IN 2011, AFTER EIGHT YEARS at the National Institute on Aging, I was ready to make a major move, and my daughter, Alina, was old enough that I could now do this, even though I knew she would struggle with missing our neighborhood and her friends. I knew I was asking a lot of my husband, too. After leaving Hopkins, Pat had started his own lab at the National Institutes of Health focusing on ovarian cancer. He was the first to discover that proteins called claudins, which normally acted as tight junctions between cells, were altered in ovarian cancer, allowing the cancer cells to pick up and metastasize. Abnormal claudin expression was then found in breast cancer and is now a factor that is considered in the staging of breast cancers.

Although Pat’s work was flourishing, he sensed that I needed to be around more researchers who were specifically studying melanoma and other skin cancers, so he encouraged me to accept a new position as an assistant professor in the molecular and cellular oncogenesis program at The Wistar Institute in Philadelphia, an independent nonprofit research
institution on the campus of the University of Pennsylvania focusing on the biomedical sciences. For nearly two years I commuted between Baltimore and Philadelphia, and eventually we made the move north.

Wistar was a new and empowering beginning for me. For the first time, I was allowed to do my research independently, with my own resources to allocate as I saw fit. It was so different from being at NIA because I was in charge of the direction of my laboratory, and as long as I got the grant funding to do so, I could study whatever I wanted. It was my first experience with grant writing, and I absolutely loved it. Each grant serves as a blueprint for the next few years of scientific direction. Then and now, I love thinking through the problems I want to solve, coming up with experiments and plans on how to do so, and then receiving both criticism and positive feedback from colleagues on what would work, what would most certainly fail, and how it all needs to be communicated. My colleagues didn’t hold back—if they didn’t agree with the data presented, they would say so. But in the next breath, they’d say, “If you really want to answer that question, you need to use these models. I have many, and I’d be happy to share them with you.” Their disagreement wasn’t rooted in criticism, but in their commitment to having everything studied as accurately as possible. You received the brutally honest critiques—and sometimes those stung—but you also got the support you needed to move ahead. That’s what made Wistar a crucial
place in my development as a cancer researcher. The specific expertise of my colleagues, the research freedom, the abundant feedback, and the heavy emphasis on grant writing there all made Wistar a turning point in my research.

Within three years, I was named an associate professor in tumor microenvironment and metastasis, and I eventually became the program co-leader in immunology, microenvironment, and metastasis. By adding aging to the overall picture, we were making strides in our ability to one day manage and control more facets of cancer—to work against some of its current inevitabilities. I knew we were on the verge of major discoveries, and I felt like I was opening a treasure chest and pulling out one insight after another. We soon realized that several of the processes of cancer and aging, which appeared to be in opposition sometimes or have little in common other times, were actually shared by the disease. Such hallmarks include cellular survival, metabolic changes, decreased fitness, and an abnormally high rate of proliferation of rapidly dividing cells. We also began to see how intracellular communications, mitochondrial dysfunction, cellular senescence, and other key factors could be shared by the majority of cancers. We observed that normal cells “talked” to cancer cells and that cancer cells responded, but also, critically, that the types of conversations the cells had changed with age.

Sometimes in research, a seemingly simple shift you make away from a tried-and-true, decades-old practice can make a
The Business Side of Research

It’s always thrilling to learn about major scientific and technological breakthroughs in the news—of the promise of new treatments and even cures, exciting new discoveries, and inventions that solve long-standing problems and make our lives easier. But even for researchers at leading research institutions like Johns Hopkins University, with our state-of-the-art labs and field stations and highly trained, inspiring colleagues, there are obstacles that make those victories more difficult, including securing immigrant scientists’ visas (discussed on page 60), the cost of funding laboratory personnel, and the complexities and high fees associated with publishing findings of the research.

