Just the Components of Forensic Biology and DNA

Introduction [00:00:05] Now this is recording RTI International Center for Forensic Science Presents Just Science.

Voiceover [00:00:18] Welcome to Just Science, a podcast for justice professionals and anyone interested in learning more about forensic science, innovative technology, current research, and actionable strategies to improve the criminal justice system. In Episode five of our Strengthening the Forensic Workforce Season, Just Science sat down with Dr. Robin Cotton, Director of the Master of Science Program and Biomedical Forensic Sciences at Boston University School of Medicine, and Dr. Daniele Podini, a professor in the Department of Forensic Sciences at the George Washington University to discuss forensic biology and DNA. Forensic biology can be described as the application of biochemistry and cellular biology to solve forensic problems. These techniques have evolved over the years with increasing sensitivity, are routinely used to identify individuals through DNA and provide information on biological materials present at a crime scene. Listen along is Dr. Cotton and Dr. Podini discuss their interesting careers, the importance of criminal law and ethics training, and the value of student research involving statistical analysis and interpretation. This episode is funded by the National Institute of Justice's Forensic Technology Center of Excellence. Here's your host, Gabby DiEmma.

Gabby DiEmma [00:01:28] Hello and welcome to Just Science. I'm your host, Gabby DiEmma, with the Forensic Technology Center of Excellence, a program of the National Institute of Justice. This season, Just Science will discuss forensic science programs and NIJ funded research at universities accredited by the Forensic Science Education Programs Accreditation Commission or FEPAC. Here to guide us in our discussion is Dr. Robin Cotton, Director of the Master of Science Program in Biomedical Forensic Sciences at Boston University School of Medicine, and Dr. Daniele Podini, a professor in the Department of Forensic Sciences at the George Washington University. Robin, Daniele, welcome. It's great to have you on the podcast.

Robin Cotton [00:02:11] Thank you.

Daniele Podini [00:02:12] It's great to be here.

Gabby DiEmma [00:02:13] Robin, I'd like to hear more about your professional background and current role at Boston University School of Medicine.

Robin Cotton [00:02:19] Well, my original background is in molecular biology and biochemistry and when I finished my Ph.D., I did a series of postdoctoral studies in two different locations and at that time, I wasn't having a great time. I mean, it was nice, but I just thought, well, maybe I should look for something else and I heard about the lab in Maryland that was opening up. It was a private lab. It was the original Cellmark lab. And I went to work there just thinking it would be temporary. And I worked there for 18 years. And then when that lab closed and I was looking for another happy accident and the happy accident turned out to be Boston University. So I came up here to be the director of the program, and I'm still here.

Gabby DiEmma [00:03:08] And Daniele, tell us a little bit about your professional background and current role at George Washington University.

Daniele Podini [00:03:15] I also have education in molecular biology, and I was finishing my - the equivalent of a master's in molecular biology, and I found an article about DNA fingerprinting that was fascinating. At the time in Italy, the military service was still obligatory. And so I thought maybe I can do the military service in a way that I can apply molecular biology. And so I applied to enter the Carabinieri, which is a military institution that does law enforcement on the territory. But in order to maximize my chances, I had to go through officer training school and initially I didn't end up in the crime lab. I actually ended up in the battalion doing public disorder prevention, searching for people that were kidnaped in the mountains. It was a lot of fun, actually, but it wasn't forensics. And eventually I ended up in the crime lab. And so I stayed there for another two and a half years, actually. And after that, I opened up the forensic section of a genetic laboratory. I was doing clinical genetics and they wanted to create a forensic section. So I did that. And four years later, while getting what's equivalent to a Ph.D. at the same time, I ended up at the George Washington University. And this was 18 years ago. I came here with the first round of cicadas and now I'm the chair of the Department of Forensic Sciences.

Gabby DiEmma [00:04:45] So I'd like to dive into today's topic a little bit and start with a question about DNA in general. In the 21st century, everyone has heard of DNA and its potential to help solve crimes. But the field of forensic biology encompasses more than just DNA. Can you define for our listeners what is forensic biology?

