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In Conversation with Sir David Spiegelhalter and Professor Sylvia Richardson

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Abstract. Sir David Spiegelhalter and Professor Sylvia Richardson are two eminent statisticians of our time who have made pioneering contributions to Statistics and Data Science with careers spanning over more than four decades. They have a long and celebrated legacy built through foundational research in Bayesian statistics, impactful collaborations, steadfast professional service and superb scientific communications. They have won many prestigious awards and recognitions throughout their distinguished careers. During my sabbatical in 2022 at the University of Cambridge I had the honor of sitting down for a conversation with these two remarkable individuals. We discussed early career influences and digressions, research philosophy, role of mentors and advice for the future generation. We hope this conversation with David and Sylvia will inspire many future statisticians.

Key words and phrases: Bayesian Statistics, Imperial College, Markov chain Monte Carlo, Medical Research Council, Royal Statistical Society, scientific communication, University of Cambridge.

Sir David Spiegelhalter and Professor Sylvia Richardson: two celebrated statisticians currently based in the United Kingdom as professors at the University of Cambridge. Both have created a legacy of statistical innovation, leadership, public service and mentoring. Their distinguished careers span over more than 40 years. Together, they edited a highly influential book on Markov chain Monte Carlo methods in 1995 (with WR Gilks). More recently, they co-chaired the COVID 19 Task Force of the Royal Statistical Society (RSS), the British learned society for statistics, a professional body for statisticians and a charity which promotes statistics for the public good. They both have been presidents of the RSS. Along with being impactful statisticians, David and Sylvia are also inspiring human beings and role models. During my sabbatical at the University of Cambridge I had the privilege to sit down and ask David and Sylvia a multitude of questions. It was a conversation with two renowned scholars that I hope will be of interest to the next generation of statisticians. A live video of this conversation is available at this link https://www.youtube.com/watch?v=Qjoo6ZRQmiM.

Bhramar: Let us go to the very beginning. How did you end up in statistics?

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David: I started off doing mathematics at school, of course, and carried on with it at the university. But to be honest, by the middle of the second year, the pure mathematics got too difficult, and I was struggling. But I was fortunate enough to have an inspiring mentor at that point who was incredibly enthusiastic about statistics. And so, I moved into statistics, although I didn't like it at first. The very first lecture was just showing the proof of the Neyman–Pearson lemma with no justification or context, and I hadn't a clue what was going on. I nearly gave statistics up as well, but fortunately I stuck to it. I've enjoyed it ever since and it has been a great career choice.

Sylvia: Very much in a serendipitous way! I met my husband in Paris in 1972 and we moved to England after I finished my first degree in mathematics (with only one course in probability). I enrolled in a MSc in Statistics and Stochastic processes in Nottingham, but preferred the stochastic process side and pursued a PhD in ergodic theory. I joined the Statistics Department of Warwick University as a lecturer in 1979, and enjoyed the lively discussions that took place. It was in Warwick that I got a first impression of Bayesian statistics. Motivated by the start of a collaboration with an epidemiology unit within INSERM, the French National institute for Health and Medical Research (pretty much the equivalent of the Medical Research Council), I got interested in spatial processes and spatial statistics. This INSERM Unit was focused on health and environment questions and what

could be learned from the analysis of aggregated geographical data. This was the start of my journey into spatial statistics, branching later more broadly into biostatistics. I say "serendipitous" because my initial contact with the head of the INSERM unit was through a French mathematician working in ergodic theory, who happened to be sitting next to the head of the INSERM Unit at a committee meeting!

I often say to young researchers, be open to new problems, curious of new ideas and explore opportunities. When you meet smart colleagues who are enthusiastic about research, then do not hesitate to pursue new avenues. Much of life is a random walk!

Bhramar: Over your careers, you have seen the field of statistics and biostatistics, in particular Bayesian statistics, evolve and change. What do you think are the most significant opportunities and challenges for us as a field right now?

Sylvia: The field of biostatistics has evolved alongside (i) the changing nature of scientific questions arising in public health, epidemiology, clinical medicine, biology and genetics, and (ii) the availability of data to answer these questions. The problems that are tackled changed in terms of:

- The nature of the underlying data structure—away from simplistic identically and independently distributed (i.i.d.) structure to correlated data (in time, in space, networks, etc.);
- the recognition of the "imperfect" nature of the data (missing with all sorts of missingness patterns, measured with errors, aggregated versus individual level),
- the recognition that deeper understanding of questions of interest (scientific, medical) can be gained by synthesizing information from different data types;
- and of course, the advent of large p, small n issues in genetics and molecular biology, and more recently large n challenges with biobanks and large administrative databases.