As with most businesses, operating income is a primary concern for laboratory work. Most researchers are reliant upon grants from the government and philanthropic foundations to complete their studies, which requires equipment, materials, staffing, and more. But some of the major sources of financial support, including the National Institutes of Health, haven’t increased their funding amounts for individual grants in the last thirty years, and annual modular budgets remain at $250,000 per grant. During this same period, salaries for graduate students and postdoctoral fellows have doubled—which is welcome news. But to pay them, lab directors have to spend much more time writing and applying for ever more grants to supplement their finances, which is an enormously time-consuming (and nerve-wracking) job—even though thinking through what the proposed project’s experiments
could reveal, and what work is necessary to get to those revelations, can be an exciting, creative process.

Another major consideration of research is the increasingly high bar set for publications, and the associated costs. If you think back to the 1953 *Nature* paper by James Watson and Francis Crick describing the structure of DNA, it was exactly one page long, with one figure composed of a single panel. Today, articles for that journal involve so much more. Our 2016 *Nature* paper (discussed on page 51), for example, included a total of fourteen figures (five main, nine supplementary), each with multiple panels of data. Further, the publishing costs alone—in addition to the research costs—of a single article in such leading journals can run a lab as much as $10,000. This is particularly true if you want the piece to be open access—to share it with as wide an audience as possible—which puts smaller labs doing great work on limited budgets at a disadvantage in getting their work recognized and accessed widely.

On the bright side, this has driven a positive change in recent years toward collaborative grant writing, where multiple labs nationwide and even worldwide apply for grants together, bettering their odds for successful applications. I’m a big believer that diversity at every level, from gender to race to ways of thinking, is critical in finding creative solutions to solve and better understand cancer, so bringing in other teams is a great way to overcome some of the roadblocks while gaining the best understanding of the problems at hand.
big difference. One of the basic changes we made in our lab as we started at Wistar in 2011 was the age of the mice we were working with. The mice we were using at first were six to eight weeks old, which is the age that most researchers work with. But when you equate that to humans, that’s only 14 to 16 years old, and it makes little sense if you’re trying to study how cancer works in patients ages 65 and older. So, in my lab, we used mice for our research that were 12 months to 18 months old, which correlate much better to older human beings. That’s the human equivalent of 50 to 70 years old.

Soon after we made this switch, we noticed that if we treated younger mice and older mice with many of the same cancer drugs, the two groups responded much differently. At first, we focused on tumors and specific genetic mutations. For example, we had a drug that targeted a particular genetic mutation, and we put those tumors in young mice. Then we put the same tumors in the older mice, and we gave both the same drug. The tumors in the young mice soon went away, but the tumors in the older mice grew during the treatment. It was becoming more apparent to us that targeting age-related changes in cancer would provide novel and intriguing new paths of therapy and care.

When it came to aging, and the role it plays in cancer, I was lucky to be in the right place at the right time. I now had a foot in cancer research at Wistar, and after my work at the National Institute on Aging, I had my other foot in aging research. It
was natural for me to explore the intersection of these two worlds. As I did so, I realized that while I’d been surrounded by researchers focused on aging during my eight years at NIA, they weren’t really thinking about cancer, or its microenvironment, which was becoming a much bigger part of my thinking. Certainly, genetic changes are important. But so is the microenvironment that informs and impacts the cancer.

Mina Bissell is one of my heroes who’s done amazing work in this area. Born in Tehran, Iran, she’s another feisty immigrant who’s made her mark in the medical world. She’s the former head of life sciences at the Lawrence Berkeley Laboratory in California, and in researching breast cancer she’s made major breakthroughs in our understanding of the microenvironment and tissue architecture. I first heard Mina speak when I was 20 years old, at the American Association for Cancer Research meeting in Washington, DC. It’s an annual meeting, attended by a large number of cancer researchers from all over the world—about 20,000 of us. She discussed the microenvironment and how you could take a prostate cell and turn it into a milk-producing mammary cell, simply by changing the environment in which it was set. It was fascinating because it demonstrated how such cell plasticity could be another major factor in our understanding of cancer biology and how to better eliminate tumors.

In a popular TED Talk she gave in 2012, Mina emphasized how puzzling deciphering cancer’s form and function can be
given that we have upward of 70 trillion cells in our body.³ Mina’s research revealed that the microenvironment and extracellular matrix can tell the cancer cells what to do. In essence, the cancer’s growth and malignant behavior is regulated at the level of tissue organization, and tissue organization is dependent on the extracellular matrix and microenvironment.

