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Erik Munson

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Biographical Feature: Karen C. Carroll, M.D.

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The following passage is an unofficial transcript from an early 1970s postlecture exchange between a freshman college student and a Roman Catholic nun teaching an undergraduate biology course at a small liberal arts college in the Mid-Atlantic region of the United States.

Student: Sister Marie Judith, I am so sorry for being late for your class. I commute to school every day, and this morning's snowstorm made it difficult to drive to campus.

Nun: WHAT IS your name?

Student: Karen Carroll.

Nun: Ah. . .Karen Carroll. You have gotten 100% on all of my quizzes.

Student: (in matter of fact tone) Ah, well, Sister. They're just so easy.

Nun: (taking umbrage) Well, they are NOT easy. You come talk to me. What is your major?

Student: Elementary Education.

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Editor Alexander J. McAdam, Boston Children's Hospital

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Nun: What a waste of talent. You come talk to me. If you're going to do education, you should at least do secondary education. You should major in science.

Student: OK, I will think about that. I love biology, Sister.

As one delves into the career of Karen C. Carroll, M.D., Professor of Pathology at The Johns Hopkins University School of Medicine in Baltimore, Maryland, and Director of the Division of Medical Microbiology (Department of Pathology) since 2002, one finds several unplanned, pivotal events that eventually guided Dr. Carroll toward a highly successful and productive career as a clinical microbiologist. Wrote Alexander McAdam, M.D., Ph.D., Editor in Chief of the *Journal of Clinical Microbiology*, "Karen is one of the most influential clinical microbiologists of our time." Peter H. Gilligan, Ph.D., (1), currently Adjunct Professor at the University of North Carolina School of Medicine, added that Dr. Carroll is "one of the most respected clinical microbiologists of her generation." Rather than strictly focus on the accomplishments (and these are plentiful) and bountiful *curriculum vitae* of Dr. Carroll, this quarter's *Journal of Clinical Microbiology* Biographical Feature attempts to chronicle additional spontaneous and transformative events that turned a would-be elementary school teacher into a practicing infectious diseases clinician into a preeminent clinical microbiologist and full professor at The Johns Hopkins University School of Medicine, describe a multifactorial role in essentially shepherding a clinical microbiology laboratory, and provide insight into the past and present-day status of women in medicine (including clinical microbiology).

After beginning a recent interview with the disclaimer, "I want to tell you that I do not relish being the center of attention, so this is not easy for me," Dr. Carroll proceeded to place her tongue firmly into cheek, mentioning that she is a native "Baltimoron," having been born and raised in a suburb of Baltimore. Her father was a World War II Navy veteran-turned-laborer, and her mother worked in the home. Neither of her parents completed a high school education. Indeed, her father had to support his family as a teenager due to the death of his father. Dr. Carroll recalled, "My dad really stressed the importance of education. . . I think one of the reasons why education was so important to him is because he didn't have a high school education. He was very limited in how far he could go in terms of promotion. He saw the lack of education as an impediment to a life that could have been better for him in terms of profession."

Dr. Carroll credits her Roman Catholic upbringing for her discipline and resilience (her own father passed away from a chronic illness when she was 13 years old). She was educated in the Catholic school system, as her father believed that Catholic schools provided a better education. She attended an all-girls Catholic high school in Baltimore where she immersed herself in as much science pedagogy as possible. Dr. Carroll was quick to relate the story of a "lovely" teacher during her sophomore year, Miss Britt. "She taught us microbiology and she just made it fun. You could tell she loved it. And that really made an impression on me. Here was someone who was standing before us, not because it was a job for her, but because she absolutely loved the discipline. She loved science. She had us going on the roof, collecting air samples and when we saw what grew, we were horrified!" Dr. Carroll claimed that the "seedling" was always there (at the time, to become a teacher) and it "just took someone pointing it out to me that, 'Hey, this is something that you're good at and this is something that you seem to really like.' You know, you're right (hit me over the head with a hammer)! I do like this, but I wasn't really sure what to do with that interest. I like sharing knowledge with other people. Maybe I will teach. It really didn't occur to me that this could be the foundation for medicine."