Robin Cotton [00:05:06] It's really the application of what we know about biology to a forensic question. And that's a very broad definition, right? It allows for all kinds of things, but that's really it. Everything that's done in forensic biology and DNA comes from what we know about biochemistry and cellular biology. The techniques are coming into forensics from those things. Some of them are old techniques, some of them are brand new. But forensic is the adjective, right? So biology is what you're doing and the application is a forensic application.

Daniele Podini [00:05:43] So I could add to that, that for the most part, we borrow methods that have been optimized and developed for other purposes. I guess the - an example that anybody can relate to, and that doesn't necessarily apply to DNA but to forensics, is blood group identification. Blood groups were studied for the purpose of for medical reasons, right? To enable effective transfusions. And then blood groups were then used and borrowed by forensic scientists to exclude individuals because they're not that identifying, but as an example. And DNA is the same thing. It has a lot of other applications and we kind of borrowed that knowledge to help us identify individuals.

Gabby DiEmma [00:06:32] That's a great description. Thank you. So now I'd like to hear more about your programs. Both of your universities have great FEPAC, accredited forensic biology and DNA programs. Daniele, I read that the George Washington University's forensics program is one of the oldest in the country. Can you tell us a little bit more about that?

Daniele Podini [00:06:50] Yes, it's one of the oldest graduate programs in the country. It was initiated in the late sixties. At the time, the FBI crime lab was very close to the Foggy Bottom campus where our university is located, and the FBI wanted to allow their scientists to get a higher level of education. Also because they were then testifying in court and it was important for them to be more reliable witnesses and have a slightly higher level of degree. So that's how it started. Eventually, it developed in what it is today, which has three different fields of studies. One is forensic molecular biology, which is DNA, one is forensic chemistry, and the other one is a Master of Science in crime scene investigation.

Gabby DiEmma [00:07:39] Excellent. And Robin, you university offers a master of science in biomedical forensic sciences. Tell us a little bit more about this program and how it differs from other general forensic science programs.

Robin Cotton [00:07:51] Every FEPAC program is going to have a certain level of things in common. But based on our faculty expertise, the program has three tracks. One is biology and DNA, one is chemistry and toxicology, and one is pathology and death investigation. And there is no undergraduate program here. So we have a set of core courses that cover, as FEPAC requires, all the various disciplines to some extent. But our strong coverage is in the areas that I mentioned, and the program is organized mostly around those areas.

Gabby DiEmma [00:08:30] So one thing I noticed when looking at your curricula is that both of your programs require a criminal law and or ethics course. So I want to kind of talk about the importance of an understanding of criminal law and ethics for students planning to enter the workforce as a forensic scientist.

Robin Cotton [00:08:49] When you're in the lab and you're doing a case, you know, you're working very hard on a case, you're applying the best scientific techniques that you understand will help answer that question. But the real end to that case is taking that information to a jury or a judge if it's a judge trial. And if you can't do that effectively, then all the hard work you did, all that scientific expertise that you applied to that case isn't getting communicated. I mean, you have to be able to do that. And I've testified over 250 times in Frye hearings, in other kinds of admissibility hearings and in trials. If you can't do that communication in a competent way, in a relaxed and balanced way, then you're - haven't really fulfilled your role as a forensic scientist. And when I started, our training was they took us down to a mock courtroom at GW and we had an afternoon of practice. That was it. And most of what I know about the law, I learned over the period of time that I was testifying. But your learning curve ought to be better than that. Right. It turned out that I didn't make any huge mistakes, which was a good thing. But you can tell when people do make huge mistakes or they simply don't do a very good job because they're having trouble making that transition from talking about science to another scientist to talking about scientists to people who aren't scientists. And so our program has two courses. They're both taught by practicing attorneys who are either prosecutors or defense attorneys. It happens are two attorneys currently are prosecutors. And the first course is just about the law. You know, what is criminal law and what are all the features of that, that they need to know? So it's basically a lecture course. The second course is all testimony practice starting out from just like a question, like tell us what your undergraduate background is. And at the end of the semester, they're doing a full trial with a judge and all the attorneys and defense attorneys. And I hope what that does is help them to understand what their role is, because trials can be difficult. Attorneys can be very difficult, and they're not all great. If you understand better how to navigate that courtroom, you're going to be able to do a better job at fulfilling the end part of your role, which is explaining the data that you produced.

