**10 Elspeth Garman**

Elspeth - I didn’t know at that stage what a protein was, I didn't know what an amino acid was.And the very first day I started the job I had a big argument with one of the graduate students who came up and said, "Oh, I've just seen a nucleus." And I'm like, "No, I've spent the last 11 years looking at nuclei. I never saw one. That's amazing." And then after a bit of an argy-bargy, we realised that he was talking about the nucleus of a cell, and I was talking about the nucleus of an atom.

Kat - This is the Suffrage Science podcast: How women are changing science, brought to you by the MRC London Institute of Medical Sciences. I’m Kat Arney and over this series we’ve been exploring the journeys of women in science - reflecting on progress we’ve made and the challenges still to be addressed - through conversations with an incredible group of women scientific leaders, who have all received one of the Suffrage Science awards over the past ten years.

We’ve heard from inspirational figures from the world of science like former Chief Medical Officer Sally Davies, computing legend Wendy Hall and climate scientist Tamsin Edwards, so make sure you’ve subscribed to the Suffrage Science Podcast through Apple podcasts, Spotify or wherever you get your podcasts so you don’t miss a single episode.

This is the final episode in the current series of the Suffrage Science podcast, and I’d like to say a huge thank you for coming along with us. I hope you’ve enjoyed listening to these conversations as much as I’ve enjoyed having them - it has certainly kept me busy and inspired during the past few months while we’ve all still been stuck at home. If you’ve enjoyed the series, please do leave us a rating and review on Apple Podcasts, and spread the word about the show to your friends and colleagues.

The guest for our final chat is structural biologist Elspeth Garman, who received her life sciences Suffrage Science award in 2020, after being nominated by Professor Jenny Martin. By coincidence, the first woman to receive this particular piece of jewellery, back in 2011, was fellow structural biologist Professor Dame Louise Johnson who - as we’ll hear - played a major part in Elspeth’s scientific career.

Now Professor of Molecular Biophysics at the University of Oxford, Elspeth has developed pioneering methods in X-ray crystallography. This is a technique that allows researchers to take X-rays of biological molecules like proteins and figure out their three-dimensional structure, and underpins an enormous amount of modern biology, from metabolism to drug development. In recognition of her contributions to the field, Elspeth is recognised in the eponymous ‘Garman limit’, which is the maximum dose of X-rays that can be beamed through a biological material before the technique stops working properly.

She’s also the winner of the European Crystallographic Association’s Max Perutz prize, has given prestigious lectures in honour of crystallographers Rosalind Franklin, Lawrence Bragg and Dorothy Hodgkin, is a Fellow of the American Crystallographic Association, and past president of the British Crystallographic Association. Not bad for someone who didn’t even know what a protein was when she started working in the field.

So, what first got her interested in science?

Elspeth - My father was an engineer in World War Two. And then when he was discharged, he decided that he would train to be a priest. And he had left school when he was very young and knew no Latin and Greek. So he had to go and learn that first and then go to theological college. But he was a fantastic electrical engineer who worked on mending radar in the war. And about six weeks before I was born, he lost his sight in a week. So he saw my two other brothers, but he never saw me very well. You know, he had a bit of residual sight out of the side, but he could still mend plugs, he could teach us how to do things and he was just fantastic. And my second brother, he became a mechanical engineer and invented the Garman Turbine, which is for irrigation, using the power of fast flowing rivers in the Amazon and the Nile. Yes, I got really interested in sort of physics and astronomy and the stars and the universe when I went to school one morning and we were in a very large class, over 40 children in the class, and the teacher had put all the desks to one side and had drawn a chalk circle on the floor. And she had an orange with a knitting needle stuck through it, which was the earth on its axis. And she walked around this chalk circle, which was the sun and explained how a year worked and how a day worked. So I went home and I looked out of my bedroom window that I shared with my little sister and I saw what was out there. And then the next morning I looked again and I was expecting it to be 180 degrees different because I didn't understand that I was actually moving with the earth. So I learned about relative motion. And then the other experiment that got me in big trouble was that my mother brought some Signal toothpaste home from the nearest town, which was about 30 miles away. And it was new and it had red stripes in it. And I said, "Oh, are they in there already? Or do they come when you press it out?" And I was always asking things and there were four of us and she was very busy and she said, "Oh, Elspeth, you know, I don't know how it works". So I got up and found the nail scissors and I cut the end off the toothpaste tube and I spread toothpaste everywhere, trying to find out how it worked. I got in quite a lot of trouble for that.

