MAPPING THE POSSIBLE:
Unsung Heroines in Science, Technology, Engineering and Mathematics

Speech by Katie McCabe
Army National Guard Readiness Center -- March 21, 2013
For Women's History Month 2013

I'm proud and honored to be speaking, during Women's History Month, to an audience with so many members of the military in attendance. It's especially meaningful to me because I spent 15 years of my life writing about one of America's great military women, Dovey Johnson Roundtree, who led the vanguard of African American women in the Army as a member of the first class of black women to train as officers in the Women's Army Auxiliary Corps, as the WAC was called in its original incarnation.

She went on to become one of the most revered lawyers in Washington, DC, someone who made history with a groundbreaking bus desegregation case and shattered barriers for women and for blacks in the courtrooms of Washington at a time when people of color were forbidden to use the courthouse restrooms or eat in the cafeterias. She is the subject of *Justice Older than the Law*, a book she and I wrote together. Dovey Roundtree's service to America in impossible times helped me to understand patriotism in a way I never had before.

Dovey Roundtree wanted to be a doctor, but despite her stellar record at Spelman College, she was turned down by both of the black medical schools to which she applied – and there were *only two*, back in the late '30's, Fisk and Howard -- because in the late 1930's women of any racial or ethnic background were unwelcome, in the extreme, in medical school, and of course, in the sciences in general. She became instead what she was meant to be – a lawyer, and a great one. She changed the world, as a lawyer. But in becoming a lawyer she also disqualified herself for a spot in my talk this morning!

So be it. She and I created *Justice Older than the Law*, and I hope you'll read it. For now, I leave the great unsung heroine Dovey Johnson Roundtree, who laid down such big footsteps in the courtrooms of Washington, and I pass on to three great women of science:

- The pediatric cardiologist **Dr. Helen Taussig**, who in 1943 asked a question that penetrated the cloud of mystery surrounding congenital heart defects and paved the way for modern heart surgery in infants;

- The biophysicist **Rosalind Franklin**, whose 1953 X-ray diffraction images of DNA led to the discovery of the DNA double helix;

- The theoretical mathematician **Emmy Noether**, who in 1916 developed a theorem considered as important as Einstein's Theory of Relativity in providing the basis for the identification of the Higgs boson, and in fact, all of modern physics.

I'm not a doctor, nor a mathematician, nor a biophysicist. I'm a storyteller. That's what I do, how I make my living. I believe that by telling stories we change the world. And for the 28 years that I've been writing professionally, I've chosen, again and again, to tell very particular kind of stories -- stories of unsung heroes, people who have laid down big footsteps but whose names have not made it into the limelight. So this morning I want to tell you about three great women whose names are probably unfamiliar to you. Their stories remind us of the stunning and often uncredited contributions of women to the sciences, and they give us a way of looking at the role of women in science today.

Let me begin with the great pediatric cardiologist, Dr. Helen Taussig. Here you see a picture of her taken by the famous photographer Yousef Karsh, and it captures, in my mind, the unity of the doctor and patient that defined Helen Taussig. Look at the way she is cradling the child. *Look especially at her hands*. Helen Taussig's hands were more important to her than perhaps to any other specialist besides a surgeon, because she used her hands, at least as much as her stethoscope, to diagnose the cardiac anomalies she saw in the babies she treated at Johns Hopkins Hospital, in the Harriet Lane Home for Invalid Children.

She made use of her hands for a reason. By the time she graduated from Johns Hopkins Medical School in 1927, Helen Taussig was deaf. She relied on hearing aids and lip reading for the rest of her career. Her stethoscope was equipped with a huge amplifier. But when she set out to make fine discriminations, she would place her hands upon the chests of her tiny patients and distinguish the rhythms of normal and damaged hearts by touch, rather than by sound.

Taussig was no stranger to insurmountable obstacles. She'd managed to overcome dyslexia by dint of hard work and tutoring by her father. Upon her graduation from University of California at Berkeley, she set her sights on medicine, a field inhospitable to women, in the extreme, in the 1920's and '30's. Turned down by Harvard School of Public Health because of her gender, she'd gone to Boston University, then transferred to Hopkins, only to confront discrimination yet again when she was denied an internship in internal medicine. Undeterred, she chose to accept an internship in pediatrics – a move that would prove monumental to her career and to medical history as well.

She refused to admit defeat when it came to the babies and children she saw in her clinic, despite the fact that the mortality rate for children with heart disease when Taussig entered the field in 1928 was 100%. Children died either of rheumatic fever, or of any one of dozens of poorly understood, and totally untreatable congenital heart defects.