At the time, the nearby all-women's College of Notre Dame was commemorating its 75th anniversary by offering competitive 4-year scholarships to graduating seniors from all Catholic high schools throughout Maryland. Dr. Carroll received this scholarship, and her attendance at this college was transformative. In addition to the conversation with Sister Marie Judith described at the beginning of this piece, Sister Coralee was another biology professor-turned-mentor who taught advanced-level biology classes at the college. "I had professors who encouraged me and basically told me that I could do it. I could go to medical school if I wanted to. And I did. That was a pivotal

moment. I think that is one of the values of small classrooms and colleges where the professors can get to better know the students and can provide that guidance," recalled Dr. Carroll.

Dr. Carroll earned a baccalaureate degree in biology in 1975 and matriculated at the University of Maryland School of Medicine in Baltimore for medical school. She reported struggling through her first two didactic years (perhaps a bit difficult for some to imagine), "I was one of a minority of students who had a liberal arts education and not 'pre-med'." The reward, however, was quite rich. "When I got to the clinical years (voice rising with exuberance), I just absolutely loved patient care. I saw the value of the first 2 years in terms of applying that knowledge to help figure out what was going on with patients. Once I got to the clinical years, I felt that I had made the right decision. I just really enjoyed the clinical medicine." Internship training was completed at the University of Maryland, with internal medicine residency training (including Chief Residency) at the University of Rochester in Rochester, New York. Not surprisingly, Dr. Carroll enjoyed a number of subspecialties during residency. "I basically liked every rotation (including hematology and gastroenterology), but I really enjoyed infectious diseases. It just seemed like the infectious diseases physicians were the consummate doctors. They just seemed to know a lot and what was interesting is the fact that infections touch all organ systems. So, in a way (with specializing in infectious diseases), I could still see patients with hematologic problems and patients with colitis. Infectious diseases as a subspecialty crossed all disciplines, including pediatrics."

Dr. Carroll proceeded to a 2-year clinical fellowship in infectious diseases at the University of Massachusetts Medical School in Worcester, Massachusetts "with the idea that I would be a practicing clinician." Richard B. (Tom) Thomson, Jr., Ph.D. (2), medical microbiologist at NorthShore University Healthcare in Evanston, Illinois, foreshadowed a discussion of a next spontaneous and transformative event in Dr. Carroll's career by succinctly stating, "Karen is a cross-over between microbiology and infectious diseases. Fortunately, her stronger suit is in microbiology. She commands attention from experts in both disciplines, providing microbiology credibility in the clinical realm." Dr. Carroll recollected her experience this way, "During my ID fellowship, I found myself in the micro lab a lot and that's where I met Gary Doern (3). Similar to the experience I had as a freshman in college. Gary said to me one day, 'You really love this stuff. You know, you could do a career in microbiology.' I said, 'tell me more.' I spent an hour in his office and he just talked about how this was just a fantastic career and, you know, I could still see patients and direct the lab. I could do clinical research as a part of that combined career." Gary V. Doern, Ph.D., Professor Emeritus in the Department of Pathology at the University of Iowa College of Medicine and previous Editor in Chief of the *Journal of Clinical Microbiology*, recalled the exchange in this fashion, "Karen was an infectious diseases fellow at UMass Medical Center. As part of her training, she did an extended rotation through the clinical microbiology laboratories. Even at that stage in her training, it was abundantly clear that she was going to be very successful in whatever endeavor she chose to pursue. I was extraordinarily pleased when she decided on a career in clinical microbiology. The winner in all of this has been the discipline."