Kat - I bet you did. And then what led you into actually a life as a scientist? What were your first steps into the kind of career that you've had?

Elspeth - I think the moment I knew I was going to be a physicist was when I was on a bus aged about 13 with the rest of my classmates. I was at a Church of England convent school in Whitby, Yorkshire, St. Hilda's school. And my physics teacher was very young and she was a nun, Sister Janet Elizabeth, one of my heroines in life. And we had to go up to the senior school, which was about four miles away to do all our experiments because we didn't have a lab at the junior's bit where I was, and she stood at the front of the bus and she would start teaching us the minute we got in the bus to go there and tell what we're going to do in the experiments in the lab. And she said, "does anyone know how long it takes light to get from the sun to the earth?" And I just shouted out the answer and they all turned on me and from that moment on, they mocked me regularly by calling me prof, which I never thought would be true, but in fact has become true.

Kat - Yeah, who's laughing now?

Elspeth - So I ended up doing physics A-level at the school, but nobody had done physics A-level for at least 10 years. And we, me and my one friend who became a high court lawyer actually, who did physics with me, we were sent to York University for four days and put in the care of two or three undergraduates who did a load of experiments with us. And, you know, that confirmed me completely, that I wanted to do physics. And then I applied to Cambridge and did the third year sixth form exams, had to go back to school. Sister Janet Elizabeth has only just admitted to me, she's over 80 now, she's only just admitted to me that she couldn't do the entrance questions for Cambridge either. Anyway, I catastrophically failed to even get an interview, but it allowed me nine months between the exams and when I started at Durham University to do physics, to go to Africa and teach. And I started off going to Ghana, and then there was a coup and I couldn't get in. I couldn't get a visa to go to Rhodesia, and I ended up in Swaziland and every time I got 2000 miles further away from England.

Kat - And so how was that experience going at that age to Africa and teaching?

Elspeth - It was life changing, completely life changing. I mean, I've been teaching maths only, but I found myself teaching every lesson apart from Zulu, because I didn't speak Zulu, but you know, I had to teach games and until I learned to row, when I went to university, I was completely, always the last person in the class to be chosen for any team. I was hopeless, no coordinating skills. It was life-changing, completely. I learnt so much more than I ever managed to teach. The classes were huge, it was a secondary school, I was teaching science to the first form, we had two classes of 50 girls each. Quite a lot of the time there was no electricity, I was supposed to be teaching electricity and you know, things like there was a snake in the prep room, a sort of 12-foot black mamba when I went in to get my display one day and the prep room was right behind the board and the door to the classroom, which went straight outside was right next to me. And I knew that if I told the girls there was a snake in there, you know, they'd get killed trying to escape. So I had to say, "Oh, we're not doing physics today. I've changed my mind. We're going to go outside. You've all got to catch a locust and bring it back and we'll have a look at it". And they thought "the sun has got to Miss at last!" You know? And then I had to shut the door I get when I got them all out safely, go and get the gardener with a rake. And I mean, this was a huge snake. So things like that, you know, you grow up quite fast.

Elspeth - But the most long lasting and wonderful result of this is that one of my pupils, this is 1973 I was there, but in 1995, she died and she left a note to say that her 15 year-old daughter Precious would be looked after by me. And it had my address in Oxford. And I hadn't heard from this pupil for two years or so, but it's a long story how it happened, but just got a fax one morning in the lab saying that Maria, my pupil, my ex-pupil had died and that Precious was, was ours, mine. And they were putting her on a plane to Heathrow and I knew I would never get her in. So I rang up my late husband who was at work and said, "I think we've just won a third daughter, is that okay?" And he said, "I'm very busy, as long as you see to it, it's fine." So, obviously we couldn't get her in, I faxed back saying, yeah, we take responsibility for her until she can earn her own living. And she's now 41, she's got two little boys who are 10 and 12 who call me Ugogo, which is Zulu for granny. Yeah.