All she was able to do, in the 1930's, was to administer what is called palliative care, and when her babies died, she herself – with the parents' permission – performed the autopsies, and she studied those tiny malformed hearts, preserving them in a laboratory she created for that purpose.

One anomaly she saw constantly in the clinic was a defect called Tetralogy of Fallot, a complex malformation that prevents the blood flowing from the heart from going to the lungs to be oxygenated. Fallot's Tetralogy is complicated, and has four parts, as its name suggests, but basically, it's characterized by a leak in the septum, the wall separating the heart's chambers, and an underdeveloped artery leading from the heart to the lungs. Babies born with this defect turned blue – hence the popular name, "Blue Baby syndrome." The lips and nail beds of these children were purple and they squatted to rest. Sooner or later, they all died.

For years, Dr. Taussig stood by helplessly, watching these Blue Babies perish, but she was watching, very closely, the whole time, and she became convinced, early in the 1940's, that there was a way to correct the defect surgically. She wasn't a surgeon. But she had a very clear picture in her mind of the defect, a picture created over years of listening to those hearts, that enabled her to frame the problem for the surgeon Alfred Blalock, who had come to Hopkins in 1942 with his brilliant lab technician, a remarkable African American man named Vivien Thomas.

Taussig had been watching Dr. Blalock, and she pegged him as just the kind of maverick surgeon who might take a risk like the one she had in mind. Medical lore has it that she'd gone to another surgeon, Dr. Robert Gross of Boston, with her problem, and was summarily dismissed. No one really knows whether that story is true or not. But we have it straight from Blalock's genius of a lab tech, Vivien Thomas, that Taussig came to them, one morning in 1943, in their lab, and talked to them about her babies. In the most precise terms, she described what she'd seen in these Tetralogy hearts

It was, she told them, "a plumbing problem." She said she thought there ought to be a way to "change the pipes around" to get more blood from the heart to the lungs. And here we have a stunning example of the phenomenon that Louis Pasteur described when he said, famously, "Chance favors the prepared mind." Blalock and Thomas had been doing heart surgery in the canine model for years, back in their days together at Vanderbilt University, long before they came to Johns Hopkins. They had done a surgical procedure to correct pulmonary hypertension that involved precisely the kind of "pipe changing" Taussig was proposing. Their operation had failed to produce hypertension, but at that moment, that didn't make any difference. They knew it wasn't lethal.

As they stood in their lab listening to Taussig, it dawned on both of them simultaneously, as Vivien Thomas tells the story, that they *had the procedure*. A whole lot had to happen before they could try the operation on a baby – they had to replicate the Blue Baby syndrome in the laboratory dogs, and then experiment to see whether the surgery they had in mind actually fixed it. This they did, for more than a year. On November 29, 1944, Dr. Alfred Blalock, with Vivien Thomas coaching him from a step stool at his right shoulder, performed the first operation ever done on a Blue Baby. The operation did not cure the disease, but it ameliorated the symptoms, and bought the children years of time. The operation, known as the Blalock-Taussig shunt, launched the field of heart surgery in infants.

It was, predictably, Dr. Alfred Blalock who became world famous, while Helen Taussig remained very much in the background. Blalock was promoted immediately; Taussig had to wait 15 years for her promotion to full professor. Blalock became known as "The Blue Baby Doctor," making headlines around the world. Helen Taussig, a woman in a man's field in the 1940's, was relegated to a footnote in the wake of the operation. It was Helen Taussig's longevity that enabled her to receive recognition, though it was to come decades after the Blue Baby accomplishment. She lived to be 88, dying in 1986 in an automobile crash. The four decades in between her role in the historic operation and her death saw enormous changes in terms of the recognition of women in medicine, and women in the professions in general, and by the end of her life, Helen Taussig had received numerous awards and honors and had become the first woman president of the American Heart Association.

The passage of time, for women, has been critical. And I'll speak, in a moment or two, about just how far we've come in terms of opportunities for, and recognition of women scientists in the half century since Helen Taussig did her groundbreaking work.

But first let me tell you the stories of two other women, largely unknown, who laid down enormous footsteps in science, anonymously. Their lives speak volumes to us about the passion for knowledge that drove women to pursue their quest for answers in impossible times.

Let me tell you about Rosalind Franklin, a British biophysicist and X-Ray crystallographer whose work provided the basis for the discovery of the DNA Double Helix, the spiral-shaped molecular structure in which genetic information is encoded. The two names we associate with the Double Helix, of course, are the American scientist Francis Crick and the British scientist James Watson, the men who, along with Maurice Wilkins, received the Nobel Prize in 1962 for their discovery, in 1953, of the so-called "double helix."

