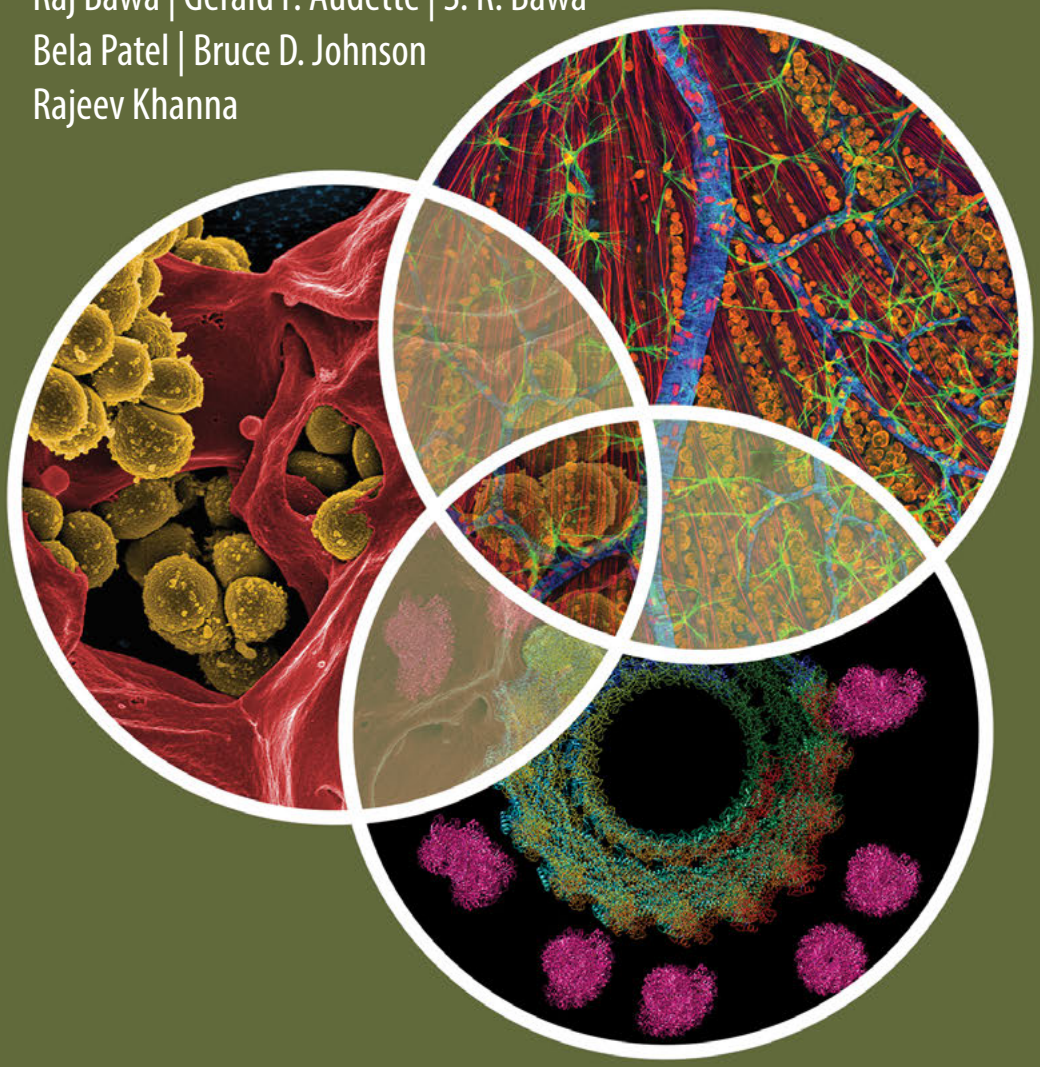
Current Issues in Medicine Vol. 4

ADVANCES IN MEDICAL IMAGING, DETECTION, AND DIAGNOSIS

edited by

Raj Bawa | Gerald F. Audette | S. R. Bawa
Bela Patel | Bruce D. Johnson
Rajeev Khanna



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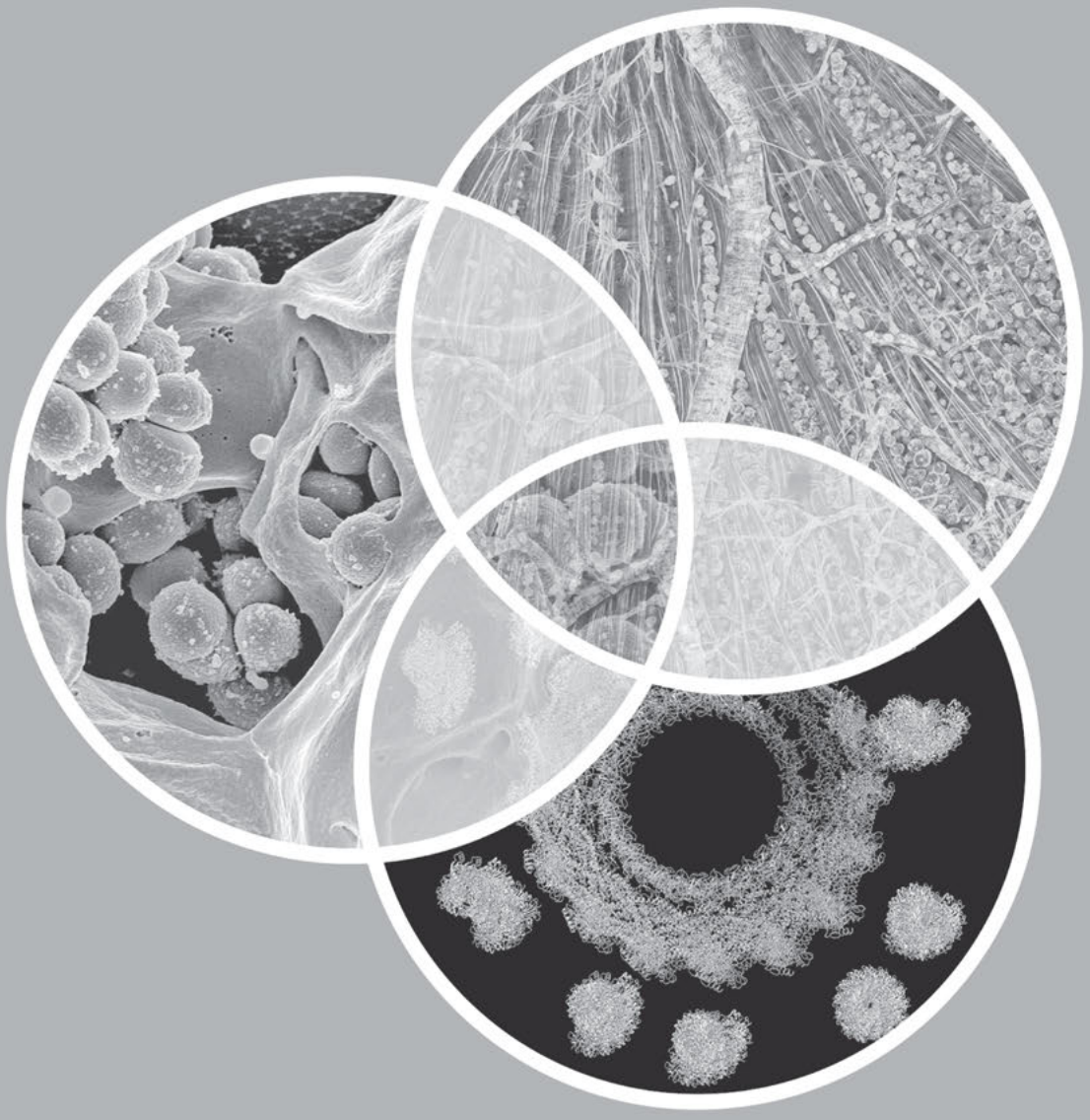

Current Issues in Medicine

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Current Issues in Medicine Vol. 4

Advances in Medical Imaging, Detection, and Diagnosis

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Published by

Jenny Stanford Publishing Pte. Ltd.
101 Thomson Road
#06-01, United Square
Singapore 307591
Email: editorial@jennystanford.com
Web: www.jennystanford.com

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Advances in Medical Imaging, Detection, and Diagnosis

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ISBN 978-981-4877-46-6 (Hardcover)
ISBN 978-1-003-29803-8 (eBook)

Dedication

It is an honor and privilege to dedicate this volume to our friend, colleague, mentor, and collaborator

Prof. Howard E. Gendelman, MD

For demonstrating the determination and ingenuity to not only revolutionize the field of neuroimmunology but to develop the cross section between pharmacology and neuroscience in the novel therapies for neurodegenerative disorders.

For his pioneering leadership and ceaseless energy as a physician-scientist, and as a mentor to countless young professionals dedicated to building the next generation of scientific leaders.

For his innovative research in therapeutics for Parkinson's and Alzheimer's diseases that serve to slow or improve clinical disease outcomes.

For the co-development of ultra-long-acting antiretroviral and CRISPR excision therapies for treatment, prevention, and elimination of viral infections.

And for serving as a tenacious advocate for building collaborations, and being an inspirational role-model of the power of never accepting 'no' as the final answer. Today but not tomorrow.

Margaret R. Larson Professor of Internal Medicine and Infectious Diseases
Professor and Chair, Department of Pharmacology and Experimental Neuroscience
Head, Carol Swarts MD Laboratory of Innovative Neuroscience
Co-Director of the Center for Neurodegenerative Disorders
University of Nebraska Medical Center, Omaha, Nebraska, USA

The Editors

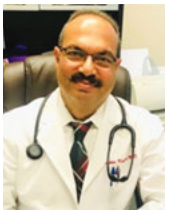
Raj Bawa, PhD, MD, is president of Bawa Biotech LLC (founded in 2002), a biotech/pharma consultancy and patent law firm based in Ashburn, Virginia, USA. Trained as a microbiologist and biochemist, he is an inventor, author, entrepreneur, professor, and registered patent agent (since 2002) licensed to practice before the US Patent & Trademark Office. He is currently a scientific advisor to Teva Pharmaceutical Industries, Israel (since 2010), and full professor (adjunct) at Northern Virginia Community College, Annandale, Virginia (since 2004). He is vice president and chief IP officer at Guanine, Inc., Rensselaer, New York (since 2017), a company focused on rapid, accurate detection of infective pathogens. He has served as a principal investigator of various National Cancer Institute (NCI) research grants; most recently as a principal investigator of a Centers for Disease Control and Prevention (CDC) grant to develop an assay for *Klebsiella pneumoniae* carbapenemase (KPC)-producing bacteria. He was an adjunct professor at Rensselaer Polytechnic Institute, Troy, New York, from 1998 to 2018. After earning a BSc (Honors School) in microbiology, he earned an MS in cancer biology, a PhD in biophysics/biochemistry, and an MD. In the 1990s, Dr. Bawa held various positions at the US Patent & Trademark Office, including primary examiner from 1996–2002. Currently, he is a life member of Sigma Xi, cochair of the nanotech and precision medicine committees of the American Bar Association, and founding director of the American Society for Nanomedicine (established in 2008). He has authored over 100 publications, edited 10 texts, and serves on the editorial boards of numerous peer-reviewed journals, including serving as an associate editor of *Nanomedicine* (Elsevier).

Gerald F. Audette, PhD, is associate dean, Faculty of Science, professor of chemistry, and member of the Centre for Research on Biomolecular Interactions at York University, Toronto, Canada. His research focuses on the correlation between protein structure and biological activity of proteins involved in bacterial conjugation, in particular, the type 4 secretion system from the conjugative F-plasmid of *Escherichia coli*. In addition, his research targets the type IV pilins and associated assembly systems from multiple bacterial pathogens and is exploring the adaptation of these protein systems for applications in bionanotechnology and nanomedicine. Dr. Audette is the co-editor of volumes 1–4 of the *Jenny Stanford Series on Nanomedicine* and is a subject editor of structural chemistry and crystallography for the journal *FACETS*.

S. R. Bawa, MSc, PhD, is currently scientific advisor at Bawa Biotech LLC, a biotechnology and patent law firm founded in 2002 and based in Ashburn, Virginia. Previously, he was Founding Chairman and Professor of Biophysics at Panjab University, Chandigarh, India (1964–1992). At Panjab University, he also served as Dean of Foreign Students (1986–1988) and Coordinator of the Biotechnology Center (1986–1988). He was president of the Electron Microscopy Society of India (1986–1992), Secretary of the Indian Biophysical Society (1986–1988), and Founding Secretary of the Northern India Science Association (1966–1992). Dr. Bawa received his BSc (University Gold Medal), MSc (University Gold Medal), and PhD degrees in 1949, 1951, and 1954, respectively, from Panjab University. He was a Fulbright Fellow and Instructor (1958–1960) and a Boese Postdoctoral Research Fellow (1959–1960), both at Columbia University. He was an Instructor (1961–1963) in the Department of Anatomy at Cornell University Medical College. In 1964, at the age of 34, he assumed the position of Founding Head and Reader of the newly established Biophysics Department at Panjab University, Chandigarh, India. He was promoted to Professor and Head in 1969. After retiring from Panjab University in 1992, Dr. Bawa joined the David Axelrod Institute of the New York State Department of Health in Albany, New York, from where he retired in 1999. Dr. Bawa has published over 150 scientific papers in peer-reviewed journals, books, and conference proceedings. His numerous accolades include Alexander von Humboldt Fellowship, Germany (five times); Fulbright Fellowship, US; US Alumni Research Travel Grant, US; Boese Postdoctoral Fellowship, Columbia University, US; British Council Invitee, UK; Diatome Award of the Electron Microscope Society of America; PL-480 Research Project and Appreciation Award, US Department of Agriculture; Kazato Research Award, Japan; and National Lectureship, India. He is an elected member or life member of various professional societies and organizations. He has served on various international scientific committees, advisory boards, government expert panels, and held visiting professorships in the US, Canada, and Europe. He has been a member of various peer-reviewed international journal editorial boards, including *Ultramicroscopy* (1986–1995, Elsevier), *Andrologia* (1993–1995, Blackwell/Wiley), *Acta Anatomica* (1974–1977, Karger), *Journal of Ultrastructure Research* (1969–1985, Elsevier) and *Journal of Submicroscopic Cytology* (1970–1977, Università di Bologna). Since 2004, the *Dr. S. R. Bawa Merit Scholarship* is awarded by Panjab University to a student standing first in the BSc (Honors School) class in biophysics. In 2022, Panjab University presented Dr. Bawa the *Distinguished Alumnus Award*.

Bela Patel, MD, is a professor of medicine, vice dean of Healthcare Quality, and division director for Pulmonary, Critical Care and Sleep Medicine at the McGovern Medical School at the University of Texas Health Science Center in Houston. She is regional chief medical officer and executive medical director of Critical Care for Memorial Hermann Hospital Texas Medical Center. Dr. Patel attended the University of Texas in Austin and the University of Texas McGovern Medical School in Houston. She completed her training in internal medicine in 1996 and subsequently a fellowship in pulmonary, critical care and sleep medicine in 1999 also at the University of Texas Health Science Center in Houston. Dr. Patel was appointed as the chief of Pulmonary, Critical Care and Sleep Medicine in 2002 and later appointed the chief of Medicine at Lyndon B. Johnson General Hospital and vice chair of the Department of Medicine in 2007. In 2009, she became the assistant chief medical officer and subsequently regional chief medical officer in 2017 for Memorial Hermann Hospital Texas Medical Center. Through her work in quality and patient safety, she was inducted as a fellow in Clinical Safety and Effectiveness by the University of Texas System. Dr. Patel was appointed as the assistant dean of Healthcare Quality in 2011 and the vice dean in 2017 and supports the 18 vice chairs of quality in Medicine at McGovern Medical School. Dr. Patel's research interest includes sepsis, ARDS, pulmonary hypertension, cognitive complexity and error reduction in critical care, and quality improvement implementation.

Bruce D. Johnson, PhD, is a professor of medicine, professor of physiology, and a consultant in the Department of Cardiovascular Medicine at the Mayo Clinic, Rochester, Minnesota. Additionally, he has joint appointments in the Division of Preventive, Occupational and Aerospace Medicine and in the Department of Physiology and Biomedical Engineering. He is the director of the Mayo Clinical Research Unit's Energy Balance Core Laboratory and directs his own research laboratory in human integrative and environmental physiology. The majority of his research has focused on factors limiting human performance in various clinical syndromes, in athletes, and under extreme environmental conditions. He has led field studies in Antarctica, funded through the National Science Foundation (NSF), and on Mount Aconcagua in Argentina, Mount Everest, and Mount Kilimanjaro. His research has involved studying unique populations such as breath-hold divers in Croatia and F-22 pilots from the US Air Force. His clinical research focuses on novel methods for the detection and tracking of chronic disease as well as environmental factors that may be involved in disease risk. His laboratory also works closely with consumer and medical device companies that track health status through wearable or passive sensing as well as with early-phase supplement and pharmaceutical company products. His research has been funded by the NIH, DOD, NSF, State of Minnesota, and industry.



Rajeev Khanna, MD, is an internal medicine consultant practicing in a group practice in Northern Virginia, as a part of Loudoun Medical Group. He is an internist with interest in long-term management of chronic health problems such as diabetes, high blood pressure, heart disease, and heart failure. He obtained his MBBS and MD in internal medicine from Dayanand Medical College, Ludhiana, Punjab, India, Dr. Khanna was in training for neurology postgraduation (DM) at the Postgraduate Institute of Medical Education and Research, Chandigarh, India before moving to the United States. He completed his residency in internal medicine at PG Hospital Center, Maryland, USA, in 1994. He has been published in multiple peer-reviewed journals.

Note from the Series Editor

A hallmark of medicine is that is continuously evolving, its knowledge base continuously expanding. Clearly, the pace and sophistication of advances in medicine in the past two decades have been truly breathtaking. This has necessitated a growing need for a comprehensive reference that highlights the current issues in specific sectors of medicine. Keeping this in mind, each volume in the *Current Issues in Medicine series* is a stand-alone text that provides a broad survey of various critical topics in a focused area of medicine—all accomplished in a user-friendly yet interconnected format. The series not only highlights current issues and advances but also explores related topics such as translational medicine, precision medicine, nanomedicine, regulatory science, neglected global diseases, emerging pandemics, FDA and patent law, immunotoxicology, theranostics, big data, artificial intelligence, novel medical instrumentation, clinical procedures, combination drug products, and novel therapies. While bridging the gap between basic research and clinical medicine, this series provides a thorough understanding of medicine's potential to address health problems from both the patient's and the provider's perspectives in a healthcare setting. Each volume is an excellent resource for medical practitioners, medical students, nurses, fellows, residents, undergraduate and graduate students, educators, venture capitalists, policymakers, and biomedical researchers. The multidisciplinary approach of the series makes it a valuable reference for health care systems, the pharmaceutical and device industry, academia, and governments. However, unlike other series on medicine or medical texts, this series focuses on current trends, perspectives, and critical issues in medicine that are central to healthcare delivery in the 21st century.

The first two volumes in this series focus on the current issues in basic medical sciences, subjects that are fundamental to the practice of medicine. These subjects, traditionally taught in the first two years of medical school that precede clinical instruction, provide a core of basic knowledge crucial for the success in clinical medicine during rotations, training, and medical practice. The subsequent volumes are dedicated to clinical topics or specialties in medicine. A separate volume on medical history and another on perspectives/editorials are part of the series.

Medical imaging, detection, and diagnosis have all aided in treatment and prevention of disease throughout human history. Technological innovations in these critical sectors of medicine continue to provide for safer, more accurate and faster diagnosis for patients. They have revolutionized medicine. Hence, it is critical that practitioners stay current with these latest advances to provide the best care for nursing and clinical practices. Given this backdrop, the current volume focuses on the tools, technologies, techniques, and testing protocols related to diagnostics and imaging that currently impact medicine. Fundamental coverage

on the use of technology in clinical practice is highlighted. The range of topics covered here and the expertise of the contributing authors accurately reflect the rapidly evolving areas within medical diagnostics and imaging.

Raj Bawa, PhD, MD
Series Editor

Chapter 10

My Personal and Professional Journey: *Reflections, Memories and Confessions*

S. R. Bawa, MSc, PhD[1]

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10.1 My Life: An Overview

Hereby, too, I shall indulge the inclination so natural in old men, to be talking of themselves and their own past actions.

—Benjamin Franklin (1706–1790), American Statesman and Scientist, *Memoirs*

یہ دولت بھی لے لو، یہ شُہرت بھی لے لو بھلے چھین لو مُجھ سے میری جوانی
مگر مُجھ کو لَوٹا دو، بچپن کا ساون وہ کاغذ کی کشتی، وہ بارش کا پانی

…take this wealth too, take this fame too, take away my youth from me,
but give me back the dawn of my childhood, that paper boat, that rainwater…

—Mirza Ghalib (1797–1869), Indian Poet of Urdu and Persian

…we are not given a short life but we make it short, and we are not ill-supplied but wasteful of it…Life is long if you know how to use it.

—Lucius Seneca (4 BC–65 AD), Roman Philosopher

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Advances in Medical Imaging, Detection, and Diagnosis
Edited by Raj Bawa, Gerald F. Audette, S. R. Bawa, Bela Patel, Bruce D. Johnson, and Rajeev Khanna
Copyright © 2023 S. R. Bawa
ISBN 978-981-4877-46-6 (Hardcover), 978-1-003-29803-8 (eBook)
www.jennystanford.com

I always have lived my way; I did it my way ("*Your time is limited, so don't waste it living someone else's life. Don't be trapped by dogma—which is living with the results of other people's thinking. Don't let the noise of others' opinions drown out your own inner voice. And most important, have the courage to follow your heart and intuition.*"—Steve Jobs). This chapter serves as an autobiographical memoir. It relates my experiences of the past 75 years in science, education, research, teaching, and administration; each has held equal importance in my professional life. This chapter also sheds some light on my youth under British colonial rule (1929–1947). The traumatic British partition of my beloved Punjab and loss of its ancient capital city of Lahore that resulted in me becoming a refugee in my own country is covered in detail (August 1947). I will reflect on my early life through the lens of historical events, nostalgia, and loss. It will then trace my undergraduate and graduate education (1947–1954), marriage to the sunshine of my life at the age of 24 (1954), and subsequent relocation with my young family to New York City (1958–1963). There, I was a Fulbright Scholar and Lecturer at Columbia University (1958–1960) and, later, a Lecturer (1961–1963) at Cornell University Medical College (now Weill Cornell Medicine). These venerable institutions provided me a firm foundation of scientific knowledge and academic tradition. New York City was a global epicenter of groundbreaking research in cell biology, biomedicine, and microscopy from the 1940s until the 1960s. I was lucky to have witnessed and participated in some of it with the giants of science and medicine. This resulted in a publication record of a dozen single-author papers in *Nature*, *Journal of Cell Biology*, *Journal of Ultrastructure Research, Journal of Morphology*, and many more. Lahore of the 1930s and 1940s was the old world to me—steeped in tradition, culture, architecture, poetry, and history. New York City of the 1950s and 1960s was the new world to me—stunning skyscrapers, limitless human creativity, optimism, diversity, modernism, and education. Both great cities will always occupy a tender corner in my heart.

The chapter is dedicated to my late-wife, Sudesh (Photos 1–3). Although she was an angel, I only referred to her as *Rani* (Punjabi, "Queen"). She was this and much more: kind, beautiful inside and out, thoughtful, gentle to the core, always smiling, exuding warmth, and helpful to all. She made my soul blossom ("*The best and most beautiful things in the world cannot be seen or even touched—they must be felt with the heart.*"—*Helen Keller*). I feel her absence every second of every minute. It is a void that nothing, and no one else, ever can fill. This chapter is also dedicated to my teachers, students, and colleagues, who taught me much and whose efforts are responsible primarily for what has been accomplished in our work—that is, the research focused on the "why" behind the problems that I have encountered over the past 75 years. These reciprocal relationships formed throughout my research and teaching career have fostered a depth of thinking and problem solving.

Photo 1. My wife "Rani" at age 12 in Lahore, Punjab, British India (c. 1947).
(*आपकी नज़रों ने समझा प्यार के काबिल मुझे दिल की ऐ धड़कन ठहर जा मिल गयी मंज़िल मुझे/Aapki nazaron ne samjha, pyaar ke kabil mujhe, dil ki ai dhadkan thaher ja, mil gayee manzil mujhe.* Translation from Hindi: Your eyes have found me worthy of your love; Oh, beats of my heart stop now, I have found my destiny.—Raja Mehdi Ali Khan)

Photo 2. Wedding photo following ceremony, 1954.

(*कभी-कभी मेरे दिल में ख़्याल आता है कि जैसे तुझ को बनाया गया है मेरे लिए तू अब से पहले सितारों में बस रही थी कहीं तुझे ज़मीं पे बुलाया गया है मेरे लिए/Kabhi kabhi mere dil me khayaal aataa hai ke jaise tujhko banaaya gayaa hai mere liye; Tu ab se pahle sitaaron me bas rahee thee kahin, tujhe zameen pe bulaaya gayaa hai mere liye*. Translation from Hindi: *Sometimes, in my heart a feeling emerges that you've been created just for me; Until now you were living among the stars somewhere, you've been called down to earth just for me.*—Sahir Ludhianvi)

Photo 3. Photograph taken at home a few months after our wedding in 1954 in Hoshiarpur, Punjab, India. I was 24 and Rani was 19.

(ਰਲ ਗਈ ਸੀ ਇਸ ਵਿੱਚ ਇਕ ਬੂਦ ਤੇਰੇ ਇਸ਼ਕ ਦੀ, ਏਸੇ ਲਈ ਮੈਂ ਜ਼ਿੰਦਗੀ ਦੀ ਸਾਰੀ ਕੁੜੱਤਣ ਪੀ ਲਈ/*Rall gai si es vich ik boond tere ishq di; Esse layi main zindagi di saari kudattan pee layi.* Translation from Punjabi: *Because a drop of your love had blended in, that is why I drank the entire bitterness of life.*—Amrita Pritam)

The great city of Lahore, the ancient and beloved city of the Punjabis, had shaped my youth. Colonialism and the partition of Punjab had shaken my faith in humanity. America and New York City had reestablished that lost hope and reshaped my life. In 1958, there were few Indians in the New York City and only a handful at Cornell.[2] In fact, minorities were rare in the higher strata of American academia of the 1950s. They were especially scant at Ivy League schools such as Cornell and Columbia. After spending five gloriously happy years in New York City—where I learned how to manage a laboratory, write grants, lecture medical students, present at major conferences, and conduct top-notch biomedical research—I was ready to embark on a solo academic career. I had my sights set on MD Anderson Cancer Center in Houston, Texas. I had a wonderful visit there and, subsequently, was offered a position. However, my wife did not prefer Houston due to its stifling heat and humidity. Family has always been most important to me ("*A man should never neglect his family for business.*"—Walt Disney). So, I reapplied and finally accepted the position of assistant professor in the Anatomy Department at Georgetown University School of Medicine in Washington, DC. Along with this position came the coveted Green Card.[3]

This was an era without the Internet, Skype, or Facetime. Long hours in the research lab and teaching meant that I was away at work from early morning until late evening without access to my family. I almost always worked on the weekends. When I accepted the position at Georgetown, I requested the department chair for a leave of absence to visit the extended family (my wife's and mine) in India after five long years. The department chair kindly agreed and even encouraged that we spend at least six months there prior to joining Georgetown. His gracious gesture left a deep impression on me. I would return the favor to my colleagues and students throughout my career. With his blessings and a tenure-track appointment letter in my pocket, we boarded the gorgeous RMS Queen Elizabeth, a luxury ocean liner operated by the Cunard Line, for London (Photos 4 and 5). Following a month at sea on another luxury liner, we finally arrived in India to the delight of our families.

[2]From humble beginnings, Indian immigrants have overcome great odds to become one of the most influential communities in American society today. Indians trickled into the US beginning in 1790, when the first settlers from the subcontinent landed in Massachusetts. Only 523 Indians immigrated between 1820 and 1898. In 1900, only 2,050 people of Indian heritage resided in the US. In 1946, the Luce-Cellar bill was signed into law that provided for the admission of 100 Indians per year and allowed them to become citizens. As a result, 6,474 East Indians entered between 1948 and 1965. Indians in the New York Metropolitan Area now constitute one of the largest Indian communities in the US. (Data cited here is courtesy of the US Census Bureau of the US Department of Commerce.)

[3]A Green (or Permanent Resident) Card holder is a US resident who has been granted authorization to live and work in the US on a permanent basis. US immigration laws provide a variety of ways for people to apply for a Green Card, including through one's family, a job offer/employment, refugee/asylum status, or several other special provisions. Someone else usually must file (sponsor) the petition, although one may be eligible to file it themselves in some cases.

Photo 4. My wife and I, photographed in 1963 on board the ocean liner RMS Queen Elizabeth, *en route* from New York Harbor to Southampton in the UK. Operated by Cunard Line, it provided weekly luxury transatlantic service between New York City and Southampton, via Cherbourg in France. At that time, it was the largest passenger liner.

Photo 5. RMS Queen Elizabeth approaching her berth at Pier 90 in the North River at New York City in the late 1940s. Photograph of the painting by Robert Lloyd.

I was 33 years old and felt that I already had experienced a lifetime of upheaval during India's partition when I was forced to flee Lahore. I also felt the weight of responsibility having married at age 24. I had tasted professional success after working at some of the planet's most prestigious universities in a country that I had always admired. Naturally, I felt a huge sense of personal and professional achievement. However, little did I know that I was just a rookie and life was just beginning!

A few months after arriving in India, I was approached by Dr. A. C. Joshi, the Vice-Chancellor[4] of Panjab University in Chandigarh, a city that did not even exist prior to 1947. I was heavily recruited and given an impressive initial offer to serve as Founding Head and Reader of the Department of Biophysics at the newly founded university. Frankly, I was not interested at all to stay in India and was eagerly looking forward to joining Georgetown to start my research and teaching activities. My wife was in contact with a realtor in Washington, DC, for the purchase of a small house near the campus. I also was reluctant to stay in India, fearing that I would not be able to conduct cutting-edge biomedical research in a university that was barely getting off the ground. Moreover, the department had no faculty, instruments, or staff. The Basic Medical Sciences (BMS) building (Photo 6), where the department would be eventually based, was still under construction. Nevertheless, I decided to visit the university and meet the Vice-Chancellor. I had two meetings with him and, during the second meeting, was seated next to other highly-sought-after recruits to lead various departments. I was impressed to learn the credentials of the other candidates as we were seated in the ornate waiting room. One of them was Dr. Manmohan Singh, who had completed his doctorate at Oxford in 1962 and was slated to be the Economics Chair.[5] Dr. Singh ultimately would serve as the Prime Minister of India from 2004 to 2014. Dr. Joshi sealed the deal once he offered to construct a new Electron Microscope Facility for me, only the fourth or fifth one in India at that time. The closest one was in Delhi at the prestigious All India Institute of Medical Sciences (AIIMS), under the charge of my colleague, Dr. R. K. Misra, who was the Professor and Head of the Biophysics Department there. I accepted the position at Panjab University in Chandigarh in spring 1964. By then, my parents also had resettled in Chandigarh, having built a beautiful home there. Thus, the first part of my professional journey began in Lahore ("The City of Gardens"), unfolded via New York City ("The City that Never Sleeps"), and ended in Chandigarh ("The City Beautiful").

[4]The chief academic and administrative officer of the university, equivalent to a president at a US university.

[5]A year later in 1965, I purchased a new car, a rare event in India at that time. In fact, there were a handful of motor vehicles on the sprawling Panjab University campus in the 1960s. Dr. Singh, who had taken over as the economics department chair, rode a bicycle to work. Since our office buildings were close by, often we would pass each other; he would wave at me as I drove by.

Photo 6. The Basic Medical Sciences (BMS) building where my Department of Biophysics was housed for 50 years from its founding in 1964 until 2014. The Electron Microscope Laboratories occupied the basement of the building. The distinct modern architectural style of Pierre Jeanneret is evident.