Daniele Podini [00:11:33] And I agree with everything that Robin said, and we have similar courses here at GW. And to add to that, I would say that it's important for our graduates to have an understanding of the laws that apply to the evidence and bringing the evidence and building the evidence into court and to understand the ethics and the professional responsibility that they have throughout the process and how to not be biased by a detective that comes in with the evidence and says, I think we got it. And so they

should know that they've been immediately biased and the analysis on that case should be done by somebody else. So we try to give them the perspective - and we talk about mistakes that have been done by previous scientists and also some actual crimes that were committed by forensic scientists, by dry labbing some evidence, by misrepresenting the results, and also understanding how to present the evidence and the results of their analysis in the appropriate manner to the juries. Understanding that the average juror has an eighth grade science education. It might not be somebody that understand exactly what DNA is and what DNA extraction is and how that works. So they have to be able to explain complex scientific concepts in a simple way that is correct. That is right. So that the jury can then make a right decisions based on their understanding of the results. So that that is something very challenging and somewhat unique to our discipline. When I say professional responsibility, we have a big responsibility as forensic scientists because we practice a science that the next day has an immediate impact on society. A DNA match could represent, you know, an innocent suspect being exonerated or a missing person being identified and a family finding closure or, you know, somebody that might be hurt, other people being taken off the streets. And so our students have to understand their role in this whole process. And so we try to do that in our courses. And also these are also FEPAC requirements. So we are required by FEPAC in order to be accredited to give these courses, this knowledge to our students.

Gabby DiEmma [00:14:10] So we've discussed some of the criminal law and ethics courses that are both required by FEPAC for accreditation, but also are essential to forensic science careers in general. But one topic that is more specific to forensic biology and DNA is statistical analysis and interpretation. So what types of courses, what types of work are your students doing to be well versed in statistical analysis so that they're able to interpret their data further down the line?

Daniele Podini [00:14:38] Well, in our program, we have specifically for the forensic molecular biology field of study, we have a course in population genetics, which helps students understand the statistical analysis that are performed on the evidence for DNA purposes to determine the frequency of a profile and the chances of observing that profile, if the suspect is included rather than if it's somebody else in the population. Then we have a required course. The name of the course is Statistics in Forensic Sciences and there students learn about the statistic applied to all the forensic science discipline and the limitation of some of our disciplines in applying the appropriate statistics to the interpretation of evidence. But throughout the program, students learn statistics directly in each class that has components of it. So in the molecular biology classes, students learn about applying probabilistic genotyping, for example, to the interpretation of evidence and they learn how to report it. They learn the limitations of it. And there's one of the courses it's called Forensic Molecular Biology III, which specifically focuses on probabilistic genotyping and on developing validation studies for the appropriate interpretation of the evidence. And statistics is a major component of those courses and about interpreting DNA results.

Robin Cotton [00:16:21] We have a slightly different set up, but the importance of statistics is becoming more and more and more obvious. So it's really critical that students either come to the program with sufficient statistics from undergraduate. We don't have a specific course in the program, but because we're here at the medical school, there are several statistics courses and we are able to direct our students in there and we accept those courses as part of the program. So we don't have anything exactly like what Daniele's talking about. We cover, as he mentioned in the individual courses, you're covering the statistical applications that are particularly relevant to those courses. And

then in the research projects. Now you're getting serious because now you've got a lot of research data. And how do we show that that research data, the results from experiment one are statistically significantly different than the results from experiment two. So in that case, they're learning the applications. They might be using probabilistic genotyping at an application, or they may be using one of the statistical applications just to get away from Excel and look at a bigger statistical package to apply to their data and things like that. So the faculty are guiding those decisions and it's just so critical that you don't leave without having some training in that.

Gabby DiEmma [00:18:05] Yeah, you can have a whole bunch of data, but if you don't have the statistics to analyze it, it's just a spreadsheet. So you mentioned research and I kind of want to jump to talking a little bit more about research. In your experience, what is the importance of students doing research in order to foster creative problem-solving skills and address forensics problems through hands on research?