Aspirations of becoming a renowned clinical microbiologist took a brief pause, as Dr. Carroll and her husband, pulmonologist Bruce C. Marshall, M.D. (currently Executive Vice President and Chief Medical Officer for the Cystic Fibrosis Foundation in Bethesda, Maryland), moved to Memphis, Tennessee, following fellowship training. Dr. Carroll set up a private community hospital infectious disease practice in the Memphis area from 1986 to 1988. "They made me director of infection control during the beginning of the AIDS epidemic. I wrote the HIV policy for the hospital, saw outpatients, did the inpatient consults, and directed the hospital infection control committee. I worked with some really lovely people."

In 1989, the family (now with two young sons) moved to Utah for professional considerations. Another fortuitous fork in the road for Dr. Carroll was the fact that an American Society for Microbiology (ASM) Committee on Postgraduate Educational

Programs (CPEP)-approved fellowship program was well established at the Salt Lake City Veterans Affairs Health Care System and the University of Utah Department of Pathology, under the direction of Larry Reimer, M.D. Dr. Carroll completed a 1-year fellowship program which also included stints at the Utah Public Health Laboratory and Primary Children's Hospital. One of Dr. Carroll's mentors during the fellowship was Judy A. Daly, Ph.D., Director, Microbiology Laboratories at Primary Children's Hospital. Dr. Daly commented, "As a trainer in that program, I interacted with Karen every week for a year. That is when I began to appreciate Karen's eager thirst for all knowledge in clinical microbiology. She happily completed every assignment with exceptional interest and devotion. It was a true pleasure to experience Karen's excitement. With her high energy and bubbly personality, she is always fun to be around."

In addition to the aforementioned Dr. Reimer, Dr. Carroll also credits John Matsen, M.D. (4), for facilitating her entry into a faculty position in the Department of Pathology at the University of Utah. At the time, Dr. Matsen had become Chair of the department, as well as maintaining directorship of the clinical microbiology service at Associated Regional and University Pathologists Laboratories (ARUP). While gesticulating a line with a slope value greater than 10, Dr. Carroll recalled being employed at ARUP during a time of rapid growth for the laboratory, "Very fortuitous; I was very lucky to be there at a time when ARUP Labs was really taking off. [Dr. Matsen] was really very busy and so appointed me Assistant Director of the lab. At the time, we weren't even doing TB work. By the time I left, we had a whole new lab, a BSL-3 suite. . .it was phenomenal and for the longest time, I was the only Director (chuckles). I rode the wave of building a new lab and evaluating molecular technologies." David R. Hillyard, M.D., Medical Director, Molecular Infectious Diseases at ARUP, reminisced about introductory work in developing molecular diagnostics at ARUP, "Although Karen's principal responsibilities were for the vast landscape of traditional non-molecular testing, she also had a keen interest in the rapidly emerging field of molecular ID testing. Together we worked in those early years on the development and implementation of tests for various pathogens. A significant early contribution was her participation in studies demonstrating the great utility of central nervous system testing for enterovirus in infants (5). In all of her activities, Karen was much loved and respected at ARUP. She played a pivotal role in the expansion and diversification of ARUP's clinical testing and consultative capacities. She also quickly gained a national reputation in testing and test interpretation, including molecular testing, which was foundational for her illustrious career at Johns Hopkins."

During her tenure, Dr. Carroll also shared the responsibility of fellow training as associate director of the CPEP program. One of those fellows was James J. Dunn, Ph.D., who currently serves as Director of Medical Microbiology and Virology at Texas Children's Hospital in Houston, Texas. Dr. Dunn spoke of his training, "Once I started the program there, she was the one who most fostered my training on a daily basis. No matter how busy she was (which was most of the time), she was always accessible and available to help further my training. It was apparent that my education and development was a priority for her. She was and still is the most consequential mentor in my career." Dr. Dunn is one of a number of trainees who are successfully directing clinical microbiology laboratories in the United States and beyond.