I became a scientist in 1951 and, in a sense, continue to pursue that profession to this day. At 93, though, it takes me a bit longer to read and hear. Perhaps I need more time to grasp cutting-edge concepts and novel scientific terminology. While these developments about my diminishing abilities are topics of interest and concern to some, I am less bothered by them. In my view, these are normal and to be expected with aging as the brain atrophies and the ventricular width increases. Since my retirement in 1992, there have been numerous advancements in the tools and techniques in the areas of my research that often mystify me. Frankly, I am astounded at the explosion of information, which leaves me in a state of "information overload." There was a time when I was on top of publications and literature pertaining to my research. Now, there are so many more journals and publications than when I was a young scientist.

Not everything is positive in biomedical research. I notice some trends that I am not too pleased about: plagiarism, recycling of data, scientific fraud, sloppy science, non-disclosure of financial research support, improper or incomplete oversight of researchers by professors/advisors, broken peer-review system, marketing of basic research as translational, rise of provocative statements on university or company websites, misinformation journalism, and so on. The current pervasive culture of science rewards flashy, eye-catching, and positive findings.

Negative data is often shielded from peer reviewers and the scientific community. Over the past 30 years, I have noticed that the drive to succeed, ambition, and pride cloud scientific judgement. The distinction between creative thinking and biased interpretation is a narrow one. There is also the negative impact of the rise of predatory journals (i.e., publications that accept articles and payments from authors, while bypassing scientific due diligence and fact-checking)—all contributing to the pollution of scientific literature. The honor system in academia—by which I have abided religiously—is in a shambles. I will shed further light on these troubling issues later (Section 10.16).

In addition to my academic endeavors summarized above, and detailed ahead, this chapter should give the reader some insight into my personal life. I hope it provides a glimpse into my strong motivation and powers of survival under suppressive conditions. My life's joys, tribulations, confessions, and twists are highlighted. While my journey may have had its share of potholes and roadblocks, there have been many more sun shines and rainbows. My intentions are always good; this is paramount to me. I believe that if you have good intentions and are honest in your actions, the results will reflect your sincerity. Remember that failures and successes are relative, one often leading to the other. Always keep your focus on the prize; ignore background chatter. Value life, love, and time. Learn to forgive and forget. I always have treated everyone with respect—faculty members, staff, students, children, family members, and strangers—even if they did not appreciate or reciprocate ("*I've learned that people will forget what you said, people will forget what you did, but people will never forget how you made them feel.*"—Maya Angelou).

We all forget how fragile we are. When I used to teach anatomy, I often incorporated parts of my colleague Dr. Vid Persaud's classic *The Developing Human: Clinically Oriented Embryology*[6] into my lectures. I was constantly reminded of the numerous human embryonic and fetal syndromes that can appear before the miracle of birth. We arrive on this planet with odds stacked against us. And, when we are here, we are so temporary in the grand scheme of things. Plans and dreams can alter in a flash. As I reflect on my history, I realize that life is full of contradictions and extremes, including ups and downs. I have slept on the cold ground of a refugee camp, yet also walked the hallowed halls of the Ivy League. I have gained much in professional life and yet felt that there was nothing much left when I lost my young son. I have endured the betrayal of false friends and certain family members and yet have been embraced by the unconditional love of many more. Nevertheless, I continue to seek the best in mankind ("*I believe in the sun, even when it is not shining. I believe in love, even when feeling it not. I believe in God, even when God is silent.*"—Anonymous).[7] I strive to make an honest effort and difference each day, providing a bit of

[6]Moore, K. L., Persaud, T. V. N., Torchia, M. G. (2019). *The Developing Human: Clinically Oriented Embryology*. 11th edition. Elsevier, Philadelphia, Pennsylvania, USA.

[7]Horvath, M. (1988). Even when God is silent. University of Houston. Available at: https://www.houstonpublicmedia.org/articles/arts-culture/2018/02/01/263905/composer-michael-horvit-talks-about-his-piece-even-when-god-is-silent/ (accessed on April 30, 2023).

bliss to those around me. I believe that we all contribute to the world's problems and, therefore, have a moral obligation to respond—a sense of duty to make a difference, even if it is tiny ("*To leave the world a bit better…To know even one life has breathed easier because you have lived. This is to have succeeded.*"—Ralph Waldo Emerson). I continue to press on because, in the words of Robert Frost, "*I have promises to keep, And miles to go before I sleep, And miles to go before I sleep.*"[8]

10.2 Early Days in Lahore, British India

I was born in Lahore, in the prosperous state of Punjab in British India (Map 1), on Christmas Day 1929 to a family that greatly valued education, culture, philosophy, music, and poetry. I lived in Lahore until August 15, 1947, when Punjab was partitioned by the British colonists as they made a clumsy and hasty exit out of India.[9] Both of my parents were Punjabis—my mother a Sikh and my father a Hindu. Their ancestors possibly could be traced to Western Punjab, bordering Persia and Afghanistan. Discipline, honor, truth, love, and spiritual growth shaped my youth and adult life. Prior to August 15, 1947, Punjab, the "Land of Five Rivers," had the shape of a beautiful butterfly (Map 2).

A year before my birth, in November 1928, the prominent freedom fighter Lala Lajpat Rai, the "Lion of Punjab," had been brutally beaten in Lahore during a peaceful protest, which ultimately led to his death.[10] Six days after I was born, on December 31, 1929, Pandit Jawaharlal Nehru (1889–1964) as Congress President at its Lahore session unfurled the tricolor (Indian national flag) on the banks of the river Ravi and gave the call for *Purna Swaraj* (Hindi, "complete self-rule or sovereignty") from British colonial rule in India. The year 1929 also marked the 10th anniversary of a horrific episode in world history, which lasted a mere ten minutes but reverberates to this day in the conscious of every Punjabi.[11] It is the *Jallianwala Bagh* (Punjabi, "the garden of the Jallah-man") massacre in Amritsar, the sister city of and only 34 miles from Lahore. Here, 150 British troops (British India Army) assumed positions on elevated ground towards the main entrance of the Jallianwala Bagh. Then, at six minutes to sunset, they cold-bloodedly opened

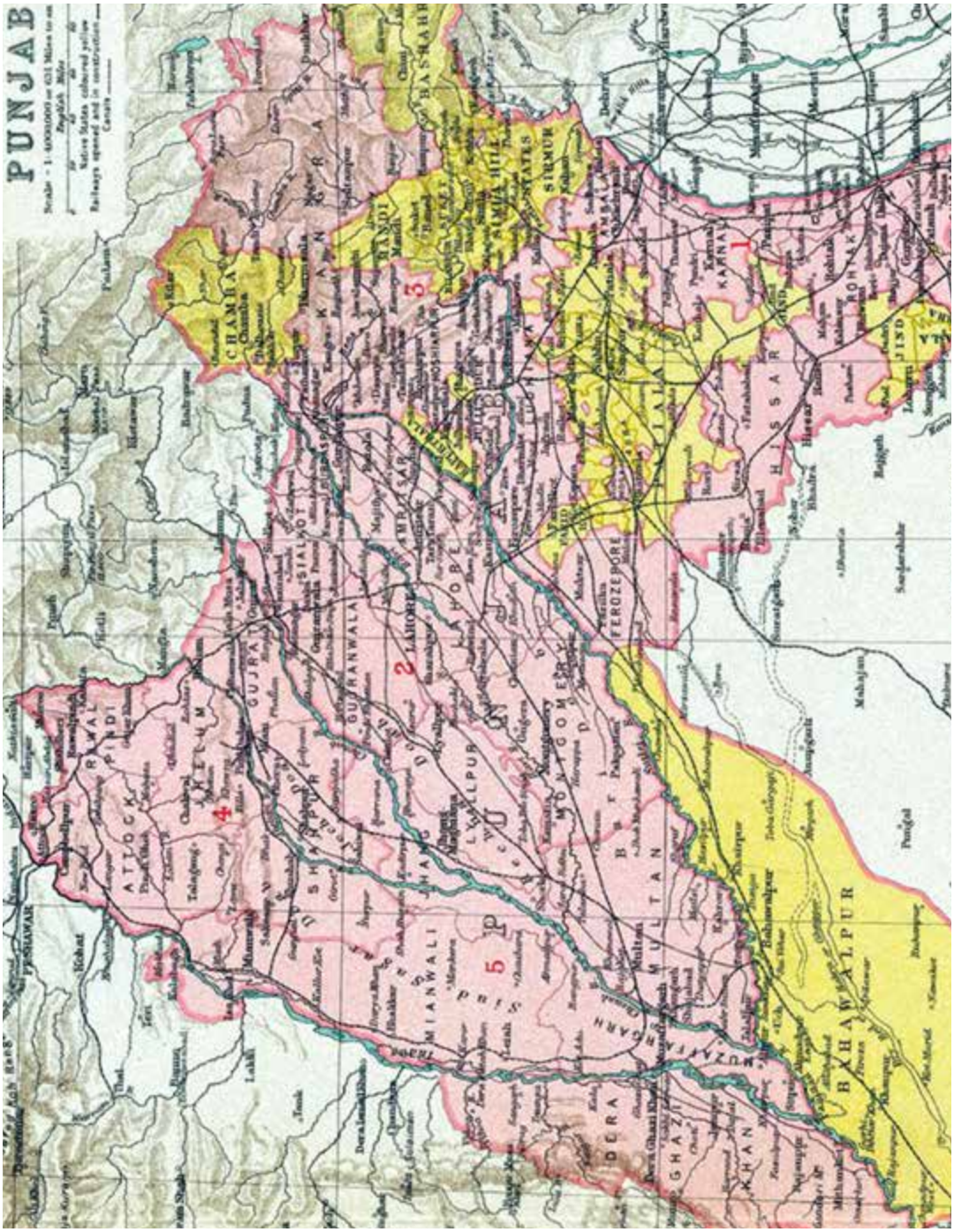
[8]Frost, R. (1923). Stopping by woods on a snowy evening. *The Poetry of Robert Frost: The Collected Poems*. Lathem, E. C. (editor), Henry Holt and Co., New York, USA.

[9]Punjab Province (British India). Available at: https://www.youtube.com/watch?v=a216QAFnaFE (accessed on April 30, 2023).

[10]Lala Lajpat Rai. Available at: https://www.youtube.com/watch?v=-cJtrZSWsM0 (accessed on April 30, 2023).

[11]The Irish War for Independence (*Cogadh na Saoirse*) started in 1919. The summer of 2022 marked the 75th anniversary of The Partition of India and the 100th anniversary of the Irish Civil War (*Cogadh Cathartha na hÉireann*). The British were involved in both horrible events; their leadership even involved a few of the same players. In the case of India, they partitioned the country as they made a hasty retreat. In the case of Ireland, they forced it to cede six northern counties.

Map 1. Map of India under British occupation prior to August 1947. It shows British India in two shades of pink and Princely States in yellow. The Partition was the parting gift of the British colonists that tore India into three pieces—West Pakistan (now Pakistan), India, and East Pakistan (now Bangladesh). Burma and Ceylon (now Sri Lanka) at one time were also part of India. On the eve of independence in 1947, India comprised nearly 600 states, each with its own maharaja, nizam, or prince. The process of their absorption brought many problems, including their reluctance to cede power as well as the integration of administrative/legal systems into a common and secular national structure.



Map 2. Map depicting Punjab province, with its five rivers, on the north-western front of India as it existed in 1909 prior to its partition in August 1947. Bengal Presidency in the eastern front of India was similarly carved out in 1947 by the British imperialists as East Pakistan (now Bangladesh). Therefore, among Punjabis and Bengalis, The Partition resonates at an almost visceral level as a moral tragedy. In this chapter, I focus entirely on Punjab's partition although the enormous Bengali story runs parallel to and intersects with it, which I have neither skill nor space to address.

fire without warning on an unarmed crowd of 20,000 Punjabis celebrating Baisakhi.[12] They continued shooting until their ammunition was exhausted, thus killing and wounding hundreds.[13] In the end, roughly 1,650 rounds were fired. The bullet marks still can be seen on the walls of Jallianwala Bagh, which is now a national memorial. This monstrous episode[14] marked the beginning of the end of the British rule in India. Shamefully, no British government official or member of the British monarchy has ever apologized for the massacre ("*One cannot and must not try to erase the past merely because it does not fit the present.*"—Golda Meir). Hopefully, the current UK Prime Minister Rishi Sunak, whose parents are Punjabis, can ease the century-old grief of the Punjabi people by offering an official apology. I was born into this climate of freedom and patriotic fervor. I was named "Sukhdev"[15] as a homage to a Punjabi freedom-fighter by the same name.

Both my parents had a strong work ethic. At an early age, I too acquired this characteristic and was motivated to do my best at whatever task I encountered. My father was Secretary of Education at Lahore Corporation, a prestigious government position. His massive library, including the *Encyclopedia Britannica* and *National Geographic* magazines, opened my eyes to the outside world at a young age ("*A room without books is like a body without a soul.*"—Cicero). He was a sensitive, calm man, who always was open to new ideas. His most impressive trait was that he was a good listener—patient and never interrupting ("*Nature hath given men one tongue but two ears, that we may hear from others twice as much as we speak.*"—Epictetus). The only times I witnessed anger on his otherwise

[12]*Baisakhi*, also pronounced *Vaisakhi*, marks the first day of the month of *Vaisakh* and traditionally falls on April 13th or April 14th as a celebration of the spring harvest, primarily in North India. It is also known as the harvest festival of Punjab and is celebrated by people across religions.

[13]The Indian philosopher-poet Rabindranath Tagore, who had been awarded the Nobel Prize for literature in 1913 and subsequently was knighted by the British government, returned his knighthood as a sign of dismay. In his letter to the Viceroy, he summed up the fury of the Indian people: "*The time has come when the badges of honour make our shame glaring in their incongruous context of humiliation and I for my part wish to stand shorn of all special distinctions, by the side of those of my countrymen, who for their so-called insignificance, are liable to suffer a degradation not fit for human beings.*" Source: Jallianwala Bagh Massacre: 103 years of Tragedy. Available at: https://www.jagranjosh.com/general-knowledge/jallianwala-bagh-massacre-causes-and-its-impact-1446016915-1 (accessed on April 30, 2023).

[14]100 Years of Jallianwala Bagh: How the massacre unfolded. Available at: https://www.youtube.com/watch?v=lYpgHP7hjjg (accessed on April 30, 2023).

[15]Sukhdev Thapar was a major Indian freedom fighter who along with his best friends and partners, Bhagat Singh (1907–1931) and Shivaram Rajguru (1908–1931), swore to avenge the murder of Lala Lajpat Rai, as well as the Jallianwala Bagh massacre (and they did). He, along with Bhagat Singh and Rajguru, was hanged in Lahore Jail in 1931 by the British government at the age of 23. This trial is an important event in Indian history, as it went contrary to the fundamental doctrine of criminal jurisprudence. An *ex-parte* trial was against the principles of natural justice according to which no man shall be held guilty unless given an opportunity to defend in a hearing. The Communist Party of Great Britain condemned the case at that time: "*The history of this case, of which we do not come across any example in relation to the political cases, reflects the symptoms of callousness and cruelty which is the outcome of bloated desire of the imperialist government of Britain so that fear can be instilled in the hearts of the repressed people.*" Source: Rana, B. S. (2008). *Bhagat Singh: An Immortal Revolutionary of India*. Diamond Pocket Books, New Delhi, India.

smiling face was when he suspected deception or distortion. It is a wonderful characteristic, one which I wish I had inherited from him. At various points in his life, he taught and published textbooks on mathematics and physics. My mother was a homemaker, who rose early to clean and cook for the entire household. She was the glue that held everything and everyone together. She was fair yet firm, which was the only way to keep our large brood in check. My mother liked to entertain and invite guests to eat with us. She was exceptionally good in the kitchen. While my father's features almost always were composed, those of my mother rarely were. Moods and humor slipped across her face like images passing across the waters of a lake.

Ours was a joint family that lived in a magnificent home in one of Lahore's impressive neighborhoods. I grew up surrounded by my ten siblings, loving parents, deep friendships, and a feeling of community. Our cohesiveness was characterized with love, kindness, honesty, honor, and generosity—important features of the Punjabi culture that are gradually eroding (*"Kindness is the language which the deaf can hear and the blind can see."*—Mark Twain). I made several very close friends, a few of whom still keep in touch; most are gone now. Our infrequent conversations generally are hard to decipher over the phone, given our poor hearing and other issues associated with advanced age. One of our neighbors was a widow with two young children, a boy and a girl. The widow had returned from Kenya, where she had lost her husband, a civil engineer employed by British Rail. Her daughter was Sudesh, who was born near Nairobi and became my wife in 1954. I was 24 then and a newly minted PhD; she was 19.

Ours was city life with amenities found on prosperous farms. Milk, eggs, vegetables, honey, meat, and fruit all were obtained from the massive garden on the rear of our property. At an early age, I learned to herd cows into the courtyard, milk them, and clean their udders. Life was carefree, and I relished daily chores. It felt as though we lived in a cocoon in contrast to our surroundings. British treatment of the tough Punjabis was especially harsh, because we were perceived as a major threat to Britain's precarious hold on India. Central Lahore Jail (also called Kot Lakhpat Jail) was the site of frequent hangings of Punjabi freedom fighters.

Our schooling was supplemented with regular private lessons at home, often by my father from his math and physics textbooks. He felt that such home schooling was important to take control of the narrative of our own country's history, art, culture, philosophy, and poetry, which had hitherto been dominated by European voices. I became fluent in English, Punjabi, Hindi, and Urdu. I also studied Farsi (Persian)[16] and Sanskrit. Gurmukhi and Shahmukhi as Urdu and

[16]Persian is known as Farsi in Iran, Dari in Afghanistan, and Tajik in Tajikistan. Note that Punjabi and Urdu were our languages in the western part of Punjab province in British India. The languages of the Indian Punjab state (called East Punjab in 1947 at the time of The Partition) today are primarily Hindi, Punjabi, and English. The languages of the Pakistani Punjab province (called West Punjab in 1947 at the time of The Partition) today are primarily Punjabi, Urdu, and English. In other words, Punjabi continues to be the language of Punjabis today, whether they reside in India or Pakistan.

Farsi were compulsory subjects at the primary level in public schools of the pre-partitioned Punjab.[17] Relative to the lives of my peers, it certainly was a life of luxury and comfort, though I did not fully appreciate it at the time. Listening to music was my refuge and escape from loneliness ("*Music expresses that which cannot be put into words.*"—Victor Hugo).

Being quite athletic, I learned horseback riding and archery. However, kite flying or *patang* (Hindi, "fighter kite") was a passion of mine. I especially enjoyed this ancient Indian tradition during Basant. Basant is a springtime kite-flying event during the Basant Panchami festival in Punjab. It is no exaggeration to say that the sky used to turn into a rainbow and that there used to be no space for the birds to fly. Brought into the country by Chinese travelers, the earlier kites were used for measuring distances, signaling and for communicating military operations. The kites I used in Lahore and later in Hoshiarpur were delicate ones made of paper and wooden sticks. I hear that they are now made with flexible materials that make them more resilient. Kites were generally shaped like a diamond, with a center spine and a bow shaped intersecting the spine that gives them their shape. In addition to other typical rural Punjabi childhood games like *Punjabi Kabaddi* (*Circle Kabaddi*), *Gilli-Danda,* and *Pittu Garam (Seven Stones)*, I played field hockey and cricket. Field hockey and cricket are part of growing up in Punjab, like ice hockey in Canada or soccer in Germany. Field hockey and cricket were sports of obvious choice, given the dominance of Punjabi players on the national teams of both sports as well as their impressive performance at international events. The Indian teams dominated the international hockey scene, winning six straight Olympic gold medals and 24 consecutive matches between 1928 and 1956 and two more gold medals in 1964 and 1980. There are historical records that suggest early forms of hockey were played in Egypt and Persia around 2000 BC. A game like field hockey was played in the 17th century in Punjab under the name, *khido khundi* (*khido*, Punjabi, "woolen ball"; *khundi*, Punjabi, "to the stick"). "*Hockey, more than any other game, is etched in the Indian psyche. It is hockey that brings out the magic and mystery, the poetry and prose in Indian sport.*"[18] In the 1980s, the international governing body introduced AstroTurf, which provided an edge to European teams. It was a carefully crafted move. I feel that this took the beauty and finesse out of the game. Political clout and money have corrupted international sports whether it is the Olympic Games, test cricket, or the FIFA World Cup.

[17]The two scripts used for Punjabi are Gurmukhi and Shahmukhi. Shahmukhi came in use by Punjabi Sufi poets to write the Punjabi language, starting in the 12th century. Shahmukhi script is the standard script in Pakistani Punjab province used for Punjabi while Gurmukhi script is used in the Indian Punjab state. Shahmukhi is generally written in the Nastaʿlīq calligraphic hand, which is also used for Urdu. Shahmukhi is written from right to left while Gurmukhi is written from left to right.

[18]Sardesai, R. (1992). *Sunday Times of India*.

10.3 Punjab: Land of Five Rivers and India's Gatekeeper

Punjab (Gurmukhi: ਪੰਜਾਬ; Shahmukhi: پنجـــاب) is a geopolitical, cultural, and historical region in the northwestern part of the Indian subcontinent, comprising areas of eastern Pakistan and northwestern India (Maps 1 and 2). Although the name Punjab is of Persian origin, its two parts (پنج, *panj*, "five" and آب, *âb*, "water") are cognates of the Sanskrit words, पञ्च, *pañca*, "five" and अप्, *áp*, "water," of the same meaning. The word *pañjâb* thus means "The Land of Five Waters," referring to the rivers Jhelum, Chenab, Ravi, Sutlej, and Beas. All are tributaries of the Indus River, the Sutlej being the largest. The ancient Greeks referred to the region as Pentapotamía (Greek: Πενταποταμία), which has the same meaning as the Persian word.

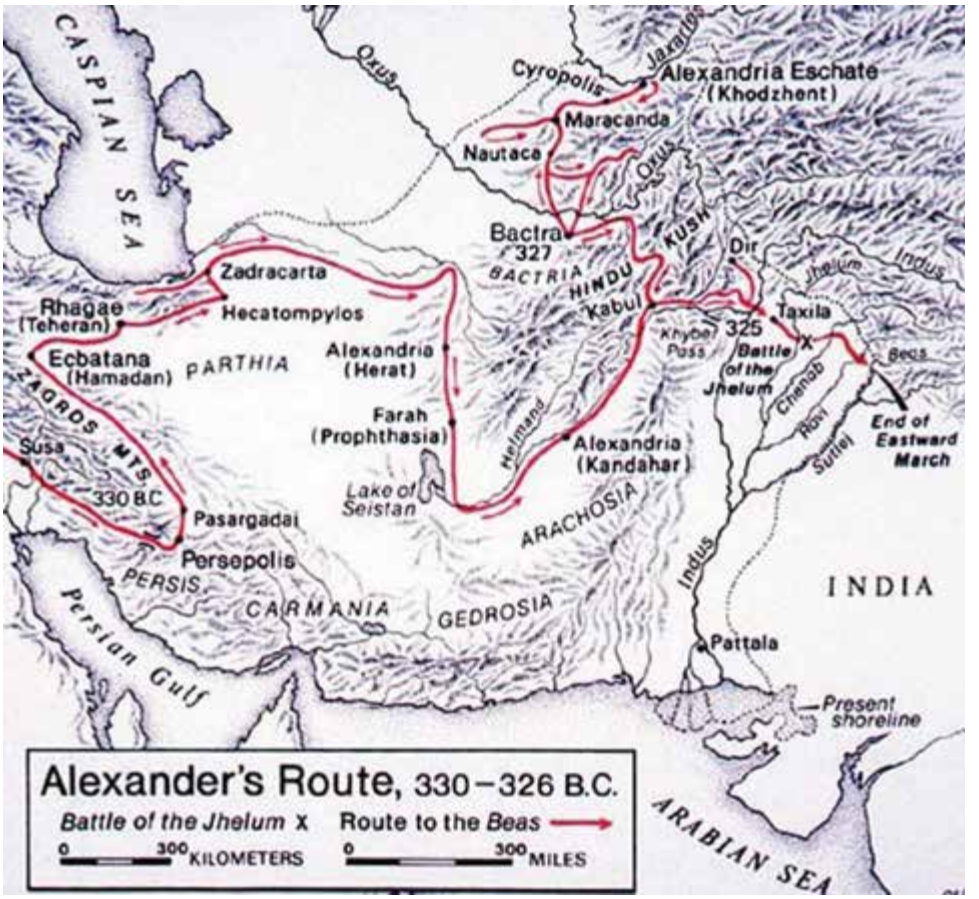
Punjab also happened to be the land of tremendous intellectual ferment. The Vedas, Ashtadhyayi, Guru Granth Sahib, Yoga Sutras, the Bhagavad Gita, Puranas, and many of the Dharm Sutras were composed here. References to a land of five rivers may be found in the Mahabharata (Sanskrit, "Great epic of the Bharata dynasty"). Mahabharata is one of the two major Sanskrit epics of India, valued for its literary merit and its religious inspiration (the other being the Ramayana). It is a text about both *dharma* (Sanskrit, "Hindu moral law") and *itihasa* (Sanskrit, "that's what happened"). Contained within the Mahabharata is the Bhagavad Gita (Sanskrit, "The beautiful song by God"), Hinduism's most important religious book. The sage Vyasa (c. 5 BC) is traditionally named as the Mahabharata's author and the poem reached its present form around 400 AD. The poem is made up of almost 100,000 couplets—about seven times the length of the *Iliad* and the *Odyssey* combined—divided into 18 *parvan*s (Sanskrit, "sections"), plus a supplement titled Harivamsha (Sanskrit, "Genealogy of the God Hari"; i.e., of Vishnu). Its various incidents have been portrayed in stone, notably in sculptured reliefs at Angkor Wat and Angkor Thom in Cambodia and in Indian miniature paintings.

The geography of Punjab has influenced its history. Being the gateway of India, attacks by foreign invaders for thousands of years was borne by Punjab, which suffered heavy human and monetary casualties. In contrast, the rest of the country continued to live a life of splendid isolation. The plains of Punjab were sites of decisive battles, which were fought by Punjabis to check invaders from entering the interior of India. Every invader sought possession of Punjab and a road to fame. Among those who occupied Punjab until the 18th century were the Persians (Cyrus and Darius), Macedonians (Alexander the Great), Scythians, Parthians, Kushans, Huns, Arabs, Turks, Mongols, and British. In fact, Punjab was the last part of India to be annexed by the British. In 1849, Punjab fell to the troops of the British East India Company and subsequently became a province of the British Crown.

Alexander the Great (356 BC–323 BC) (Map 3) was one of the most famous warriors to venture into Punjab (Image 1).[19] There, at the Battle of the Hydaspes

[19]The true story of Alexander the Great, History Channel. Available at: https://www.youtube.com/watch?v=imRNmDnkUcE (accessed on May 5, 2023).

in 326 BC, he *might* have lost to the Punjabi King Porus, a legendary warrior whose territory spanned the region between the Jhelum River (Hydaspes) and Chenab River (Acesines) in Punjab. A fierce battle in a raging thunderstorm was fought, and, for the first time, the Greeks encountered elephants in war. It was by far the toughest battle of Alexander's entire military campaign. Apparently, the huge beasts and their awful trumpets made the Greek horses tremble. The death of his beloved horse, Bucephalus, is attributed to the battle. In the aftermath of this epic battle, an impressed Alexander not only reinstated Porus as his satrap but also granted him dominion over lands to the south-east extending as far as the Hyphasis (Beas River). Since Porus is only mentioned in Greek sources, which differ considerably among themselves, it is hard to confirm the details of the battle with certainty. Historians have argued that Alexander was, in fact, defeated by Porus and that the two men became friends, and that this explained why Alexander left him enormous territories ("*History is a set of lies agreed upon.*"—Napoleon Bonaparte). One thing is undisputed: Alexander's eastward march into India ended in Punjab; unable to wage war, he was forced to return home. Did his army mutiny in Punjab or was he defeated by Porus?



Map 3. Alexander's eastward march into Punjab and his route to the Beas River.

Image 1. An oil-on-canvas painting titled *Alexander and Porus* by Charles Le Brun depicting Alexander and Porus during the Battle of the Hydaspes (Jhelum River). It was painted in 1673 and currently hangs in the Louvre Museum in Paris.

The predominant ethnolinguistic group of the Punjab region is the Punjabi people, who speak the Indo-Aryan Punjabi language. Punjabi Muslims are the majority in West Punjab (now Punjab province of Pakistan), while Punjabi Sikhs and Punjabi Hindus are the majority in East Punjab (now Punjab state of India). Other religious groups include Christians, Jains, Zoroastrians, Buddhists, and Ravidassias. Punjab, which consists of rich and fertile plains, emerged as an important agricultural region, especially following the Green Revolution from the mid-1960s through the mid-1970s. It continues to serve as the breadbasket of both India and Pakistan.

10.4 Lahore

جس نے لاہور نہیں دیکھا وہ پیدا ہی نہیں ہوا/*Jis Lahore Nai Vekhya O Jamyai Nai*

(*One who has not seen Lahore has not been born.*)

— Anonymous

Lahore in British India—now in Pakistan[20]—was one of the largest cities and the historic-cultural center of Punjab and the entire northern region of the subcontinent (Photo 7). It was the seat of Urdu poetry, splendid Mughal architecture, Punjabi cuisine, and philosophy. It was one of India's most sophisticated, socially liberal, progressive, and cosmopolitan cities. Lahore's origins date from antiquity. The first document that mentions Lahore by name is the *Hudud al-'Alam* (Urdu, "The Regions of the World"), written in 982 BC.

[20]Following independence, India has had its share of political turbulence. However, nothing compares to the grim state of politics in Pakistan. Pakistan has struggled with instability and military coups since its founding in 1947. The two established political dynasties clash and take turns falling in and out of favor with the military, with the victors targeting their rivals via the judiciary.

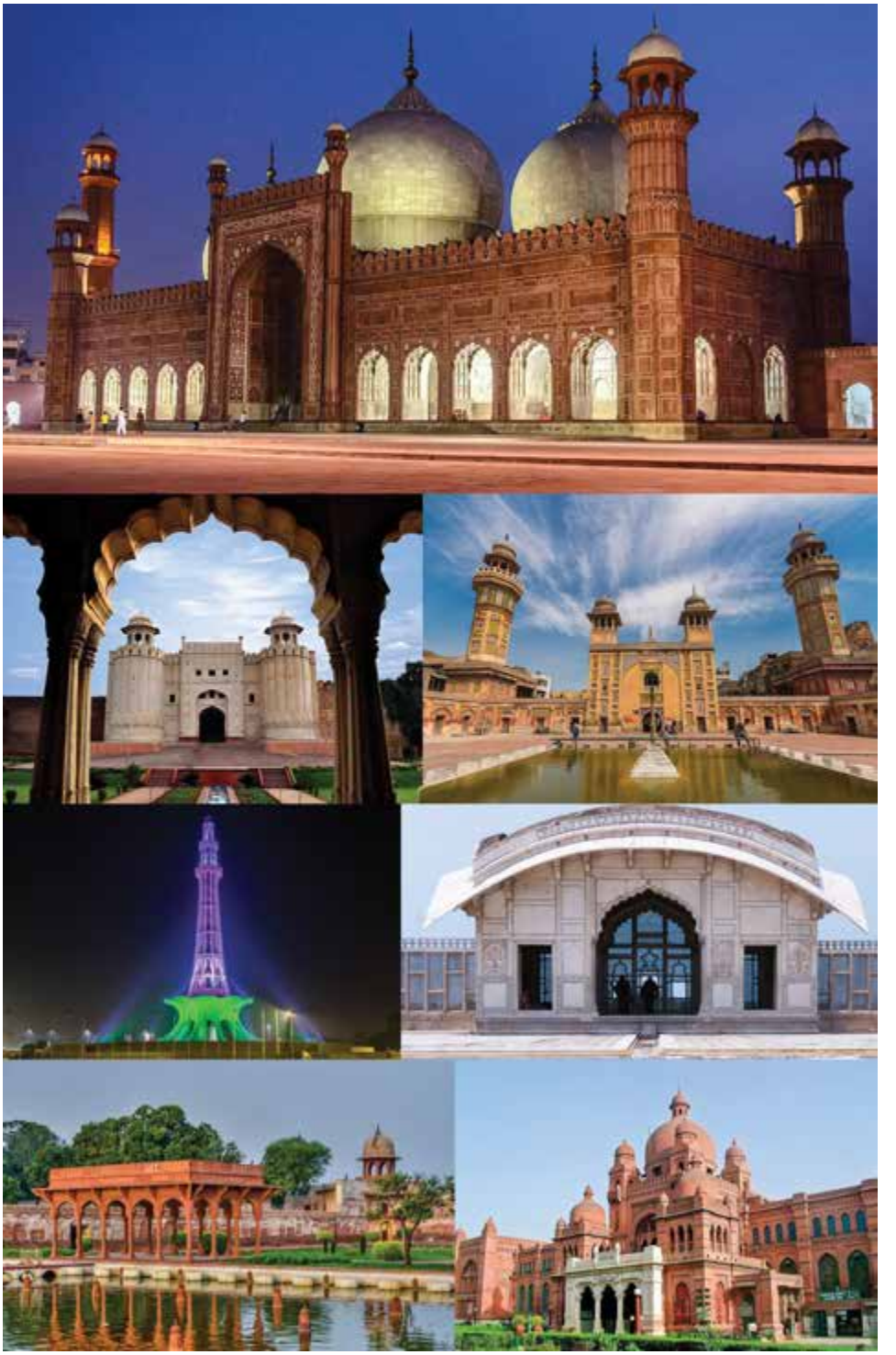


Photo 7. Major architectural attractions of Lahore. Clockwise from the top: Badshahi Mosque, Wazir Khan Mosque, Naulakha Pavilion, Lahore Museum, Shalimar Gardens, Minar-e-Pakistan, Lahore Fort, Greater Iqbal Park.