The story of that discovery is a story of two labs, two groups of scientists, both working on the same problem at the same time. There are hundreds of such stories in science, and we all remember the fight for credit for the discovery of the HIV virus between the American scientist Robert Gallo, and the French scientist Luc Montagnier. I'm not sure to this day whether any of us knows exactly who knew what first, and whether there was piracy of ideas involved, as one of the scientists alleged, but the two principals, after some very prolonged and public shouting and pouting, agreed to share credit, though it was only Montagnier who received the Nobel Prize in 2008.

The story I'm about to tell you is one of those kind of stories, with a twist. The twist is that one of the scientists involved in the discovery of DNA was a woman, a brilliant woman whose self-assurance and occasional abrasiveness threatened angered her male colleague. And that woman, Rosalind Franklin, paid a price. When the Nobel Prize was awarded for the DNA discovery, it was given to Crick and Watson, whose names are widely known, and to Rosalind Franklin's colleague, Maurice Wilkins. She was left out. Here's what happened.

In 1951, in a biophysics lab at King's College London, 31-year-old Rosalind Franklin was deep into the study of DNA fibers, using an X-Ray diffraction technique she'd learned during World War II by studying COAL, of all things – specifically, its porosity. When Rosalind was seeking a research position after the war, she asked one of her tutors to let her know of job openings for "a physical chemist who knows very little physical chemistry, but quite a lot about ***the holes in*** ***coal*****.**" She was half right – she did know a lot about the holes in coal, but she also knew a great deal about physical chemistry. She'd excelled in her studies in chemistry at Cambridge, and although Cambridge didn't award B.A. and M.A. degrees to women when she graduated in 1941 – it took them until 1947 to do that – her performance in her final exams was so stellar that it qualified her for employment. So what she brought to the lab in King's College London was an extraordinary scientific mind and a skill in a branch of crystallography that uses X-rays diffraction to study proteins and lipids in solution. Using what she'd learned in studying the holes in coal, she trained her sights on DNA, with her student Raymond Gosling, and another researcher named Maurice Wilkins. Wilkins was under the impression that he was heading the DNA unit, and was none too pleased to discover that the lab's head had assigned Rosalind to that position.

Rosalind used a fine focus X-ray tube and microcamera ordered by Wilkins, and she refined and focused that equipment, skillfully manipulating her specimens to get the clearest possible images. The renowned British scientist J.D. Bernal, who pioneered the technique Rosalind Franklin used, called her X-ray diffraction pictures "amongst the most beautiful X-ray photographs of any substance ever taken."

But Rosalind Franklin's photos of the DNA molecule were far more than pretty pictures. They were a cross section of the molecular strands, and they showed that without a doubt, the molecule was helical, or coiled. Here is the photo, known as Photo 51, that showed this most clearly. On the basis of this photo, and her other findings, Rosalind Franklin drafted a series of three journal articles and mailed them out for publication to the British journal *Nature*.

Meanwhile, at a lab at Cambridge University, the young scientists Francis Crick and James Watson were also deep into the study of the DNA molecule. They were closely in touch with the American scientist Linus Pauling, who had just sent them a description of the DNA molecule they believed to be erroneous. They were also very much aware of the fact that Rosalind Franklin and Maurice Wilkins were working on the same problem, and were in close touch with Wilkins – close enough that on January 30, 1953, James Watson, puzzling over results Linus Pauling had sent them, made a trip to Franklin and Wilkins' lab.

And this is where things get interesting. As Watson tells the story in his book *The Double Helix*, he arrived at Franklin and Wilkins' lab with the Linus Pauling results, in search of Wilkins. Finding him absent, he approached Rosalind Franklin and urged her to collaborate with them quickly, before Linus Pauling discovered his error. According to Watson's account, Rosalind took offense when Watson questioned her interpretation of her own data, and he retreated, backing into Wilkins, who'd heard the shouting and rushed to the lab. Then, without Rosalind's permission, or knowledge, Maurice Wilkins showed Watson Rosalind's "Photo 51." The photo so clearly confirmed the helical structure of DNA that Crick moved forward instantly to publish the results.

A month of so later, in a Cambridge pub, he proclaimed that he and Watson had "found the secret of life." On April 25, 1953, the British journal *Nature* published a series of three articles on the double-helical structure of DNA. The first two, by Crick and Watson, included only a footnote acknowledging "having been stimulated by a general knowledge of" Rosalind Franklin and Maurice Wilkins' 'unpublished' contribution." Franklin's article, mailed just days before Crick and Watson had visited her lab, was published third.