It was around this time that Dr. Carroll began to transition her career from near-patient clinical infectious disease practice to patient-centered clinical microbiologist. She recalled that this transition was not difficult at ARUP "because I sort of learned infection control on the fly. When I was in practice, I collaborated with the hospital epidemiologist on *Clostridium* (now, of course, *Clostridioides*) *difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus*, which were really taking off in the late 1980s and 1990s. I worked collaboratively on helping with surveillance and diagnostics for health care-associated infections and that continued to be an interest here. I will say that I was at a disadvantage, not having a strong background in molecular techniques. That was hard to acquire while trying to do the administrative, teaching, and clinical aspects of directing. But I had a good teacher in

Dave Hillyard and tried to take advantage of as many seminars as I could on PCR and other molecular diagnostics.”

Dr. Doern commented, “Karen’s background in infectious diseases has given her a valuable perspective that most clinical microbiologists, whether they are Ph.D. trainees or pathologists, simply don’t have.” Dr. Carroll herself related an experience at ARUP relative to laboratory utilization. “I continued to see patients and I could use my knowledge of microbiology and how to utilize the laboratory to teach residents, fellows, and interns. At the same time, as a user of my own lab services, I had the ‘customer’ perspective to help drive assay development, quality improvement, and turnaround time. We were one of the first labs to develop *mecA* detection directly from positive blood culture bottles (6) and I was stunned that people didn’t see the immediate clinical value of that. I certainly did.” While Dr. Carroll believes that her training as a physician and clinician has helped her become a better microbiologist, she respects doctoral-level scientists who practice as clinical microbiology laboratory directors. She even stated, “I wish I had had more research experience because it would have been helpful to me as I’ve traveled in my academic circles.” She summarized with zeal, “the clinical application of what we do has just been fun and the desire to really do the best for patient care has been my mantra throughout my career.”

Dr. Carroll also stated the importance of maintaining an effective dialog with our clinical practice partners. “When people call you and say, ‘Hey, look, you need to follow up on this’, you should follow up on it because you never know where it’s going to lead.” She related the specific example of the emergence of *C. difficile* ribotype O27. “Clinicians were calling and telling me, ‘There’s something wrong with your test. I just took someone’s inflamed colon out and the toxin EIA was negative.’ It sure led me to re-evaluate toxin EIAs. I was horrified at the low sensitivity and we got rid of it immediately in the middle of the flu season. We went back to cytotoxin testing. I thought that my virology lab was going to kill me!” Dr. Carroll’s current research trajectory is largely in the area of bacteremia and sepsis. Even though Dr. Carroll has already published more than 30 peer-reviewed articles on diagnostic and outcome aspects of sepsis (7, 8), she opined, “I feel like that’s an unconquered (area). Until we are able to speed up the diagnosis directly from whole blood testing in a meaningful way. . . I don’t think we’re going to have the impact on mortality that we want to see. I think that the syndromic panel tests have been impactful, but I don’t think they’ve really had an impact on mortality.” Dr. Carroll reasoned that an approach of sequence-based characterization of host biomarkers at the time of pathogen direct detection may provide a future advantage in clinical management of these patients. Dr. Carroll has formed collaborations with biomedical engineers at The Johns Hopkins University for preliminary studies involving microfluidics and nanotechnology (9).

Robin Patel, M.D. (10), Elizabeth P. and Robert E. Allen Professor of Individualized Medicine at the Mayo Clinic in Rochester, Minnesota, lauded Dr. Carroll as “the idyllic clinical microbiologist. She knows the field like the back of her hand, thinks futuristically, and looks out for her technical staff in unprecedented ways.” Trish Simner, Ph.D., Associate Professor of Pathology and Director of Bacteriology at The Johns Hopkins University School of Medicine, as well as Editor of the *Journal of Clinical Microbiology*, related “I’m not sure there are enough positive adjectives to describe Dr. Carroll. She is one of the best-rounded individuals I know. Despite Dr. Carroll’s stature in the field of clinical microbiology and infectious diseases, she is one of the kindest, most caring and genuine individuals. She has an open door policy and is ready to share her time and knowledge at any moment. One example that comes to mind is that she has a list of birthdays in her office of our 100+ staff for which she makes sure to wish everyone a ‘Happy Birthday’ on their special day.” Brandon C. Ellis, M.L.S., Laboratory Manager in the Medical Microbiology Division at The Johns Hopkins University School of Medicine, echoed “Dr. Carroll has always fostered a culture of caring, collaboration, and development for the staff. She goes out of her way to engage all staff in professional development opportunities. Whether this be educational opportunities, research projects, or improving clinical testing, she engages all staff and supports them as they develop their skills and confidence. She has mentored and supported countless laboratory staff members, providing them the tools for success as they advance their careers.”