It describes it as a town that had "impressive temples, large markets and huge orchards." As previously discussed, Lahore had been controlled by numerous empires throughout the course of its history and reached the height of its splendor under the mighty Mughal Empire between the late 16th and early 18th centuries. During this epoch, Lahore served as its capital city. The Mughals lavished their love and their considerable talents on the city. However, upon its capture by Nader Shah's forces in 1739, it fell into a period of decay while being contested between Afghans and Sikhs. Lahore eventually became the capital of the Sikh Empire under the great Maharaja Ranjit Singh of Lahore (Image 2) in the early 19th century, regaining much of its lost grandeur. Lahore subsequently was annexed to the British Empire and made the capital of British Punjab. Central to India's freedom movement, the city served as the site of the declaration of Indian independence in 1929 (Section 10.2).

Image 2. Oil painting of Maharajah Ranjit Singh by the artist Manu Kaur Saluja. The painting depicts Ranjit Singh, who was blind by one eye, sitting on his golden throne within the walls of the Lahore Fort. He is in full dress armor, with the spectacular Koh-i-Noor diamond on his right arm in its original setting. Contrary to whatever story the British government may spin, it was looted by the British East India Company during the annexation of Punjab in 1849, during the reign of the then eleven-year-old Maharaja Duleep Singh. Part of the British Crown Jewels, the 105-carat diamond is currently set in the crown of the late Queen Elizabeth. The British Crown Jewels, stolen from around the world, are housed in the Tower of London and disgracefully displayed to the public as a proud mark of British colonial pride. Image courtesy of Manu Kaur Saluja and the Royal Ontario Museum, Toronto, Canada.

It is no exaggeration that since the early 1900s, including my youth (1930s and 1940s), Lahore was a unique center of intellectual interaction and activity which produced or influenced a long and distinguished line of writers, poets, artists, lawyers, movie stars, and political activists. Without a doubt, Lahore was the most highly cultured city of north India, arguably India. Distinguished intellectual centers like The Oriental College, The Mayo School of Arts, and Government College Lahore were flourishing. The city boasted of the largest number of Urdu literary journals, newspapers, and books, and two of India's best English language dailies. Distinguished journalists hosted literary events. The annual plays staged at Government College Lahore and Dyal Singh College were a treat awaited by the city's elite. The city rang with the echoes of the poetry of Urdu and Persian masters. Legendary movie stars and playback singers of Indian and Punjabi cinema—household names today—originated from Lahore.

The vibrance and pulsating intellectual activity of the Lahore of my youth of the 1930s and 1940s is beautifully captured in a memoir published in Lahore in 2012[21]:

> *The well-to-do Westernized elite drank and danced and talked in the Gymkhana and Cosmopolitan clubs. The home-grown dazzling lights set off their fireworks at the Arab Hotel, Nagina Bakery, Mukham Din's teashop, Halqa-i Arbab-e Zauq, India Tea House and India Coffee House. The greatest in the land like Tagore, came and spoke at the SPSK Hall. Political debates were held at Bradlaugh Hall. Amrita Sher Gill painted, and B. C. Sanyal sculpted. The best British and American films were screened at Regal and Plaza…The baithaks in the walled city trained young musicians and singers and invited the connoisseurs to come and listen to classical music. The radio came a little later and the literati wallowed in a new channel which immediately enlarged the circulation of what they wrote, said or composed. With Bokhari's genius presiding over the radio network, the first generation of literary broadcasters was in the making…Impressive edifices adorned the landscape*: *Lawrence Hall, Chiefs' College, Government House, High Court, Masonic Lodge, Legislative Assembly, General Post Office, Museum, Mayo School of Art, the University, Government College, and Central Training College. The queen of all roads, the Mall, was bordered by tall trees and wide footpaths, and boasted a glittering array of expensive shops. The racecourse and the Lawrence Gardens were the lungs of the city. No high-rise buildings existed. With no encroachments the roads looked wider. The bungalows of Davis, Empress, Egerton, Queens and Jail Roads were elegantly built and located in the middle of green lawns. The skyline was soothing. Nature's green was the dominating colour of the city. Breathing was easy, and so was enjoying life…The serene Faletti's was centrally located on Egerton Road, behind the assembly chamber and facing Rai Bahadur Ram Saran Das's mansion. Jinnah, Abul Kamal Azad, and Ava Gardner stayed here…Built in 1940–43 in the Lawrence Gardens, [The Open Air Theater] is a magnificent imitation of a Greek amphitheater.*

[21]Aziz, K. K. (2012). *The Coffee House of Lahore, a Memoir 1942–57*. Sang-e-Meel Publications, Lahore, Pakistan.

Theatrical companies of those days, all non-Muslim, staged plays here and young college students or fresh graduates acted in them, like [legendary future movie stars] Kamini Kaushal, Gita Bali and Om Prakash.

Furthermore, growing up in Lahore in the 1930s and 1940s, it was impossible to miss the rich history of the great city as described by esteemed Indian scholar and jurist S. M. Latif at the turn of the 20th century[22]:

Although the capital of the Panjáb could never vie with the Imperial city of Delhi, the Rome of Asia, in the variety and profusion of its ancient monumental remains, or with the city of Akbar (Akbarabad, or Agra) in the splendour of its architecture, it, nevertheless, possesses as many and as interesting historical sights and reminiscences as any other famous city in India; while no Indian city can boast of having been the seat of so many Imperial dynasties as Lahore. Its lofty houses, gilded minarets, and bulb-like domes, visible from afar, give it an imposing appearance, while its crowded streets, busy markets, and thriving industries, furnish internal evidence of great prosperity and successful progress. It is situated in a region famous in history as the camping ground of the early Aryan migration and civilisation, as the seat of the holy singers of the Vedic hymns—the fairer race, who, reducing to bondage, or driving back the black-skinned servile races, spread eastwards, and whose records, side by side with the Egyptian records and the Chinese philosophy, go back further than those of any other country. The Panjáb was the home of Northern Buddhism…The region calls attention from the interest attaching to it as the classic ground of Alexander's conquests, which materially influenced Brahmanism in the Panjáb, and gave the first impulse to sculptural art in Northern India…Viewed from a political standpoint, nature has given the Panjáb a crowning position in the great Indian Peninsula. It is aptly termed the steel-head of the spear of this great empire, the guard-room of India on the north. From the earliest times, the Panjáb has served as a bulwark of defence against foreign aggression, the outpost of the line of battle; and it has proved one of the greatest recruiting grounds of armies in the East. It is pre-eminently the soldier's land, "the sword in hand of India," whose warriors have fought bravely…But it is in its position as the chief city of this land of great traditions that its political interest chiefly consists. Lahore claims the attention of both the student of history and the general reader. Here, in his royal palace, did the politic Akbar held his cabinet councils. The place is associated with the loves of Jahángir and Núr Jabán, and is memorable as the birth-place of the magnificent Shah Jahán. When the reflecting mind of the pious Nanak conceived the amelioration of man's social condition and the combination of conflicting creeds into one, enjoining the worship of one invisible God, the political position given to Lahore contributed, in no small a degree, to the development of the religious order [Sikhism] established by him…In more recent times we find it remarkable as the capital of a kingdom founded by Ranjit Singh, the lion of the Panjáb…How many conquerors have fixed their eyes on this glittering prize [Lahore], the very key to India!

[22]Latif, S. M. (1892). *Lahore: Its History, Architectural Remains and Antiquities.* New Imperial Press, Lahore, India.

Lahore today is *not* the same.[23] History has dealt the lovers of Lahore more than their share of broken hearts. According to *The New York Times*: "*This graceful and cultured city, with a history that stretches by some accounts back into the days of the epic Ramayana, passed through many conquering hands—Hindu, Mogul, Persian, Afghan, Sikh and British—on the way to becoming an intellectual center of the Indian subcontinent, only to be relegated with the partition of British India to the status of a provincial Pakistani capital.*"[24] Lahore used to be called the City of Gardens. However, due to rapid urbanization, pollution, and poor planning, it has lost its aesthetically important urban vegetation, trees, and greenery. The "urban farm-life" of my childhood is gone. I still mourn the loss of my mother city, which I can visit no longer but never will forget. Lahore is the place to which I always will belong. In this context, I direct the reader to Amrita Pritam's (1919–2005) (Photo 8) masterpiece titled ਕਿਉਂ ਉੱਥੇ ਦਿਲ ਛੱਡ ਦਿੱਤਾ?/*Kyun Uthhe Dil Chhod Dita?* (Punjabi, "Why did you leave your heart there?"[25]) which reads in part

Photo 8. Amrita Pritam at All India Radio Lahore, pre-1947. She was the grande dame of Punjabi letters, who nurtured two generations of Punjabi writers and poets. Her career spanned six decades and produced over 100 books of poetry, fiction, biographies, essays, and Punjabi folk songs that have been translated into several Indian and foreign languages. Pritam was the product of the other side of Punjab (i.e., Western Punjab, now in Pakistan), and she religiously remained so all her life drawing her strength and symbols with all the sublimity embodied in the works of great Sufi poets and saints.

[23]Lahore - Before Partition (Technicolor Footage). Available at: https://www.youtube.com/watch?v=apEk8Yu0KXU (accessed on April 30, 2023).

[24]Crossette, B. (1981). *The New York Times*, June 14 Issue, Section 10, p. 1.

[25]Kyun uthhe dil chhod aaye? (Punjabi, "Why did you leave your heart there?"). Available at: https://www.facebook.com/285689198213/videos/981496262471491?__so__=permalink (accessed on April 30, 2023).

(Translation from Punjabi):

> *My grandmother used to remember Lahore all her life. She used to narrate the stories of Bano Bazar morning and evening. Wet eyes and a blind throat couldn't stop them…What kind of reality was this, which was now just a dream, what kind of city was this, which belonged to us even after leaving it, once I asked why did you leave the heart, why did you leave your heart?...Every day, we used to listen to the songs of Noor Jahan sitting on the temple and the velvet voice of Surya was spoken in the sweater. Thoughts with threads in the evening. We used to roam around in Fulkari, spreading a machete in every boat, careless…This is a matter of the time when all five rivers of Punjab lived in one country…*

10.5 Urdu: The Language of Love

I consider Urdu India's embattled language of love.[26] Urdu is a gorgeous language. It is a language of romance—more beautiful than French or Italian. Urdu, a member of the Indo-Aryan group within the Indo-European family of languages, is spoken chiefly in northwestern India (e.g., Punjab) and Pakistan. Urdu was born in north India (around Delhi) in the 12th century. It was heavily influenced by Arabic, Persian, and Turkish. For centuries, it has been the prominent language of culture and poetry in India, often promoted by Mughal rulers. Let us not forget that its literature and journalism have played major roles in India's independence movement. Apart from this, Urdu is central to romantic expression in the songs of Indian cinema that are entrenched in Indian life. Urdu has been my language of angst, heartbreak, and celebration. I grew up humming songs from India cinema that draw heavily on Urdu poetry. If Urdu is lost from India cinema, we will lose the manner with which we communicate our thoughts and feelings, our decorum. At this age, television serves as my great friend and the major source of my daily entertainment. I get a substantial dose of Urdu, Punjabi, Hindi, English, and Persian programming. Almost every night, I watch a combination of old Bollywood movies that are rich in Urdu poetry, American Westerns, old Bollywood film songs, variety programs, cricket games, and talk shows.

Contrary to what many believe, Urdu is not foreign to India or a language of Pakistan, which adopted it as its national language. Urdu is not related to any religion; it is related to culture, especially Punjabi culture on both sides of Punjab (i.e., Indian Punjab state and Pakistan Punjab province). Still, in recent years the language has taken on an Islamic identity in India. I hope this trend can be reversed. In this regard, the Rekhta Foundation, and its poetry festival, Jashn-e-Rekhta (Urdu, "celebration of Rekhta") started by Sanjiv Saraf, offer encouraging signs.[27] The foundation is devoted to the preservation and promotion of the Urdu language and culture. I also commend the superb poet Javed Akhtar and his lovely wife, the multi-talented Indian movie star Shabana Azmi for their support of this wonderful foundation and for being a regular at Jashn-e-Rekhta.

[26]Romancing Urdu. Available at: https://www.youtube.com/watch?v=mkm-6DN5guQ (accessed on April 30, 2023).

[27]Jashn-e-Rekhta 2022: The charm of Urdu is back. Available at: https://www.youtube.com/watch?v=-0UClEfxgE8 (accessed on April 30, 2023).

Much of Urdu poetry is a simple "sher"[28]—two versed lines in which the first sets up an idea and the second completes it. M. J. Akbar's 2004 "Byline" column from *The Asian Age* newspaper beautifully sums up how I feel about this lovely, sophisticated language:

> *With the ebb of Urdu, a civilization has diminished. Urdu is utterly civil, rooted in values and anchored in two words that supersede translation*: *tehzeeb and akhlaq. A "practical" Urdu-English dictionary defines tehzeeb as civilization, etiquette, manners, politeness, courtesy, polish, refinement, instruction, education, discipline, culture. It is all this and much more, including that very delicate wit that nuances an idea or a sentiment with a sensitivity that becomes a bridge between lovers and a gulf between antagonists. Akhlaq is the practice of tehzeeb.*

10.6 India: The Economic Jewel in the Crown

India was governed for the benefit of Britain. Britain's rise for 200 years was financed by its depredation of India.

—Shashi Tharoor (b. 1956),
Inglorious Empire: *What the British Did to India,* 2017.

A commercial company [British East India Company] enslaved a nation comprising two hundred million people.

—Leo Tolstoy (1828–1910), Letter dated December 14, 1908.

Indian civilization (i.e., the Indus Valley civilization) began around 5,000 years ago in the northwestern part of the subcontinent because it was watered by the regions' rivers. It was a highly sophisticated civilization of advanced cities that traded with the civilizations of Mesopotamia (Iraq) and Egypt. It featured an advanced economic system, well-developed agriculture practices, domestication of animals, and production of sharp tools/weapons from copper, bronze, and tin. There is archeological evidence of exceptional urban planning as evidenced by the well-laid streets, drainage systems, and water supply found in the valley's major cities, namely, Dholavira, Harappa, Lothal, Mohenjo-daro, and Rakhigarhi. After 1500 BC, India faced its first major wave of invaders and migrants from the north. These were the so-called Indo-Aryans, branches of a larger tribe of Indo-Europeans who settled in Persia and throughout Europe, as well as India. Originating probably in southern Russia and Ukraine, the Indo-Europeans were creative agriculturalists who were likely the first people

[28]A *sher* is a couplet in Urdu poetry; a *ghazal* is a form of poetry which is a collection of various shers. Each sher consists of two lines, and each line is called *misra*. A ghazal commonly consists of five to fifteen couplets, which are independent, but are linked—abstractly, in their theme and more strictly in their poetic form. The first line of a ghazal must include a refrain, which is a word or a phrase that can be easily fitted into the other couplets. The first sher is known as *matla*. The last Sher is called *maqta*, but only if the poet uses his *takhalus*. Note that every sher is a poem in itself; it is the smallest unit of Urdu poetry.

to domesticate horses and use war chariots in battle. India has served as the birthplace of several major religions: Hinduism, Sikhism, Buddhism, and Jainism. North India's major languages (like Punjabi) are related to Latin and Greek and therefore modern English, whereas those of South India are completely different. Also, the subcontinent has attracted visitors and invaders for centuries: Some came in numbers large enough to alter the Indian civilization, while others (merchants or pilgrims) settled there and were absorbed into the diversity of India.

European imperialism and its dehumanizing effects on the colonized are well documented.[29] They need no further analysis here; I have experienced it first hand. In the 300 years following the discovery of a maritime route to India by the Portuguese explorer Vasco da Gama, European powers—primarily the British, the French, the Dutch, and the Portuguese—made a beeline for India. Though they ostensibly came for trade and commerce, the lines between exploration and exploitation blurred rapidly. Their focus on the so-called trade devolved into an intense rivalry to loot India's fabled riches, gold, diamonds, art, spices, tea, and cotton. The result was a systematic, almost surgical striping of India's riches. It was theft on a grand scale.[30] The Mughals were an exception. The mighty Mughals weaved a fine net of harmony and safeguarded India's culture and integrity.[31] On the other hand, the British kept Indians at bay in every possible way. The Mughal empire was producing about one fourth of the world's industrial output up until the 18th century when the British showed up. In fact, India's Gross Domestic Product (GDP) had a faster growth rate during the Mughal era than in the 1,500 years prior. While the Mughals served India, the British methodically looted India.

India was the centerpiece of the British colonial empire, its economic crown jewel. India remained essential to Britain's economic well-being, a major market for exports of both goods and capital; it kept its factories humming and bank accounts expanding. All of this helped Britain, but it did not benefit Indians in any way. For example, local textile weavers and manufacturers lost their livelihoods because of cheap cloth imported from Britain. The railroads and telegraph lines in India were useful only for British commerce and administration. Unlike other colonies during the age of British imperialism, India was designed to pay for itself—without direct assistance from the home government or British taxpayers. Under the British rule, India's share of the world economy declined from 24.4% in 1700 down to 4.2% in 1950. During the 1600s, Indian GDP was 60% of British GDP; by the end of the 19th century, it had decreased to less

[29]Colonialism and imperialism. Available at: https://www.youtube.com/watch?v=x4DpXd5US9c (accessed on April 30, 2023).

[30]Dr. Shashi Tharoor, MP: Britain does owe reparations. Available at: https://www.youtube.com/watch?v=f7CW7S0zxv4 (accessed on April 30, 2023).

[31]Whenever Indian cinema is discussed, one name always surfaces. It is the 1960 movie, *Mughal-e-Azam* (Urdu, *"The Great Mughal"*), the gold standard by which all Indian cinema is judged. This magnum opus of cinema remains one of the most impressive works in terms of story, direction, set design, costumes, Urdu and Persian poetry, musical score, songs, and dialogues. In my view, it rivals Hollywood movies like *Gone with the Wind* and *Sound of Music*. Mughal-e-Azam. Available at: https://www.youtube.com/watch?v=e7hP9UNp0Hw&t=1693s (accessed on May 1, 2023).

than 15%.[32] From the 1st century until the start of the British colonization in the 17th century, India's GDP varied between 25% and 35% of the world's total GDP—more than Europe's combined GDP.[33] It dropped to 2% by the time the British hastily departed India in 1947. Few know that a primary cause of India's post-independence poverty is the interest of the loan of INR 1,800 to 2,000 crore for which responsibility of repayment was inherited by the government of independent India, as per the Transfer of Power Agreement.[34] These economic examples are merely brushstrokes that paint a picture of how British colonial rule negatively affected India—not only during colonial rule but also after The Partition of India.

The British drained the resources of India, damaged its economy, and financed the British expansion for 200 years.[35] In my opinion, nothing good came from the British colonial rule. The British journalist Richard Gott has been unsparing in his denunciation of Britain's imperialism[36]:

> *We now know that the British Empire was essentially a Hitlerian project on a grand scale, involving military conquest and dictatorship, extermination and genocide, martial law and "special courts", slavery and forced labour, and, of course, concentration camps and the transoceanic migration of peoples. Whatever way we now look at Empire, this vision must remain dominant.*

10.7 India's Independence, Partition of Punjab, and My Exodus from Lahore

There's no place like home.

—*The Wizard of Oz*, 1939.

India is the one land that all men desire to see, and having seen once, by even a glimpse, would not give that glimpse for all the shows of all the rest of the globe combined.

—Mark Twain (1835–1910), American Writer

To other countries, I may go as a tourist, but to India, I come as a pilgrim.

—Martin Luther King, Jr. (1929–1968), American Civil Rights Leader

[32]Broadberry, S., J. Custodis, and B. Gupta. (2015). India and the great divergence: An Anglo-Indian comparison of GDP per capita, 1600–1871. *Explorations in Economic History* **55**:58–75.

[33]Tharoor, S. (2017). *Inglorious Empire: What the British Did to India*. C. Hurst & Co., UK.

[34]See: Dr. Rajendra Prasad's *India Divided*, originally published in 1946 and reprinted by Penguin Books in 2010 in India, pp. 401–405. This book puts an estimate of public debt at Rs. 2,000 crore (refer to table XLVII on p. 405). To really appreciate the value of 1,800 crore rupees in 1947, one must take into account that the exchange rate of the British pound was 13.50 rupees per pound, the exchange rate for the American dollar was 5.00 rupees per dollar, and pure gold was selling at 88.62 rupees per 10 grams.

[35]British Imperialism in India. Available at: https://www.youtube.com/watch?v=6KGdAdX3H8k (accessed on May 1, 2023).

[36]Gott, R. (2001). Whitewash. (Book Review). *Ornamentalism: How the British Saw Their Empire* by D. Cannadine, *The Guardian,* May 5th.

After the Second World War, freedom from the British suppression and colonial rule appeared imminent. The Punjabis, who had fought in large numbers for the British in both World Wars, were pressing for freedom. As previously discussed, Punjabis had a military legacy that spanned centuries. Just as they had protected India from earlier invasions, they wanted to defend themselves from British occupation, even if it meant employing brute force. It appeared that the Indian freedom struggle against the British had reached a breaking point ("*If there is no struggle, there is no progress.*"—Frederick Douglass).

But at what cost? As they withdrew, the British proposed carving a new Muslim nation—Pakistan—from India. Lord Mountbatten, the last British Viceroy of India, formally proposed the Partition Plan on June 3, 1947, at a press conference. At that time, he stated that India would become an independent country on August 15, 1947. The two Indian states that would be divided to achieve this would be Punjab in the west and Bengal in the east.[37] Pandit Nehru and Mahatma Gandhi (1869–1948) opposed the proposed partition plan of the British colonial government (Photo 9).

Displacement is central to Punjabi identity as it is to Jewish and Armenian identity («...Տնահան արեք ուղարկեք անապատները։ Թողեք առանց հացուջրի։ Հրդեհեք տներն ու եկեղեցիները։ Տեսեք՝ նորից չե՞ն խնդա, երգի եւ աղոթի։ Քանի որ երբ նրանցից երկու հոգի հանդիպեն աշխարհի որեւէ մի վայրում, տեսե՛ք, թե ինչպես են ստեղծելու նոր Հայաստան։» Վիլյամ Սարոյան; translation from Armenian: "*Send them into the desert without bread or water. Burn their homes and churches. Then see if they will not laugh, sing and pray again. For when two of them meet anywhere in the world, see if they will not create a New Armenia...*"—William Saroyan).

Panic crept into the minds of residents in Lahore, Punjab's ancient capital. I personally recall a pervasive feeling of impending doom. The detailed plans and precise demarcations were kept secret from the public until the very end, which created further confusion and uncertainty. The fate of Lahore hung in the balance. Was Lahore to remain in India or was it to be partitioned into the new nation of Pakistan? With each passing day, it appeared that peaceful coexistence between Muslims and non-Muslims in Punjab was in serious jeopardy. As events unfolded, it became clear that the foolish and hasty decision of the British colonialists to partition Punjab resulted in the mass exodus, ethnic cleansing, and deaths of millions.[38,39]

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[37]Why was India split into two countries? Available at: https://www.facebook.com/TEDEducation/videos/why-was-india-split-into-two-countries/2976780925934102/ (accessed on April 30, 2023).

[38]India and Pakistan: What was partition? Available at: https://www.youtube.com/watch?v=YkLFGWTKPY4 (accessed on May 1, 2023).

[39]Pakistan was created through The Partition of India based on religious segregation. This concept of dividing a nation along religious lines resulted in the displacement of fifteen million people, the murder of more than one million, and the rape of 75,000 women. This alone demonstrates that this was a catastrophic error. Opposition to The Partition of India—and its hideous underlying "two-nation theory"—was widespread in British India in the 20th century. It was opposed by most Hindus, Christians, Anglo-Indians, Parsis, and Sikhs, as well as many Muslims.

Photo 9. The land of the sacred Ganges and the towering Himalayas has given the world some personalities whose ideals were as pure as the water of this ancient river and whose aims were as lofty as the mighty Himalayas. This is a classic photo of two such pillars of world history. "Pandit" Jawaharlal Nehru (left) is sharing a joke with "Mahatma" Mohandas K. Gandhi (right) during a meeting of the All India Congress in Bombay on July 6, 1946. The honorific *Pandit* (Sanskrit, "knowledge owner" or "learned man") has been commonly applied before Nehru's name while *Mahatma* (Sanskrit, "great-souled") before Gandhi's. The mutual respect and admiration of the two remarkable men is apparent. Neither man supported the partition of India. This is one of my favorite photos in the context to Indian independence. The photo was taken by Max Dresier of the Associated Press. Based on this photograph, a commemorative postage stamp was issued by India Posts and Telegraphs Department on August 15, 1973, to mark the 25th anniversary of Indian independence. Then Prime Minister of India, Indira Gandhi (who was Nehru's daughter), remarked on the stamp's release, that "in spite of all their external divergence" the two men were "comrades in revolution and the remaking of man." Few relationships in history have been more emotionally earnest, intellectually intense, and politically productive. In essence, they were master and disciple, spiritual father and son, and fellow pilgrims in search of truth.

By 1946, killings, looting, and destruction of property had started all around us in Lahore. My mother, a devout temple-going person, brought daily news of friends moving from the Krishan Nagar neighborhood in Lahore, where we lived, to the Hindu and Sikh-dominated areas in India. As Secretary of Education with the Lahore Corporation, my father was in a prestigious government position and gauged the situation differently. He told us that we should not give into communal rumors. Nevertheless, the mayor of the Lahore Corporation provided

an armed guard for his protection. Shortly thereafter, the situation quickly worsened in Lahore. Arson and looting commenced in broad daylight, even in our Krishan Nagar neighborhood, which was populated entirely by non-Muslims. We heard news of the impending transfer of power from British to Indian hands. Muslims migrating from eastern Punjab brought tales, often exaggerated, of communal violence. Somehow, I assumed that these things would pass and that life, as I knew it then, would continue as before. However, this dream turned into a nightmare. I realized that the world I had known, and whose continuity I had taken for granted, had ceased to exist. Communities that had peacefully coexisted for a thousand years were caught in the wake of sectarian violence. The mass migration of non-Muslims to the eastern part of the Indian subcontinent had commenced—first as a trickle, later as a wave. This was ethnic cleansing at its worst. Our world was collapsing around us. I recalled my private tutoring at home and newspaper reports, where we learned about the mass-exodus of Jewish communities as Nazism scourged Europe.

By August 13, 1947, Krishan Nagar—my place of birth and my family's residence—had become a ghost town. Although I was not the oldest, my parents often sought my counsel in serious matters. I concluded that we all had to leave. My parents and siblings reluctantly agreed to leave on the evening of August 13th. Once the decision was made, we worked as an efficient team. We managed to grab a few belongings, packed them into cloth bundles, and frantically loaded them onto an abandoned horse cart. Given their youthful ignorance, the younger siblings considered this to be another fun challenge, another bonding opportunity to please the elder siblings. I physically moved everything two miles away to a local high school that served as a temporary, poorly guarded refugee camp. To this day, I do not understand how I found such superhuman strength. It must have been sheer desperation and the will to help the family survive! You can't fight instinct.

Being forced to flee one's home is a life-changing event. It is a terrifying and stunning experience. We reached the crowded and poorly managed refugee camp. Its inhabitants were dazed. Things were in chaos and misery surrounded us. Families literally were pushing against the walls of the camp. (Throughout my life, I have witnessed similar cruel images on TV or in print, the only difference being the geographic location of the traumatized faces.) Once we entered the refugee camp, we claimed a small space of land, spread a few bedsheets, and sat on them in anticipation of assistance. Things had unfolded so quickly. Were we in denial at what had transpired? Were we waiting for a miracle? This was 1947, a mere two years after the Second World War, and the world had no time for "third world" refugees in the Indian subcontinent. Soon the realization set in that we were alone in this mess. Nevertheless, we were overwhelmed by deep anguish to have been driven so mercilessly out the place we fondly called "home."

Amid this backdrop of turbulence, my youngest brother, Devinder Bawa, who was five months old developed a fever of 103°F.[40] With great difficulty, I managed to locate a cot for him. Sensing his deteriorating condition, the family searched for medical care—a fruitless task in the chaos of a refugee camp. Something needed to be done fast. Then, at grave personal risk, I decided to walk the two miles back to "our" house in Krishan Nagar to fetch medicine and other essentials. The neighborhood was pitch dark on a very warm and sultry August night. Not a soul was around. The sizeable population of stray cats and dogs normally found in the neighborhood had dwindled remarkably. Miraculously, I returned to the refugee camp with the essentials in hand and without incident. This proved to be pivotal in my brother's recovery. Devinder's shivers became less intense, and he started to show signs of life again. This settled us down a bit, and we dozed in and out of sleep. Even on the summer night, the temperature had dropped, and we could feel the freezing air against our cheeks. In the moonlight, the faces and eyes of the refugees reflected their helplessness. You could hear sobbing and children crying ("*Not all screams are heard…Not all prayers are answered.*"—Grace Andren). It was a quest for survival. We all were too numb to feel anything, too fatigued to express the palpable grief, too broken to beg, too traumatized to contemplate our future.

Merely one day later (August 14, 1947), as the conditions both inside and outside turned treacherous, we felt the need to depart from the refugee camp. Clearly, the governmental void had resulted in a deterioration of law and order. The meager resources allocated for the refugee camp had diminished. There was no real government. No one could ensure our safety. During the night, we could hear looting taking place in the nearby neighborhoods. Vagabonds roamed the streets with impunity, robbing, molesting, and worse. People wrote their names on houses that had been deserted, claiming them as their own. We were unsure about what to do. We clung together as a group, grasping onto the few bundles that were now our sole possessions (our home had been seized at that point). But family was most important to us; we were all alive and together. We ate some of the dry fruit and stale bread that we had brought with us two days back. Obtaining clean water was virtually impossible. The day blended into the evening. Then, just a few minutes before midnight of August 15, 1947, someone nearby

[40]There is a story tied to Devinder that unfolded three decades later. In an interesting twist of fate, in the late 1970s, Devinder married Sunita Bhatia (now Sunita Bawa), a graduate student in the Microbiology Department at Panjab University. The Microbiology Department was located on the same floor as my Biophysics Department. Devinder, who became an engineer and worked at Ford in the US, was visiting me in my office and saw Sunita. He wanted to see if I could arrange a meeting. I approached my colleague, Dr. D. V. Vadhera, Professor and Head of the Microbiology Department. As they say, the rest is history. I must add that five years earlier, I was on the joint admissions committee, interviewed Sunita, and signed off her admission as an undergraduate to the Microbiology Department. The Basic Medical Sciences building housed four basic medical science departments of the university—Biophysics, Microbiology, Pharmacy, and Biochemistry, and a joint admissions committee interviewed all top applicants.

turned on a radio and a cracking voice came on. It was Pandit Nehru and we were about to hear one of the greatest speeches of the 20th century. It was his iconic speech about the denouement of the British colonial rule in India[41]:

> *Long years ago, we made a tryst with destiny; and now the time comes when we shall redeem our pledge, not wholly or in full measure, but very substantially. At the stroke of the midnight hour, when the world sleeps, India will awake to life and freedom. A moment comes, which comes but rarely in history, when we step out from the old to the new—when an age ends, and when the soul of a nation, long suppressed, finds utterance...*

Unsure of our next move and fearing for our safety in the now-muddy refugee camp, we barely slept after Nehru's landmark oration. Later that day, Louis Mountbatten lowered the Union Jack as the last Viceroy of British India and hoisted the Indian tricolor flag as the first Governor-General of free India. The newly composed Indian national anthem, written by Nobel Laureate Rabindranath Tagore, played in the background.[42] The first stanza of the national anthem referenced "Punjab:" *जन-गण-मन अधिनायक जय हे, भारत भाग्य विधाता! पंजाब-सिंध-गुजरात-मराठा...* (Hindi, "*Thou art the ruler of the minds of all people, dispenser of India's destiny. Thy name rouses the hearts of Punjab, Sindh, Gujarat, and Maratha...*"). The British rule in India began in 1757, when the [British] East India Company had commenced with control over the country. The Company ruled India for 100 years until the British Crown replaced it following the Indian Mutiny of 1857–58, which was India's First War of Independence. Although freedom had come to India on August 15, 1947, we in the refugee camp had mixed feelings, for our beloved Punjab state had been partitioned. The butterfly had lost its wings ("*Nations are born in the hearts of poets; they prosper and die in the hands of politicians.*"—Muhammad Iqbal).