Bayesian biostatistics evolved in parallel. The unifying concept of hierarchical and graphical models played a big part in this evolution. Stochastic simulations, such as MCMC algorithms then enabled inference for complex models adapted to a range of challenging questions. In the 1990s, the community was quick to pick these ideas, build expertise on how to borrow information and the consequent bias/variance trade-off. Starting in 1993, the European Science Foundation network and program on Highly Structured Stochastic Systems (Figure 1) was instrumental in facilitating cross-fertilization of techniques and ideas between different fields and different domains of application (Gilks et al., 1996; Green et al., 2003).

In the late 1990s, early 2000 years, with the genetic revolution and the advent of genome wide data from DNA and data on downstream biological processes, biostatisticians were faced with huge sets of covariates! Suddenly, the idea of joint inference seemed illusive and much of the progress was initially made using one-at-a-time analyses and meta-analysis of simple summaries. It felt to

FIG. 1. *Arnoldo Frigessi, SR and DJS in Luminy near Marseilles, at an ESF workshop for Highly Structured Stochastic Systems*, 1995.

me like a backward step. Adapting to this new context spurred research on high-dimensional prediction, generating a flurry of shrinkage approaches based on penalties and efficient optimization techniques. Parallel Bayesian approaches came more slowly to the fore, as they hit computational challenges when implementing vanilla stochastic algorithms. This stimulated the development of scalable Bayesian algorithms, approximating posterior distributions and relying on some form of optimization, like variational Bayes (Blei et al., 2017).

One of the main challenges ahead for Bayesian biostatistics lies, in my opinion, in developing a happy marriage of approximate joint inference and scalable computations that will allow tackling complex data synthesis required to make progress in biomedicine and population health. Keeping a focus on progressing scientific and population health, understanding and extraction of interpretable inference and not simply solving pure prediction tasks is important. Scalability issues now have to address both the large p and the large n contexts, keeping track of propagation of uncertainty. We need to focus on the middle ground, away from oversimplistic modeling, which ignores the structure/complexity of the data, but going beyond full joint modeling, which mostly does not scale up to real world applications.

David: Yes, things have changed a lot. I was brought up in a very strict, subjectivist Bayesian ideology. In the early 1980s, we were trying to put those ideas into practice, for example, through elicitation of subjective probability distributions for the likely effect of new cancer drugs. We were interviewing oncologists and showing how that could be included into the design of a new intervention trial, enabling a more realistic power calculation, not based on some optimistic desire, but on a realistic expectation of what the drug might deliver. These ideas are still relevant. Then by the late 1980s MCMC had arrived, which finally allowed us to take proper advantage of the framework of hierarchical models.

Development of Bayesian models has accelerated enormously over the last 30 years, and it has been very exciting to be part of that revolution. It is truly extraordinary what has happened in terms of translation of Bayesian methods to practice. For example, I am an executive director on the UK Statistics Authority, which oversees the Office of National Statistics, the census and so on. To be honest, I always thought that official government statistics was rather tedious. However, things are changing. For example, we have been running the COVID infection survey (which is the envy of the world) since April 2020 (University of Oxford, 2023), being the only large scale nationally representative survey that has been looking not only at people who are positive in terms of having the virus, but also looking at antibody levels in the population stratified by age, by area and by other factors.

The survey is analyzed in a fully Bayesian way, using the multilevel regression and post-stratification model (MRP) proposed by Andrew Gelman (Pouwels et al., 2021). This is a very sophisticated analysis, bringing together, as Sylvia said, our understanding about the potential sources of uncertainty into a full probability model and producing estimates with proper uncertainty quantification. I was teaching journalists about statistics last week, and I now have to explain what credible intervals are.

There is now a discussion in this country about whether to have another census, after a very successful one during the pandemic in 2021. Are we going to have one in 2031? Obviously, alternatives are being considered, which include a massive Bayesian dynamic population model, in which multiple administrative data sets are linked to produce a credible interval for the posterior distribution of the population in specific strata. The 2021 census offers a fine opportunity for calibrating the model.

Now, as Sylvia said, the problem is that although we can write down what we want to do, the computation is so huge that sadly, even with modern computing, great effort is needed to implement this model and make it a sustainable technology that can produce population statistics rapidly at a microlevel. This is a real challenge.

Yet, I still go back to the importance of subjective probability assessment. I've just been part of a major public inquiry in this country, which looked into the impact of infected blood products in the 1970s and 1980s, and we had to conduct a subjective probability assessment, because we have no data about a particularly important factor: the influence of guidance to potential blood donors in the mid-1980s at the start of concern about AIDS. So, we have seen quite a revolution in foundational ideas, boosted and powered with modern computation.

Bhramar: Both of you have made such important contributions in theoretical statistics, applications, policy work and working with the government. What do you consider your most significant contributions to statistics and to the world of science?