Kat - Amazing. So how did you then get into crystallography and then the kind of work that you've done in crystallography on biologicals, proteins, you know, following the footsteps of wonderful crystallographers like Dorothy Hodgkin and of course, Rosalind Franklin. What got you on that path?

Elspeth - That's another very unlikely sounding story. I mean, I think if, if I wrote a book, nobody would really believe that these things happen, just like getting Precious. You know, people are just amazed how that happened. After Durham physics I had been a summer student at CERN at the end of my second year, and I'd enjoyed that very much. And I'd worked on the magnetic moment of the muon experiment, which is of course extremely topical at the moment, but this was 1975 and I enjoyed that very much, but there was a team of 35 and I was put on analysing some data from their last run. And I wanted to do the sort of nuclear physics where you understand the vacuum systems, the electronics, the assembler code. I didn't want to be just in a little niche, so I didn't want to become a high energy nuclear physicist. So I looked around and I ended up coming to Oxford to do a PhD DPhil in low-energy nuclear structure physics. And I was the first woman, I think, for 15 years in that part of the nuclear physics lab and that had some major challenges associated with it, but it was also advantageous as well in some ways. So, after that I became a science research council fellow and then a research officer in nuclear physics. And during that research officership, I had my first child, I'd got married when I was a graduate student in the third year of my graduate studies. And that was interesting because I went to the administrator and said that I was going to have a baby. And he said, "well, research officers, you know, none of them have had any maternity leave before. I don't know what the, you know, whether there is any, what the system is".

Elspeth - And I'm like, well, yeah, I'm the first female research officer in nuclear physics, that's why none of them have had babies before!

Kat - Bit of a clue!

Kat - You have to be careful what you say, it's so obvious. Yeah. So, I took leave from that job because it wasn't clear whether I could have maternity leave and I was asked to cover at St. Anne's college to be a tutorial fellow for a sabbatical leave. And so a week into that job, I actually had Ruth and I had her in the hospital here. One of my graduate students from nuclear physics covered my tutorials for a week. And then when I came out of hospital, the students came round to the house and had tea, biscuits and cuddled the baby. But St Anne's didn't know about this. It turned out that the tutor who had engaged me who didn't know I was pregnant, hadn't actually told St Anne's I was going to have a baby.

Elspeth - And so there was a bit of an issue by the end of term, when they said, well, "we realise that you've had a baby this term". And I sort of said, "well, I realise that I have as well". Yeah. Anyway, it was fine in the end. They were fine about it because I'd gone on teaching. So I then got a job with Somerville and Worcester College, teaching physics; I really, really enjoyed that. And at Somerville College, I met Professor Louise Johnson, she was Dr Louise Johnson then, who was in the biophysics area, which at the time was in the zoology department for historical reasons. And she'd obviously been to some teaching committee where they'd been discussing my contract, that it was going to run out the following year, so I still had, I think 15 months of it. She said, "Elspeth, what are you going to do when the contract runs out? What's your next steps in your career?" And I'm like, I don't want to think about this. I've got a two year-old and a resident mother-in-law who I'm nursing, who's 83. And I really don't want to think about what I'm going to do in a year and a half time, but it was quite right that she should ask me. And in order to sort of get rid of the question, I said, "Oh, I don't know, I'll probably have to change fields because nuclear physics isn't being funded anymore in Oxford". And she lit up and she said, "Oh, we're looking for someone just like you in molecular biophysics to run our new x-ray generator. And would you come over there tomorrow and have a look?" So I thought, well, she's a really nice lady and I don't want to upset her, maybe I'll go and have a look - I'm a very curious person so I'll go and have a look. So I met the head of the lab who was professor Sir David Phillips. And he started the interviews as he thought it was by saying, "I hear you only want to work part-time". And I said, yes. And then the best sentence of my entire life came out, which was, "yes, I only want to work part-time, but you'll have part of my time and all of my brain".