It took nearly a decade for the scientific community as a whole – that is, the community beyond the geneticists – to accept the notion of the double helix as the structure for the DNA molecule. Tragically, Rosalind Franklin did not live to see that acceptance. She died of ovarian cancer at the age of 38, in 1958, three years before the awarding of the Nobel Prize to Crick, Watson, and Maurice Wilkins, the man who so resented her that he showed her work to outside researchers without asking her permission. The Nobel is not awarded posthumously. Would she have shared the Nobel, had she lived? We have no way of knowing that. The Prize was given for the total body of work each of the three men did on nucleic acids, not just for their discovery of the structure of DNA. James Watson speaks of Rosalind Franklin patronizingly in his 1968 book *The Double Helix*, referring to her as "Rosy" and denigrating the significance of her work. But Francis Crick stated unequivocally that Franklin's data were "the data we actually used."

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All of this, you may be saying, is from a long ago time ago, "in a galaxy far far away." So let me rush us forward in time to last Friday, March 15, 2013, when news media around the world reported that physicists in Geneva have, after 50 years of searching, found "The God Particle." That's the name sometimes given to the subatomic speck known as the <u>Higgs boson</u>. If the army of 6,000 scientists at the Geneva-based European Organization for Nuclear Research, or CERN, really have found the Higgs boson, then that means they now know how the universe began. REALLY.

For the non-scientists among us, it's incomprehensible that physics may really have given us the explanation for how the Big Bang worked, that is, how it created something – that is, mass – out of nothing, about 13.7 billion years ago.

In my feeble non-scientific mind – remember, I'm a storyteller, not an expert on science or anything else – I wonder: Can't matter just inherently have mass without the Higgs boson to help it out? That's the kind of stupid, naïve question that we non-physicists ask. But it turns out that this Higgs boson, named after Peter Higgs, the Scottish scientist who theorized about it in 1964, *actually transfers mass.*

It took years for scientists to find out how. The Higgs boson is so elusive, according the explanation provided by the Associated Press last week, that only about one collision per trillion will produce a Higgs in the 17-mile collider at the Swiss-French border where these subatomic firings take place. This past Fourth of July, CERN announced it had identified a particle that "acted like a Higgs boson." And last Thursday, they said they were almost sure – scientists are almost never *really* sure – that it was.

And so the Big Bang – the notion that sometime in the infinite past, the universe began out of nothingness – begins to make sense. What if all particles have no inherent mass but instead *gain mass* by passing through a field – known as the Higgs field, which is a kind of gooey mass like molasses that causes the subatomic particles passing through it to stick together, slow down, and form atoms? If that's the case, then that means that everything that has mass got it by interacting with this all-powerful Higgs field, which occupies the entire universe. The carrier particle in the Higgs field is known as the Higgs boson.

Now, what does all this boson business have to do with women in science? Is there, you ask, a woman physicist at the center of this quest, a genius whose name is even now being etched on the Nobel Prize for 2014? In today's scientific world, this is entirely possible. CERN reports that 17 % of the scientists on staff are women, and it may well be that one of those women is leading the Higgs boson charge.

But I'm looking beyond the here-and-now, to the work of a female mathematician from the early twentieth century, who laid the foundation for all of modern physics, including the study of mass that undergirds the reasoning behind the Higgs boson.

This woman's name is Emmy Noether. I doubt that there's a person here who's ever heard of her; in fact, I'm told that even among mathematicians and physicists her role is unknown, or underappreciated. And yet she altered the way that physicists look at the world as profoundly as Einstein did, with his Theory of Relativity. In fact, she

mentored Einstein, when the two worked as young scientists. *She mentored Einstein*. He applied her math on what is called "warp space times" to his work on relativity.
In 1915, the same year that Einstein published his Theory of Relativity, Emmy Noether devised the mathematical formula known as **Noether's Theorem**, and in 1918, she published it. This is what Einstein said about her work:

"In the realm of algebra, in which the most gifted mathematicians have been busy for centuries, she discovered methods which have proved of enormous importance…Pure mathematics is, in its way, the poetry of logical ideas…In this effort toward logical beauty, spiritual formulas are discovered necessary for deeper penetration into the laws of nature."

What laws of nature was Einstein talking about? To answer that question in any meaningful, scholarly way would require a knowledge of higher mathematics far beyond my poor ability. Simply put, Emmy Noether's Theorem proves that any physical system (an experiment, a rock) that behaves the same no matter how it's oriented in space has a certain symmetry, and thus conserves its momentum. What that means, in wildly simplistic terms, is that she showed that the laws of motion are symmetrical, that the universe has an underlying symmetry. And this idea is the basis for the reasoning behind the Higgs boson.