David: The first thing I want to say is that, yes, I've had a couple of good ideas, but they wouldn't have gone anywhere if it wasn't for the people I worked with. I don't like seeing them as solely my contribution, because pretty much all of it was done in deep collaboration with some extraordinary people. The first one is with Steffen Lauritzen in 1988 on putting probability into Bayesian graphical models (Lauritzen and Spiegelhalter, 1988). I spotted the work that Steffen and others were doing on graphical modeling for contingency tables with undirected and directed graphs. Although I suppose I made the initial connection with uncertainty in artificial intelligence, I could not have progressed without the critical collaboration with

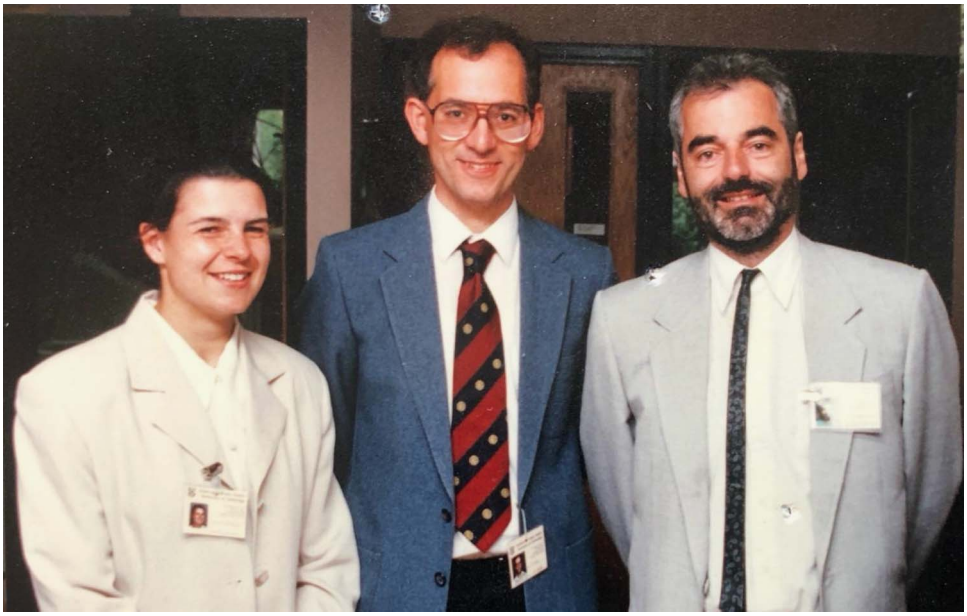

FIG. 2. *Nicky Best, Wally Gilks and DJS at the MRC Biostatistics Unit, when the Duke of Edinburgh visited in* 1994.

Steffen. And then of course realizing the close connection with efficient sampling and Bayesian graphical modeling that led to the WinBUGS work (Lunn et al., 2000). I collaborated with many people on that idea, particularly Nicky Best, Wally Gilks, Dave Lunn and Chris Jackson, and I think it has been influential (Figure 2).

Then I was involved in public inquiries into health care scandals, such as the Bristol heart babies and serial murderer, Dr. Harold Shipman, and worked with others on more rigorous performance monitoring measures, both sequentially and cross-sectionally, for comparison of various healthcare institutions. That required producing risk-adjusted versions of classical sequential analysis such as sequential probability ratio tests, and so adapting industrial statistics to medicine, which was cool (Spiegelhalter et al., 2003).

We stole these techniques, adapted and improved them, and then sent them back into the industrial setting, where users realized they could do much more sophisticated analyses with these developments.

Finally, I am best known now for my work as a "performing statistician," trying to turn statistics into effective communication material. Not just with radio or television but also in writing—trying to write in an entertaining way, through popular articles and books, such as *The Art of Statistics* (Spiegelhalter, 2019). I've been doing this now for 15 years, and I really like it—explaining statistics can be fun, and you can include humor and storytelling with good graphics and a bit of performance. I think that in a sense this is almost my biggest innovation, and I'm just going to carry on with it.

Bhramar: This is incredibly important work. And we have discussed that you need the past 30 or so years of deep foundational understanding of the field to do this well.

David: And those 30–40 years of doing the methodological slog, and vast amounts of critiquing papers that use stats, really helps when you're teaching journalists about statistics. I can get up and talk about odds ratios and hazard ratios, but also explain credible intervals and Bayesian hierarchical modeling. I'm old and I am not going to do anything clever anymore. Fortunately, I just like doing this explanatory work.

Sylvia: I totally agree with David. I've had many fantastic collaborations and my contributions are truly a group effort. In very broad terms, I have tackled some of the methodological challenges created by advances in health sciences and aimed to bring hierarchical modeling and Bayesian computations to the heart of environmental and spatial epidemiology, biomedicine and genomics. The work I did on testing spatial association, hierarchical modeling in ecological studies of health-environment effects and understanding ecological bias has been used beyond spatial epidemiology in fields like geography and ecology (Richardson and Best, 2003). If I were to single out one particular area of statistics, I would highlight my work on flexible modeling of heterogeneity, which takes its root in the joint work with Peter Green on the Bayesian analysis of mixture models with unknown number of components (Richardson and Green, 1997). I have pursued methodological work on different facets of Bayesian mixture models ever since, to gain new insights into their suitability and scalability for different contexts of application, such as precision medicine or characterizing patterns of multimorbidity. In particular, I became interested in semi supervised clustering, where the clustering structure

is informed by the outcome (Molitor et al., 2010). I have also worked on variable selection in genomic data sets with large p, with the ambitious goal of finding multivariate structures in very large genomics data sets (Ruffieux et al., 2020).