Kat - Amazing.

Elspeth - And he was really taken aback by this. And anyway, to cut a long story short, well, not a very long story, I rang up a few days later and said, I'd like to apply for the job. And there was huge confusion. and the secretary, a wonderful lady called Pam Bachelor said, "Elsbeth, I don't understand, You've got the job". You don't have to apply." And sure enough, when I cleared out, Louise Johnson's paperwork, which I did after she died, what was left in biochemistry, there was my personnel folder, all the personnel folders, which obviously got shredded, but mine was completely empty, there were no CV, there was nothing in it. Anyway, I ended up changing. I didn't know, at that stage what a protein was, I didn't know what an amino acid was. And the very first day I started the job I had a big argument with one of the graduate students who came upstairs from the microscope room and said, "Oh, I've just seen a nucleus." And I'm like, "no, I've spent the last 11 years looking at nuclei. I never saw one. That's amazing". You know? And then after a bit of an argy-bargy, we realised that he was talking about the nucleus of a cell, and I was talking about the nucleus of an atom. And at that point I realised unless I ask whenever I don't understand, I'm just going to ask, ask, ask, or I'm never going to learn. You know, I'm 33,. I don't know any biology at all and I still know woefully little compared to my biochemistry students, but, you know, I've had to pick up enough to get by. And what I found was something magical, which was that I'd be in a meeting and somebody would say something and I really wouldn't understand what they were on about, so I'd ask. And then afterwards people would say, you know, I've always wondered that, but I've never liked to ask because I should know that. And because nobody had the expectation that I knew anything, I could ask everything. And that actually opened up discussion for everybody, not just for me. So that was really positive.

Kat - You told me at the beginning that your brother has something named after him, the Garman Turbine, but you also have something named after you, which is a bit of a rarity in science, and particularly for women to have things named after them, the Garman Limit! Now, simply what is the Garman limits and briefly, how did you figure it out?

Elspeth - It was my favourite experiment that I've ever done. I had a wonderful graduate student who worked with it on me and believed in it enough to put in all the hard work, that's Robin Owen, who's now at Diamond Light Source. But when you hit a crystal with x-rays, some of them scatter elastically, so you get the diffraction pattern and that's what we use to get the structure. But of course, some of them get absorbed by the crystal. So when you go for an x-ray at the hospital, you get an image of your bones, a negative image of your bones and your flesh, because your bones have absorbed more of the x-rays than your flesh has. So protein crystals also absorb these x-rays and they result in energy loss within the crystal, which causes damage, radiation damage. And that's true for any biological object. So for instance, let's take a human brain tumour such as my husband had. He had 60 gray of radiation, that was two gray a day for 30 days. So what's a gray? It's a Joule per kilogram of energy lost in something. So if I've got an object and I put radiation into it and a Joule of energy is deposited per kilogram of the object, that's one gray. So what we did was take the iron containing protein ferritin, which is our iron storage protein, and it's like a football, and at the places where the sections meet, there's a little hole and the iron goes in and out through that little hole. And it has about 2000 iron atoms in it. So it's got an iron atom for every two amino acids. It makes it the densest and heaviest protein that exists, but you can also get the version where it's hollow and it just has normal solution in water mainly. So you've got two different crystals grown in the same conditions, but very, very different absorption. It's a bit like having bone and flesh. So we figured if we could calibrate how many x-rays we were giving these crystals, measure how the intensity died off, get to half and see what that number was. And then, using that, we could convert to dose. And we found the number was 43 mega-gray to lose half. But if you do that, then you damage a huge number of the amino acids. And so it was too much. So we said, you can't take it to half, you can only take it to 0.7 of the intensity. And that's what other people, not me, call the Garman limit, I call it the experimental limit. What it enables us to do is say the maximum exposure that a protein crystal can take before the biological information will be compromised. So that's why it's used as a sort of yardstick, you might not reach the limit because we haven't taken into account the chemistry, only the physics, but it very, very unlikely that the crystal will last longer than the limit.