At daybreak, fearing for our safety in the refugee camp, we reluctantly decided to depart Lahore, now a part of Pakistan. My father, still believing in the goodness of men and hoping to return to our home in Krishan Nagar two miles away, decided to stay back in the refugee camp. With unimaginable grief and tears, the rest of the family left the refugee camp and Lahore forever on the afternoon of August 15, 1947. India was now independent of the British colonialists, but we were refugees with an uncertain future and an unknown destination. Even today in 2023, more than 75 years later, the memory of this painful exodus is vivid in my mind: It haunts me when I see similar events unfold on TV.

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[41]"Tryst with Destiny" was an English-language speech delivered by Jawaharlal Nehru, the first Prime Minister of India, to the Indian Constituent Assembly in the Parliament House in Delhi on the eve of India's independence before midnight on August 14, 1947. Available at: https://www.youtube.com/watch?v=lrEkYscgbqE (accessed on May 1, 2023).

[42]Eminent artists, actors, and sportspersons contribute to The Official Anthem of #HarGharTiranga. Available at: https://www.facebook.com/gkishanreddy/videos/eminent-artists-actors-sportspersons-contribute-to-the-official-anthem-of-hargha/625334715975134/ (accessed on May 1, 2023).

We boarded a military truck, still clinging to our few bundles of belongings. Everyone was packed like sardines. The humidity and the bright August sun were merciless. We were part of a military convoy, supposedly taking us to somewhere in India. Everyone appeared dazed by lack of sleep and from the uncertainty of where we were headed. On our way to the newly established "unofficial" international border, we passed the famous Lahore Canal. On its banks each summer, we used to have picnics and mango parties. We would keep the mangoes in ice water to cool them down. Oh, such sweet memories! As we drove on, I saw refugees travelling in both directions—towards India and Pakistan—on foot and in bullock carts (Photos 10–13). We felt lucky to be in the relative comfort and safety of a military vehicle. I also witnessed scenes that are too difficult to fathom or describe. Suffice it to say that humans had turned barbaric. A scene that haunts me to this day is that of people cooking food on fires lit for burning dead bodies ("*What the eyes had seen could not be erased.*"—Frank Herbert).

How was it possible for people to do this to one another? On both sides of the border, inhuman incidents had taken place—by Hindus, Muslims, and Sikhs. How could it be that this ancient land, which had produced so many sages—Jain Mahavira, Gautama the Buddha, Kabir, and Guru Nanak—had been consumed in an orgy of violence? I wondered if the voice of sanity was silenced forever. Was Gandhi correct in his Kingsley Hall Speech of 1931: "*In the midst of darkness, light exists. In the midst of untruth, truth exists.*"

As we crossed the border, I realized that I had become a refugee in my own homeland. I was heartbroken at having left our lovely home and the luxurious lifestyle that we had known. After a few hours that seemed like years, we reached Khalsa College, Amritsar.[43] There, men and women labored in the sweltering August heat to serve us *daal* (Hindi, "lentil soup"), *roti* (Hindi, "Indian bread"), and water. What a paradox! Here was humanity at its best, serving brothers and sisters; and yet, we had left behind humankind at its worst, butchering each other. Everything seemed so senseless: the murders, looting, and burning. For days, we wandered the streets aimlessly. There were no schools or colleges open. We managed to find an abandoned house, but we knew that our life would never be the same again. My poor mother carried water up four flights of steps; the days of butlers and servants were a distant memory. Food was provided by a local temple.

Almost a year after the Partition, during the summer of 1948, we were traveling to Dehradun in the Himalayas. Near Cheru Bridge, I saw hundreds of steel trunks lying abandoned in the now-dry riverbed. You could see bodies scattered everywhere. The stench was intolerable. Apparently, Muslims traveling in a *kafila* (Urdu, "group") were overcome by the rising river waters and had tried to escape by climbing onto trees. However, poisonous snakes had also climbed up those same trees. It was a quest for survival. Yet, I could see people down in the riverbed removing jewelry from the dead.

[43]Amritsar lies about 15 miles (25 km) east of the international border with Pakistan and where the Jallianwala Bagh massacre took place in 1919.

Photos 10–13. Photographs depicting one of the biggest mass migrations in history, triggered by Britain's chaotic withdrawal from India in August 1947. People who lived together for centuries were forced out of their homes as one of the largest and most ethnically diverse nations in the world was divided ("The Partition"). Mistrust, large-scale violence, and upheaval ensued as millions were uprooted from their homeland. They were forced to escape on foot, bullock carts, and trains across the newly established international border "to nowhere." The horrific event displaced between 10 and 20 million people along religious lines, creating overwhelming calamity in the newly constituted nations of India and Pakistan. Unquestionably, it is one of the largest refugee crises in history. The violent nature of The Partition created an atmosphere of hostility and suspicion between India and Pakistan that affects their relationship to this day (*continued*).

Photos 10–13. (*Continued*)

Although the British had just ceded the reins of power to the new Indian Government, their indifference to the violence was appalling. Only a few weeks before The Partition, Viceroy Mountbatten, was confident of a peaceful transfer of power, assuring all that he "*shall see to it that there is no bloodshed and riot… that there are no communal disturbances anywhere in the country…*"[44] The Partition and subsequent rushed British withdrawal led to exactly the opposite result. Mountbatten was wrong: his vison flawed, his misjudgment fatal. But did he really care? Did he lose sleep over the mess that he and his imperial government had created? The new artificial international borders sparked mass migration and widespread sectarian violence that engulfed village after village, private homes, and even women and children, who were once considered beyond the societally constructed boundaries of communal violence. In fact, the traditional forms of violence gave way to genocidal massacres. After The Partition, the fledgling governments of India and Pakistan were left with all responsibility to implement the border. This was not enough to protect the cities much less the caravans of the hundreds of thousands of refugees who continued to flee their homes for months. Scholars have argued that the unprecedented violence was not a sudden wave of anger and madness but was anticipated by the colonial rulers themselves. In any case, the British are to blame for triggering this genocide. I agree that The Partition meets all the elements of genocide.[45] The Partition was one of the great tragedies of the 20th century.[46] By some estimates, it created approximately 15 million refugees; around 2 million people died[47] ("*Мирно они умрут, мирно иссякнут во имя Твое, и за гробом не найдут ничего, кроме смерти. Но мы сохраним тайну, и за их счастье мы прельстим их наградой небес и вечности*".—Федор Достоевский; translation from Russian: *Peacefully they will die, peacefully they will expire in Thy name, and beyond the grave they will find nothing but death. But we shall keep the secret, and for their happiness we shall allure them with the reward of heaven and eternity.*—Fyodor Dostoyevsky).

[44]Jagmohan (2005). *Soul and Structure of Governance in India.* Allied Publishers Pvt. Ltd., Delhi, India, p. 49: "*At least on this question I shall give you complete assurance. I shall see to it that there is no bloodshed and riot. I am a soldier and not a civilian. Once the partition is accepted in principle, I shall issue orders to see that there are no communal disturbances anywhere in the country. If there should be the slightest agitation, I shall adopt the sternest measures to nip the trouble in the bud.*"

[45]Since the scale and level of brutality during the partition massacres was (a) manifested with genocidal tendencies that included mass killing; and (b) designed to obliterate an existing generation and prevent its future reproduction, I label the British Partition of India a genocide. For example, see, Hansen, A. B. (2002). *Partition and Genocide Manifestation of Violence in PUNJAB: 1937–1947.* India Research Press, New Delhi, pp. 195–197.

[46]Partition: The day India burned. Available at: https://www.youtube.com/watch?v=jGiTaQ60Je0 (accessed on May 1, 2023).

[47]India-Pakistan partition explained. Available at: https://www.youtube.com/watch?v=OnTYLyNUPMc (accessed on May 1, 2023).

Amrita Pritam (Photo 8) was a pioneer of modern Punjabi poetry and literature. Her bold, deeply romantic, and spiritual poems have a universal appeal. They are admired on both sides of the Punjab border. Amid communal rioting in August 1947, she evoked the spirit of the 17th century Punjabi Sufi poet, Waris Shah (1722–1798) of *Heer Ranjha*[48] fame, with her immortal poem titled *Ajj aakhan Waris Shah nu* (Punjabi, "*Today I call forth Waris Shah*"). In this elegy to Waris Shah, she implores him to rise from his grave and rewrite the devastating narrative that marred Punjab during The Partition in 1947. Penned on a piece of paper during a train journey from Dehradun, she expressed her anguish on the genocide in Punjab.[49]

The following are the three opening verses of the poem[50] in Punjabi and their translation in English:

ਅੱਜ ਆਖਾਂ ਵਾਰਸ ਸ਼ਾਹ ਨੂੰ ਕਿਤੋਂ ਕਬਰਾਂ ਵਿਚੋਂ ਬੋਲ।
ਤੇ ਅੱਜ ਕਿਤਾਬੇ ਇਸ਼ਕ ਦਾ ਕੋਈ ਅਗਲਾ ਵਰਕਾ ਫੋਲ।
ਇਕ ਰੋਈ ਸੀ ਧੀ ਪੰਜਾਬ ਦੀ ਤੂੰ ਲਿਖ ਲਿਖ ਮਾਰੇ ਵੈਣ।
ਅਜ ਲੱਖਾਂ ਧੀਆਂ ਰੋਂਦੀਆਂ ਤੈਨੂੰ ਵਾਰਸ ਸ਼ਾਹ ਨੂੰ ਕਹਿਣ।
ਉੱਠ ਦਰਦਮੰਦਾਂ ਦਿਆ ਦਰਦੀਆ ਉੱਠ ਤੱਕ ਆਪਣਾ ਪੰਜਾਬ।
ਅਜ ਬੇਲੇ ਲਾਸ਼ਾਂ ਵਿਛੀਆਂ ਤੇ ਲਹੂ ਦੀ ਭਰੀ ਚਨਾਬ।
ਕਿਸੇ ਨੇ ਪੰਜਾਂ ਪਾਣੀਆਂ ਵਿੱਚ ਦਿੱਤੀ ਜ਼ਹਿਰ ਰਲ੍ਹਾ
ਤੇ ਉਹਨਾ ਪਾਣੀਆਂ ਧਰਤ ਨੂੰ ਦਿੱਤਾ ਪਾਣੀ ਲਾ

I say to Waris Shah today, speak out from your tomb,
and let a fresh page unfurl from the Book of Love's womb.
Just one daughter [Heer] of Punjab's woes caused your laments to flow,
today a million daughters weep, and you they do implore.
Arise you chronicler of pain and witness your Punjab,
where the fields are lined with corpses and blood flows down the Chenab.

From August until the autumn of 1947, we took refuge with relatives in various villages and rural towns of Punjab, eventually landing in Amritsar. It was a far cry from the carefree life of Lahore. I think it made us grow up much faster than we wished. We also had lost all contact with our father. We were desperate

[48]Waris Shah is longed for by lovers. *Heer Ranjha* is the immortal love legend of Punjab from 250 years ago. The story of *Heer Ranjha* is sung and found anywhere where there are Punjabis and the Punjabi language. Along with other tragic love tales from Punjab such as *Laila Majnu* and *Sassui Punnhun,* this true story is often compared to Shakespeare's *Romeo and Juliet*. The famous song from Bollywood classic *Heer Ranjha* is available at: https://www.youtube.com/watch?v=WTjNfr449ac (accessed on May 1, 2023).

[49]In her autobiography, *The Revenue Stamp*, Amrita Pritam recalls the train journey thus: "*Uprooted from Lahore, I had rehabilitated myself at Dehradun for some time. I went to Delhi looking for work and a place to live. On my return journey in the train, I felt the wind was piercing the dark night and wailing at the sorrows the Partition had brought. I had come away from Lahore with just one red shawl and I had torn it into two to cover both my babies. Everything had been torn apart. The words of Waris Shah about how the dead and parted would meet, echoed in my mind. And my poem took shape.*"

[50]Aaj aakhan Waris Shah nu (Amrita Pritam)—narrated by Gulzar. Available at: https://www.youtube.com/watch?v=rBvFabOMPVs (accessed on May 1, 2023).

to find him. Uncertainty fuels worry and anxiety. Once again, everyone in the family looked up to me for help and once again, I stepped up to the plate. On Diwali[51] of 1947, I returned to Lahore—now in Pakistan—to locate and persuade my father to join us in India. For my safety, I went in an Indian military convoy which handed me over to a Pakistani soldier at the international border. I learned that the refugee camp had been disbanded a few weeks after we left. So, I requested to go to Krishan Nagar instead in hope that my father had taken refuge in our old home or with some Muslim neighbors. I did not know what else to do. I was shocked to learn that the Pakistani soldier did not know how to get to Krishan Nagar. It was because he was a refugee from a farm on the other side of Punjab (East Punjab) and had been in Lahore for only a few months. Somehow, this was now to be his new homeland and he was expected to adjust to city life. Holding back tears, he recounted his lost world. I could relate to his pain. We strangely bonded in those moments, realizing that both of us were pawns of political and religious upheaval. I directed him to Krishan Nagar. When we reached there, I embraced him and quickly disembarked. I was anxious to locate my father. I was not sure if I would find him or if we had lost him to the madness of The Partition. As soon as I descended from the truck into my old neighborhood, by then pillaged, Muslim youths surrounded me. I realized that I was wearing a *khadi kurta-pyjama* (*kurta*, Hindi, "long shirt;" *pyjama,* Hindi, "baggy pants"), a sure sign of being a Hindu or a Sikh. Clearly my life was in jeopardy. Fortunately for me, the youths were called away to help loot a store on the corner. Upon reaching my old street, I was relieved to find out that my father already had left for Amritsar. Somehow, I managed to make it back to India safely without any further incident. In the end, my family had made it out alive. We had lost all our possessions, but we were all together—this was most important ("*Happiness resides not in possessions, and not in gold, happiness dwells in the soul.*"—Democritus). What a great Diwali it was! Adjusting to our *new* homeland was another matter though.

Eventually my father got an excellent job in Rohtak, Punjab (now in the state of Haryana). He was appointed as Secretary, Municipal Corporation, a position second only to the Deputy Commissioner of Rohtak. This high-ranking governmental position provided him with a massive bungalow and all possible amenities, including a house staff. Amazingly, life became comfortable again. Since then, life has rolled on. Most of my ten siblings and elderly mother migrated to the US. My mother died at 100; my father in his late 80s. My sisters and my eldest brother all have passed away. The remaining brothers all reside in the Midwest; most have retired from productive professional careers. I went to

[51]Diwali (also called Divali or Deepavali) is the Indian "festival of lights" that celebrates the triumph of light over dark and good over evil. It symbolizes blessings of victory, freedom, and enlightenment. The name comes from *dipavali* (Sanskrit, "row of light"). On the night of Diwali, which is on the day of the new moon when the sky is at its darkest, celebrants decorate their homes with candles and *diyas* (Hindi, "clay oil lamps"), and *rangolis* (Hindi, "colorful art circle patterns"). As children we looked forward to Diwali celebrations mainly because of the dazzling array of Punjabi sweets served at home and the fireworks celebrations in which we all participated in the wee hours of the night.

Columbia and Cornell on a Fulbright Fellowship in 1958 and never looked back. That said, my large family never lived under one roof again as we all had dreamed of while growing up in Lahore.

Navigating life's most difficult challenges is never easy. However, most of the pain and hardships of life were only minor prickles after 1947. Few tribulations ever fazed me again. The potholes that I encountered in my journey felt like minor bumps, the roadblocks mere temporary bypasses to my ultimate destinations.

10.8 Divide-and-Rule: A British Specialty

Make sure you divide India into three, four, five pieces. Make sure you do that.

—Winston Churchill to the Viceroy of India, 1946

Borders certainly are among the most important factors that have influenced the development of world affairs. European expansion in the 18th and 19th centuries imposed new borders on Africa and Asia. Many native people viewed these boundaries as arbitrary and, after independence, continued to contest their legitimacy. At the end of both World Wars in the 20th century, world leaders (especially European colonial powers) drew artificial and impermanent lines separating assorted people around the globe. This has contributed to ethnic cleansing, refugee crises, famines, military conflicts, ecological damage, unemployment, rise of militancy, and much worse.

Punjab always has been a land of shifting borders, culturally as well as geographically. Punjab of both Pakistan and India have borne the unequal burden of The Partition of 1947. The border between India and Pakistan has been disputed ever since. This classic example of an arbitrary border was especially pronounced because there was no geographic reason for the boundary and no history legitimizing it. It was only done to carve out a Muslim-majority state out of India.[52] In fact, the well-tried, cruel British tactic of "divide-and-rule" was on full display as they made a hasty exit from the subcontinent. Clearly, such lingering effects of British colonial legacy reverberate even today in conflicts ranging from Palestine to Armenia. Borders can physically separate people but rarely prevent their economic, political, social, and cultural interaction. It is hard to split the Punjabis along religious lines when they share much more culturally: food, music, habits, clothing, and language, just to name a few examples.

As discussed, the British partitioning of Punjab in the north-west and Bengal in the east created the Hindu-dominated secular nation of India and a separate Muslim nation of Pakistan (now Pakistan and Bangladesh). It was a plan formed in haste and disregard for those whose lives were split by a line drawn on a map by a London lawyer, Cyril Radcliffe (1899–1977), and his committee of eight judges (Maps 1 and 2). Shockingly, Radcliffe destroyed all his papers related to

[52]Divide & rule: Rajmohan Gandhi. Available at: https://www.youtube.com/watch?v=roISI9RjHJ4 (accessed on May 1, 2023).

his work on The Partition of India before he departed India on Independence Day itself. What was he trying to hide? According to the veteran journalist and author Kuldip Nayar (1923–2018), Radcliffe flew over these parts of northern India only once in a Dakota before demarcating borders.[53] He had never even been east of Paris. Remarkably, he admitted that he lacked fitness for the Indian climate, and was eager to depart India. He constantly complained that the time at his disposal was so short that he could not do an adequate job. Although I lived through the horrors of this mess, all of this is incredible to me even in 2023! Why was Radcliffe in India in the first place? Should the demarcation representing 175,000 square miles (450,000 km^2) of territory with 88 million people have been handled by such an ill-prepared and incompetent person? Why was he provided outdated maps and inaccurate census figures to do a rush-job of gigantic consequences in a mere 36 days? Apart from Radcliffe, I also place the blame on the British government for their appalling indifference for appointing him and for Mountbatten for pressuring him to conclude his assignment at the earliest ("*To avoid criticism, do nothing, say nothing, be nothing.*"—Elbert Hubbard).

In 1987, forty years after The Partition, I got an opportunity to visit Lahore. It was to attend a scientific conference at the Center for Advanced Molecular Biology of Punjab University arranged by my son's US college roommate, an exchange student from Lahore. I drove in my car from Chandigarh to Lahore with my colleague, the late Dr. P. L. Wahi, who was Director of the Postgraduate Institute of Medical Education and Research (PGIMER) in Chandigarh. Like me, Dr. Wahi was also a refugee from western Punjab (Sargodha). Upon my arrival, we were treated very well and given a fantastic reception, the famous Punjabi hospitality on full display. Between dinner receptions and social events, there were stories to tell and reminiscences to share of my past life in Lahore. Some of the old-timers lamented the lost beauty of the city, its gardens and architecture neglected by a series of corrupt politicians and military dictatorships. The city was certainly more crowded, much noisier, with more dilapidated buildings. My hosts took me to a few of the same *mohallas* (Urdu/Hindi, "neighborhoods") that I used to frequent as a youngster to pick up legendary Punjabi snacks and dishes: lassi, phirni, chhole bhature, halwa poori, falooda, makhni doodh, samosas, kebab, karrhi, paneer, kulfi, pinni, rabri, kulchas, dahi vada, khoa, paya, sarson da saag, makki di roti, taftan, roti, kachori, aloo parathas, kheer, chure, panjiri, tandoori chicken, pakoras, aloo chaat, jalebis, and so on (Image 3). I sampled some of the food—it tasted the same, if not better! It was as if nothing had changed. But life in Lahore was so different then. In my mind, I made comparisons of life past and present. I visited my old home, which I was able to locate easily, despite the maze of modern construction and large-scale urbanization. It felt as if I had never left, though. I also visited my old school, Government College Lahore, where a group of enthusiastic students gave me a guided tour of the then-famous institution. They asked me if I studied with famous alumni (called *Ravians*), including novelist Khushwant Singh; Nobelists Dr. Har Gobind Khorana and

[53]Nayar, K. (2006). *Scoop! Inside Stories from Partition to the Present.* HarperCollins, New York , USA.

Dr. Abdus Salam; and legends of Indian cinema, Balraj Sahni and Dev Anand. When I finally located my old classroom, my mind raced with questions: Was this the price of independence? Was it worth it? Was the partition of Punjab and India necessary? The pictures of those horrific days and months still were vivid in my mind, even after four decades. I was overcome with grief and raw emotion; my hosts and students comforted me. It felt like they were my own students back at Panjab University in Chandigarh.

Image 3. A sampling of Punjabi food.

On our final evening, we dined at Faletti's Hotel, Lahore's grand hotel since 1880, where pre-independence society congregated. As I gazed at its marvelous mélange of Victorian, Colonial, and Art Deco interiors, my memory, once again, flashed back to those horrific days of August 1947. It was here then that much of British colonial society in Punjab danced to the music of a genteel orchestra—oblivious or callous to The Partition—while the neighborhoods around them burned.

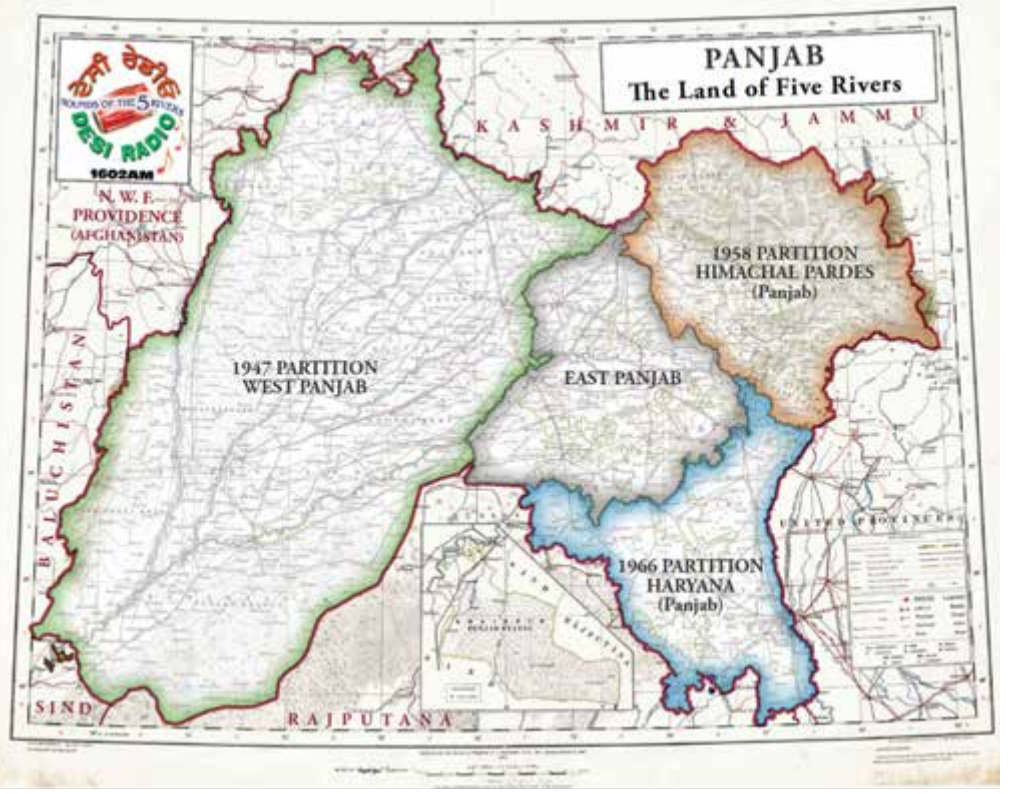
10.9 The Second Partition of Punjab

इक दिल के टुकड़े हज़ार हुये, कोई यहां गिरा कोई वहां गिरा/Ek dil ke tukde hazaar hue, koi yahaan gira, koi wahaan gira.
(*One heart broke into a thousand pieces; some fell here, some fell there.*)

—Qamar Jalalabadi (1917–2003), Punjabi and Urdu Poet

Punjab was a different country for a large part of its history. It was largely distinct from the rest of the area we know today as India. Punjab was under Islamic rule from the 1100s to the 1700s. The first king to shake off Islamic rule over Punjab was Banda Bahadur. From the 1700s to the 1790s, a large part of the then-Punjab was an independent confederation of Sikh States, extending

from Afghanistan in the west up to Rewari, Haryana, in the east. From 1795 onwards, almost all of Punjab from the banks of the Sutlej to the Khyber Pass (near Peshawar) was Maharaja Ranjit Singh's (Image 2) independent country. Although the British had taken over most of India by 1818 (following the Maratha Wars), Punjab alone stood as an independent country until 1845 before it lost the First Anglo-Sikh War. It was only after the Second Anglo-Sikh War of 1849 that the prized Punjab was merged into British India.



Map 4. The Second Partition of Punjab. Note that both "Punjab" and "Panjab" are correct while referring to the state. Map kindly provided by The Panjabi Centre/Desi Radio, UK.

British rule in India finally came to an end in 1947. On the way out, they portioned the subcontinent (Punjab in the west and Bengal in the east). Punjab that was left in India was referred to as East Punjab, while the part that had been carved out into Pakistan was known as West Punjab (Map 4). After 1947, East Punjab was foolishly further reduced in size by shortsighted politicians and religious fanatics. East Punjab was trifurcated into two additional states (Map 4). These two new states were created on a linguistic basis: The hilly regions of Punjab were carved out as *Himachal Pradesh* (Hindi, "snow-laden mountain province") and *Haryana* (Hindi, "the abode of God"). The sad reality of the British Partition (i.e., The Partition) was that the once-huge Punjab became devoid of

its five rivers and more than half of its land. The Second Partition resulted in a further loss of substantial territory, pride, and economy. This latter mess was the result of the *Punjabi Suba* (Punjabi, "Punjabi-speaking state") movement, a long-drawn out political agitation launched mostly by Sikhs and the Akali Dal that demanded the creation of a distinct Punjabi state from the newly portioned East Punjab. In my view, the Sikhs, who were accustomed to a privileged position under British colonial rule, had failed to fully adjust to their diminished political status in East Punjab under a Hindu majority. Basically, this calculated move has resulted in two additional sets of political entities: two legislative assemblies, two chief minister posts, and two governorships. The old British trick of "divide-and-rule" was very much alive and too tempting to resist for self-serving politicians; now everyone had their respect fiefdoms. It is ironic that Punjab bore the brunt of The Partition and was at the forefront of India's freedom struggle (in real numbers of martyrs), only to ultimately be diminished in size and prestige (Map 5).

Map 5. District map of Punjab state in 2023.

I must add that I strongly believe in the Punjabi ideology that is known as *Punjabiat*—a vision of Punjabi-speaking people transcending limitations of geography. Maybe someday the butterfly will reacquire its clipped wings and fly again.

10.10 My Education in Independent India

Be aware of your own worth, use all of your power to achieve it. Create an ocean from a dewdrop. Do not beg for light from the moon, obtain it from the spark within you.

—Muhammad Iqbal (1877–1938), Indian Poet of Urdu and Punjabi

We can't change the direction of the wind, but we can adjust the sails.

—Indian Proverb

Although I was a refugee at a chaotic time, I knew my worth. Clearly education was the way out. As I charted the uncertain voyage of my professional career, education and hard work were themes that resonated with constancy. During grammar school in Lahore, I was taught the fundamental subjects: science, arts, history, philosophy, and multiple languages (including Punjabi, English, and Urdu). Most importantly, my education instilled discipline and the motivation to succeed. At home, there was reading of the classics and holy books at night by the light of a kerosene lamp (the Bhagavad Gita, the Holy Quran, the Guru Granth Sahib, and the Holy Bible). Poetry (Urdu, Persian, and Punjabi) and music (American, British, Indian film, and Punjabi folk) was foundational for us. College education was considered essential ("*Education is the best provision for old age.*"—Aristotle).

I always felt a strong inclination toward literature and history, akin to my feelings towards science. As far back as I can remember, though, I wanted to be either a doctor or a scientist. I was always an excellent student and encouraged by my teachers and family to pursue medicine. Very early in my career, however, I became attracted to exploration rather than to medical practice or patient care. I was feeling restless and remember having serious conversations with my parents about what I should do with my life. Should I study medicine, or go into biomedical research? I felt I was taking the easier pathway if I pursued medicine. If I did research, though, I would always face skepticism and challenges from colleagues, who would demand clarity from my scientific investigations and data. This felt much healthier to me, and so I decided to pursue research with a passion. I could imagine wonderful discoveries in the future ("*You see things and you say 'Why?' But I dream things that never were and I say 'Why not?'*"—George Bernard Shaw). Furthermore, our extensive library at home excited me about science and biomedical research. I entered college at the age of 15. At the time of India's independence, I was in the first year of BSc (Honors School) at the prestigious Government College Lahore (Photo 14). The College (now a university) was established in 1864 by the British India government and produced notable scholars.[54] I must highlight Dewan

[54]Secrets of Lahore: Government College University. Available at: https://www.youtube.com/watch?v=ErLAlHjKyg4&t=355s (accessed on May 1, 2023).

Anand Kumar,[55] a gifted teacher of mine at the College, who later became the first long-term Vice-Chancellor of the newly formed Panjab University at Chandigarh in independent India. He served for eight years beginning 1949. A remarkable personality from a royal family, his engrossing lectures were matched by his exceptional presentation style. He was ambidextrous and drew stunning biological images using both hands with different colored chalks on a slate blackboard. I have never witnessed this unusual ability since.

Photo 14. Shown above is Government College Lahore in the 1880s, with its spectacular Gothic architecture. Photo courtesy of the British Library, London.

When I became a refugee and had to migrate from Lahore to the eastern part of Punjab, I continued my undergraduate studies in zoology at the newly formed East Panjab University, based in Hoshiarpur, Punjab. There, a segment of the teaching faculty had relocated from the parent university in Lahore. I was an interested student, full of questions (*"He who asks a question is a fool for five minutes; he who does not ask a question remains a fool forever."*—Chinese proverb). My reputation for being an outstanding student was cemented after I stood first-class-first (equivalent to *summa cum laude*) during both my undergraduate education (BSc, Honors School, 1949) and my master's program (MSc, Honors

[55]Dewan Anand Kumar was educated at Cambridge. He was appointed a Reader in the Zoology Department at Punjab University at Lahore in 1920, and Department Head in 1942. In 1946 he was made the Dean of University Instruction (DUI). A few years later, he became the Vice-Chancellor of Panjab University, a time when the university remained scattered at various cities.