Part of the contribution David and I made together was with Wally Gilks. We three were the editors of the book titled *Markov Chain Monte Carlo in Practice*, published by CRC Press in 1995 (Gilks et al., 1996). That was largely because of an exciting Bayesian modeling workshop that we organized in 1992 in a splendid setting near Paris, which led to this highly influential book.

David: Those were special times, with ideas buzzing around. A feeling Heisenberg must have had when he was meeting with Niels Bohr. That was early 1990s for MCMC folks.

Bhramar: I feel like we are standing at a similar time now with statistics and data science coming together and new ideas from the machine learning community being presented to statisticians. It's been 20 years since Leo Breiman's famous paper in statistical science, *Statistical Modeling: The Two Cultures* (Breiman, 2001). At that time, algorithmic modeling and stochastic modeling were quite separate worlds. But we have seen convergence of these two schools of thought in modern statistics. We as a community are thinking about causal estimands and then starting to use machine learning methods for assumption-lean inference, and we are moving toward a more unified view.

Both of you have led the RSS during a time when people were battling over statistics versus data science. How do you feel about statistics and data science/AI/ML coming together?

Sylvia: I am very positive about this development, there is a lot of common ground and mutual benefit to be had.

- First, I think that putting the role of practice and solving real world problems at the core, which is emphasized in DS, is important for the future of statistics.
- Second, I think that transdisciplinarity and reducing fragmentation is a good and necessary direction, so that concepts or tasks which are similar or related, but called differently, are identified. We know that "covariates" become "features," and "estimation" becomes "learning," but it is less easy to fully understand the impact of a specific loss function on inference, or to tailor a loss function for a particular decision problem.
- Third, we need to keep stressing the fundamental need to use probability to deal with uncertainty, and the importance of statistical thinking in designing training and validation data sets and evaluating the reproducibility of results. I am sure that David has more to add on the matter.
- I fully expect that from this "coming together" unifying views will emerge, for example, related to optimal data acquisition and estimation sequence to achieve a set goal. Quantifying uncertainty of algorithmic outputs is an area that is bread and butter for statisticians.
- It is with the importance of evolving our discipline in mind, that during my presidency, I set in motion an RSS Data Science Task Force at the beginning of 2021. Its aim was to devise how the Royal Statistical Society could develop an overall strategy of visible engagement with data science. Currently, the RSS is actively implementing some of its recommendations, which include the creation of a new data science journal.

David: I had a change of mind about more algorithmic methods. I was initially a skeptic because I used to be a complete probability modeler, who aspired to capture how nature works through a stochastic system. I didn't like the idea of pulling a formula off the shelf and seeing if it works or not.

A stochastic model-based framework is nice because it has properties derived internally from how it is constructed, but with huge amounts of data, one can get spuriously narrow model-based uncertainty intervals. As Sylvia emphasized, the statistical issues really arise in the evaluation of the algorithm. Is it fair? Does it work? Can you transfer to another population? We need a statistical approach to evaluating algorithms, and statisticians have been doing this sort of thing for decades, and we can help. Establishing the trustworthiness of algorithms is largely a statistical issue.

Bhramar: It is also important to understand how the data are collected.

Sylvia: Yes, the study design must be good! For example, during COVID there was such a hype on using image classification algorithms, such as CT imaging of the chest to diagnose severe patients. The vast majority of algorithms were not reproducible (Roberts et al., 2021).

David: I no longer trust an algorithm based on the claim of its "good internal historical performance." Prove to me that this is going to work in a range of new areas.

Bhramar: Let us now turn to leadership. Both of you have assumed leadership of different forms: of a department/unit, of a scientific research group, of a professional society, or of a center. What has been the motivation, guiding principles and rewards?

David: Oh, dear. I'm not a very good leader. I'm truly the most reluctant, begrudging leader that you can have. I never wanted to be head of anything. I haven't applied for administrative leadership roles, because I know I wouldn't be very good at it. I feel very fortunate that I've managed to find my way into quite a good position while never really having that much managerial responsibility. I think this is a great achievement.