Mina uses the term “dynamic reciprocity” to describe the conversations cells are having with each other—how the normal cells are sending chemical signals—communicating to the tumor cells—and the tumor cells are talking back to the normal cells. It’s similar in many ways to the back and forth in conversations we participate in during everyday life. Mina’s work was groundbreaking in its challenge of existing paradigms, and it inspired my own work on the tumor microenvironment in trying to interpret these conversations.

At Wistar, the developments and insights we were gaining regarding correlations between cancer and aging were complex and challenging to fully comprehend, but we were increasingly enthusiastic about what we were seeing. It took us seven years to put together the first set of data because we wanted to be absolutely sure of everything. We were seeing the major influences aging has, especially once we switched to older mice, and some of these changes could be queried in patient samples—for instance, the expression of proteins that changed in aging human skin as well as mouse skin, or similar responses (or lack thereof) to therapy in both older mice and
older humans. As we continued, it became absolutely clear that aging is an important characteristic of cancer, especially in older patients.

“Cancer is a disease of aging.” That was the opening line in a landmark study from my Wistar laboratory, published by *Nature* in 2016. While there are of course childhood cancers, they occur less frequently and are in general more curable. And while cancers that are more prevalent in older patients also strike younger patients, when we look at the disease as a whole, more than 70 percent of all cancers diagnosed worldwide are seen in individuals over the age of 65, and almost 90 percent of the deaths from cancer occur in the same age group.4

Our work in this initial study laid out techniques for focusing on molecular changes that occur in aging skin cells and understanding how those changes can drive melanoma metastasis and therapy resistance in older patients. Such insights shifted our views on how we should be treating patients with melanoma. In many ways, this initial study was the foundation of much that has followed with my research. The study wasn’t completed that long ago, but when I look back on what we had just started to uncover, it amazes me how much we’ve learned so quickly: the impact of age on a few factors that play a role in tumor progression; the involvement of the aging immune microenvironment; how different organs age differently, which governs metastatic outgrowth; and the involvement of fats
as well as proteins. The gratifying part has been identifying actionable changes, molecules we can target, to overcome some of this age-related therapy resistance, and we’re anxious to introduce drugs that target these changes into the clinic.

In hindsight, the correlation between aging and cancer makes a lot of sense, given that cancer is basically defined as cell growth without normal barriers. We’ve learned that as we age, we accumulate more mutated, distorted genes that have been lying in wait. These can crowd out the normal genes, which perform vital cellular functions. Until only a few generations ago, many of us didn’t live long enough for cancer to be a major problem. Diseases like cholera, smallpox, and tuberculosis were considered more dire because they usually impacted younger patients.

We often see major changes in how cancer can grow and move throughout the body in people 65 and older. While this was recognized, in part, by the National Cancer Institute and others a half-century ago, there were cost and complexity barriers to running trials and extensive investigations that extend over years and decades. Such longitudinal studies can be difficult to carry out and are sometimes prone to error as they take place over a longer period of time. That’s why until recently there’s been limited data from clinical trials in older patients. Only 40 percent of patients enrolled in cancer clinical trials were over 65, and fewer than 10 percent were over 75. As a result, age was often overlooked as a major factor in detect-
ing and treating cancers like melanoma. Now we know it’s as important as skin type, family history, and spending too much time in the sun.

What was common knowledge was that you’re more prone to chronic inflammation as you grow older, which makes many people more vulnerable to a variety of different diseases as they age. But few researchers looked in-depth at what was going on at the molecular level—at how aging could alter and influence not only the tumor cells, but the surrounding cells as well. The incidence of cancer could escalate further as life expectancy continues to rise. That’s the door we’ve begun to open, and what we’re discovering gives hope to future therapy and care for many forms of cancer.