Daniele Podini [00:18:30] Both of those things. But primarily, I think it's important for their growth as a scientist. If you don't do research, you end up being a lab technician that gets really good at pipetting and performing the tasks that they're assigned at following a protocol, right? Whereas the research makes you think outside the box, makes you have to solve problems. And research is not easy. Most of the students are, aah this didn't work I have to re-do it. Yeah, you have to read to it, but you have to redo it. But before you redo it, try to figure out what went wrong and see out how you can improve it. So read some papers on that topic. Go back and look at your results. Maybe try something different. But before you try it, you have to know why you want to try something different. So it forces them to read papers to think about things, to sometimes to work hard, to stay late in the lab or to come in on the weekends. It's not something necessarily enjoyable for for every student. And some are - some love it. Some not so much. But eventually they all appreciate the process and that what they, what they come out with on the other side. And it also helps the community, of course, because we try to select research projects that can generate the new knowledge and help the practitioners and the industry develop new tools, new methods for improving human identification via DNA.

Robin Cotton [00:20:11] The idea that you might go into a crime lab and you're going to do DNA analysis and you're going to have a protocol and everything is going to be the same, doesn't actually work out in practice. And there are lots of issues, whether it's DNA or whether it's chemistry. I mean, people in toxicology, when a new drug is developed, they have to develop a new assay. You know, they can't just say, well, it's kind of like cocaine, so we'll just see if that assay will work. And the same thing is true that not all DNA samples are the same. Occasionally something goes wrong in the lab and isn't working properly or you're not getting very much DNA out. Somebody's got to be able to think that problem through, and that's really what research is all about. I have a problem. How do I figure out what the answer to that problem is in a very systematic way? And it's critical. And then the other thing that Daniele mentioned is reading the scientific literature. The requirement for reading the scientific literature for laboratories is that you have to demonstrate that you read some papers. In some labs that, you know, a paper a month. In some labs, that's a paper a year. The number of papers that are published during the year that are significant go way beyond that. In the laboratory with a lot of practicing professionals and a heavy caseload, it's work that they may feel that they don't have time to do. But sometimes it's really critical. And, you know, the role of the technical leader is to guide the lab. The technical leader needs these skills, needs these research skills, needs to be able to read the literature and keep up and implement improvements that have come out of the research that's been done. And the other thing is, at least from my perspective,

the most fun I have is not teaching a big course. It's doing research projects. And sometimes it's not just the student who doesn't understand what went wrong. You're going like, Oh my God, what went wrong? I thought I knew how this was going to turn out and it didn't turn out that way. Why? So that's really the most fun.

Daniele Podini [00:22:28] Inspired by what Robin said, the best part of my job is definitely working with the students on research projects. It's a moment in which we learn a lot too, because we're doing something that we've never done. We're doing research. So we we don't know what's going to happen. We don't know necessarily the answer. So we're figuring it out together. Yes, we have more experience, so maybe it's easier for us to troubleshoot. But it really teaches you how to learn, which is a tool. I always tell my students, I know for sure what the technique you're going to use the first case you process because it's what I'm teaching you. But I have no clue of the technology you're going to be using when you're about to retire. You know, however many years from now and you're going to have to learn everything in between. And when there's something new in order to use it appropriately, you need to understand that. You need to learn how that works and learn its limitations and learn how you can make mistakes. And so research really helps students be prepared to do that.

Robin Cotton [00:23:38] And I want to bring that thought back to the courtroom question, because I've read transcripts where an analyst has gone to court and in response to some question, has said, that's what my technical leader decided. When they answer that question, that's what my technical leader decided, they just gave up their expertise. They just said, I don't really totally understand that and I'm going to tell you I just accepted what my technical leader said. That's the point. So the lab is doing validation, making a change based on that validation and implementing that change in the protocol. That research experience that the student got at the master's level needs to go backwards then and be applied, even if they weren't part of that validation, they need to go look at that data, understand what it said, how that change to the protocol was made, and then they don't - they just say, yes, we made a change to the protocol based on our validation. They can answer a question about it. They don't have to sit there. And basically, in so many words say, I don't know. Now, there are times in court when you do have to say, I don't know because you really don't. But that's not the time.