Kat - We’ll come back to Elspeth soon, but now it’s time to hear a few words of advice from another Suffrage Science awardee, neuroscientist Mona Xu.

Mona - The best piece of advice I've gotten is to be kind and compassionate towards yourself, and to give yourself grace, particularly if you are a woman or minority, to recognise that there are spaces, including science, that are not historically nor currently really welcoming and safe spaces. So, just being in those spaces and existing in those spaces is a fierce form of resistance.

Kat - If you’re enjoying this series of the Suffrage Science podcast, please do rate and review us on Apple podcasts, and make sure you’re following on Apple podcasts, Spotify or wherever you get your pods, so you don’t miss a single episode. Let’s return to our conversation with Elspeth Garman, to hear about the unorthodox application process that landed her a job with Louise Johnson, and before that what it was like being a woman in such a male-dominated scientific field as physics.

Elspeth - In nuclear physics, it was really tough, because they didn't really want me because they didn't think I could move the trolleys of helium gas that we had to move around between the Clarendon Lab and Nuclear Physics. But I had two postdocs in the group that I was in, Keith Fifield and Frank Watt were both really very kind and mentoring. The problem with being the only female in the lab is that any mistake you make is because you're female, it's not because you're a rookie graduate student, who's learning a huge amount of new stuff. It tends to get blamed on the fact that you're female. And that's quite tough if you're doing a lot of mechanical work and workshop work. So actually with a colleague in Spain, who's a very good coder, a few weeks ago said, you know, Elspeth, it's going to be equal when there are as many incompetent women as men and nobody remarks on it.

Kat - It's absolutely true.

Kat - And that that's actually quite, quite deep. So Louise was terrific because way ahead of her time, she didn't have meetings after three o'clock. I mean, I worked part time, that meant school hours, and was supposed to have Friday off as well. Although I often got called in and had to take one of the children with me because I didn't have any childcare that day. And she would always think about things because she'd had two children that she'd brought up herself here in Oxford. She would think about it from our point of view. And molecular biophysics was wonderful because I went from a completely male environment, I mean, I'm talking a hundred percent apart from me, to one where it was about 50% women and being, you know, I was technical person in the lab and that was okay, which was really a wonderful change. And the other wonderful change was that Louise was trained as a physicist, as was I, but in the lab, there were people who'd done biochemistry, food technology, computer science, maths, you know, it was just a hotchpotch, which meant that the expectation that you knew everything wasn't there. Whereas if you're in nuclear physics, it's like a long dark tunnel and all the people who you could talk to about anything else have dropped off it. And I would have conversations with colleagues in nuclear physics where we would miss out at least three steps in the conversation because we didn't need them because we were all thinking along these railway lines. So for me to come to a place where we weren't on railway lines anymore, it was really intellectually, extremely stimulating and Louise didn't interfere, but she was very supportive and she was always open to suggestions and would let you just get on with it and not interfere. So I really appreciated that. I mean, I think I'm unmanageable, to be honest.

Kat - You've mentioned that during your time as a researcher, you've had two babies and also your adoptive daughter, how has that been? You've mentioned that it has been a bit of a struggle at times. And do you think things have changed since then?

Elspeth - I think things have improved hugely, really, really enormously. No. So my first maternity leave, as we said was a week, well, it wasn't even leave really. And the second time, which was 1991, my three months maternity leave was at the end of one of these endless contracts. So I had nine temporary contracts between my PhD and getting a job, which was fine because my husband had a permanent job. So I had the luxury of being able to say, okay, you know, I'd go and be a laser physicist if nothing works out. So in 1991 and I was at the end of one contract and I wanted more maternity leave because the child, I was 36 when she was born, nearly 37, and she didn't sleep for more than an hour and a half for 10 and a half months. And I was really going crazy with sleep deprivation.

