much more commercial, called G42, that was run by a guy called Peng Xiao. And there was a kind of gap between these two companies. There was no real collaboration, and I, I think if you had to say, there was kind of mutual suspicion.

[1:37:20]

Anyway, Ling from the Inception Institute of AI had asked me to give a talk, and so I, I stood up, and I gave a talk about… I think there were about 150 people there. I gave a talk about image analysis, medical analysis, and, both in the laboratory and its transfer to companies. And of course, my talk sat exactly halfway between G42 and the IIAI lab. So, both Ling and Peng were intrigued by this, and wanted, and we then had a bunch of conversations. So we started conversations, and then, I got asked if I would go and visit Dr Sultan, who was the, and is, Chief Executive of the Abu Dhabi National Oil Corporation, who explained to me about the Mohamed bin Zayed University of AI. Mohamed bin Zayed is the Crown Prince, and a remarkable character, as indeed is Dr Sultan. And Dr Sultan explained to me about the national strategy for Abu Dhabi, which is to transform their economy to reduce its reliance on oil. So, they wanted to… They had identified renewable energy, financial services, healthcare, and material science. And when they boil those down into, what are the enabling technology, they realised that one of them, one of the key ones, was AI. And they realised that, whilst they could cover some of the other stuff, they just did not have in the UAE the trained workforce that could take the senior positions of these various sectors of the economy that were based around AI. And so they decided to set up a graduate college, which the Crown Prince put in a very substantial amount of his own money into, and so it became the Mohamed bin Zayed University of AI. And, I asked him what the role of women would be, and he explained to me what a key role women have, and how, how the highest, Abu Dhabi's got one of the highest percentages of women in the government of any country on Earth. It's got one of the highest percentages of women in boardrooms of companies of any country on Earth. This was a surprise to me, a delightful surprise I have to say. And so he asked me if I would join the board of trustees of the Mohamed bin Zayed University of AI, MBZUAI. And I said I would.

[1:40:24]

And then… This was in early March, mid-March, something like that. And, then, they were scheduled to open on October the 19th. And the idea was that they would have a president of the university, very much like our, very much like our chancellor rather than vice-chancellor by that point. And they didn't have one, and still haven't to this day, but they are, they are recruiting. And so they asked me if I would be interim President, because, they wanted to avoid the embarrassment of the launch

without having a president in place. So I have done that. So I went out to Abu Dhabi for the official launch in October, and, so I've been involved in recruiting some of the senior personnel, in putting together the processes for searching for students and so forth. And they've had, within the first week of the launch they had 1,900 applications for 50 studentships in the initial cohort. So, I'm very keen that it finds a, a distinctive, distinctive brand, a distinctive mission, based around the relationship between AI and the transformation of the economy and the society that is under way in Abu Dhabi. And that is shared by the board of trustees, and in particular by Dr Sultan, and his Royal Highness, who is a really fantastic guy.

[1:42:19]
What do you think are the biggest challenges and opportunities for AI in the next ten years?

In the next ten years? It's very difficult. So, let me start with something which I think will be controversial, and I can imagine my old mate Geoff Hinton screaming. I think that, AI has become too much identified with machine learning. And I think that one of the things that will happen over the next ten years is that, a number of… That's not to decry the incredible contributions and strides forward that machine learning has made. Of course. I use, I use machine learning for finding hepatocellular carcinomas, for segmenting the livers, for understanding the topological structure of the biliery tree within the liver. Of course, we use AI, we use machine learning. But AI is not all machine learning. And I think that, some of the things that are going to really come to the fore are going to be causal reasoning. I see that happening more and more in medicine. If you want to understand the aetiology of diabetes, people talk about Type 2 diabetes, but you know, that's bullshit. There are several different aetiologies that lead to, lead to diabetes. And it depends on the interplay of the liver, the pancreas, the spleen, the kidneys. And there are many ways in which they causally interact with each other. And, frankly, correlations are, ridiculous. As Judea Pearl says, you know, the outbreaks of serious fires are highly correlated with the appearance of the fire service. So, presumably, if you want to reduce the risk of serious fires, you get rid of the fire service, because then you would break the correlation. Right? [both laugh] Which is, tells you that statistics has set its face since the days of Ronald Fisher, and right from the very foundations of

statistics has embraced correlation, and correlation is not causation. And now, through Judea Pearl, and through AI, we have a representation of causal reasoning. And I think that that is going to, I think that that's going to have a resurgence. I think also, whilst machine learning will continue to be important, there will be a resurgence in planning and reasoning, reasoning in finance. I think reasoning in medicine, in finance, I think Abu Dhabi have got it dead right. Finance, energy, energy deployment, energy budgets. I think, so much of what we will do will bring back explicit reasoning, will bring back image analysis, will bring back natural language into the core of AI. And we will understand how intelligence is situated in robots that interact and move in the real world. And I think the whole idea of situated robotics is going to transform AI as well.

[1:46:37]
What advice would you give to someone willing to pursue your career today? And also, what do you think academic curricula should include that maybe they don't include yet?

I think… I think the most important thing for anybody in any walk of life is that you only have one life. And you should be fearless. You should… You're never working… You should figure out what it is you want to do in your life, and you should tackle a really hard problem that you care about. I think there's too much puzzle-solving, you know, the next four-page little abstract that will go to a conference. It's puzzle-solving. I think that, if you really want to have a life in science, and it's a fantastic life, you should identify something that you care deeply about. And the hell with departmental boundaries. The hell with what anybody thinks. The hell with fashion. Because if you are doing something that's really good, it's almost certainly going to be unfashionable. Screw fashion. To thine own self be true, as Polonius says in *Hamlet*. Just believe, chart your own life, chart your own course. That's the most important thing. Be courageous. Control your own destiny.

Thank you Mike, it has been a real pleasure talking to you.

It's been an absolute pleasure, I've really enjoyed it.

Thank you very much.

OK.

[End of Interview]