Gabby DiEmma [00:25:00] What you both are saying is really resonating with me. I did research all throughout undergrad and graduate school and I always tell people I love research. But I mean, Murphy's Law, anything that can go wrong will go wrong. And you experience that firsthand through research. And you have to adapt and solve the next problem. Okay, why didn't it work? And I think that's a really important aspect and I'm really glad you brought that up. Building off something that Daniele mentioned, the field of DNA analysis is always rapidly evolving in terms of both the technology that's being used and our ability to detect lower and lower levels of DNA, degraded DNA, low copy number, sequence variance. How does your program stay on the cutting edge and how has it evolved over the years?

Daniele Podini [00:25:53] So we try to expose students to the latest technology that is being used in crime labs, and we try to anticipate what's the next big thing that's going to be used in crime labs. So in our case, and also in Robin's lab, we're doing - applying massively parallel sequencing technology to forensic DNA analysis. Now, I want to say something that, it's kind of a slight criticism to the forensic world, we are very slow in adapting - adopting new technologies, and we still specify that when we talk about sequencing, we're talking about - you referred to it as massively parallel sequencing or

people call it also next generation sequencing. Nobody else in the DNA sequencing world specifies that because that's how you sequence DNA everywhere else. So in forensic, we're still using a technology for DNA analysis that is somewhat obsolete for the clinical genetics world. And that's because we don't necessarily focus on the sequence of DNA, but rather on the size of certain fragments of DNA. But the sequencing technology is getting us access to a lot more information that we can get from DNA. And so I think it's eventually going to be common practice. And our research here is to support that shift. But I don't know exactly when. We're also for the class I mentioned earlier on the probabilistic genotyping. So one of the things that we've seen is that the community is now shifting to the use of these types of software for interpreting DNA evidence. And validation is a big component of implementing appropriately these technologies. And so we try to prepare students to validation of these types of tools. And the idea is to maximize the chances of our students to be employed, to make them very attractive to employers. As they hire them, they may not be able to use them for case work immediately because they have to go through some training, but if they are aware of how a validation study is being performed and how the software works, they can support that process immediately. And so becoming impactful immediately as they enter a crime lab.

Robin Cotton [00:28:37] We have a similar situation here. We are also doing some DNA sequencing. I'm a little behind Daniele in my exposure to DNA sequencing, but we're getting there. In fact, we had a research problem a couple of years ago, and we had these sequence differences and I simply couldn't really figure out why we were seeing this. And Daniele was the person that I called up to say, hey, I have a sequence issue and maybe you can help me understand that a little bit better. And it's really fun because there are university to university collaborations, or at least - and sometimes those are discussions and sometimes they're collaborations and they're also within the research realm of the projects that the students are doing, there's also collaborations with industry where they have a new instrument or a new technique or something that they want to work out. And it's not quite ready for the crime lab, but it's definitely ready for people outside of their own company to look at it. So there's all kinds of opportunities to do things that are brand new. And then sometimes the brand new questions are just questions that you can apply the techniques you already have to, but the question is not been asked before.

Gabby DiEmma [00:30:05] I'd be interested in hearing about any NIJ funded research or any research in general that your students have been conducting in forensic science.

Daniele Podini [00:30:13] I guess the first funded project was in 2009, and that was to develop an assay for targeting single nucleotide polymorphisms, which are single base changes in the genome that could help predict the ancestry of individuals and also physical traits like eye color, hair color, skin pigmentation. And the idea was to give investigators an extra tool when a DNA profile obtained from the evidence doesn't match any of the suspects or any of the DNA profiles in the database. What other information can we provide to the investigators that might help them narrow the pools of suspects and maybe corroborate the testimony of a witness and maybe cameras that are around knowing that a person with certain traits walked by at that time might be useful. So interestingly, the technology that we used, that which was kind of a strong point of that proposal, was that it was a method called the snapshot, which could be used with the genetic analyzers that were used for forensic DNA analysis in crime maps, which is now kind of obsolete because now you can use these other technologies that we have available. And then another project on developing an assay to automate sperm detection from evidence. So we developed this technology which was called proximity ligation assay, which is a method to detect the proteins very, very sensitive. It worked really well, but it

ended up not being picked up by the industry. So no kits were developed for the forensic community. And so it was never really turned into a product, unfortunately. Now we've been working for a few years on a new type of genetic marker called microhaplotypes, which are a set of snips within a region that are closely connected with each other, that can be very informative and have some advantages over the technology that is normally used in crime labs, which is based on short tandem repeats. So I've been working on that and on adapting probabilistic genotyping technologies to the use of these new types of markers.