In that 2016 study, we focused on the role aging can specifically play in the development of melanoma. For example, melanoma patients 65 and older often have significantly higher serum levels of a protein known as sFRP2 than patients younger than 40. Secreted frizzled-related protein 2 is a protein that is encoded by the sFRP2 gene and an important factor with Wnt signaling. Elevated levels of sFRP2 can cause a decrease in beta-catenin and, ultimately, the loss of a key redox effector, or multifunctional protein, called APE1. The loss of APE1 can result in melanoma cells being more prone to DNA damage, more genetically unstable, and more resistant to therapy. Our findings in this study also supported the hypothesis that dynamic changes with an aged microenvironment play
a key role in increasing resistance to therapy. With melanoma, mutations in the BRAF gene, a key driver of melanoma, are present in nearly 70 percent of patients under the age of 45. However, these tumors are less aggressive in younger patients and more responsive to targeted therapy. In the 2016 study we compared outcomes in patients who had been treated with the drug vemurafenib, which targets the BRAF mutation in melanoma. We obtained these data from multiple centers that had treated these patients, in the United States and other centers across the world. This study involved so many different centers that the final author count on the ensuing publication was more than 50! The most surprising thing to us was that at the start of this study, we didn’t expect to find huge differences with age, because we were targeting a specific mutation (in the BRAF gene) with a drug designed to hit that mutant gene product. In our minds, nothing else should have mattered: one gene, one mutation, one drug. But instead, all of the changes that occurred with age combined to provide avenues for cells to escape that therapy and rendered it less effective in older patients. The study concluded, “Our data suggested that, as the general population ages, new efforts must be made to understand and treat cancer in an age-appropriate manner.” That may seem like a simple statement, but this was a wholly new direction in cancer research.

Many of the key factors and processes were now established. The next step was to carry out the rigorous work to
ensure that future data and insights were solid and indisputable—to build on this new knowledge in the smartest, most effective way.

Fibroblasts are the cells that are responsible for maintaining the extracellular matrix and for supporting cellular and microenvironmental homeostasis (the healthy state that is maintained by the constant adjustment of biochemical and physiological pathways). This is accomplished through the regulated secretions of cytokines, chemokines, growth factors and other key signaling proteins. Because we were studying a tumor in the skin, it made perfect sense to look at the fibroblasts as the orchestrator of those changes. Most of our studies focused on the interaction between fibroblasts and the melanoma cells. We soon realized that the age of the fibroblasts was critical in the impact they had on tumor cells. Previously, work from Judy Campisi’s lab at the Buck Institute in California had shown that irradiating embryonic fibroblasts and making them senescent (mimicking aging) drove tumor progression. To our knowledge, we were the first to isolate normal fibroblasts from younger versus older patients and assess their impact on melanoma cells. What our work found was that with age, these factors changed dramatically. Further, our work also showed that tumor cells didn’t need to be in direct contact with fibroblasts in order to be influenced by them—we found that fibroblast-secreted factors were even more potent influencers of tumor behavior. That was import-
ant because it meant that these age-related changes could be systemic, impacting not only the primary tumor, but also metastases at different sites; this also meant that targeting these age-related changes could impact metastatic disease.

We’ve also learned that persistent inflammation can lead to tissue degeneration and is heavily associated with cancer induction and progression. One of the hallmarks of aging is an increase in systemic low-grade chronic inflammation, which occurs due to age-related changes in microbiota of the gut, genetics, chronic infections, cellular senescence, and other changes, termed “inflammaging.” Cellular senescence is recognized as a key contributor in linking inflammaging with age-related malignancies. As Campisi detailed in a 2007 report, cellular senescence is a multifaceted process that arrests cell growth, and it can affect key tumor pathways controlled by p53 and retinoblastoma proteins. Another element linked to inflammaging is the recruitment of a specific type of immune cell known as myeloid-derived suppressor cells (MDSCs). These cells can be potent repressors of effector T cells, which play a central role in our immune system, and MDSCs are associated with increased disease progression in cancer. We’ve studied how these and other subpopulations of immune cells (including T cells, natural killer cells, macrophages, and dendritic cells) change during the aging process. In older patients, cells such as neutrophils and macrophages appear to switch toward more immunosuppressive states. This can promote
tumorigenesis, or the production of tumors, and is leading to an increased understanding of how the age-related changes in additional cells, immune cells, in the microenvironment contribute to tumorigenesis.