School, 1951). As I look back at my MSc graduating class photograph from 1951 (Photo 15), I recall a memorable time in my life: I was 21 years old and proud to celebrate this milestone. Also, I had earned gold medals from Panjab University. Academically, this set the tone for accolades to come.

Photo 15. Farewell to the third year Zoology Honors School class of East Panjab University. This photography was taken in 1951 when East Panjab University was temporarily based in Hoshiarpur, Punjab. It includes faculty and students of the Zoology Department. (Sitting) S. R. Bawa, Bhupinder Sud, S. D. Malik, Dr. Vishwa Nath (principal), N. K. Gupta, Ramesh Satija, O. P. Dhingra. (First Row) Om Bahadur, Rajinder Rishi, Sudershan, F. C. Vohra, Shayama Vermani, Balbir Dhillon, Devki Jolly, Baldev Singh, Karta Krishan, Mohan Lal Jaiswal, Kulbir Singh. (Second row) Joginder Nath, Joginder Singh, Gian Sood, Sohan Lal, Khushi Ram, Ram Parshad, Manohar Lal, S. D. Sharma, Prem Chand, J. L. Gabba. (Third row) Asket Singh, Sarni, Harish Chopra, Swaran Singh, B. S. Bhimber, Jaggi.

I found it relatively easy to breeze through the curriculum, except for the labs, which always required careful application. Those who knew me were convinced that I was destined to do great things. I was lucky to have magnificent teachers, who made their subjects come alive. This was possible, in part, because some had worked in industry and could relate the classroom to the real world more convincingly than our textbooks could. I genuinely looked forward to going to class. It was wonderful to be guided by superb professors, who conveyed complex scientific concepts with elegant simplicity and infused their lectures with flare ("*It is the supreme art of the teacher to awaken joy in creative expression and knowledge. If you can't explain it simply, you don't understand it well enough.*"—Albert

Einstein). One professor from whom I learned a great deal was Dr. Vishwa Nath, the Cambridge-educated Zoology Department head who would later become my master's (Photo 15) and PhD advisor. I am grateful to him for his skillful guidance throughout my research and for his many acts of kindness that sustained me in many a moment of doubt that every graduate student or medical student experiences. He was an internationally renowned cytologist and spermatologist. The Indian National Science Academy has instituted the "Vishwa Nath Memorial Lecture" in his honor.

Dr. Nath's patron was Maharaja Sir Bhupinder Singh (1891–1938), the flamboyant and uber-rich ruler of the princely state of Patiala in Punjab. The *Maharaja* (Sanskrit, "great king"), whose reign was from 1900 to 1938, lived an extravagant life of excess. He was owner of the world-famous "Patiala Necklace" designed by Cartier, one of the most expensive pieces of jewelry ever created (Photo 16). It is often said that besides his passions for beautiful women and sparkling gems, the Maharaja's addiction to Rolls-Royce practically kept the firm in business.[56] I believe that the Maharaja and Dr. Nath got to know each other while the former was a student at Aitchison Chief's College in Lahore. Dr. Nath told me that the Maharaja financed his trip and PhD studies to Cambridge. The two close friends shared a common passion: cricket. In fact, the Maharaja was the captain of the Indian cricket team that toured England in 1911. Even during my college years, Dr. Nath did not miss an opportunity to watch cricket test matches, partake in the sport, or serve as an umpire.

Dr. Nath was a dedicated scientist, who had an incredible aptitude for discovering the right problem and the most elegant experiment to solve it. I was delighted that one of my early publications was co-authored with Dr. Nath and published in *Nature*. After several more papers, visits to other labs, and presentation at various meetings, I began to get a little recognition in microscopy and cell biology research communities. Working under Dr. Nath's supervision not only was rewarding scientifically but also instilled skills that guided me in later years—as when I directed my own large laboratory and electron microscope facility. Dr. Nath taught me order and precision in the laboratory, which served me well throughout my scientific career. In fact, his pedagogy continued to resonate when I started teaching medical students at Cornell University Medical College and, later, biomedical students at Panjab University in Chandigarh. Exposure to a variety of professors, who talked convincingly about all manner of subjects, made me a better teacher. Dr. Nath was particularly brilliant at explaining histological and zoological concepts, as well as newer topics in molecular biology—like the Central

[56]It has been reported that up to one-fifth the number of Rolls-Royce cars that were manufactured before the First World War had Indian owners. Maharaja Bhupinder Singh toured London incognito and went into a Rolls-Royce showroom; the salesman sneered at him and said that the Maharaja should take his leave because he would not be able to afford anything in there. The salesman's manner infuriated the Maharaja, so he ordered 50 Rolls-Royces to be shipped to India where the cars were then used to collect municipal trash. Until a Rolls-Royce representative came to personally apologize to him in India, the garbage collecting job continued for the expensive cars. Source: Indian Auto. Available at: https://indianauto.com/ (accessed on May 1, 2023).

Dogma, which just had been formulated a few years earlier. To him, I credit my career in research, although there were many other central influences along the way. When my growing appreciation of life in academia inspired me to become a "super teacher," Dr. Nath was my role model.

Photo 16. Bhupinder Singh, Maharaja of Patiala (c. 1911).

While at Panjab University under the guidance of Dr. Nath, I employed bright field light microscopy to examine Boudin's osmium tetroxide-fixed and paraffin-embedded testicular cells from a variety of insects. At that time, microscopic images were reproduced by *camera lucida* (Latin, "light chamber"). Around 1953, with the availability of the phase contrast microscope, I demonstrated the existence of fibers and mid-body granules in live spermatocytes of the grasshopper (*Chrotogonus* sp.) and the house cricket (*Gryllus domesticus*). Until that time, cytologists considered them to be artifacts of fixation. Later, also employing phase contrast microscopy, I obtained photomicrographs of various cytoplasmic organelles during spermatogenesis in the firebrat (*Thermobia domestica*).[57]

[57] *Thermobia domestica* (sometimes called firebrat or *Thermophila furnorum*) is a small hexapod (typically 1–1.5 cm) insect. Firebrats look like silverfish but lack the silvery sheen. The firebrat prefers higher temperatures and requires some humidity, and can be found in bakeries and near boilers or furnaces.

During my undergraduate years at East Panjab University in Hoshiarpur (Photo 15) I resided in a large rented residential building known as Amba Bhawan. Here, a few of my zoology classmates and I tried to focus on our studies, though it was a far cry from what would be perceived as today's typical carefree college life. We all shared a common thread, though: We all had been uprooted from various towns of western Punjab (Lahore, Rawalpindi, Peshawar, Gujranwala); we all were often broke; we all had seen grief in our teen years; we all considered education as our ticket to success. Amba Bhawan was located on Railway Road, a few miles away from the temporary university campus. We all walked to the campus. Finally, there was some degree of stability after the tumultuous few years following The Partition. Another advantage was that we all were zoology students and could exchange class notes and textbooks. Some of the upperclassmen would tutor the lower classmates. During this time, one bizarre episode is worth mentioning. One morning, as I stepped out of the shower and onto the interior courtyard, I came face-to-face with a tiger. I was stunned and froze in terror. Thankfully, it turned out to be an escaped circus tiger, and after a few seconds that felt like minutes, the tiger simply turned away and scaled the six-feet-high wall. I quickly entered my room, dressed, and described the incident to my housemates. They initially joked with me that I must have mistaken a cat for a tiger since I did not have my glasses on.

After obtaining my master's degree, I decided to sit for the prestigious Indian Military Academy (IMA) examination (Photos 17 and 18). Established in 1932 and located in Dehradun, the 1,400-acre IMA trains officers for various branches of the Indian military. The selected cadets undergo rigorous training after which they are permanently commissioned as lieutenants. The IMA's mission is to train future military leaders of the Indian Armed Forces. Specifically, I was interested in joining the Indian Air Force. I prepared for the grueling written examination taken at Ambala Cant. To the surprise of many, I passed it with flying colors. After clearing the written exam, I went to Delhi for further evaluation and physical fitness tests. I passed these successfully as well, thereby followed by a few assessments at the Air Force Selection Board (AFSB). I survived these also. Then, I had to undergo certain medical tests to make it to the merit list to finally join the Armed Forces. It is at this final stage that I failed my eye exam and was not selected. Some of the candidates who cleared this final hurdle eventually rose to the highest ranks in the Indian Air Force.

10.11 My Life with Microscopes: An Ongoing Affair

I have always been impressed with microscopes, stains, microtomes, and micrographs. Early on, I realized that the biochemist's view of the cell was, at best, a blurry one ("*A picture is worth a thousand words.*"—Fred R. Barnard). Moreover, my relative lack of fluency in biostatistics and higher mathematics was apparent ("*True knowledge is to be aware of one's ignorance.*"—Rudolf Virchow, letter to his father, c. 1830s).[58] Hence, I decided to focus on microscopy, histology, and cell

[58]This is ironic because my father, Bhagat Ram Bawa, not only was brilliant at mathematics but also had authored a few textbooks on mathematics and physics that were standard reading in high schools in Punjab from the 1940s until the mid-1970s.

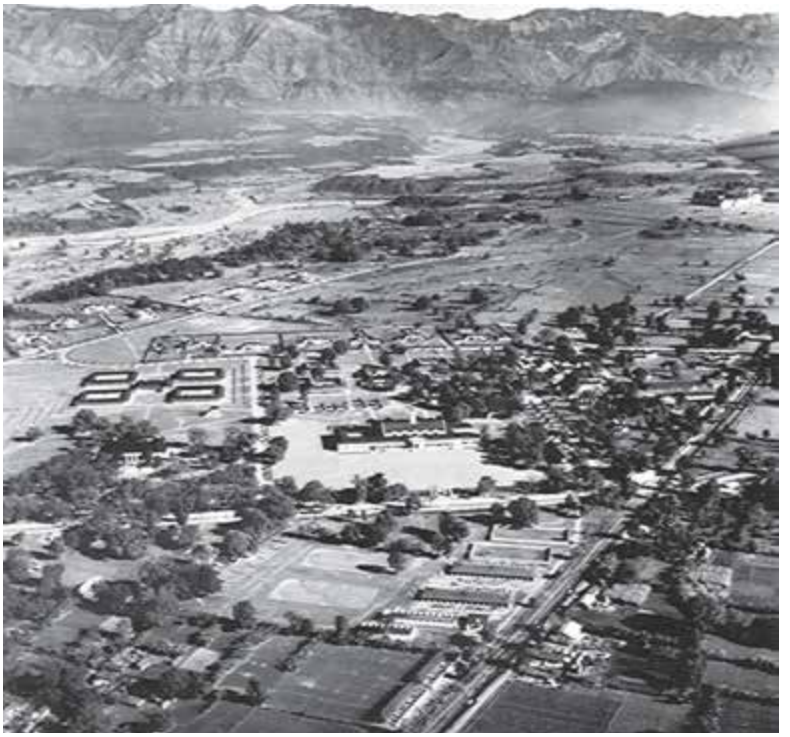


Photo 17. Aerial view of the Indian Military Academy (IMA) in 1932, the year it was established by General Sir Philip Chetwode, the Supreme Commander-in-Chief of the British India Army. The IMA was established for the training of Indian gentlemen as officers independent of the Royal Military Academy Sandhurst (RMAS), the British Army's initial officer training center. The photograph is courtesy of the estate of Colonel A. J. G. Bird of the Bengal Sappers and Miners, 1922–1932.

Photo 18. Air Force Candidates' Selection Board in Dehradun, February 6, 1952 (Batch No. FAG/5083). I am seated second from the right.

biology. The study of cells and tissues became a part of my life. My fascination and affair with microscopy and cell biology began in earnest during my graduate school years in India. During my early research years, a lot of these instruments were off-limits in the lab, available only to professors and postdoctoral fellows—and only at the universities with well-funded research facilities.

The light microscope (or optical microscope) can be used to view living and dead specimens (Images 4 and 5). While the transmission electron microscope (TEM) uses an electron beam to visualize the specimen, the light microscope employs a light beam to illuminate it. Also, the magnification is much lower than that of an electron microscope. The electron microscope is useful for viewing intracellular components not visible via light microscopy (Image 6). Electron microscopy commonly magnifies 100X to 300X more than the highest magnification of light microscopy. Typically, the sections must be ultra-thin cut to allow adequate penetration of electrons. The histological stains most useful for electron microscopy are those with heavy metal salts, as they create a phase-contrast needed to visualize structures. TEMs are better for investigating internal structures (Image 7), while scanning electron microscopes (SEMs) are typically the choice for topology or surface structures (Images 8–10). TEMs have accelerating potentials of several thousand volts and produce an electron beam that penetrates tissue and cell slices/sections of ~0.2 nm thicknesses. The development of high-voltage electron microscopes (HVEMs) in the 1970s was a major advance in microscopy. The HVEM was capable of accelerating electrons over a potential of one million volts, making it possible to study the specimens having the thickness of whole cells. Basically, the interior of the cell is revealed in depth. I was lucky to have access to HVEMs soon after the first prototypes were available for biomedical research: first in 1980 at the University of Wisconsin-Madison in the Hans Ris Lab and, later, in the 1990s at Wadsworth Laboratories in Albany, New York. These microscopes are quite spectacular, usually occupying two floors of a laboratory (they are approximately 30 feet tall) and weighing about 20 tons.

The major limitations of biological electron microscopy are due to the damage that high-energy electrons inflict on the specimen and that the liquid water present in the biological sample cannot be retained in the high vacuum of the microscope. Since my Columbia days in the early 1960s, cryo-electron microscopy (cryo-EM) had been considered a potential route to overcoming both of these limitations.[59] In the early 1980s, while I was at Downstate Medical Center in New York City and at the HVEM Facility of the University of Wisconsin-Madison, it was discovered that biological specimens can be vitrified for cryo-EM whereby water is immobilized in a vitreous state in which biological structures appear perfectly preserved. As a result, I started to employ cryo-EM in my research around the early 1980s. This finding also opened the avenue that led around 2010, through the contribution of researchers like Dr. Richard Henderson and Dr. Joachim Frank (who was at Wadsworth Laboratories in Albany when I worked there), to major advances in molecular structural biology and eventually to the 2017 chemistry Nobel Prize.

[59]Fernandez-Moran, H. (1960). Low-temperature preparation techniques for electron microscopy of biological specimens based on rapid freezing with liquid Helium II. *Annals of The New York Academy of Sciences* **85**:689–713.

Image 4. The hand-crafted, leather, and gold-tooled Hooke microscope, originally manufactured by Christopher White of London. Hooke is believed to have used this microscope for the observations that formed the basis of his book *Micrographia*. Photographed at the National Museum of Health and Medicine, Silver Spring, Maryland.

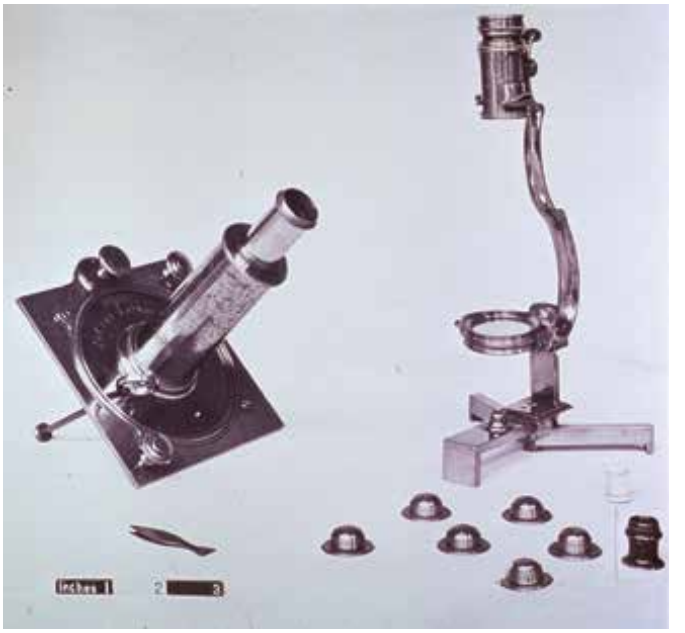


Image 5. General view of an early light microscope with various attachments.

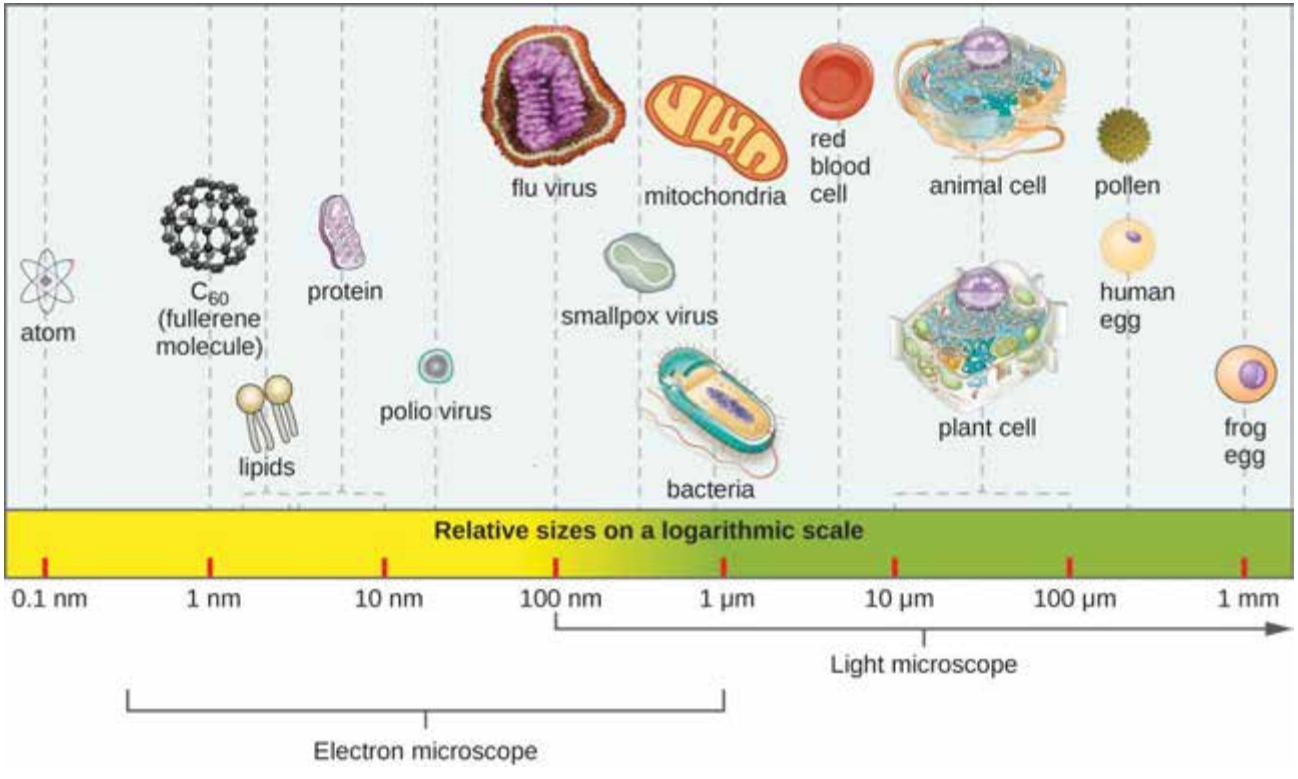


Image 6. Size does matter. The relative sizes of various microscopic and non-microscopic objects. Note that a typical virus measures about 100 nm, 10 times smaller than a typical bacterium (~1 µm), which is at least 10 times smaller than a typical plant or animal cell (~10–100 µm). Most microbes are unicellular and so small that they require magnification to be seen. However, there are some unicellular microbes that are visible to the naked eye, and some multicellular organisms that are microscopic. An object must measure about 100 µm to be visible without a microscope, but most microorganisms are many times smaller than that. For some perspective, consider that a typical animal cell measures roughly 10 µm across but is still microscopic. Bacterial cells are typically about 1 µm, and viruses can be 10 times smaller than bacteria. Courtesy of OpenStax.

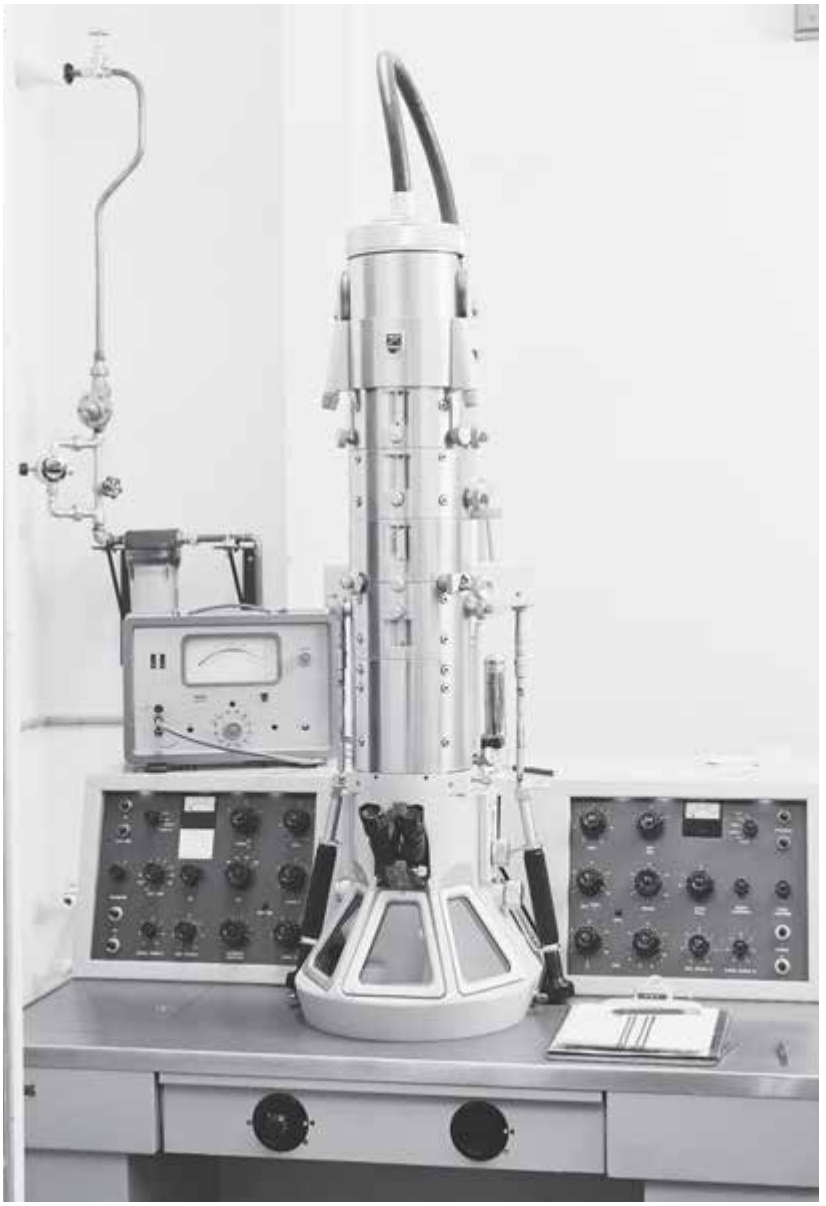


Image 7. This historic 1965 image depicts a transmission electron microscope (TEM). This remarkable instrument uses a beam of electrons that passes through an extremely thin specimen and on to an imaging surface. Rather than having a glass lens focusing the light (as in the case of a light microscope), the TEM employs an electromagnetic lens which focuses the electrons into a very fine beam. Sometimes a fluorescent surface is used, and at other times a sheet of photographic film, or in the case of modern-day technology, a digital camera captures the image. The electron microscope can reveal details that are tens of thousands of times smaller than can be seen by even the highest quality light microscope. TEMs can magnify objects up to 2 million times. Image courtesy of the Centers for Disease Control and Prevention.

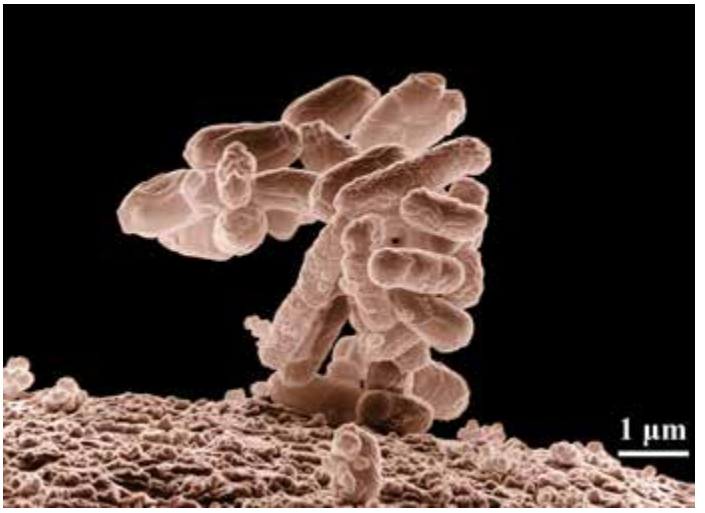


Image 8. SEM of *Escherichia coli* (*E. coli*). Low-temperature electron micrograph of a cluster of *E. coli*, magnified 10,000X. *E. coli* is a Gram-negative, facultative anaerobic, rod-shaped, coliform bacterium that is commonly found in the lower intestine of warm-blooded organisms. There are six classic pathotypes of *E. coli*: enteropathogenic *E. coli* (EPEC), Shiga toxin-producing *E. coli* (STEC), enteroaggregative *E. coli* (EAEC), enterotoxigenic *E. coli* (ETEC), enteroinvasive *E. coli* (EIEC), and diffusely adherent *E. coli* (DAEC). Most *E. coli* strains are harmless, but some serotypes (EPEC, ETEC, etc.) can cause serious disease. The harmless strains are part of the normal microbiome of the gut and can benefit their hosts by producing vitamin K2, and preventing colonization of the intestine with pathogenic bacteria, having a mutualistic relationship. *E. coli* is expelled into the environment within fecal matter. Courtesy of the Agricultural Research Service of the US Department of Agriculture and Wikipedia.

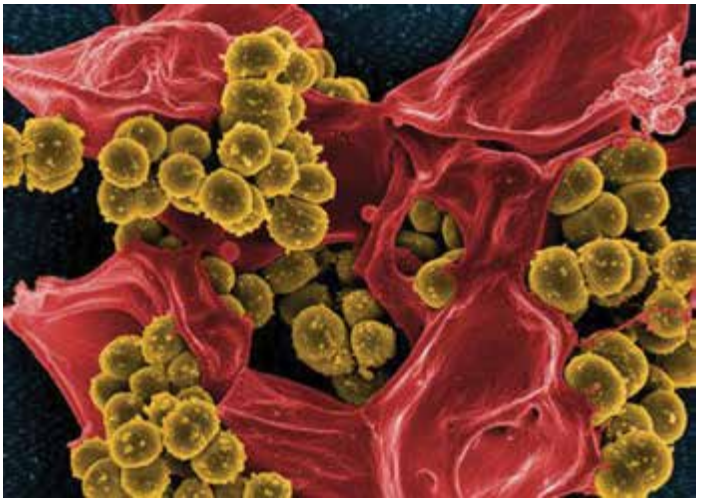


Image 9. Scanning electron micrograph of methicillin-resistant *Staphylococcus aureus* (MRSA) and a dead human neutrophil. Courtesy of the National Institute of Allergy and Infectious Diseases.

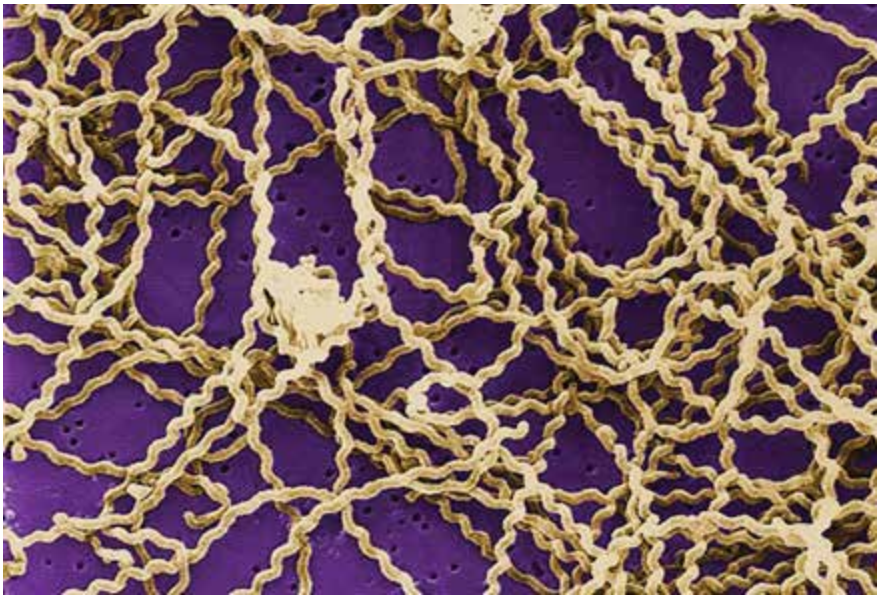


Image 10. This digitally colorized SEM image depicts a number of corkscrew-shaped, *Leptospira* atop a 0.1 µm polycarbonate filter. Courtesy of Janice Haney Carr, Centers for Disease Control and Prevention.

Histology—sometimes referred to as microscopic anatomy or histochemistry—is the microscopic visualization of tissue structure and the characteristic changes that tissue may have undergone. The tissue sample processing involves sequential steps of fixation, embedding, sectioning, staining, and microscopic examination (and sometimes antigen retrieval). Today, in a modern histology laboratory, most of these steps are automated. However, for a large part of my scientific career, this was not the case.

All chemicals in a laboratory setting should be handled appropriately. Current safety guidelines are a must for success in the laboratory or clinic. I feel a need to add this short note of precaution here as my extensive experience in the lab has shown me that often proper protocols for handling toxic chemicals are not fully followed. Stains, fixatives, and embedding agents employed in microscopy can be toxic. The introduction of the fixation of tissue with osmium tetroxide by Nobelist Dr. George Palade in the 1950s ushered in the modern era of electron microscopy of biological materials (Photo 19). However, a need for greater contrast and greater resolution in visualizing internal membranous and other structures has led to the introduction of methods for staining with heavy metal salts to enhance cell ultrastructure. Glutaraldehyde and osmium tetroxide fix cells by cross-linking their proteins via the amine groups (glutaraldehyde) or their phospholipids (osmium). Fixatives are harmful, volatile agents that can fix any cell they contact, including respiratory epithelium, corneas, and skin epithelial cells. On the other hand, the plastics used to embed tissue are often carcinogenic. During the embedding process, these plastics are dissolved in solvents that can penetrate through any plastic glove and exposure to them often causes permanent damage.