Elspeth - My husband was building this space instrument, he started in 1987 and it was launched in 2004. So he was going to NASA once a month, approximately. And he was in charge of a big team, a huge amount of money, lots of responsibility. He had to raise the money in the UK and it was joint with the US, and he was really preoccupied with that. And in fact, famously, he said to me about 10 days before the second one was born, "is this baby coming soon?" And I said, "yes, next Friday". And he said "it's not very convenient", you know? And he said, "actually, I've looked at my diary and if you could possibly have a, between 8:00 AM and 10:00 AM this Friday, which was a week early, that would be much better". So I won first prize by giving birth to her at 8:22 in this window.

Kat - Oh my goodness!

Elspeth - Anyway, I couldn't have any more maternity leave and I had to go back to work and my computer was just going in and out like this. It was really terrible. But then, you know, through various other things, things have improved usually. So when my husband was terminally ill, you know, the department were absolutely fantastic. I just can't fault them. They, you know, I went in and I delivered my lectures, but I was on a very loose reign. And I worked at home a lot, but he needed care here for eight months and I was here most of the time with him. And that was very precious time, of course. So I think this daughter that never slept has just had a baby a few weeks ago and she's got six months off work and it's like, Whoa, that's fantastic! You know, she's not in the university, but the university has improved a lot.

Elspeth - And I think the awareness that just small things like visiting speakers get to meet people, but you know, if you've got to go home at three o'clock because you're part-time and you never get to meet the speakers so your profile doesn't increase. And I think the Athena Swan scheme has really, really helped hugely. And I want to give a lot of credit to that because when it started, I was interviewed as were some other women in my department about it. And I thought, this is just window dressing. Nothing's going to change. Yeah, they're finding out what's wrong, but it won't change, but it has. Even, you know, Athena Swan, we ought to do this, that means something. And I think that's good. I think we've got a long way to go. And as I say, when there is many incompetent women as men and nobody remarks on it, then we'll have reached where we ought to be. That's just a small example. So I'm on an EU assessment panel for experimental time on Ion Beam, all over Europe, it's called RADIATE. So we had a meeting at an airport of all the assessors to train us basically two years ago. And I walked into this room and ion beam physics is fairly male dominated, as you can imagine. And I was stunned, there were seven women and one man. And I said, "Oh, this is absolutely fantastic". I mean, we were all like, "Whoa, you know, this is really wonderful". But then I realised what it is. And I said to the one man who was the organiser, you know what happened to all the men? He said, well, they're too busy. They don't have time to do the assessments because you don't get the time yourself. You're judging other people, whether they should get the free time on the - not the free, but you know, through the EU funding - whether they can have beam time. So that just says it all, you know, we've got seven women who are willing to do 22 assessments a year or whatever it is for nothing! For no credit or nothing, but they're willing to step up to the plate and do things like assessing other people's things for which there's no recompense in any way, nothing for you. No beam time because you assess other people's beam time. So that was just a small example of how things have still got to change.

Kat: Thanks very much to Elspeth Garman, and to all our guests for this series - Mandy Fisher, Viv Parry, Helen Pankhurst, Martin Baker, Sally Davies, Tamsin Edwards, Wendy Hall, Mona Xu, Maggie Aderin-Pocock, Carron Shankland, Hayaatun Sillem and Hannah Dee. You can catch up on all those conversations from Suffragescience.podbean.com or wherever you get your podcasts.

If you’ve enjoyed the series, please do leave us a rating and review on Apple Podcasts, and spread the word about the show. And before we go, here’s a final word from Mona Xu about her hopes for the future.

Mona - In the future I would like to see a scientific community where it is not at all remarkable that someone is a woman or someone is a minority.

The Suffrage Science Podcast: How Women Are Changing Science is presented by me, Kat Arney, with audio production by Georgia Mills. It is produced by First Create The Media for the MRC London Institute of Medical Sciences Suffrage Science scheme. Find out more and read profiles of previous awardees at [suffragescience.org](https://www.suffragescience.org/) and follow @MRC\_LMS on Twitter and the hashtag #SuffrageScience for all the latest news. Thanks very much for listening, and goodbye.