However, it’s not a simple concept. For example, our immune system weakens as we grow older. Immunotherapy is the treatment of disease by activating or suppressing the immune system, and that’s one of the main tools we use to fight cancers these days. But when you’re dealing with immunotherapy, specifically immunotherapy that targets the checkpoints or regulators of the immune system, it turns out that a slightly weaker immune system can sometimes actually help, because the regulatory systems that would normally tamp down the immune response boosted by immunotherapy don’t function as well. If you’d told me before we did these studies with older mice that they would respond better to this example of immunotherapy, I would have laughed. But they did. In these cases, having a weaker immune system is an unexpected advantage, which, of course, isn’t usually the case with cancer. We showed that this was true in patients, where we studied approximately five hundred patient outcomes, and found that largely, older melanoma patients had better results than younger patients after treatment with immunotherapy. These results have been validated by other researchers now, in much larger melanoma patient data sets, and with multiple forms of immunotherapy. However, in other tumor types like breast
cancer, work from Sandra McAllister’s laboratory at Brigham & Women’s Hospital finds this is not always the case, and older breast cancer patients do not respond as well to immunotherapy. This dichotomy between tumor types further highlights the complexity of the impact of aging on cancer.

We continued to study and extrapolate the data, shifting the focus from mice to what happens in humans. It’s been demonstrated that older patients’ metastases can be further away from their cancer’s origin site. In melanoma, we see that young patients develop more lymph node metastases than older patients, but older patients develop more of the deadly distal metastases (liver, lung, heart, brain) than younger patients. Our work has shown that in part, these different routes of metastasis occur because of changes in the aging microenvironment, many of which are orchestrated by the fibroblasts. Some of these changes are mechanical, meaning that the tumor cells in the older patients have more “room” to sneak into blood vessels, while other changes may be more molecularly driven, through changes in some of the growth or immune factors.

What we’ve learned in a few short years is that aging can amplify many factors governing cancer. The mechanisms between the disease and aging underscore the time-dependent aspect of cellular damage. Fibroblasts and immune cells appear particularly susceptible to this age-related impact. The data strongly indicate that we need a paradigm shift in our approach to aging and how it influences our understanding of cancer.
We’ll need all of the best cancer research minds available to solve these puzzles—to determine better diagnostic methods and treatments to reduce even more of cancer’s mortality rates.

THE PRICELESS ROLE OF IMMIGRANTS

I’ve been so fortunate to work with many incredible trainees. They’re the engine that drives the research in the lab, and mentoring them is my greatest pride and joy. This is not to ignore the contributions of either the amazing immigrants who’ve gone before them, or the incredible American students who have spearheaded innovative research in my lab, and now in their own, such as Marie Webster, who was instrumental, along with fellow Americans such as Curt Kugel III, and other immigrant scientists like Aman Kaur and Michael O’Connell, in establishing my lab at Wistar. Before them came trainees from all over the world: Tura Camilli from France, Reeti Behera from India, even one trainee, Samudra Dissanayake from Sri Lanka where I was born, and another, Poloko Leotlela, from Lesotho where I grew up, and so many more! Currently in my lab I have two Black women scientists, two Latina scientists, and half of us are immigrant scientists. I have always been amazed at the deep friendships we form despite our cultural differences.

What is worrisome is that many of my international trainees first came to this country as I did on an F-1 or a J-1 scholarly visa. In recent years, such visa holders have been subjected
to draconian restrictions, with paltry explanations provided for such treatment. These complications have occurred even though such visa holders are required to return to their own countries after five years here in the United States. Usually, they have to wait two years before being able to return.

Why do we need immigrant scientists in the United States? Why don’t we simply rely on American-born professionals to fit the bill? The fact is, we don’t have enough specialists to go around. Many labs in this country are looking for grad students, technicians, and postdoctoral fellows. By not fully filling those positions, we’re limiting the science we can do right now. We’re restricting what our labs and programs can accomplish here, in America, not just for medical research, but for the wider range of studies that move society forward. Hopefully, that will change with the recent shift in administrations in Washington.