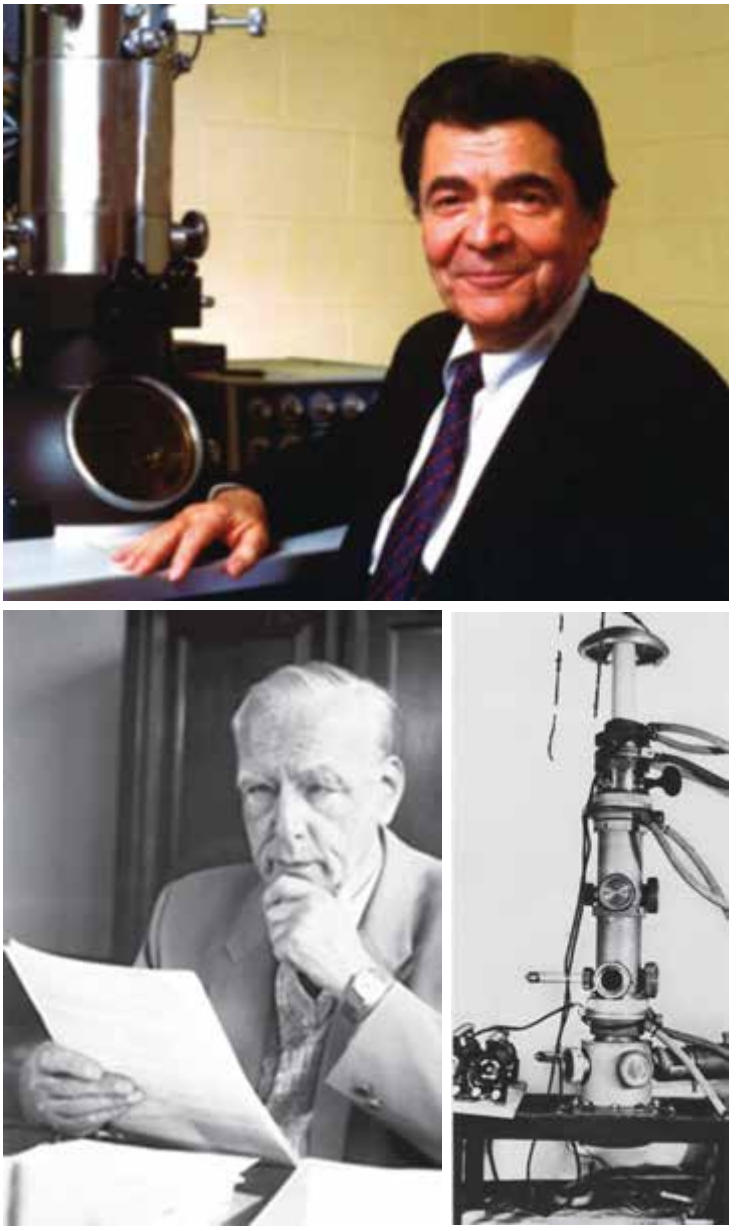


Photo 19. Giants of Electron Microscopy. Photographs of Nobelist Dr. George Palade (1912–2008) (top) and Nobelist Dr. Ernst Ruska (1906–1988) (lower left). Dr. Palade, "the father of modern cell biology," shared the 1974 Nobel Prize in physiology or medicine with Dr. Albert Claude and Dr. Christian de Duve "for their discoveries concerning the structural and functional organization of the cell." The first operational electron microscope was constructed by Dr. Ruska and Dr. Max Knoll in 1932 and, six years later, Dr. Ruska had the first version of it on the market. A later generation Ruska high resolution electron microscope from around 1934 is shown above (lower right). In 1986, Ruska received the Nobel Prize in physics for his "fundamental work in electron optics and for the design of the first electron microscope."

Medical histology—that is, tissue studies in which the samples are obtained from a patient—involves findings that are interpreted by a pathologist. The histochemical analysis of a tissue specimen allows the pathologist not only to diagnose but also to determine the severity of disease. Advanced interpretation in conjunction with a patient's medical history ultimately dictates the prognosis and treatment course. Obviously, the choice of histological stains for a given specimen depends on the investigational question at hand. Special stains for specific tissues not only aid in distinguishing structural alterations therein but also alert the physician to alterations in cellular physiology, both of which are highly relevant to making a diagnosis. In my view, histological examination and, subsequently, staining are the gold standard for the diagnosis of many pathological diseases. While we may automate the various tissue processing steps, or even incorporate the over-hyped Artificial Intelligence (AI) for data interpretation, I am concerned about over-reliance on technology in medical histology and pathology.

In contrast to AI and high-throughout technologies, I hold high regard for the microtome, which is a sophisticated cutting instrument used for sectioning a block of embedded tissue (i.e., paraffin-embedded, plastic-embedded, or frozen tissues). In a microtome, a sharp knife and the tissue block are held in a fixed orientation relative to each other, and with each pass of the tissue past the knife, the tissue block is advanced by a preset distance—the section thickness. For frozen sections, the section thickness typically ranges 8–15 μm, for wax sections 4–10 μm, and for plastic histological sections 0.5–3 μm. Typically, plastic sections used in TEM are in the range 60–100 nm.

I started my work in microscopy prior to the development of microtomes. It was the era of the "glass cutting edge." With it, I was able to cut thin sections more consistently, easily, and rapidly than with steel microtome knives. During my graduate school years, I relied on "glass knives" that I had obtained by simply breaking them from a strip of glass.[60] It was well recognized that fewer grooves or scratches are found on the face of a block of tissue after it has been cut with the glass edge. Glass knives are inexpensive. They are produced by breaking a strip of plate glass, whose subsequent edges will form clearance facets. Fractures generally are smooth and straight. Any competent glass cutter with standard equipment can produce these knives from stock plate glass. When I moved to New York City for my postdoctoral studies, I created my own glass knives for microscopy. Although unsafe, I would often enter demolished buildings to retrieve broken glass, which would then be crafted into glass knives in the lab. Such adventures by graduate students or post-doctoral fellows are no longer tolerated. In fact, they could be the basis of immediate expulsion or termination.

Since I first employed microscopy in 1951, I have witnessed numerous variations and technological advances in microscopy (Images 11–13). Examples include electron and scanning probe microscopes. Those wonderful machines—that allow us to peer at objects on the atomic and nanoscales—traditionally have been large and expensive. Increasingly, microscopic engineers and developers

[60]Latta, H., and J. F. Hartmann. (1950). Use of a glass edge in thin sectioning for electron microscopy. *Experimental Biology and Medicine* **74**(2):436–439.

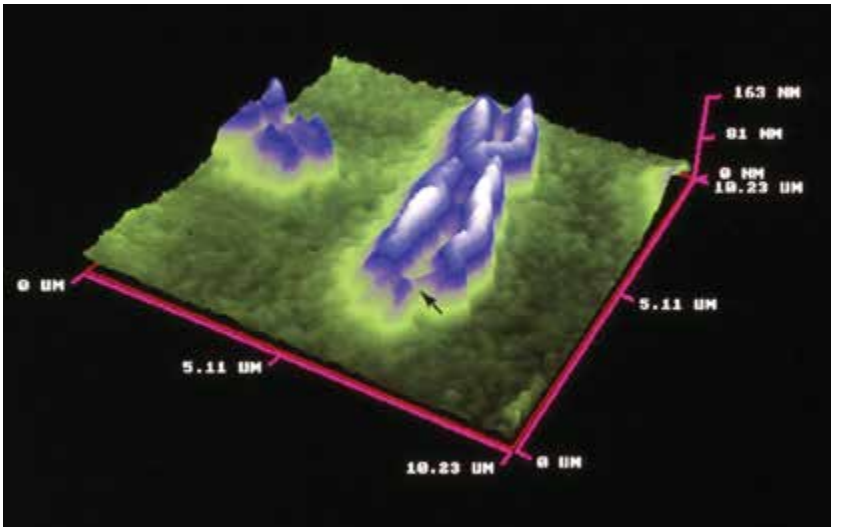


Image 11. Fragile X chromosome made visible by atomic force microscopy (AFM). The arrow indicates the fragile site. Micrograph courtesy of Dr. Ben Oostra.

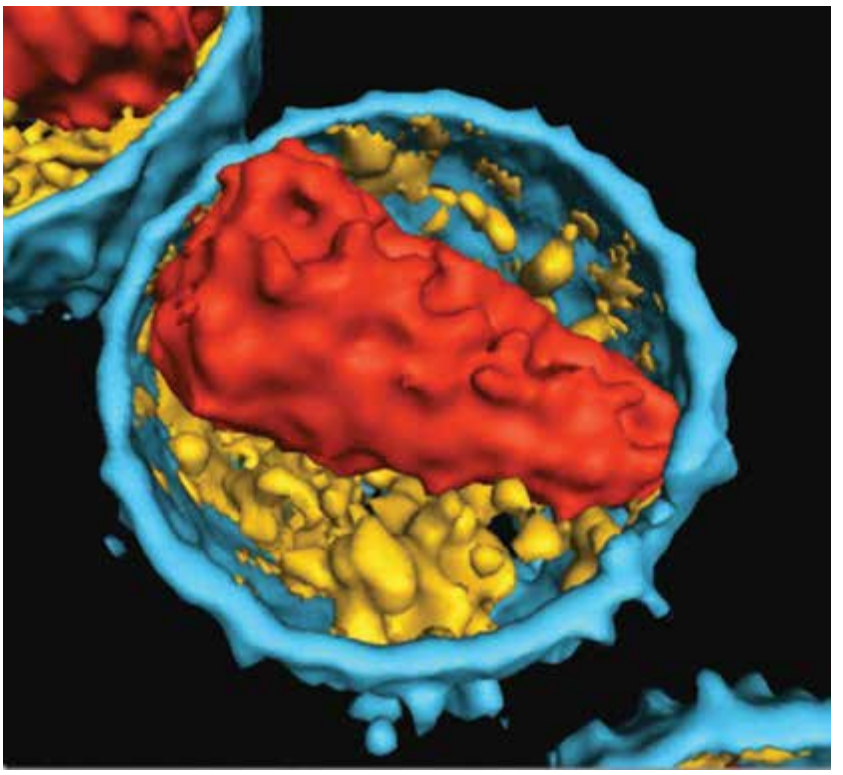


Image 12. Internal structure of a human immunodeficiency virus (HIV) particle showing the capsid surrounding the RNA-containing core in red and the membrane in blue. The yellow area is electron dense material, including proteases, between the core and the membrane. This false-color micrograph is courtesy of Stephen Fuller.

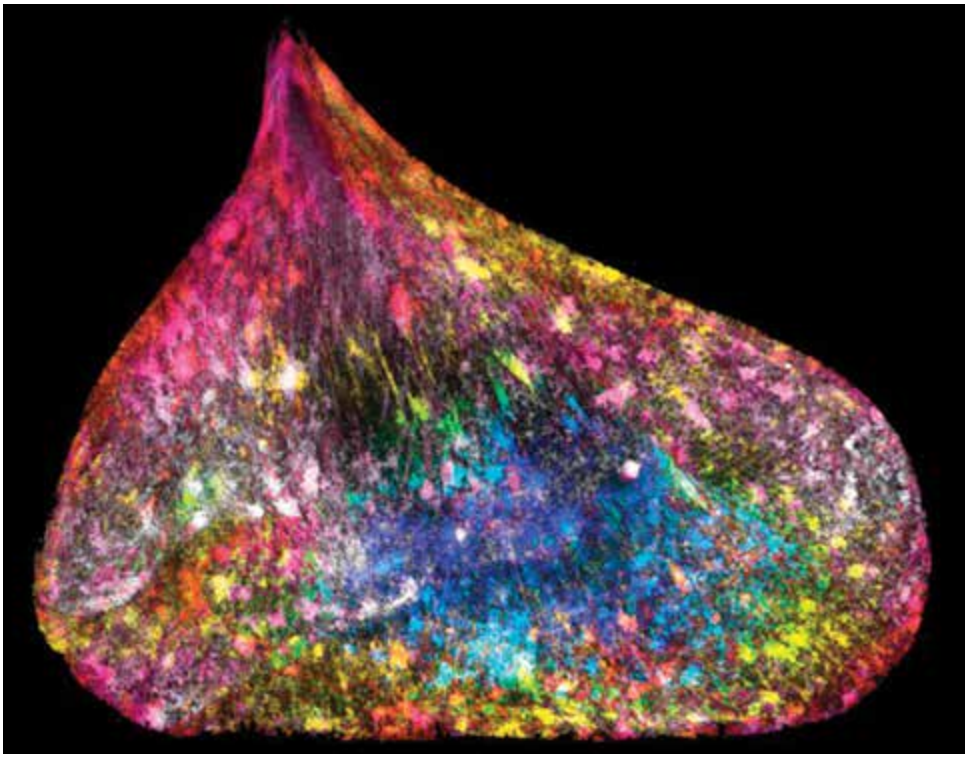


Image 13. Super-resolution optical micrograph of DNA stain in a human fetal lung fibroblast nucleus acquired with 3D structured illumination microscope (3D SIM). A rare phenomenon has occurred in this image; the majority of the genome has been caught in misreplication. If a single chromosome becomes caught and pulled between the two new cells, it can lead to the presence of small chromatin threads/bridges joining the adjacent nuclei. This leads to clearly demarcated chromatin fiber visible throughout the interior of the nucleus, and as the new cells move apart, the tension distributed by the cable-like chromatin deforms the entire nuclear envelope. The width of the image is 84 μm. Micrograph courtesy of Ezequiel Miron, University of Oxford.

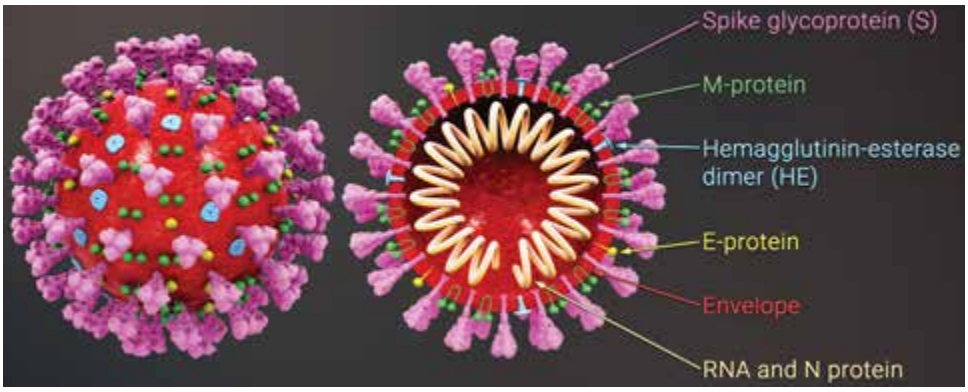


Image 14. An artist's rendition of a coronavirus. Courtesy of Wikimedia.

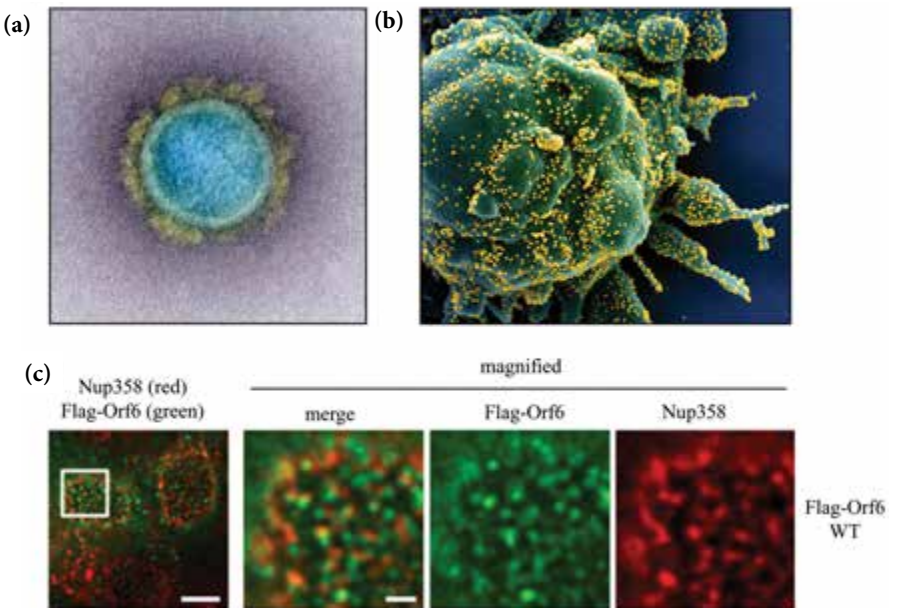


Image 15. SARS-CoV-2 and the cell. (a) Electron microscopy plays an important confirmatory role in diagnosis and determining subcellular localization. A false-color transmission electron micrograph of SARS-CoV-2 isolated from a patient. Coronaviruses are approximately 80–120 nm in diameter. (b) A false-color scanning electron micrograph of an apoptotic cell (green) infected with SARS-CoV-2 isolated from a patient. The virions can be observed as small yellow spheres. (a) and (b) are courtesy of NIAID. (c) Fluorescence microscopy can show subcellular localization. Co-localization of FLAG-tagged SARS-CoV-2 protein Orf6 with nuclear pore complex protein Nup358 in HEK293T cells as imaged by stimulated emission depletion (STED) super-resolution microscopy. The scale bar in the left-most panel is 5 μm. Scale bar in the magnified panels is 1 μm. This panel is adapted from Miorin, L. et al. (2020). *PNAS* **117**:28344–28354.

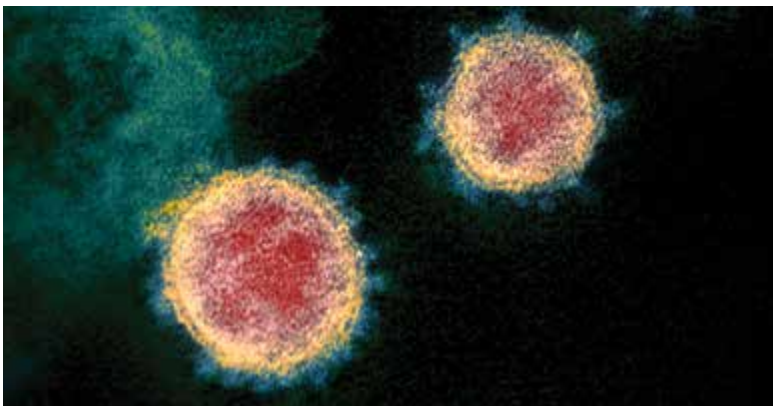


Image 16. Digitally colorized transmission electron micrograph of SARS-CoV-2 virions. Virion nanoparticles, isolated from a patient in the US, are shown emerging from the surface of cells cultured in the lab. The coronae (bluish) are visible on the surface of the virus (yellow-red). Courtesy of the National Institutes of Health.

are introducing smaller, less expensive, and sometimes portable versions of these devices. Last year, I read a report from Washington University in St. Louis about the Vortex Microscope, which captures 3D motion of molecules in a liquid. Advances in cryo-EM, driven by single-particle analysis and *in situ* tomography, have been phenomenal since I used them in the late 1990s. For example, cryo-EM has contributed to antibody development against the SARS-CoV-2 spike protein (Images 14–17).[61] I have also recently seen reports that electron microscopy of biological tissue of large tissue blocks (e.g., whole brains) is underway. In my view, this has a long way to go because homogeneous, high-quality electron microscopy staining of large biological samples will be a major challenge. I recently visited the Advanced Imaging Center at the prestigious Howard Hughes Medical Institute (HHMI) Janelia Research Campus close to my home here in Ashburn, Virginia. The HHMI houses a marvelous collection of well-maintained, cutting-edge microscopes. Currently, I am putting the finishing touches on a manuscript for publication pertaining to acrosome formation in spermiogenesis. My affair with microscopy continues...

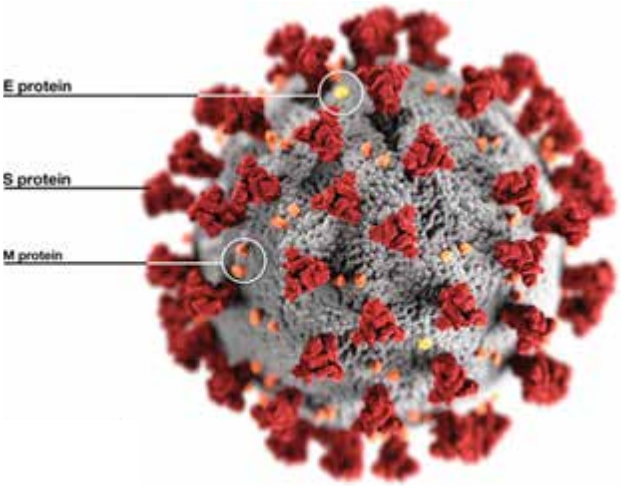


Image 17. The peplomers of a SARS-CoV-2. This classic illustration reveals the surface morphology/topography of the virus nanoparticle. Note the spikes that adorn the outer surface of the virus impart the look of a corona surrounding it when viewed electron microscopically. A peplomer (Greek, *peplos*, "robe," "[woman's] dress" + *meros*, "part") is one of the knoblike spike structures (red, orange, yellow), generally composed of glycoproteins (spike protein) and projecting from the lipid bilayer of the surface envelope of an enveloped virus. Peplomers play important roles in the infection process. Courtesy of the Centers for Disease Control and Prevention.

10.12 The Passage from India

I arrived in the US in 1958. It was my first trip abroad, and I had been awarded the prestigious Fulbright Fellowship to do postdoctoral work at Columbia University. I traveled by a cargo ship that, in addition to cargo, comprised eight passengers,

[61]Bawa, R., Editor. (2022). *Advances in Clinical Immunology, Medical Microbiology, COVID-19, and Big Data*. ISBN. Jenny Stanford Publishing, Singapore.

a few crew members, and the boat captain. We embarked on our voyage from Bombay Harbor, travelled though the Suez Canal, and arrived in New York Harbor after a month's journey. The voyage only could be described as "hell." There were few comforts, and seasickness was the name of the game. Eventually, we were greeted by the bright lights of New York Harbor—a spectacular image that is etched in my mind to this day. I initially stayed with Dr. Roop C. Sawhney in his elegant apartment on the Upper East Side. Dr. Sawhney was a Professor of Mathematics at NYU, and I owe much gratitude to him, as he facilitated a smooth transition to life in the Big Apple. He taught me how to elegantly dress for cold weather, how to properly eat steak, how to open a bank account, and how to safely drive. He was a bachelor and took me everywhere. I observed him closely and absorbed everything like a sponge. Four months later, my wife and young daughter joined me in New York, and we moved into a lovely flat on Riverside Drive (Manhattan) close to the Juilliard School of Music. My wife soon started working as Assistant Teacher at the Nursery-Kindergarten of Riverside School. Life was good (Photo 20).

Photo 20. With Rani in New York City, 1960. In 1947, we were both refugees in our own country, children of colonialism and scarred by the horrific partition of our beloved Punjab state. A decade later in 1958, we were in New York City—a city full of life, hope, vibrance, and diversity. We were excited to make a brand new start. Sampling the city's food, art, music, culture, and neighborhoods was a treat. We were redefining the present and creating our future. A decade later in 1969, at the age of 38, I was a Professor and Department Head. I had fulfilled my dream of being a tenured university professor. Over a period of two decades, I had moved from a refugee camp to the Ivory Tower. It felt that I was the king of the hill and top of the heap. I owe much to the Great City. ("*If I can make it there, I'll make it practically anywhere. It's up to you. New York, New York.*"—Frank Sinatra).

New York City was the biomedical mecca in the early 1960s. At that time, numerous pioneers and eminent researchers in biomedicine, anatomy, electron microscopy, and cell biology worked at Columbia, Cornell University Medical College, and Rockefeller University—all outstanding research institutions within

a one-mile radius. At Columbia and Cornell, I had the rare opportunity to work with the eminent minds of cell biology and microscopy.

Electron microscopes were developed in the 1930s, as the collaborative product of innumerable scientists—a truly international endeavor. The first electron micrographs were published in 1940 in Germany, and they were of bacteriophages. Cell biology emerged as a modern field after the electron microscope became more widely available in the 1940s and 1950s. The electron microscope gained prominence in biomedical research when Nobelist Dr. George Palade and Dr. Fritiof S. Sjöstrand independently published the first high-resolution micrographs of mitochondria in *Nature* in 1952 and 1953, respectively. Dr. Fritiof S. Sjöstrand (Photo 21) was a pioneer of electron microscopy and biomedicine. Dr. Sjöstrand, Dr. Keith Porter, and Dr. Palade constituted the "Big Three" in the 1950s for their exploratory use of the electron microscope to describe the details of cellular structure that anchored the burgeoning field of cell biology. Dr. Sjöstrand's work in the field of biological electron microscopy led to several pioneering developments and discoveries. As indicated above, in addition to producing the first high-resolution electron micrographs of biological tissue, he invented the "Sjöstrand Microtome" for ultra-sectioning biological tissue (Photo 21), was the first to describe the mitochondrial membranes (Image 18), and studied retinal synapses. Dr. Sjöstrand founded the *Journal of Ultrastructure Research* in 1957 (now *Journal of Structural Biology*). I extensively published in *Ultrastructure Research* and served on its editorial board from 1969 to 1985. Dr. Sjöstrand visited me at Panjab University several times, and I was a visiting professor in his lab at UCLA. In recognition of his remarkable contributions to the development of electron microscopy, the *Annual Sjöstrand Lecture* series was set up in 2018 in Sweden.

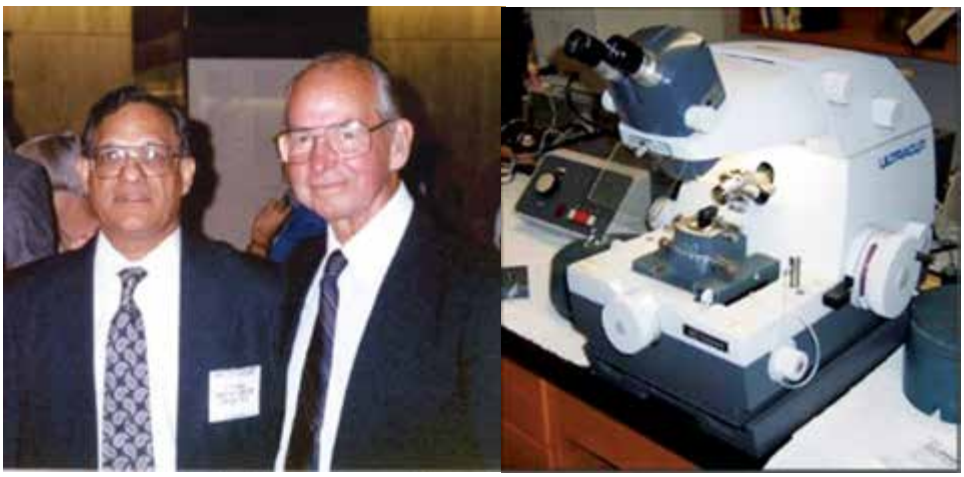


Photo 21. With my colleague, the distinguished Dr. Fritiof S. Sjöstrand (left) at the 12th International Congress on Electron Microscopy in August 1990 in Seattle. In the early 1950s, Dr. Sjöstrand developed an advanced microtome for thin sectioning, dramatically improving ultrathin sectioning with minimal distortion. He then engineered the next generation of microtomes using electrical heating of the specimen to advance it toward the knife, and the instrument became known as the "Sjöstrand Ultramicrotome" (right).

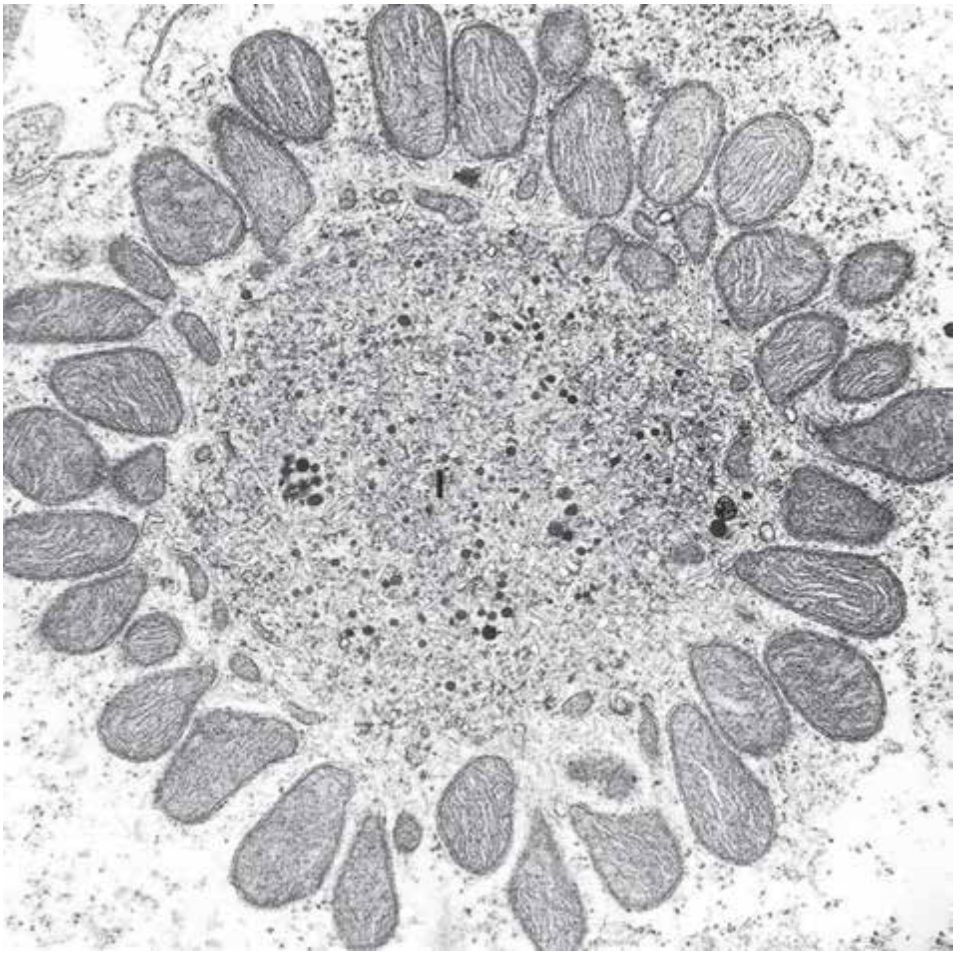


Image 18. An electron micrograph depicting sperm mitochondria essential for sperm motility. Mitochondria are organelles surrounded by double membranes, distributed in the cytosol of most eukaryotic cells and convert the potential energy of pyruvate molecules into ATP. A sperm cell contains around 50–75 pieces of mitochondria in its midpiece. The structure and function of the sperm mitochondria and mitochondria in somatic cells are basically similar. The sperm mitochondria generate ATP for the movement of the sperm. Mitochondria contain their own DNA (mitochondrial DNA), are semiautonomous, and have the capacity to replicate, divide, and fuse independent of the somatic nuclear division cycle. Further details: Bawa, S. R., and G. Werner. (1988). *Journal of Ultrastructure and Molecular Structure Research* **98(3):**281–293.

My first encounter with a transmission electron microscope (TEM) happened in 1958, while I was at Columbia's Department of Zoology. This is exactly where I wanted to do my postdoctoral studies. Being a zoologist, I had extensively consulted the 3rd edition of Dr. Edmund B. Wilson's classic text, *The Cell in Development and Inheritance* (1925), one of the most influential textbooks in modern biology.

I cherished Wilson's book and often read it aloud to my microscopic anatomy students. Dr. Wilson[62] was Professor of Zoology at Columbia in the 1890s, hence my attraction to the department.

My mentor at Columbia was the word-renowned anatomist Dr. Arthur Pollister, Professor and Chair of the Department of Zoology. He correctly predicted that chromosomal DNA carried the genetic information of the cell. Remarkably, this was done via microscopes and chemical dyes alone, in the absence of any X-ray diffraction studies or chemical analyses. In this context, it is worth referring to his obituary in *The New York Times* of October 22, 1994:

> *Dr. Pollister was among the first scientists to use the electron microscope in biological research. In 1949, he led a team that built an electronic device employing both visible and invisible light to determine the quantities of the constituents of a cell. Named the micro-spectro-photometer, it was sensitive enough to "weigh" quantities of a single cell's components existing in less than one-trillionth of an ounce. That made it possible to determine with unprecedented precision differences in the constituents of normal and diseased cells. Dr. Pollister's device, which took seven years to develop, advanced the studies of cells for research on cancer, anemia, genetics, biology, biophysics and related fields. Within a year, his team located and estimated the amount of DNA, the vital chemical substance that is responsible for hereditary control of life functions. He and his colleagues invented cutting techniques and "glass knives" that cut biological samples thin enough to view with the electron microscope. Using slices of frog's eggs one-millionth of an inch thick, they reported in 1954 the existence of tiny "threads of life" that link the nucleus of a living cell with its outer membrane.*

I was fortunate to have worked under Dr. Pollister's supervision and generate a few widely cited publications. Dr. Pollister insisted that I be listed as the sole author of all of these, as he considered the work product to be entirely mine. He felt it would be inappropriate to have him listed as a coauthor. Such was the class and character of the pioneers of cell biology and biomedical research of the 1950s and 1960s. Such episodes had a major impact on my professional life. I humbly carried on this practice whenever possible in my career, as I guided graduate students in their research. Unfortunately, nowadays I see the practice of "honorary authorship" as a norm, rather than the exception that should be shunned ("*The credit belongs to the man who is actually in the arena, whose face is marred by dust and sweat and blood…*"—Theodore Roosevelt). Dr. Pollister clearly approved of my research and teaching while at Columbia. A recommendation letter that he provided me dated February 19, 1964, attests to this:

[62]Dr. Edmund B. Wilson was a pioneering American zoologist and geneticist who wrote the famous textbook: Wilson, E. B. (1925). *The Cell in Development and Heredity*, 3rd ed. (1st ed. 1896; 2nd ed. 1900). Macmillan, New York, USA. He was one of the first researchers to describe the chromosomal basis of sex. Wilson is credited as being America's first cell biologist. In 1898, he used the similarity in embryos to describe phylogenetic relationships. By observing spiral cleavage in mollusks, flatworms, and annelids, he concluded that the same organs came from the same group of cells and concluded that all these organisms must have a common ancestor.