As one peruses Dr. Carroll's *curriculum vitae*, one notices a lack of common authorship among a majority of her peer-reviewed publications. While this represents strong evidence of interdisciplinary and interlaboratory collaboration, Dr. Carroll provided an alternative explanation: "Many of the co-authors on my papers are med techs. I had a philosophy (and I still do) that if a medical technologist has shown the gumption and the desire to participate in a validation that can lead to a publication, they should be on the paper. I have to say that I've been blessed that I've had, at both University of Utah/ARUP and here (Johns Hopkins), just incredible medical technologists, some of whom I've mentored. They've gone on (to other careers or professions) because they have had the opportunity to give a presentation at ICAAC or ASM, found a passion or desire, and went on to nursing school or graduate school. This has been mutually beneficial." Dr. Carroll chronicled one particularly salient example. "One of our med techs here at Hopkins left and decided to go to pharmacy school. A few years later, she came back and we had a little party for her. I was taken aback because she said, 'I never would have done this if Dr. Carroll hadn't allowed me to go to ICAAC and present a susceptibility testing poster (subsequently published [11]).' She fell in love with ICAAC and she went to pharmacy school! And I was stunned over my small role in this." That medical technologist is Stephanie Shulder, Pharm.D., currently an Infectious Diseases Clinical Pharmacy Specialist at the University of Rochester Medical Center.

Dr. Carroll proceeded to emphasize the everyday (and not solely restricted to activities centered around the SARS-CoV-2 infection pandemic) value of medical technologists and the profound contributions they make every day to patient care—she advocates and promotes this cause at any and every opportunity. Dr. Carroll, in fact, nominated Mr. Ellis for the 2021 ASM Scherago-Rubin Award for Clinical Microbiology (12). At the same time, Dr. Carroll believes the perception still exists that medical technologists are not health care professionals (perhaps, in part, because of the traditional basement location of the microbiology laboratory and the concomitant lack of visibility) and do not receive the monetary benefits that they deserve. Throughout her time at Johns Hopkins, Dr. Carroll has invited medical students, residents, and interns to the clinical microbiology laboratory for daily plate rounds. She added, "I fought to keep a wet lab in the medical school—not because medical students are going to be doing this hands-on stuff, but because we have the Med Techs come over and assist the medical students. This may be the only time they have exposure to these health care professionals. Every year, I get feedback from medical students, 'Mary your Med Tech knows so much and she answered all of my questions. Wow!' Fantastic!"

When asked to provide insight on Dr. Carroll's lasting contributions or innovations, Dr. Gilligan summarized them into four categories: (i) two separate appointments as Editor and Editor in Chief for the *Manual of Clinical Microbiology* (13), as well as Editor for three editions of Jawetz's *Medical Microbiology* (14), a textbook known to medical students globally; (ii) coauthor of several clinical practice guidelines, including those for the Infectious Diseases Society of America (15–18), which directly impact the practice of infectious disease specialists; (iii) generation of seminal research on *C. difficile* diagnostics (19, 20), as well as pneumonia caused by community-acquired MRSA (21, 22); and (iv) leadership of the medical microbiology fellowship program at Johns Hopkins. Of the more than 350 peer-reviewed primary publications indexed on PubMed that are authored by Dr. Carroll, over 50 have discussed salient clinical, epidemiologic, and diagnostic aspects relative to MRSA and more than 30 have done the same with *C. difficile*.