I’m a firm believer that if you look at the same problem from every available angle, you’re much more likely to find more innovative and creative solutions. Research demands a diversity of influences and streams of thought; one single approach, no matter how brilliant, will not defeat our deadliest and most debilitating threats, including cancer. Cancer cells are always changing, so we need to consistently hear from people with varied perspectives, experiences, educations, philosophies, and mindsets. Sometimes it takes a person from a different culture—perhaps one that’s more communal or collective, where the communities are more dependent upon each other—to show us the way forward. When you look at
the list of Nobel laureates in science and medicine since 1947, 43 percent of the American awardees were immigrants to this country (to read more, see page 63). They’ve demonstrably influenced the US labs they were a part of by changing the perceptions and outlooks of their coworkers, in addition to contributing pivotal scientific bodies of work.

Too few realize that immigrants have been such a major factor in US research through the years. They may have read that Albert Bourla, the CEO of Pfizer, is a Greek immigrant, and that the CEO of Moderna, Noubar Afeyan, was born in Lebanon. One of the key scientists behind mRNA vaccines is Katalin Kariko, a Hungarian scientist. These and other immigrants have worked tirelessly to help save our nation from COVID-19, its worst health crisis in a century. But the collective impact of these immigrants across the research and health care fields is rarely discussed.

These scientists have helped to form the foundation of contemporary research; their work has saved, and will save, countless lives. They also educate the next generation of scientists, further deepening their impacts. For instance, Carl and Gerty Cori were both born in Prague and came to the Roswell Park Cancer Institute in Buffalo in 1922, where they began groundbreaking work on tumor metabolism. In time, they moved to Washington University and built a department of biochemistry there, which included seven future Nobel laureates. Zena Werb was born in the Bergen-Belsen concentration camp in Germany in 1945. After World War II, her family
Immigrant Soldiers in the Battle

If we’re going to manage, control, and even perhaps cure cancer one day, it will need to be a collaborative effort with all the most original, best-trained minds from around the world contributing their ideas and findings. But many scientists are alarmed about the restrictions fellow researchers and others in our fields have faced in recent years in trying to secure visas to the United States, and also in being forced to return to their home nations even though their work was not complete. They want to join us in this multifaceted campaign against cancer, to contribute to solutions, but face often insurmountable obstacles.

That’s what inspired my husband, Pat Morin, Denis Wirtz, and me—all immigrants to America—to co-write a commentary on the subject in 2020 for Cancer Cell titled “Completing the Great Unfinished Symphony of Cancer Together: The Importance of Immigrants in Cancer Research.” Pat is executive director of strategy and implementation at the Abramson Cancer Center in Philadelphia; Denis is vice provost for research and the Theophilus Halley Smoot Professor of Engineering Science at Johns Hopkins. Beyond our personal experiences, we all share a common respect for the contributions of our international students, colleagues, and staff members.

Few realize the enormous impact immigrants have had on US research through the years, beyond famous physicists including Enrico Fermi, Hans Bethe, and Albert Einstein, who came to this country and helped America win weapons and space races. Yet the pivotal immigrant factor goes far deeper in the sciences, and many other disciplines; cancer research is a perfect example. This list of 23 US Nobel
laureates whose award-winning work contributed to cancer research illustrates a small percentage of the debt we owe to those who’ve been welcomed through our doors.