> *My association with Doctor Bawa was a close one for three years here at Columbia, when he was a laboratory instructor in my undergraduate course and then a post-doctoral fellow. He was one of the most successful of all the teachers during the thirty-two years I have been offering this course. He was always fully prepared, was patient and helpful with each student (whether good or bad) and was invariably cooperative in all the work of the course outside the classroom. Students respected and liked Doctor Bawa; it is no exaggeration to say that the laboratory morale during those two years was at its highest peak. I regard Dr. Bawa as what we often call a "born teacher", meaning that he has the rare combination of intellect and personality that qualify him most admirably for imparting knowledge to those just encountering a new area of knowledge. Dr. Bawa is also notably skilled as a research worker... As a cytologist, he has boldly studied and mastered such difficult techniques as electron and interference microscopy…The future of cytology lies in the hands of such men—and of the younger Indian workers whom I have known, Bawa is especially outstanding. His mastery of these modern ways of working with cells plus his uncommon drive and capacity for hard, persistent effort are likely to place him among the future leaders of the field. He could undoubtedly have a fine career in the United States, but quite properly feels that his service can be of much greater value in his native country.*

A decade later in 1969, upon my appointment as a full professor at Panjab University, he shared a copy of a confidential letter he had written on October 28, 1959. It reads, in part:

> *Our staff was unanimous in praise of Dr. Bawa's service in this post…He is a gifted teacher. In spite of this heavy teaching load, Dr. Bawa managed to carry on considerable research…For this year, Dr. Bawa was awarded one of the four coveted Post-Doctoral Boese Fellowships of Columbia University. This was a merited recognition of his promise as an investigator, which was amply indicated by his published research and studies during 1958–59. We have come to have great respect for Dr. Bawa as a scientist and to like him as a fine person. He is a fully accepted member of our closely knit research group—a status very rarely achieved by a visitor. We shall have genuine regret when he ends his stay with us.*

Following my years at Columbia University, I was hired as an instructor at Cornell University Medical College, Department of Anatomy, during Dr. Donald Fawcett's (1917–2009) chairmanship. I was there for three years from 1960 to 1963. In the 1950s and 1960s, great strides in cell biology and biomedicine continued to be made at Cornell. I felt exhilarated to be in the right place at the right time ("*Life is like a game of cards. The hand you are dealt is determinism; the way you play it is free will.*"—Jawaharlal Nehru). For instance, around 1960, the American Society for Cell Biology (ASCB) was founded by premiere names

in biology while I was in the department. These quintessentially descriptive scientists—whose seminal work would be advanced by later generations of cell biologists and biochemists—were Drs. Keith Porter, Montrose Moses, Morgan Harris, Hans Ris, Hewson Swift, and J. Herbert Taylor.

Dr. Fawcett was a master of electron microscopy and one of the greatest cell biologists of his time.[63] His greatest achievement was his description of the structure of spermatozoa and the male reproductive system. He used his exceptional skills in the darkroom to produce superb prints of electron micrographs to illustrate the key features of each image. In my opinion, his detailed ultrastructural works on human spermatozoa and the anatomy of male reproductive system are among the finest cellular images ever produced in this field. As a fellow spermatologist and anatomist, I appreciated the research environment and facilities in the department. Later, after I had left Cornell in 1963, I was flattered to note that two of my electron micrograph images of the Sertoli cell of the human testes were included by Dr. Fawcett in his classic textbook of histology.[64] In my mind, this validated the significance of my research work while at Cornell. It clearly met the high standards of Dr. Fawcett *viz-a-viz* embedding, staining, and sectioning of biological tissue.

The esteemed department faculty also included Dr. George N. Papanicolaou (1883–1962), a pioneer who elucidated the physiology and cytologic characteristics of the female reproductive system (Photo 22). He is best known for creating the Papanicolaou test, more commonly referred to as the Pap smear, a cytological staining technique that revolutionized the early detection of cervical cancer in female patients (Images 19 and 20).[65] Dr. Papanicolaou was a remarkable human being, a man of compassion and grace. Despite our enormous age difference (I was 29 and he was in his 80s) and academic status (he was an Emeritus Professor, and I was a Lecturer), I often found myself in his modest office. We both were interested in career opportunities in America and arrived as immigrants in New York City with little money in our pockets. Being a zoologist, I was fascinated that he had worked with Dr. Ernst Haeckel (1834–1919) in

[63]Dr. Fawcett described the early days of electron microscopy as follows: "*For morphologists the decade from 1950 to 1960 held the same anticipation and excitement that attends the opening of a new continent for exploration. The electron microscope revealed marvelous order and functional design in the organization of every tissue and organ that was examined and added significantly to our understanding of our own structure.*"

[64]Fawcett, D. W. (1997). *Bloom and Fawcett: A Textbook of Histology.* 12th Sub-edition. Hodder Arnold, London, UK.

[65]The Pap smear involves (i) sample collection, (ii) staining, and (iii) microscopic analysis. (i) Sample Collection: The cells to be stained are collected from gynecological smears, sputum samples, brushings, fine needle aspiration materials, and/or washings. (ii) Staining: The multichromatic stain involves five dyes: Hematoxylin for the nucleus, Orange G for keratin, Eosin for superficial structures, Light Green SF for cytoplasm, and Bismarck Brown. (iii) Microscopic Examination: In the setting of a cervical cancer screening Pap smear, the resulting stain of the epithelial cells from the transitional zone of the cervix undergoes analysis for precancerous and cancerous processes. Often a second slide is prepared for immunostaining with the biomarker p16INK4a for identifying dysplasia.

Germany, one of the first influential supporters of Darwin.[66] Dr. Haeckel, the "German Darwin," was a zoologist, artist, philosopher, and doctor. He discovered and described hundreds of species, coined key terms (ecology and ontogeny/ phylogeny), and popularized the "recapitulation theory" during embryonic development of animals. His artwork, comprising more than 100 exquisite illustrations and watercolors, was published in his masterwork, *Kunstformen der Natur* (Image 21). I often would quiz Dr. Papanicolaou on his encounters with other giants of science and medicine. He was most modest in his response, often downplaying his interaction with them. Eventually, I received a rare honor from him: Dr. Papanicolaou allowed me to sit in his desk chair in his office. He also gave me a copy of his 1954 classic, *Atlas of Exfoliative Cytology*.[67] This book was a milestone in the development of the rapidly expanding field of cytologic diagnosis. It contained detailed instructions on the collection, processing, and staining of a wide variety of biologic materials. In the 1950s and early 1960s, the application of exfoliative cytology to the study of cancer, endocrine, and metabolic disorders was still in its infancy. As the methods for the identification of cancer cells improved over the decades and became less expensive, exfoliative cytology became more feasible. In 1961, after nearly 50 years at Cornell, Dr. Papanicolaou decided to leave Cornell to establish the Cancer Institute of Miami (now Papanicolaou Cancer Research Institute). I was one of the first ones to bid him farewell. Sadly, he passed away a few months after arriving in Miami. Although we were in the same department for less than two years, I owe him much gratitude for his honest advice and for being a guiding star.

Dr. Fawcett left Cornell around 1960 to chair the Anatomy Department at Harvard Medical School in Boston. Our new chairman was Dr. Roy C. Swan, Jr. (1921–1996), noted for his research in kidney and skeletal muscle physiology. He remained my departmental chair until I left Cornell in 1963 (Photo 22). In fact, he was chair for 18 years, and in 1970, he was named the Joseph C. Hinsey Professor of Anatomy. His textbook, titled *Gunshot Wounds: Pathophysiology and Management*, is the gold standard in the field and is used by medical schools, emergency services workers, and medical examiners. Dr. Swan was a wonderful mentor and supported my research activities.

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[66]According to Willmann, R., and J. Voss. (2020). *The Art and Science of Ernst Haeckel.* 40th edition. Taschen, New York: "*At the heart of Haeckel's colossal legacy was the motivation not only to discover but also to explain. To do this, he created hundreds of detailed drawings, watercolors, and sketches of his findings which he published in successive volumes, including several marine organism collections and the majestic Kunstformen der Natur (Art Forms in Nature), which could serve as the cornerstone of Haeckel's entire life project. Like a meticulous visual encyclopedia of living things, Haeckel's work was as remarkable for its graphic precision and meticulous shading as for its understanding of organic evolution.*"

[67]See: Papanicolaou, G. N. (1954). *Atlas of Exfoliative Cytology.* Harvard University Press, Cambridge, Massachusetts, USA.

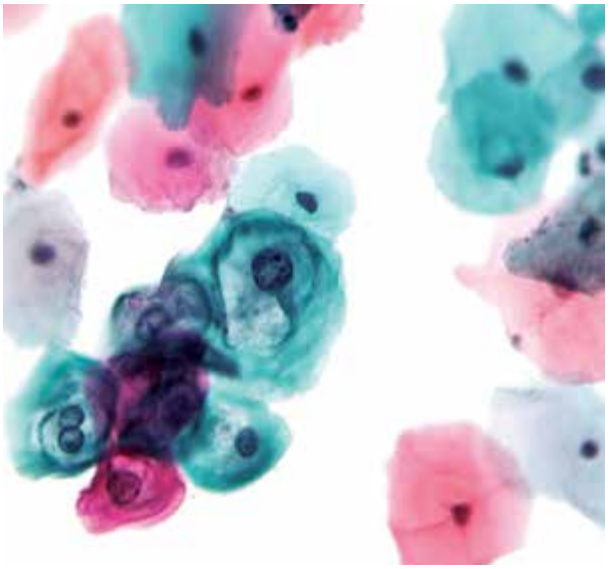


Image 19. Papanicolaou stain showing a low-grade squamous intraepithelial lesion (LSIL) from a Pap test. LSIL is an abnormality found on a pap test that consists of cells that are abnormal and may develop into cervical cancer. Abnormal cells have an enlarged nucleus, irregular chromatin, and relatively abundant cytoplasm. Binucleation and peri-nuclear glycogen are commonly seen. Courtesy of Wikipedia.

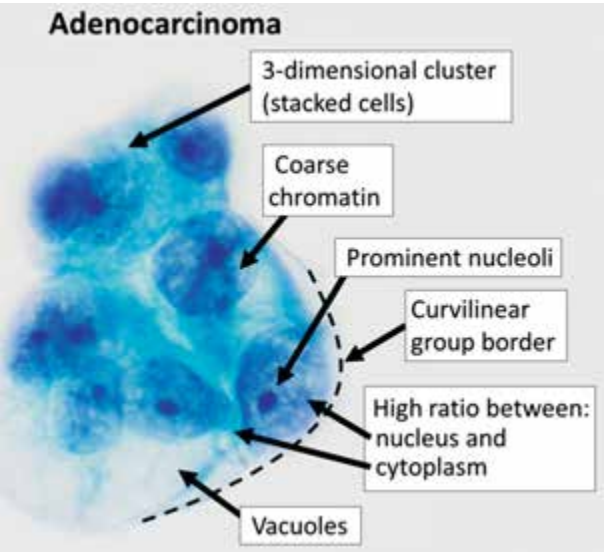


Image 20. Pap stain of adenocarcinoma in peritoneal fluid. Cytopathology of peritoneal fluid in a case of peritoneal carcinomatosis, showing typical features of adenocarcinoma. The Pap stain is one of the most widely used stains in cytology, where it is used to aid pathologists in making a diagnosis. Although most notable for its use in the Pap test or Pap smear as a reliable technique in cervical cancer screening in gynecology, it is also used to stain non-gynecological specimen preparations from a variety of bodily secretions and from small needle biopsies of organs and tissues. Courtesy of Wikimedia.

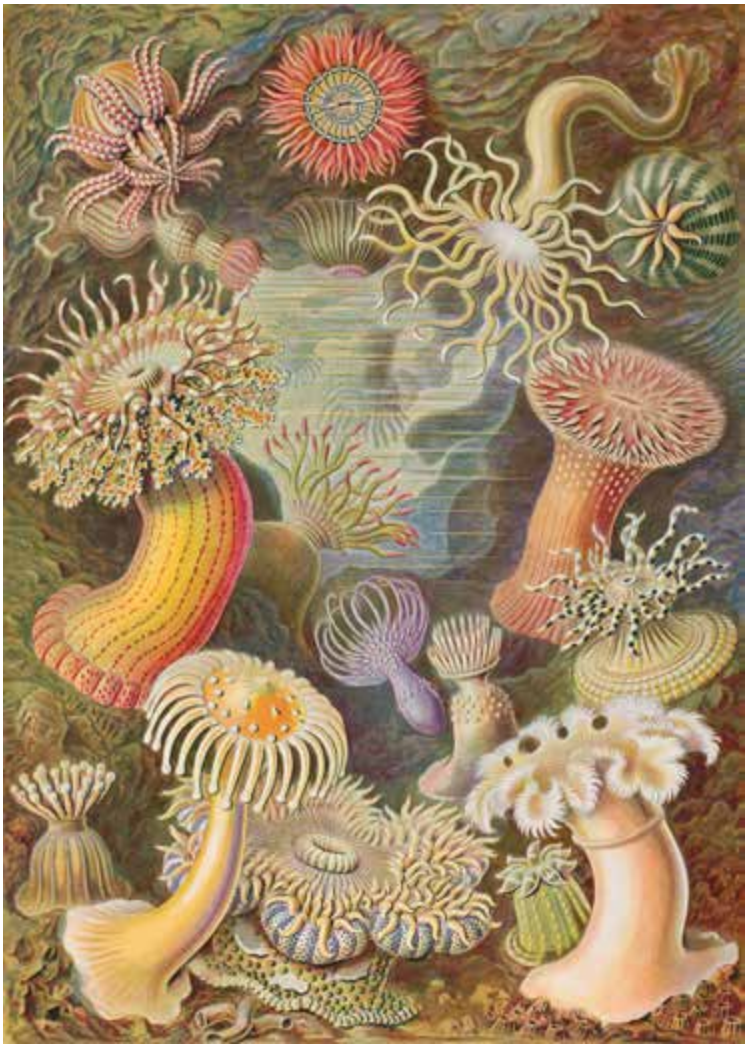


Image 21. Sea anemones from Dr. Ernst Haeckel's *Kunstformen der Natur* of 1904.

Dr. Leonard L. Ross (1928–2013), Assistant Professor in the department, was a distinguished medical scientist. Prior to his tenure at Cornell, he taught anatomy at the University of Alabama Medical and Dental Colleges in the 1950s, where he established its first electron microscopy facility. Since he was among the first to employ the electron microscope as an investigative tool, I greatly valued his guidance in my research activities. He was warm and generous, freely sharing equipment, chemicals, and technical skills. We developed a close professional and personal relationship. He was a born educator and an exceptional teacher. In the early 1970s, Dr. Ross was appointed Professor of Anatomy at Cornell before moving to Philadelphia in 1973 as Professor and Chairman of the Department of Anatomy at the Medical College of Pennsylvania. He was a terrific administrator and served as the provost of Hahnemann University and Dean of

the Hahnemann University School of Medicine, the only non-physician at that time in the country to hold that title at a medical school. Before his retirement in the late 1990s, he was Dean of the consolidated Medical College of Pennsylvania and Hahnemann University.

Photo 22. Faculty of the Department of Anatomy at Cornell University Medical College in 1960. I am standing, third from left. The legendary Dr. George N. Papanicolaou is seated fourth from the left. The department Chair, Dr. Roy C. Swan, Jr., is seated fifth from the left. Dr. Leonard L. Ross is seated first from the right while Dr. George B. Chapman is seated second from the right.

Dr. George B. Chapman (1925–2016), Associate Professor in the department, was another excellent role model with whom I formed a tight bond. He was a rare individual who made a difference by being on this planet; one of the finest human beings I have ever met. He pioneered several techniques in biological electron microscopy. He epitomized the phrase, "gentleman and a scholar." We discussed varied topics: my research on the human testes, developing new staining techniques, improving ultra-sectioning of tissues, updating the histology lectures for our medical students, life in Europe during the Second World War (he had been a radioman in the US Navy), his graduate school years under Dr. James Hillier (Hillier constructed the first practical electron microscope in 1938), my life in Lahore under the British colonial rule (1929–1947), and so on. He was a bachelor all his life and lived with his aging mother until her death in 2011. I left for India in 1963, the year he was recruited to head Georgetown University's Biology Department, where he spent 50 years and retired in 2011. He provided me with an excellent two-page recommendation letter, dated November 11, 1963. It reads, in part:

> *I was privileged to have Dr. Bawa as a colleague during the three years I served as Associate Professor of Anatomy, in charge of the course of microscopic anatomy at Cornell…Dr. Bawa was one of the few lecturers to be accorded the applause of the*

> *students at the end of a lecture…In this highly competitive field of research [electron microscopy], Dr. Bawa can be rated among the most competent…I can only add that I would, at any time, be pleased to be able to list Dr. Bawa among my colleagues. I trust that these comments have conveyed some impression of the high regard I have for Dr. Bawa as a person, as a teacher and as a scientist.*

In addition to providing life-changing connections, my research work at Cornell afforded me the opportunity to work with a Philips TEM at Columbia. I recall a feeling of great excitement and expectation when, in 1960, I finally received training on the Philips TEM at Columbia. Later, I had access to an RCA TEM while at Cornell. The spirit of research permeated these departments and institutions. It was my high privilege to be associated with the scholarly faculty, medical fellows, and students at Columbia and Cornell. Presentations at workshops, symposiums, and international scientific meetings helped me in my professional development. Since my investigations on *Thermobia* spermatozoa at Columbia had been very promising, I naturally extended them while at Cornell by employing a variety of techniques and tools. Many of them were being developed by the pioneers who surrounded me as colleagues or under whom I was training. It was an era of rapid advancements in biological sciences. Electron microscopy enabled me to delineate further the structural details of those developing sperm cells which previously had been beyond the reach of the light microscope. *Thermobia* spermatozoa turned out to be atypical flagellate sperm because their acrosome (an organelle for effecting the fertilization of the ovum) was located toward the tail end of the sperm rather than at the usual apical end. Furthermore, these spermatozoa were highly unusual in another respect: They were joined in pairs and yet exhibited motility (Image 22). In fact, unpaired spermatozoa appeared immotile. I filmed spermatozoa in motion in the laboratory of Dr. Keith Porter at the Rockefeller Institute for Medical Research (now Rockefeller University).[68] Encouraged by new preparative techniques in fixation, embedding, sectioning, and staining ultrathin sections, I subsequently extended my research to various organelles of developing sperm cells. Tubules, hitherto unreported, were found in the cytoplasm of late spermatids of *Thermobia*. Additionally, electron microscopy enabled me to unravel the complex architecture of the plasma membrane of the paired spermatozoa in the water beetle (*Dytiscus* sp). Over the years, I have also studied the complicated differentiation of the developing spermatids of the Pseudoscorpion (*Diplotemnus* sp.). This process is unique because it is accomplished without the presence of microtubules. Instead, membranous tubes (unlike those reported before) measuring about 50 nm in diameter were found in these spermatids.

[68]This 16 mm film, which I still possess, has been the subject of many a conversation at international conferences, dinner talks, and presentations. I last presented it at a departmental seminar at Rensselaer Polytechnic Institute in Troy, New York, where my son Raj Bawa, PhD, MD, was an Adjunct Professor from 1998 to 2018.

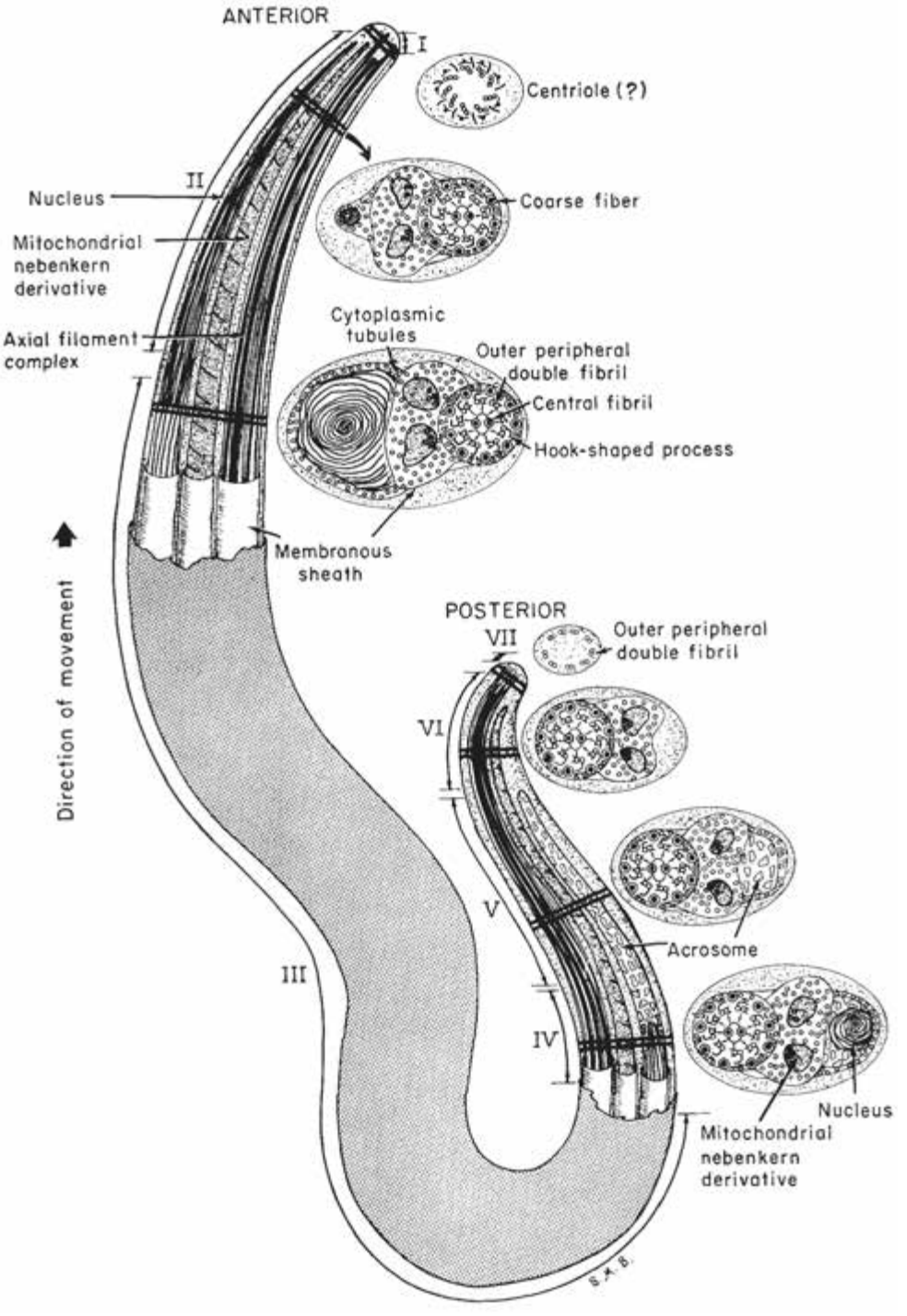


Image 22. A schematic diagram of a mature spermatozoon of *Thermobia.* It has been divided into segments I to VII. Further details: Bawa, S. R. (1964). *Journal of Cell Biology* **23**:431–445.

10.13 From Cornell to Panjab University

Upon my return to India, which was meant to be a visit to meet relatives after five long years in New York, I was approached by Dr. A. C. Joshi (1908–1971). He was the first Vice-Chancellor of Panjab University after it had been consolidated in 1958–60 at Chandigarh, a city that did not even exist prior to 1947. Panjab University (note the "a") traces its origins to the University of the Punjab (note the "u") at Lahore (now Pakistan), which was founded in 1882. After the partition of Punjab state, East Panjab University was established on October 1, 1947. Initially housed at a cantonment in Solan, it was later relocated to a newly built campus in Chandigarh, during which time it was renamed Panjab University. In fact, until 1956, the teaching departments were scattered across Amritsar, Ludhiana, Jalandhar, Hoshiarpur, and even Delhi, while the library was at Shimla. It was only between 1958 and 1960 that all the departments moved to the new city of Chandigarh under the aegis of Dr. A. C. Joshi. Being a displaced person from Lahore, I fully appreciated the adverse circumstances under which Panjab University had been called into being. The university, which is spread across 550 acres, today has 78 departments and 10 centers/chairs for teaching and research at the main campus in Chandigarh. It has 188 affiliated colleges spread over the eight districts of Punjab and Chandigarh, with regional centers at Muktsar, Ludhiana, and Hoshiarpur.

Dr. Joshi was diligently seeking talent to lead the various departments of Panjab University. As a result, I was heavily recruited by him and after my first interview was given an impressive initial offer to serve as Founding Head and Reader of the Department of Biophysics at the university. As I previously described, I had no intention of staying in India and had accepted a position at Georgetown University. Nevertheless, the exciting prospect of a job at the sprawling campus of beautiful Panjab University, in the stunning city of Chandigarh at the foothills of the majestic Himalayas, was appealing. The university campus was well planned, constructed of beautiful red sandstone (Photos 23–25). After all, the nascent university was to serve as a showcase for the country. Moreover, I believe that its cornerstone had been laid by Nehru.

Many buildings in Chandigarh and at Panjab University were constructed under the direct supervision of the revered Swiss-French architect, Charles-Édouard Jeanneret (1887–1965), known as Le Corbusier[69] (an altered form of his maternal grandfather's name, Lecorbésier), and his cousin, Pierre Jeanneret (1896–1967). Le Corbusier was an architect, designer, painter, urban planner, writer, and a pioneer of modern architecture (Photo 26 and Image 23).

[69]ART/ARCHITECTURE – Le Corbusier. Available at: https://www.youtube.com/watch?v=-sT1f1Se_9g (accessed on May 1, 2023).

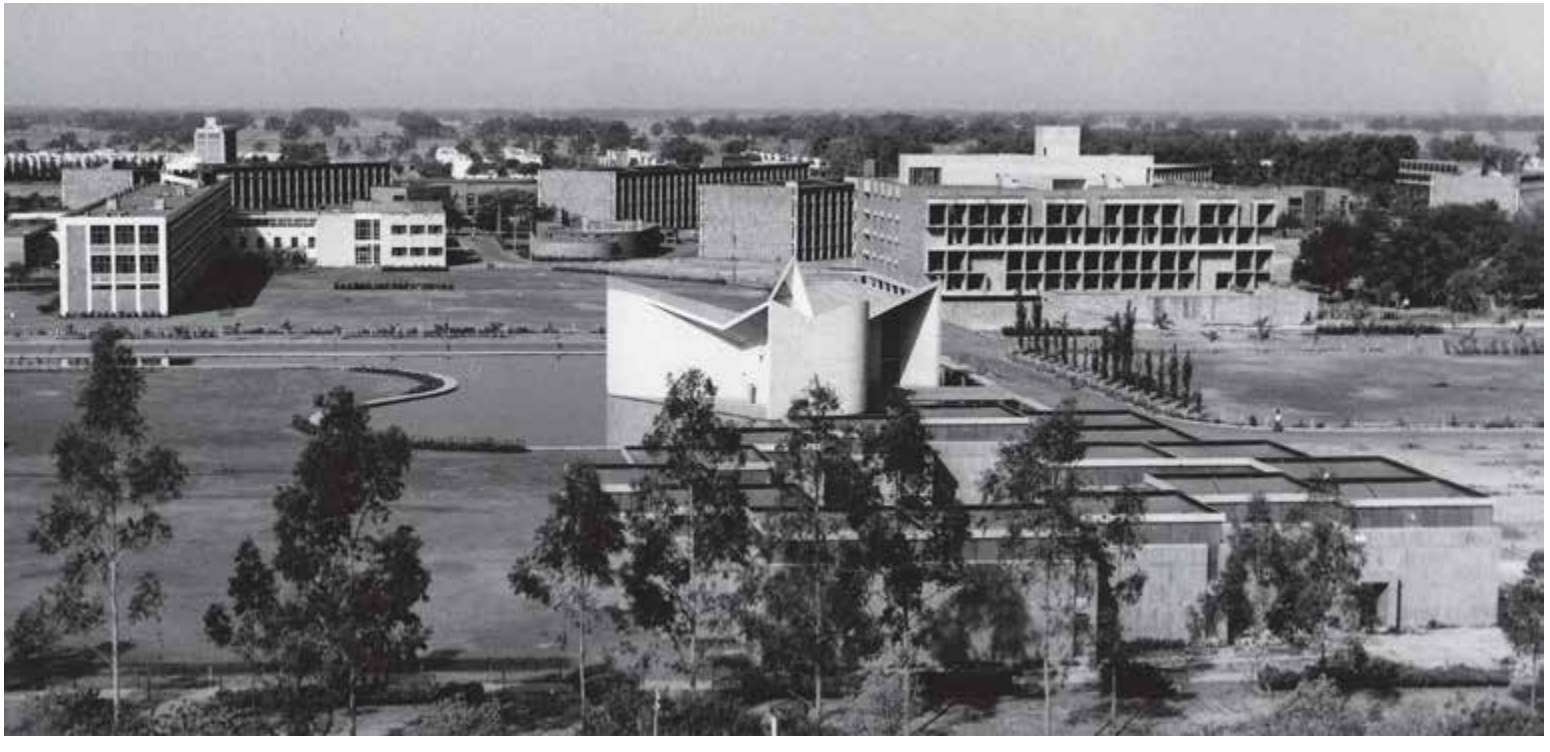


Photo 23. An aerial view of the Panjab University campus in the early 1960s, when I joined the faculty as a Reader-Head of the Biophysics Department. The Basic Medical Sciences building, under construction, is not visible in this photo.

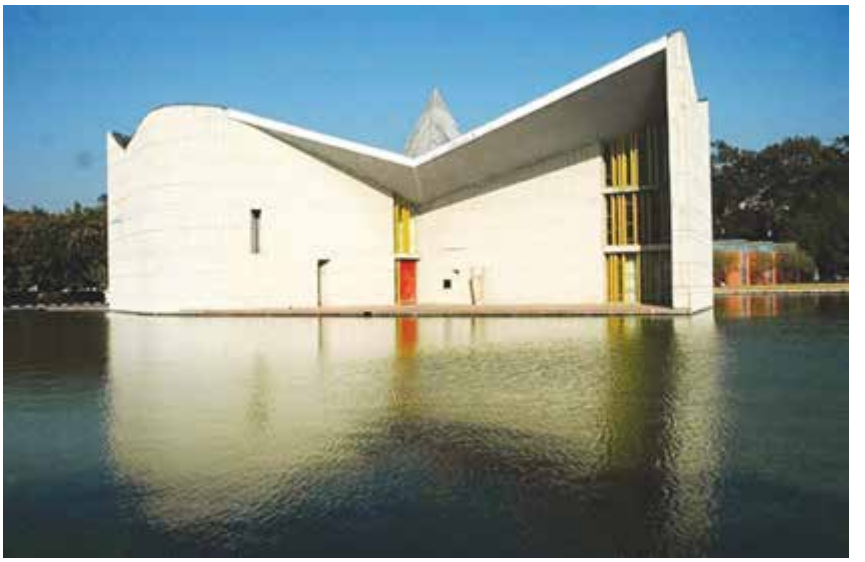


Photo 24. The Gandhi Bhawan is a major landmark of Chandigarh. It is a Panjab University center dedicated to the study of the words and works of Gandhi. Basically, it is an auditorium hall that sits in the middle of a pond. A mural by the architect greets visitors at the entry. The words "Truth is God" are written at the entrance. It was designed by Pierre Jeanneret, the Chief Architect of Panjab University. Jeanneret used innovative cast concrete to evoke an abstracted floating lotus flower, marrying angular lines with swelling organic forms, all fittingly set into a large reflecting pool.