Dr. Carroll has additionally contributed volunteer effort to several ASM entities, including membership on the International Conference on Antimicrobial Agents and Chemotherapy (ICAAC) Program Committee from 2011 to 2015, Chair of Division C (clinical microbiology) from 2016 to 2017, and membership on the ASM Board of Directors from 2017 to 2020. She has also been heavily involved in Clinical and Laboratory Standards Institute endeavors since 1996 and College of American Pathologists initiatives since 2005 (including 5 years on the Microbiology Resource Committee). Dr. Carroll spent 10 years as an Editor of the *Journal of Clinical Microbiology*. Beyond routine editorial duties, she proposed the concept of biennial microbial taxonomy minireviews (23) and has authored a number of them (24) for the

journal, as well as penning seven contributions to the *Journal of Clinical Microbiology* Biographical Feature. Three of these publications have been among the most reader-accessed Biographical Features in the series (25–27), with one summary of an important historical figure (25) likely contributing to ongoing pedagogical efforts of future microbiologists and scientists. Again, within all these accomplishments and contributions exists a common tie: education, likely tracing back to her early roots as a would-be teacher and her love of “sharing knowledge with other people.”

Beyond his insistence on placing a premium on education, Dr. Carroll credits her father for promulgating a philosophy that facilitated career aspirations, regardless of gender. “He never really said, ‘you’re a woman, so you can’t do something.’ He was sort of a man ahead of his time in terms of his mentorship, love, and encouragement. So, I have carried that with me through my entire life. That’s very important to me and I’d like to emphasize that.” Dr. Carroll also said that she was fortunate to matriculate in an all-women’s high school where one was allowed to study science with the thought of pursuing a career in science. She further described how she was additionally emboldened by her experience at the College of Notre Dame in the 1970s, as “the women’s lib movement was just getting started; I have to say that I had just wonderful mentors.”

At the same time, Dr. Carroll recalled that in the early 1990s (coinciding with completion of fellowship training) it “was difficult to be taken seriously” at times and that she was passed over for opportunities early in her career. “When I finished my micro fellowship, it wasn’t really clear that I was going to be able to stay as faculty at the University of Utah. So, I started applying for clinical jobs in the community and some of the outlying hospitals and was met with gender bias. There’s no question about that.” Dr. Carroll again credited Dr. Matsen for advocating her candidacy for a faculty position at the University of Utah. “I think that I did fly under the radar as a woman, but I don’t think that it prevented me from doing what I wanted to do. . . I found my way and I had enough mentors who were women and men to help me be successful.”

Dr. Carroll believes that the climate for advancement has significantly improved over the past 3 decades as more women have entered this profession (although pay equity for women remains an issue in some settings). She described the mission of The Johns Hopkins University School of Medicine Office of Women in Science and Medicine (founded in 2008) as one example. “A Dean within the School of Medicine created this office to find out why women were not being promoted to professorships and why so few women were Chairs of departments or divisions. The office created leadership programs for women, ensured a level playing field, and examined the issues of why women didn’t seek leadership positions. There were just a lot of changes that happened. I personally benefited from the leadership programs.” Dr. Carroll summarized this general topic by reporting, “I’m just happy to see that this field has made significant strides in leveling the playing field for women.”

Educators do not only teach—they also seek to edify their own knowledge base and develop creative means of applying this knowledge in both routine and novel settings. Dr. Carroll opined, “Let’s face it. I don’t think that anyone is in academics if they don’t have intellectual curiosity. I constantly ask, ‘Oh, this is cool; how can this help move us into the next frontier?—whatever that frontier is.’” While discussing the broad scope and rigor of a clinical microbiology laboratory directorship, Dr. Carroll briefly hinted at what she called her “sunset years” by saying, “I certainly would like to be able to contribute to our profession, even in retirement (whenever that is).” How fortunate have the fields of clinical microbiology and infectious diseases (along with scores of mentees and countless patients) been to have borrowed this would-be elementary school teacher for a substantive career of service.

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