As you get older, you learn your strengths and weaknesses. And I suppose I'm quite good at inspiring people, at educating people and at communication. I'm a

FIG. 3. *Imperial College Biostatistics group in Spring* 2012. *Photo taken at the occasion of Sylvia's leaving drinks. From left to right*: *Nicky Best*, *Lea Fortunato*, *Georgios Papageorgiou*, *Leonardo Bottolo*, *SR*, *Marta Blangiardo*, *Silvia Liverani*, *Alexina Mason*, *Yingbo Wang*, *Guangquan* (*Philip*) *Li*.

good collaborator, and I love working in multidisciplinary teams. I do not like being the one out in front leading anything.

A great benefit of working with people is sharing the burden. For example, if you start appearing in public, you sometimes get a kickback on it. When I was doing COVID work, I was publishing stuff every week, and it was all jointly with Anthony Masters. When we got abusive tweets, such as one saying we were genocidal and should be destroyed, Anthony took the lead by responding that he thought that this was a bit harsh, and that he thought it was a good article. I could then follow his tone, and add that—yes, it was a bit harsh, but I've had worse referee reports.

Sylvia: My primary motivations have been to defend and grow the discipline and increase its impact on science and society, as well as to create an environment where young researchers are encouraged to learn and flourish and become the future leaders of tomorrow. It was rewarding to see the Biostatistics Group at Imperial grow and play an important role in the Imperial College School of Public Health (Figure 3), and then to lead the MRC Biostatistics Unit (BSU) toward the vibrant outstanding research and postgraduate teaching environment that it is today. During my leadership of the MRC BSU, I have enjoyed identifying new opportunities for creative methodological or applied research. It has also been rewarding to be able to support promising researchers through targeted financial support, as well as to foster new partnerships leading to scientific or health impact.

My responsibilities increased gradually. In France, I was responsible for a biostatistics group within an epidemiology unit. The statistics research had to fit in with the overall scientific purpose of the whole unit. As I grew more independent, I became attracted to the UK, where I felt the research environment for statistics was more open. At Imperial College, my research broadened to encompass genomics and I successfully expanded the biostatistics group. This was somewhat challenging in a clinical school environment where the performance criteria are not suited to recognize our specific contribution but focus instead on obtaining large grants and publishing in

FIG. 4. *SR and DJS in front of the list of Presidents of the Royal Statistical Society*, 2021.

high impact medical journals. When the directorship of the MRC Biostatistics Unit became available, I applied for it, because I wanted to advocate for biostatistics from a recognized basis. Throughout the BSU directorship and the presidency of the RSS, I have had tremendous support both from senior colleagues and from administrative teams, which made leadership manageable.

Helping and supporting the careers of many young academics, in particular, young women, has given me great satisfaction. I could easily relate to some of the pressure women statisticians operate under. I'm proud to have concretely helped by making working conditions more flexible and putting in place a nurturing mentoring structure.

Personally, it has also made me very happy to form strong bonds with many of my ex-PhD students and postdocs and to see them developing successful careers either in academia or industry.

Bhramar: So, one prestigious leadership position that you both have held is the President of RSS (Figure 4). The learned society supports statisticians in the workforce, in government, in industry and in academia. What was it like to put forward a vision for the broader community?

David: I'm not sure how good I am at the vision thing. When I was RSS president, obviously I chaired meetings and worked very closely with the chief executive officer, Hetan Shah, who was excellent. Unsurprisingly, I was mainly interested in the idea of statisticians putting their heads above the parapet and taking on a public role. I promoted engagement with the media, which I think was timely during the pandemic—though we could not foresee it, we were ready for it. I didn't engage in any large initiatives. I think what Sylvia has done with Data Science in the process is simply outstanding. Over to Sylvia for that.

Sylvia: I was flabbergasted when I was asked to be President of RSS to be honest. Then I thought, what can I bring to this society? I decided to shake up the RSS on the data science front: data science is a big part of our future.

And then COVID hit. The alliance with David in creating the RSS COVID-19 task force (*Covid-19 Task Force*, n.d.) was a great opportunity for sharing expertise. I was a good biostatistician, but I had little training in effective communication. We needed to quickly create a group with a range of expertise because there were so many things to be thought off and actioned rapidly, particularly at the beginning. Everybody in the task force was incredibly generous with their time and in supporting each other.

David: It was just extraordinary. There was such effort across the scientific world and elsewhere in society, but we statisticians were so busy, so in demand, and that put incredible pressure on people.

Bhramar: I feel so thankful to have you two as my mentors during my sabbatical. I would like to know who have been influential in your life as mentors and colleagues in shaping your thinking and shaping who you are?

David: So many. I've done almost everything in close collaboration with people. I have to mention Adrian Smith first. When I was 18, I arrived at the University in Oxford to do mathematics and I find this young man who is my "moral tutor" (a bizarre ancient term). He was an extraordinary person, and now he's Sir Adrian Smith, President of the Royal Society. So, I've known him for 51 years, and he has been a big influence. He was translating de Finetti's *Theory of Probability* at that time (*Theory of Probability*, 1974), which starts with the wonderful line "Probability does not exist." So, he was immersed in subjective probability, and I learned at 19 that probability does not exist, and I've never ever shifted from this view (except at the subatomic level—probably).