A hundred years ago, long before the Big Bang theory, before physicists had even dreamed of a Higgs boson or a Higgs-like boson, Emmy Noether was asking the key questions about mass, and masslessness, about how mass and energy are related.

Emmy Noether is one of those great minds that can't be explained in ordinary terms. She was, according to the great mathematicians of her day, Einstein included, a person of true mathematical brilliance. She was also a person of extraordinary character, accomplishing far more than most of the highly educated men of her era, against overwhelming odds. She was a woman who loved science and mathematics in a time when these fields were closed to women. Barred from matriculating formally at the University of Erlangen, she audited all the courses, and did so well on her final exams that she was granted the equivalent of a bachelor's degree. Despite the fact that she earned her doctorate at the University of Gottingen summa cum laude, she was denied a paying teaching position. She made such an impression, though, on the leading mathematicians of her day that they took up her cause. The best she could do was to get a position as a guest lecturer. In addition to the obstacle of her gender, Emmy Noether was a Jew coming of age as Hitler was rising to power. She was a Jewish intellectual. And she was a pacifist.

It was no surprise to her, then, that she was among the first six professors to be thrown out of Germany by the Nazis. At this point, her old friend and mentee Albert Einstein intervened, using his influence and the prestige of his position at Princeton to get Emmy a teaching job at Bryn Mawr College. There, she pursued her love of mathematics and of teaching. But this too, was brief. In 1935, only 18 months after her arrival in the United States, at the age of 53, Emmy Noether was operated on for an ovarian cyst, and died within days.

We have to ask the same question about her as we did about Rosalind Franklin, who died at age 38. Had Emmy Noether lived longer, would she have received recognition commensurate with her contributions to science and mathematics? Perhaps. Perhaps if she'd lived to be 90, or 100, she would have finally won the acclaim that had begun – but only begun – to come to women in the 1970's.

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So where are we in 2013? At the beginning of the 21st century, we live in a world driven by technology to a degree unimaginable to Emmy Noether or Rosalind Franklin or Helen Taussig or to the hundreds of other women like them, who struggled against overwhelming odds to contribute to science and medicine.

What do the numbers tell us about how far we've come? That depends upon which end of the career timeline you look at – that is, whether you focus on the young women entering med school or engineering school or embarking on doctoral work in mathematics or computer science, or whether you turn your microscope on the statistics on women in the higher reaches of science.

We should celebrate the fact, on one hand, that nearly one half of all first-year medical students are females – 47 %, according to 2011 statistics. And the numbers are almost as encouraging, at the entry level, that is, for women in the hard sciences, engineering and math. Anything is possible, we are telling our young women, and they believe it. In that regard, we've come a long, long way since Helen Taussig was rejected by Harvard because she was a woman, since Rosalind Franklin had to wait six years for Cambridge to award her the B.S. she'd earned in 1941, since Emmy Noether was denied a paid teaching position despite her brilliant academic performance. Today, a bright, motivated young woman interested in the sciences or mathematics has the world as her oyster.

But a different story is told when we look at the figures for women's participation at the upper levels, particularly in the "hard" sciences like physics and computer science.

There, the statistics speak to us of the "leaky pipeline" model, in which the proportion of women "on track" to potentially becoming top scientists falls off at every step of the way – from the elementary school interest in science and math, to the doctoral and post-doctoral levels. There are many factors involved here, and work-life balance comes into play for many women, in all high-powered professions, as they make their way up the career ladder. But the vast differences in the "leakiness" of this pipe across the same countries and time periods argues for the presence of gender discrimination, albeit of a more subtle nature than in past eras.

The ground shifts beneath us, and we are presented with new, and different problems in negotiating the gender divide. In this ever-changing situation, stories, told often, and with passion and conviction, play a key role. Why? What, you may ask, is the value of recounting the struggles and accomplishments of the Helen Taussigs and the Rosalind Franklins and the Emmy Noethers?

There is enormous value in the telling of these and hundreds, thousands of stories of great people from the past and the present, as many as we can find. Why? *Because stories give us a map for what is possible in the world*. They show us how individuals have negotiated the challenges, the pain, the defeat, the prejudice, the naysaying, and how they've prevailed. They argue for those of us down in the trenches that we too are capable of extraordinary feats.

So please, take the stories I've told here today, and pass them along. Tell them again, and add stories of your own.

In so doing, you will become part of the story yourselves. You will map the possible.

Thank you.