Robin Cotton [00:32:48] Our program has a little bit more varied history in terms of financial support for projects, and a lot of that's come from other sources other than a NIJ, but we have a collaboration currently with researchers at UVA and that is NIJ funding to UVA and also to us to look at new procedures for doing differential extractions. We have some new chemistry that was developed here and they are developing instruments at UVA. And so we hope to combine that new chemistry because so many samples come into the labs that are from sexual assault. And currently those protocols, all part of them can be done on robotics are very tedious the front end where you can't do it on robotics. And people have been trying to develop new ways of doing differential extraction for 30 years. But essentially most of the procedures go back to the original procedure that was published in 1985. So they're not identical, and they may have the DNA extraction end on a robot, but the front end separation is the same. So we're working on that and we have some support from NIJ and of course NIJ has supported all kinds of fascinating projects over the years. So the contributions they've made via that research has been huge.

Gabby DiEmma [00:34:26] Very interesting. It's great to hear about the different projects you guys are working on. So we are running near the end of our time. Are there any final thoughts you would like to share for our listeners?

Daniele Podini [00:34:37] I would like to say something about the the CSI shows, right? Everybody in forensics criticizes the CSI shows because they are completely unrealistic. Absolutely unrealistic. Cases are solved in a second, DNA profiles that are used as, you know, identifying drugs. I saw once a drug profile from a GC-MS being used as a DNA profile. I saw a Y chromosome shaped like a Y in Law and Order. So all that is just ridiculous. But in the span of one episode, I went from being kind of a geek to being kind of cool. So that is really a good thing about these shows. And I think that applies to any forensic scientist. So if you're out there and you're interested in forensics, you're going to be cool if you come and become a forensic scientist, and that's really, really attractive and you'll be able to do science and have an immediate impact on society, which is what I said earlier. So it's a great career path. You continue to learn. You continue to develop as a scientist and as a human being. And the forensic community is filled with really good people, and it's great to be part of it.

Robin Cotton [00:36:01] Boy I don't think I can top that. That's pretty great. And it is true, if it weren't for those TV shows, I think we would have not that many people really thinking about this because many of the students come in and their primary driver is, I want to do something that's societally important. I want to make a difference. It's like somebody magically gave you an opportunity. That's how I felt as a practitioner. The difference between doing research and doing this is that you can go in and you can do some good science and it's useful. Like right then. Not ten years down the road. And it turned out that I thought that, you know, that immediate feedback, that immediate positive feedback was really cool. But the other thing I want to say is something I said a little earlier, and I think people that coming into the field, I want them to think about this as they're coming in and

it's the term forensic science. In that term, forensic is the adjective. It's really science first. So if they're wanting to make a difference, but they don't love science, they just want to make a difference they need another path. They need to like science a lot and then add apply it to forensics.

Gabby DiEmma [00:37:31] And that is a perfect note to end on. I would like to thank you both for joining us on the podcast and for taking the time out of your day to chat with me.

Daniele Podini [00:37:39] Thank you for the opportunity and of course it's always fun to chat with Robin.

Robin Cotton [00:37:45] It was a pleasure. I couldn't have had a greater companion for this podcast.

Gabby DiEmma [00:37:50] If you enjoyed today's episode, be sure to like and follow Just Science on your platform of choice. For more information on today's topic and resources in the forensics field, visit ForensicCOE.org. I'm Gabby DiEmma, and this has been another episode of Just Science.

Voiceover [00:38:10] Next week, Just Science sits down with Dr. Brooke Kammrath from the University of New Haven and Dr. Tatiana Trejos from West Virginia University to discuss trace evidence analytical methods. Opinions or points of views expressed in this podcast represent a consensus of the authors and do not necessarily represent the official position or policies of its funding.