A lot of my admiration for Adrian was because of his personal approach, his passion for the subject and the fact that it was quite reasonable to have loud arguments in pubs about the meaning of probability. I'm a fairly mild person, but if someone starts telling me that they think probability is an objective state of the world, I will rise to it with relish. These fundamental ideas are absolutely crucial. Every time I'm talking to the media, or to a journalist about what does the data actually mean, what is uncertainty, what does it mean to say we don't know something, I come back to the basics all the time.

I was very privileged to have an influence that was not only interested in the technicalities, but also in terms of the absolute importance of the fundamental and philosophical ideas behind the subject. Statistics is not just a bag of tricks. No, there are deep ideas behind statistics.

Sylvia: I have had the good fortune to meet exceptional colleagues and mentors throughout my career. To start with, Philippe Lazar, the director of the first INSERM unit I worked in, who was open-minded enough to talk with the pure-probability-theory person I was at that time and entrust me with an interesting question in spatial statistics. His trust gave me confidence that I could make impact in an applied domain and contributed to my transition into biostatistics. My second break was the sabbatical in 1991 that I spent with the MRC Biostatistics Unit during a time where it was a hotbed of Bayesian thinking and Markov Chain Monte Carlo/Gibbs Sampling algorithms development. Besides discussing with David S. and Nicky Best, I started to work with Wally Gilks and to develop a broad understanding of Bayesian hierarchical models, from disease mapping to measurement error problems.

Around that time, I also met Duncan Thomas who, like me, was interested in statistical issues in environment and health and created a life-long connection of common interests with him. Duncan has been supportive ever since and extremely generous in sharing his ideas and enthusiasm! The connections that I made in the MRC Biostatistics Unit in 1991 came into play first with the "famous" INSERM workshop that I coorganized with David and Wally in Paris in 1992 (INSERM Workshop in Saint Germain en Laye near Paris in 1992, "Développements récents dans la modélisation statistique de problèmes biomédicaux complexes," responsables scientifiques: D. Spiegelhalter, W.R. Gilks, S. Richardson), a workshop which led to our MCMC in the Practice book, and to my involvement in the creation of a European Science Foundation network on Highly Structured Stochastic Systems, for which I acted as Scientific Secretary. In 1992, I was also fortunate to meet Arnoldo Frigessi at the EMS conference in Bath and progressively discovered that our views of statistics and of the world were harmoniously related. It was the start of conducive exchanges with Arnoldo, which have immensely enriched my scientific vision ever since (Figure 5). The final influential colleague I would like to mention is Peter Green with whom I worked on exciting projects on Bayesian inference for mixture models and reversible jump algorithms. I learned a great deal through our interactions. There are many more colleagues with whom I had the pleasure to coauthor publications, who have helped my journey from ergodic theory to Bayesian biostatistics, from French academia to the UK statistical tradition and the nurturing environment of the RSS, and I would like to take this opportunity to collectively thank all of them. I would also like to acknowledge my late husband James with whom I constantly exchanged ideas for his support of my love of research.

David: The second part of my career has been more about performance, and I've been influenced by a different group of people. For example, Kevin McConway is a wonderful statistician, who has dedicated himself to improving the way stats are covered in the media. I am so grateful to have somebody who is there doing a similar kind of work—I can check whether what I'm saying is sensible, and he can comfort me when I screw up. I watch other performing mathematicians, such as Matt Parker and Hannah Fry, very carefully and see if there are any tricks I can steal. Similarly, Tim Harford, the Economist who does *More or Less* on the radio. My colleague, Alex Freeman, is a scientist with huge experience in media, and we first met when she was directing me for a TV program. From her, I have learned that the narrative, telling a good story and the supporting visualization, is incredibly important.

Bhramar: This is a nice segue way to my next question. For mathematically/statistically-oriented individuals, it is often a challenge to communicate with nonquantitative scientists, lay public and various stakeholders. What is your advice for effective oral and written communication?

David: Well, first, it's definitely not for everybody. You must play to your strengths. I am in fact, quite introverted. I don't naturally go out and talk to people, and like to be on my own, but I find if I think of it as a performance and I've prepared seriously, I rather enjoy it.

If I'm going to do an interview, I like working out how to tell the story and to be able to do it with a lightness that doesn't put people off. It really does require effort. Kevin McConway and I wrote an article in *Significance* (McConway and Spiegelhalter, 2021) where we emphasize that you must accept that things will at some point go wrong, and you have to be able to pick yourself back up. For example, I've had a journalist take the first-half of one sentence and joined it with the second-half of another, and so misrepresented what I thought. The one nice thing about that is to think, well, I'm never going to work with that person ever again, and I'm going to tell everybody else not to work with them.