**US IMMIGRANT NOBEL LAUREATES IN BIOMEDICAL RESEARCH, 1947–2015**

<table>
<thead>
<tr>
<th>Name</th>
<th>Nation of Origin</th>
<th>Year Awarded</th>
<th>Research Focus</th>
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<tbody>
<tr>
<td>Sidney Altman</td>
<td>Canada</td>
<td>1989</td>
<td>Catalytic properties of RNA</td>
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<tr>
<td>Baruj Benacerraf</td>
<td>Venezuela</td>
<td>1980</td>
<td>Genetic basis of immunology</td>
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<tr>
<td>Elizabeth Blackburn</td>
<td>Australia</td>
<td>2009</td>
<td>Telomerase co-discovery</td>
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<td>Günter Blobel</td>
<td>Poland</td>
<td>1999</td>
<td>Protein transport</td>
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<td>Mario Capecchi</td>
<td>Italy</td>
<td>2007</td>
<td>Gene targeting</td>
</tr>
<tr>
<td>Albert Claude</td>
<td>Belgium</td>
<td>1974</td>
<td>Electron microscopy</td>
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<tr>
<td>Gerty and Carl Cori</td>
<td>Austro-Hungary</td>
<td>1947</td>
<td>Cell metabolism</td>
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<tr>
<td>Max Delbrück</td>
<td>Germany</td>
<td>1969</td>
<td>DNA replication</td>
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<tr>
<td>Renato Dulbecco</td>
<td>Italy</td>
<td>1975</td>
<td>Cancer viruses</td>
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<tr>
<td>Charles Brenton Higgins</td>
<td>Canada</td>
<td>1966</td>
<td>Hormones in cancer therapy</td>
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<tr>
<td>Har Gobind Khorana</td>
<td>India</td>
<td>1968</td>
<td>Deciphering genetic code</td>
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<td>Rita Levi-Montalcini</td>
<td>Italy</td>
<td>1986</td>
<td>Nerve growth factor</td>
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<tr>
<td>Fritz Lipmann</td>
<td>Germany</td>
<td>1953</td>
<td>Bioenergetics</td>
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<tr>
<td>Salvador Luria</td>
<td>Italy</td>
<td>1969</td>
<td>Genetic structure of viruses</td>
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<td>Paul Nurse</td>
<td>England</td>
<td>2001</td>
<td>Cell cycle</td>
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<tr>
<td>Severo Ochoa</td>
<td>Spain</td>
<td>1959</td>
<td>RNA polymerase</td>
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<tr>
<td>George Emil Palade</td>
<td>Romania</td>
<td>1974</td>
<td>Electron microscopy</td>
</tr>
<tr>
<td>Aziz Sancar</td>
<td>Turkey</td>
<td>2015</td>
<td>DNA damage</td>
</tr>
<tr>
<td>Oliver Smithies</td>
<td>England</td>
<td>2007</td>
<td>Gene targeting</td>
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<tr>
<td>Ralph Steinman</td>
<td>Canada</td>
<td>2011</td>
<td>Dendritic cells</td>
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<tr>
<td>Jack Szostak</td>
<td>England</td>
<td>2009</td>
<td>Enzyme telomerase</td>
</tr>
<tr>
<td>Susumu Tonegawa</td>
<td>Japan</td>
<td>1987</td>
<td>Antibody production</td>
</tr>
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After Morin, Wirtz, and Weeraratna 2020
emigrated to Canada, where she began college at the age of 16 and eventually moved to the University of California, San Francisco, where she initiated classic studies on the tumor environment, focusing on the extracellular matrix and tumor microenvironment. Other outstanding immigrant researchers in the field of tumor microenvironment include Mina Bissell (Iran), Kornelia Polyak (Hungary), Rakesh Jain (India), Mikala Engeblad (Denmark), Yibin Kang (China), and many others. Min Chiu Li emigrated from China to the University of Southern California in 1947 to pursue postgraduate education. He soon became part of the team at the National Cancer Institute developing modern chemotherapy.

The list of immigrant contributions goes on and on, and it involves all types of cancer research. The best and the brightest want to be here, in this country, because the top labs and top people are here. Many have brought new treatments to our shores, including Waun Ki Hong (from South Korea), Carlos Arteaga (Ecuador), Olufunmilayo Olopade (Nigeria), Gabriel Hortobagyi (Hungary), Irene Ghobrial (Egypt), Chi Van Dang (Vietnam), Jean-Pierre Issa (Lebanon), Lieping Chen (China), Baruj Benacerraf (Venezuela), Azra Raza (Pakistan), and Kristiina Vuori (Finland).

The contributions of these and other immigrant scientists helped form the foundation of my work at Wistar—and that of other cancer researchers around the globe—and continue to aid my work today. Our breakthroughs rest on their achievements.