But for me, communicating has been a very positive experience. As I said, it's not for everyone, although I do think all statisticians should try to explain what they're doing to non-experts. I think it's part of the job.

That's how I started—I tried to make my talks to colleagues more attractive, cutting down on mathematics and using better visuals, introducing a bit of humor and personality. It's crucial to treat your audience with respect, which means looking them in the eye, keeping to time, informing them, even entertaining them, teaching them

FIG. 5. *Arnoldo Frigessi, SR and Ingrid Glad: Photo taken before a gala dinner in Oslo in September* 2017 *at the occasion of SR receiving an honorary degree from the University of Oslo.*

something, but not just doing it for your benefit, it's for their benefit. Then I progressed to local radio and newspapers, to writing blogs, using Twitter and other social media, writing articles for online magazines and for print magazines and newspapers. I found science festivals were a good platform, while the Medical Research Council gave me extensive media training, which was incredibly valuable.

We've got an excellent Science Media Center in the UK that acts as a conduit between journalists and scientists—if you develop relationships by being continually helpful, endlessly explaining odds ratios, then the journalists come back to you and ask you to do the fun stuff. It's a long slog and, of course, some things go badly, and some things go well.

In terms of writing style, you have to ditch the extraordinary formality of the academic paper and adopt a more journalistic mode, which means being happy starting sentences with "and," "but," "so" and "which."

In sum: For giving good talks and writing popular articles, get training, if possible, but crucially observe others. Who gives a good talk? Who would you want to listen to at a conference? What are their tricks? You've got to identify what goes down well, which means being sensitive to the audience, knowing what makes them laugh or pay at-

tention. You can tell you have gripped an audience when they go quiet in their seats.

My partner is my best critical friend and will just tell me when something I've said on the radio wasn't very good. She will also sometimes say that things are quite good. Some sort of support community is absolutely vital so that you don't feel you are on your own, as you are quite vulnerable, and you will make mistakes.

Sylvia: I don't have much to add, just that it is during the pandemic and my presidency that I truly appreciated the importance and the challenges of good communication to the wider public, after having mostly tuned my communication skills to engage with statistics students and colleagues. I can only repeat what I said during my presidential address: "*Learning to champion impartial evidence in an accessible way is a challenge that future generations of statisticians should engage in actively and enjoy*."

For example, when you're in an expert group and you've got one minute or less to make your comment during a video call, you've really got to think how to present your point clearly and succinctly so that it gets picked up. When the audience are not statisticians, it is crucial to make your point at the right time and communicate in a simple way.

Bhramar: And we also have to find out a system to reward them.

David: Absolutely. Cambridge is quite good in this, as public engagement and service is explicitly included in the promotion criterion. However, I should also say, I'm an old white high-status man, and I have an easy ride compared with what other people might experience. And so that's why it's essential that they have a strong support group.

Bhramar: Would you like to share one or two collaboratives or examples where your work has been translated into practice or policy?

Sylvia: Changing practice is a tall order, changing policy an even taller one! Some of the framework or tools that I created have been well cited and used as starting points for new developments: Early on, I developed a simple t test for spatial association with Peter Clifford (Clifford, Richardson and Hémon, 1989), which has been widely used in ecology and geography; then a Bayesian framework for measurement error problems, an ubiquitous issue, with Wally Gilks (Richardson and Gilks, 1993). Our split and merge moves developed with Peter Green in the context of mixture models with unknown number of components have probably been adapted to a wide variety of algorithmic contexts (Richardson and Green, 1997).

During Covid, the only time that I got close to policy was through my involvement in the Turing RSS Health Data Lab, which was supporting the UK Health Security Agency. Our practice led us to perform data synthesis under time pressure and develop the concepts of *statistical interoperability* as a goal for future disease surveillance systems (Nicholson et al., 2022). It is too early to know if the principles that we articulated will have an impact on future preparedness in the face of health threats, but I hope we have planted a seed.

David: During COVID, it was quite interesting to see that the main randomized trial for the Pfizer vaccine was designed on Bayesian principles, with prior distributions, and I suppose I might have had some influence on that way of thinking. In terms of impacting policy, perhaps more relevant is the work on performance monitoring, which probably had the most direct effect. Now you should be able to go online and find the outcomes of surgery, and funnel plots are widely used to identify outliers in a variety of contexts. I helped set up a major structure for monitoring hospitals using risk-adjusted Cusums (Grigg et al., 2003), but there does seem to be a tendency for these systems to drop out of use unless they are legally mandated.

I don't feel it's my job to tell anyone what the policy should be, although it's absolutely my job to say how the reasoning behind that policy should be communicated. For example, when there was concern about the AstraZeneca vaccine because of the blood clots identified in the middle of 2021, we designed the graphics that were used live on television to explain this to the public: how the risk-benefit balance changed dramatically as you got younger (Winton Centre Cambridge, 2021).

So, for people like me, even at low prevalence of the virus, the benefits of the vaccine hugely outweigh the harms. But when you're under 30, it was really a fine balance. The authorities went through this huge explanation using our graphics, and then said they were recommending that people under 30 should not get the vaccine. And everyone said thank you very much and nodded their heads, with no complaints, no accusations of U-turns—it was completely accepted by the media and the public.

I think that was very largely because of the transparent communication of the information. Jonathan Van-Tam, the Deputy Chief Medical Officer, is a highly respected and trusted figure, and he went through our materials in great detail. I was watching this and thought—What's he doing? Surely, he's not going to try to explain it all? But he did it and treated the audience with respect. People really appreciate being treated as intelligent adults, having a good narrative, strong visuals and a trusted communicator who is telling a story, taking his time and building up to a strong conclusion about the basis for the policy decision.

So, for me, that was a real case study on how collaboration between the policymakers, the technical experts and the communications specialists can be done in a really trustworthy way, rather than some politician getting up and just spouting statistics they don't really understand—what I have called "number theatre."

Sylvia: Which means always trying to explain the uncertainty, that statistics are mostly provisional, particularly in a fast-moving situation, and that it's good to keep adapting decisions when new or better information becomes available. As David said, you have to treat people like intelligent adults! I believe that governments throughout Europe lost the trust of people by initially saying that masks were not useful, simply because not enough masks were available at that point in time. Later, when recommendations on mask wearing changed, it did not go down well with the public.

Bhramar: I have certainly enjoyed this hour of rich conversation with two inspiring human beings. My final question, looking into the future, what do you think are the most important qualities in a statistician or biostatistician, and how do we teach those to our students? Any pearls of wisdom for the next gen, they are eager to hear your advice!

Sylvia: I am taking for granted that having a broad statistical culture is important. Besides this, for a biostatistician, it is crucial to develop expertise in several scientific subject areas, to fully understand the questions that scientists are asking and actively participate in the dialog for framing the problem. It is also important to have a vision of the route forward for delivery of the collaboration, which suits both biostatisticians and domain scientists. Ability to alternate between being in a listening mode and an active role, and to suggest a variety of potential ways forward is paramount. Being able to make connections between different application domains where similar problems may have occurred is also very useful, potentially triggering the development of innovative methodology. Finally, to have the capacity to translate any technical statistical element into language that the health collaborator will appreciate and can comment on, so that one does not end up with a good solution to the wrong problem! In summary, broad statistical culture, quick on the uptake, interested and knowledgeable in the particular health field and keeping sight of the aims of the collaboration.

David: I agree. I do think people should do as much technical stuff as they can, so they feel confident in commenting on the methods that are being used, and so they are not intimidated by somebody saying, well, what about X? We need all those technical skills, computational skills, visualization skills.

I also think you've got to have sensitivity to the audience/clients because there's an element of being a counselor. When someone walks in, I say: "Why are you here today? Tell me about your problems." I always think there should be a box of tissues on the table between me and them.

You need to have sensitivity to what the problem demands, what level of sophistication is appropriate. Statistics is an enabling technology, which exists to help other people solve their problems.

FIG. 6. *DJS, SR, and BM at Churchill College in December of* 2022, *after this conversation*

And then you teach and learn by example, being open about the problems you've encountered in the past and the mistakes you've made in collaboration, the things you've missed.

Sylvia: Mentoring is quite different to formal teaching. While training PhD students and post-docs, you must encourage them to attempt different angles to tackle any statistical problem. Then share your own experience about similar questions, give them opportunities to interact and point them in the right direction.

I recently had the experience of guiding a bright career development fellow, who was already recognized as strongly innovative on the methodological side and who wanted to deliver a piece of work which would impact biology and potentially clinical practice. Concretely, it meant working within a large collaborative project, interacting closely with clinical collaborators and aiming to write a paper suitable for the Nature journal family. When you are a rising academic, it can be an invaluable experience but also a frustrating one, with many pitfalls along the way. This is when support from a mentor is important. For me, mentoring has been a great joy throughout my career (Figure 3).

David: Working on small scale consulting is valuable because you've learned textbook tools in the classroom, but they will often not be appropriate for real data, with all its horrors. I also think it's valuable to get people to critique published or preprint papers. I think a reasonable aim is to be able to tear a medical paper apart, say find four faults, in just a few minutes—maybe critiquing papers could be made a competitive sport.

Bhramar: It has been an incredible honor and privilege to be in conversation with two stalwarts in our field (Figure 6). You've taught us to embrace imperfection and complexity in data and life. You have told us to be feisty and passionate about our profession and have the guts to tear each other apart. But also, to love and support each other. On behalf of the entire statistical community and on behalf of statistical science, I just want to thank you. As I said, not only are you incredible researchers, but wonderful human beings. Thank you for your presence in the community and your leadership.

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