Photo 25. India's first prime minister Pandit Jawaharlal Nehru with Vice-Chancellor, Dr. A. C. Joshi at the inauguration ceremony of the Panjab University Library on October 23, 1963. The foundation stone of the new Library building was laid in 1958 by Dr. S. Radhakrishnan, the then Vice-President of India. During the inauguration ceremony, the remote control to lift the curtains malfunctioned and two employees had to manually raise them. Nehru then joked with the Vice-Chancellor: "*Mr. VC mere saath dhoka hua hai*" ("Mr. Vice-Chancellor, I have been ditched").

Image 23. The 10-Franc Swiss bank note depicting Le Corbusier. Swiss francs, like most world currencies, have long featured notable faces from the past. The Corbusier 10-Franc bill was in circulation since 1995. The Swiss National Bank has now retired it. The reverse side of the note depicts the Palace of Justice at Chandigarh and the facade of the Secretariat at Chandigarh.

Le Corbusier is widely acclaimed as one of the most influential architects of the 20th century whose radical ideas, designs, and writings presented a whole-scale reinvention not only of individual structures but of entire concepts of modern living. Moreover, he gained international recognition as a designer of furniture and as an architect of sacred buildings, for example, the famous pilgrim church of Notre-Dame-du-Haut in Ronchamp. He designed buildings in Europe, Japan, India, and the Americas. He prepared the master plan for Chandigarh and contributed specific designs for several buildings, especially the government buildings. Le Corbusier used skeleton construction and prefabrication techniques in an innovative industrial approach to building. The government complex in Chandigarh was designed in this fashion. Like his contemporaries, Frank Lloyd Wright and Mies van der Rohe, he lacked formal architectural training. In 2016, seventeen of his projects in seven countries were inscribed in the list of UNESCO World Heritage Sites.[70]

[70]UNESCO World Heritage List. Available at: https://whc.unesco.org/en/list/ (accessed on May 11, 2023).

Photo 26. Le Corbusier in his studio (**"***Architecture is the masterly, correct, and magnificent play of masses brought together in light. Our eyes are made to see forms in light*: *light and shade reveal these forms."*—Le Corbusier).

The story of Chandigarh is a fascinating chronicle during which India made a bold attempt to make a break with her past. Nehru wanted "*[t]hat [Chandigarh] should be a new city, a symbol of India's freedom, unfettered by the traditions of the past…an expression of the nation's faith in the future.*"[71] Clearly, Chandigarh is the brainchild of Nehru (Photo 27). There are numerous elements embodied in this city that make it interesting and its story one worth telling. At the backdrop was the confusing and compelling circumstances of The Partition whereby the proud Punjabis had suffered more than anyone in India. The contribution of Punjabis to India's freedom speaks for itself. They had now lost their ancient and beloved capital, Lahore, to Pakistan. The Indian government felt that none of the existing cities of Punjab possessed sufficient stature and magnificence to make up for the psychological loss of Lahore. Rehabilitation of the refugees from West Punjab and administering the strife-stricken state were also urgent necessities. Dr. Ravi Kalia, Professor at

[71]India: The influence of the architectural work of Le Corbusier within the states parties of the property. Available at: https://lecorbusier-worldheritage.org/en/the-influence-of-the-architectural-work/india/ (accessed on April 30, 2023).

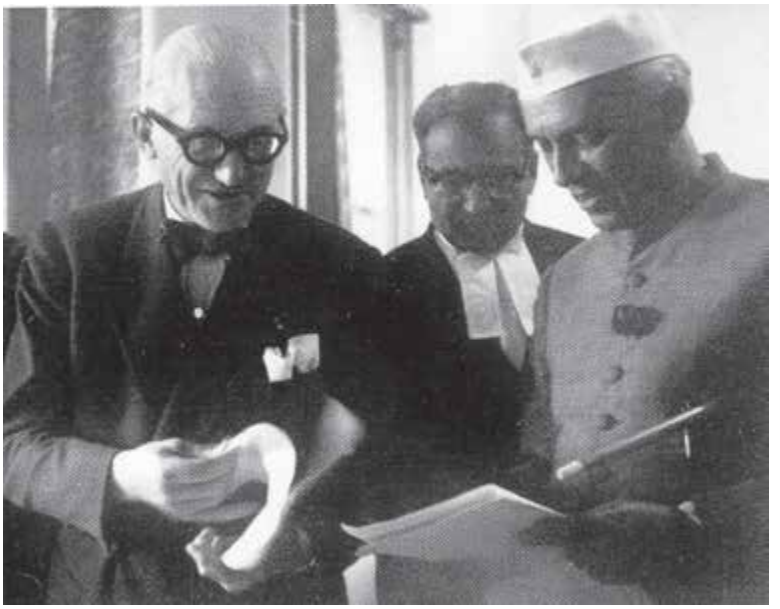
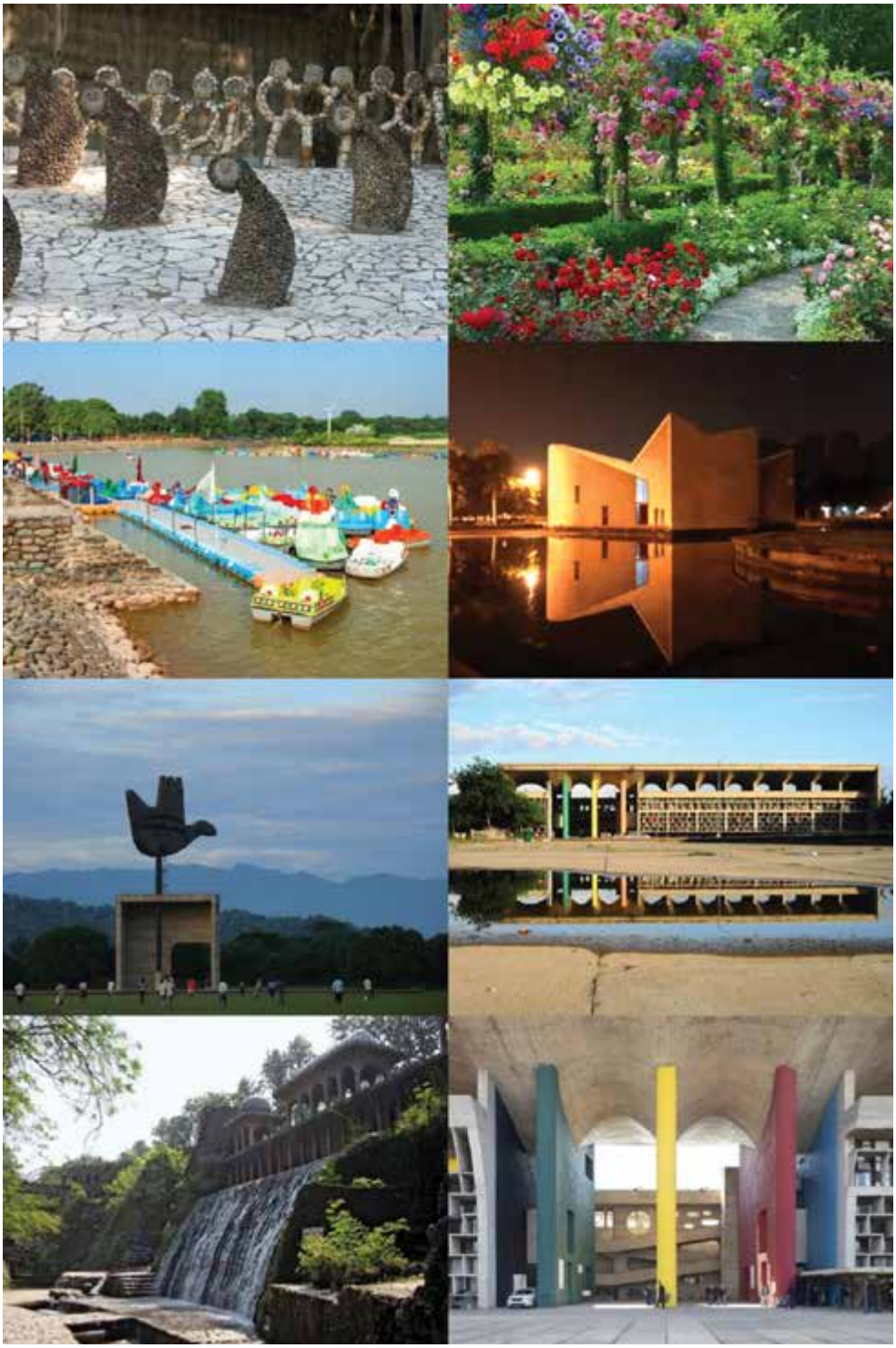


Photo 27. Le Corbusier and Jawaharlal Nehru, 1950s ("*Many people argue about Chandigarh, some like it, some dislike it. It is totally immaterial, whether you like it or not. It is the biggest thing in India of this kind. That is why I welcome it [...] because it hits you on the head, because it makes you think.*"—Jawaharlal Nehru, 1959).

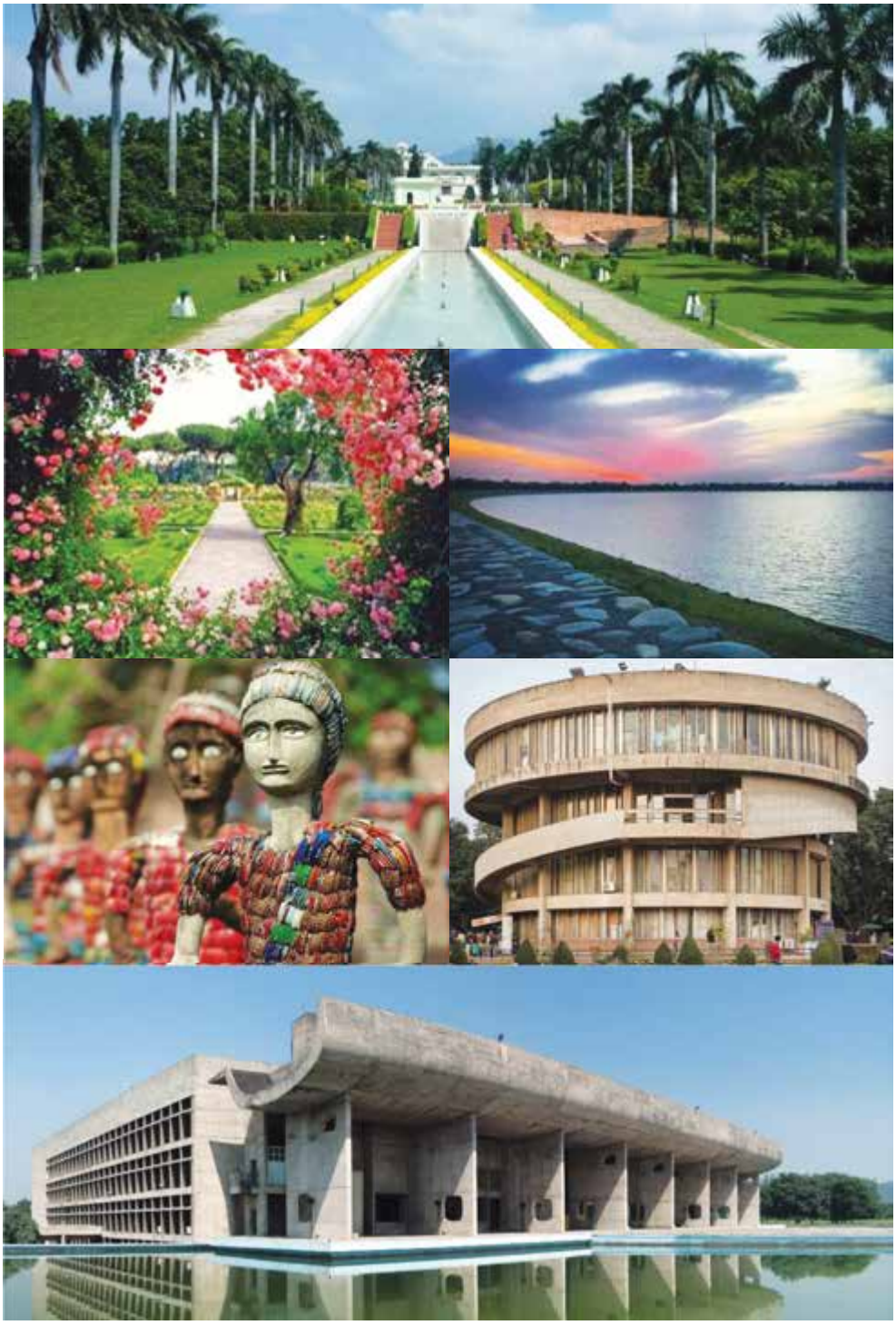
The City College of New York, provides a fascinating history of Chandigarh's planning and construction in his excellent book[72]:

> *The development of Chandigarh represents a fascinating study of practical politics, personal ambitions of politicians and planners, and the high ideals of Prime Minister Jawaharlal Nehru and the planner Le Corbusier. The new capital city of Punjab also represents India's pride and best urban hopes for the future. Chandigarh was to serve as a training school for Indian planners, who could then duplicate their experience in other cities to improve communication systems, raise economic standards, and permit light and air to penetrate tightly knit unauthorized neighborhoods. It was to rehabilitate refugees and the displaced Punjab government, to restore the dignity of the Indian Punjabi damaged by partition and the loss of Lahore. It was also hoped that Chandigarh would bring law and order to a state torn by communal frenzy, promote economic activities in the region, and improve the lot of those who had suffered losses during the partition of the subcontinent. But above everything else it was to serve as a symbol of India's break with the past…The American Albert Mayer provided the initial master plan for Chandigarh, which was finally put in place, with modifications, by the Swiss-born French architect Charles-Édouard Jeanneret, popularly known as Le Corbusier, his cousin Pierre Jeanneret, and the English husband-and-wife team of Edwin Maxwell Fry and Jane Beverly Drew…The development of Chandigarh has wider implications for communal relations, the fiscal and social wisdom of building new cities, the urban-political tradition, architectural developments, and the conflict between traditional and colonial influences far beyond a new city environment. Chandigarh*

[72]Kalia, R. (1999). *Chandigarh: The Making of an Indian City*. Oxford University Press, New Delhi, India.



Unique landmarks of Chandigarh. Clockwise from top-left: Rock Garden, Rose Garden, Gandhi Bhawan at Panjab University, Chandigarh High Court, close-up of Chandigarh High Court, Rock Garden, Open Hand Monument, Sukhna Lakea.



Unique landmarks of Chandigarh. Clockwise from top: Pinjore Mughal Gardens, Sukhna Lake, Student Centre at Panjab University, Secretariat Building of the Chandigarh Capitol Complex, Rock Garden, Rose Garden.

has shown that new designs and construction do not by themselves make the dream of planning and building a modern urban environment come true. Instead, Chandigarh demonstrates that it is not the personal narrative of a deified ruler nor an exaggerated account of a mythic planner, but rather the individual and collective account of its citizens, striving for self-determination, self-knowledge, and self-actualization.

Dr. A. C. Joshi, a man of exceptional vision and a superb administrator, was the first Vice-Chancellor of Panjab University when it relocated to Chandigarh in 1958–60 (Photos 25 and 28). A man of few words, he was articulate and focused, as if on a mission. The first Chief Commissioner of Chandigarh and my close friend, Dr. M. S. Randhawa (1909–1986), was a classmate of Dr. A. C. Joshi at Government College Lahore. Dr. Randhawa described Dr. Joshi's intimate connection with Panjab University in the *Indian National Science Academy* journal (undated entry): "*In 1957 he got the greatest opportunity of his life when he was appointed as Vice-Chancellor of Panjab University. With single-minded determination and great sense of dedication, he started building up the new campus of the university. Mr. P. Jeanneret was the Chief Architect of the campus and was assisted by B. P. Mathur, Senior Architect. Both these persons worked in close collaboration with Joshi, who examined all the building plans in great detail and gave many helpful suggestions. The result of this collaboration was the beautiful campus of the University at Chandigarh which has won admiration of educationists from all over the world. If any person can validly claim to be the father of this University, it is A. C. Joshi.*"

Photo 28. The Panjab University Library (left) and the Student Center (right) reflect unique, bold architectural styles.

Dr. Joshi was impressed by my academic credentials and extensive publication record in distinguished international journals. He had learned of my natural teaching ability. He also knew that I lacked administrative experience but did

not seem to be too concerned. I was less sure of my abilities as an administrator; indeed, I was only 33. During the interview process, Dr. Joshi had assured me that, in due time, I would succeed in building a new department from the ground up. He said time was on my side ("*All great achievements require time.*"—Maya Angelou). Many questioned his judgement in providing a high level of autonomy to a relatively young professional with minimal administrative experience. Most vocal among them was Dr. P. S. Gill, the distinguished physicist famous for his work on Cosmic Rays. In the end, my detractors failed to derail my appointment and I officially took charge of the Department of Biophysics in May 1964.

At the university, I found myself in the company of other exceptional department heads: Dr P. N. Mehra (Botany Department Head and "father of angiosperms"), Dr. Mulk Raj Anand (Literature Department Head and internationally renowned writer), Balwant Gargi (Director of Theatre and iconic playwright); Dr. Manmohan Singh (Economics Department Head and future Prime Minister of India); Dr. B. N. Goswami (Fine Arts Department Head and renowned art historian), Dr. R. P. Bambah (Math Department Head and famous for "Number Theory").

Establishing a new department was no small feat. There were many moving parts. In some respects, it was like navigating without a compass. Nevertheless, I was up to the task and knew it. Creating a blueprint for the department from the ground up was a slow process. I had to formulate curricula for undergraduate and graduate classes in the highly interdisciplinary field of biophysics. The concept of a department still existed mostly on paper and architectural maps. I also was asked to provide my input regarding the architecture of the Basic Medical Sciences building and supervise design aspects of the Electron Microscope Laboratories. Creative ways were required to tackle unique and unpredictable challenges, which seemed to sprout from nowhere. After all, we were a young university in a newly independent nation. Gradually, my vision started to take shape. Importantly, my ideas and concepts were blessed by the university's top brass. I could see the building space starting to fill up with people and equipment. I was excited at the prospect of having students and classes soon ("*Do the difficult things while they are easy and do the great things while they are small. A journey of a thousand miles must begin with a single step.*"—Lao Tzu). Looking back, I more fully appreciate that it was a daunting task. Maybe at that time, due to my youth and ignorance, I found it exhilarating and challenging.

Being at the helm of the department required long hours, endless devotion, decisive action, and a willingness to take big risks (Photos 29 and 30). Simultaneously, I just had started the construction of a lovely bungalow in one of Chandigarh's posh neighborhoods (Sector 11-A). At that time, my world revolved around building codes, architects, and construction materials. On the one hand, I was working on designs for my new home and, on the other, I was reviewing plans for laboratory facilities of my department. My wife and I also had been blessed with a nine-pound baby boy whom the obstetrician fondly nicknamed

Photo 29. At work in my office at the Biophysics Department in the late 1970s when I was the Department Chair. A large part of my day was spent on administrative duties, teaching, and research. However, I made every effort to drive home for lunch and dinner with the family.

Photo 30. At work in my office in 1988 when I served as Dean of Foreign Students. I was guided by an experienced group of assistants and clerks, whose organizational skills and support was instrumental in the smooth operation of every aspect of my professional life, whether department chair, dean, or coordinator of the Biotechnology Center.

"Pinky" (the editor of this volume) on account of his rosy cheeks and boisterous nature (Photo 31). We were on top of the world. I had made it. Was it luck, timing, talent, or a combination of all? Looking back, it is hard not to appreciate one thing: so much success and only 33 years old!

Photo 31. My young family in Chandigarh, 1964.

I knew that communication is key to building trust, ensuring alignment, enhancing research collaboration, brainstorming, and yielding innovative ideas. I had learnt this on my numerous trips to Japan during the 1960s. Keeping this in mind, I made sure that my entire department was based initially on a single floor. I found that the distance between the adjacent floors in the same building inhibited interaction. Of course, this would be somewhat less possible in later years as the department expanded. Later, in the early 1970s, I had intercom service installed throughout the ever-expanding department to supplement the notoriously unreliable phone service in India at that time. This was a novel idea, which others replicated in their own facilities. Mr. Roshan Lal and the late Mr. Gurbachan Singh were two remarkable and indispensable engineering technicians, who not only installed the intercom system but also maintained it with stellar efficiency. Their service for four decades formed the backbone of the department in some respects. They were called upon to repair or calibrate anything that had moving parts—microscopes, water distillers, Geiger–Müller counters, lathe machines, ultracentrifuges, faulty faucets, and countless other machines, devices, and gadgets. They also fabricated special devices and custom glassware for the department. Looking back, I believe some of their novel devices and fabrication methods should have been the subject of Indian and foreign patent applications.

I always valued merit over a charted agenda; hence, I grew the department faculty meticulously and gradually. I often was criticized for this and even pressured by the university Vice-Chancellor to expand the department at a greater pace. Nonetheless, I stood my ground and hired the best faculty I could find. Almost all faculty were trained either in the US or in Europe. My search for talent was constant. I even hired someone whom I met in a chance encounter at the Geneva Airport passenger lounge in 1965. He was shocked when I gave him a handwritten note hiring him on the spot. He was a brilliant physicist and an equally good human, Mr. P. K. Sharma, who reported for work a month later. He retired following more than three decades of distinguished service to the department.

I was poor at politics but adept at spotting merit ("*Politics is the art of looking for trouble, finding it everywhere, diagnosing it incorrectly and applying the wrong remedies.*"—Groucho Marx). Complicating matters, Chandigarh was a political trifecta in some ways: the capital of Punjab state, the capital of Haryana state, and a federally administered Union Territory. This meant constant interference in the affairs of the university from three distinct entities. Department heads were expected to curry favors to bureaucrats and their surrogates. I took great pride in that I did not tow the party line and was an incumbrance to their corrupt agendas. I had nothing to lose because I wished to gain nothing from them. I never hired or employed any family member or relative either. I always shunned politicians and was guarded about my own political thinking. I have always been an independent thinker with a clarity of thought when it comes to right and wrong. I have borne the consequences of standing up to evil and bad people, even in my own family, a price that I will continue to gladly pay for the suppressed voice of the helpless. A positive outcome of all this was that the department flourished on merit, diversity, and talent. Gossip and distractions were kept to a minimum ("*Great minds discuss ideas, medium minds discuss events, and little minds discuss people.*"—Hindu Proverb).

The first employee I hired was Mr. Pal Singh as personal assistant, a loyal man of great character, class, and energy. He served the department for more than forty years. Initially, I was given a few rooms in the massive building that housed the Zoology Department while the Basic Medical Sciences was under construction. Mr. Singh used to sit in the hall outside my office on a stool and respond to my buzzer. Our two-man department was up and running. Later, I hired three lecturers and two research scholars. The faculty, staff, and student body were gradually expanding. Teaching and research programs in the Department of Biophysics started in July 1965. In the session between 1965 and 1966, fifteen students (eleven boys and four girls) were admitted to the first-year class of the Honors School. Their graduation in 1968 was an exciting moment for me (Photo 32). During the next session (1967–1968), the number of students in the rolls of the department rose to forty-seven. My vision was taking shape; I had pulled it off! We were still a small, intimate group that had the feel of a close-knit family. The students and the faculty often picnicked and hosted department functions with great enthusiasm, a luxury that was not possible once the department grew larger (Photos 33 and 34). There were frequent get togethers at our home

in Sector 11-A (Photo 35). We also hosted numerous foreign scientists and collaborators (Photo 36).

Photo 32. Graduation day for the first batch of undergraduate students in 1968.

Photo 33. Photograph taken in the mid-1960s of the first batch of students and faculty members in the newly founded department. In my opinion, this batch was one of the finest with respect to their academic capabilities and career performance. They achieved great success in academia and industry around the globe. I am seated third from the right, next to my wife (checkered coat).

Photo 34. Photograph from the late-1960s of students on a Himalayan field trip. I am on the extreme left. Field trips are critical to the academic development of students as they offer students the opportunity to learn about a subject in a more hands-on and immersive way than they can in the classroom and from textbooks. It builds upon classroom instruction (*Tell me and I forget, teach me and I may remember, involve me and I learn."*—Benjamin Franklin).

Photo 35. At my home in Chandigarh with some of my students, 1970s. My students, colleagues, and staff were an extension of my family. While I always cared about the education of my students and obtaining new research results, I cared equally as much for their well-being. Almost every student was invited to my home for dinner, tea, or parties. Occasionally, it was an all-women event (as above). Sometimes it involved celebration of various Indian festivals such as Holi, Lohri, and Diwali. Other times, it was a card game or board game. Such close interactions with each other made my students into a group of lifelong friends and collaborators. However, I always adhered to one important principle: No business or departmental matter would ever be discussed or conducted at my home. It is critically important to maintain a proper work-life balance.

Photo 36. Mr. Suraj Bhan, Vice-Chancellor of Panjab University (extreme right) with some of my foreign colleagues at my home in Chandigarh for dinner.

As my department continued to flourish, I focused on other endeavors to enhance scientific activities for the faculty and students. I founded the Biophysics Society in 1965 to organize lectures of reputed scientists and, also, to provide an opportunity for occasional get-togethers of staff and students within the department. Additionally, I served as Secretary of the Northern India Science Association (NISA) with my department acting as the secretariat. NISA was founded by my close friend, the polymath Dr. M. S. Randhawa (Photo 37). NISA published an attractive monthly journal, *Everyday Science,* until the early 1990s. When I first met Dr. Randhawa in 1964, he was already a distinguished Indian historian, statesman, artist, educator, Indian Civil Service (ICS) member, botanist, and author. We instantly bonded. My association with him grew when in 1966 he was appointed the first Chief Commissioner of Chandigarh. Although Dr. Randhawa was twenty years older, we had similar upbringing: Both of us grew up in Lahore, attended Government College Lahore, and were refugees in 1947. It was an honor to work with Dr. Randhawa, a Renaissance man of India. He was a great man, a rare combination—a gifted administrator and an exceptional scholar-scientist. I often made the delightful car trip from Chandigarh to Kharar to his home, the Garden House, as he called it. We had some memorable discussions, interspersed with work-talk, at his bed-study. In 1947, Dr. Randhawa oversaw the entire function where Jawaharlal Nehru delivered his famous "Tryst with

Destiny" speech on the eve of India's independence when I was in the refugee camp (Section 10.7).[73] He played major roles in the establishment of agricultural research in India, the "Green Revolution" in India, establishing Chandigarh, resettling Punjabis uprooted by The Partition as India's Director-General of Rehabilitation, and documenting the arts of Punjab. He established the Rose Garden in Chandigarh, the Punjab Agricultural University at Ludhiana, the Government Museum and Art Gallery in Chandigarh, and the Anglo-Sikh War Memorial near Ferozepur. He wrote several books, including *Beautifying India, Beautiful Trees and Gardens, History of Indian Agriculture* (four volumes), compiled nine collections on Kangra, Basoli and Chamba paintings, and four collections of folk songs of Punjab, Kangra, Kullu and Haryana. A biographer gave him the sobriquet *Punjab da Chhewan Dariya* (Punjabi, "the sixth river of Punjab"). John Kenneth Galbraith (1908–2006), the eminent Harvard economist and diplomat, paid tribute to Dr. Randhawa[74]:

> *[Dr. Randhawa] is, indeed, an extraordinary man. His mind has ranged over nearly the whole sphere of knowledge of science and art, from soil conservation to botany, to city management, history, religion, architecture and art. And in none of these has he been content to be an amateur. In every one he has manifested both the instinct and the diligence of the professional. I continue to be puzzled that one mild man could know accurately so much and to such good purpose.*

Dr. Randhawa implemented his vision of Chandigarh with perseverance and left his footprints for future generations. I have seen his remarkable ideas blossom over the years, from 1964 to today[75]:

> *As the first Commissioner of the Union Territory of Chandigarh, Randhawa played a pivotal role that ensured his place in history. The entire lay out of the landscape and the aboriculture of Chandigarh is his gift to the successive generations. The concept of planting ornamental trees planted in a very systematic manner on both sides of the roads throughout the north of Chandigarh was to provide tree cover and ensure picturesque flowering round the year. If Chandigarh is City Beautiful today, it is solely because Randhawa was so driven by the zeal to plant trees. So much so, he inspected the watering of these plants at 4 am every day. He lived 30 km away from Chandigarh at his farmhouse in Kharar, but reached the city unfailingly at 4 every morning and went from road to road ensuring that all plants were watered and the dead saplings replaced. Today, one has a perfect view of white and golden silver oaks, jacarandas, lagerstormias, mahoganys, amaltas, gulmohars, bauhinias (kachnar), etc. Randhawa gave a green cover of majestic trees like pilkhan and Arjun. It was his vision that enabled a large number of writers, poets, painters and artists to own residential plots in Chandigarh at concessional rates.*

[73] *"It was the night of India's freedom after 200 years of British rule. Jawaharlal Nehru was to unfurl the National Flag from the Red Fort in the morning. A man was unfurling the Flag after every one hour the whole night. He was going through the motions, including wrapping the flowers, hoisting it and then unfurling it at the strategic point again and again. He was none other than M. S. Randhawa, the then Deputy Commissioner, Delhi. A perfectionist, he was afraid that something may go wrong and did not want to take any chance since it was an emotional and historic moment for all. This incident symbolizes the kind of focus that came to be associated with Randhawa."* Source: Sharma, R. (2006). Beautiful mind, dutiful life. *The Tribune,* Chandigarh.

[74] Galbraith, J. K. (1969). Introduction. *Roopa-Lekha* **38**(1–2):9.

[75] Sharma, R. (2006). Beautiful mind, dutiful life. *The Tribune,* Chandigarh.

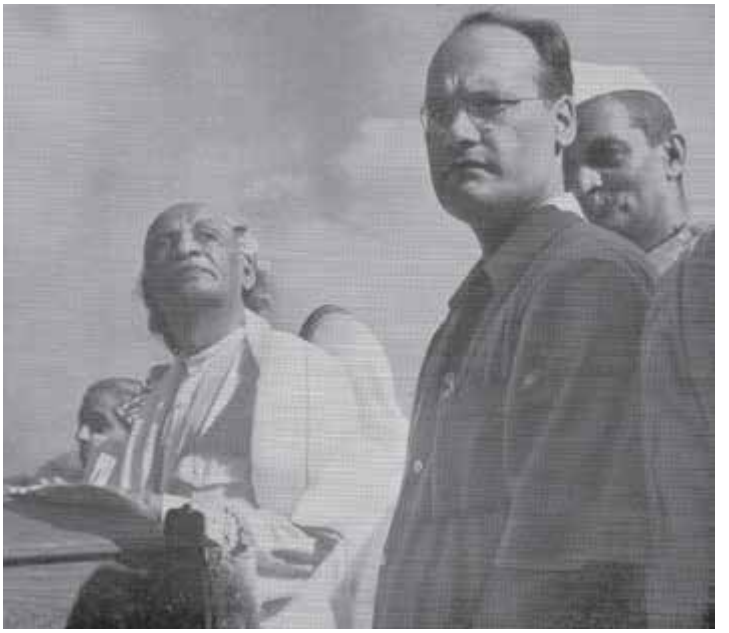


Photo 37. Dr. M. S. Randhawa on the rampart of the Red Fort in Delhi on the eve of India's independence on August 15, 1947. He is flanked by the "Iron Man of India," Sardar Vallabhbhai Patel, the first Home Minister (left) and Dr. Rajendra Prasad, India's first President (right). Both Patel and Prasad were distinguished statesmen and lawyers at the forefront of India's independence struggle from British colonial rule. Patel was instrumental in the peaceful integration of the princely Indian states into the Indian Union and the political unification of India. However, Patel's decisiveness on the partition of Punjab and Bengal was criticized by Gandhi, Nehru, secular Muslims, and socialists for a perceived eagerness to do so.

The 53rd Session of the Indian Science Congress, with the theme "Science in India," was held on the university campus in January 1966. I served as the youngest member of the organizing committee, which was given charge of all festivities, symposia, social events, travel arrangements, lodgings, sightseeing, and programing. It was a marvelous opportunity to showcase the burgeoning university. Inaugurated by the President of India, the Congress was attended by top scholars from India and abroad as well as representatives from foreign societies and academies. My entire departmental staff and students attended; the event afforded them a unique opportunity to be exposed to the latest advances in biomedicine. In January 1973, the Diamond Jubilee Session of the Indian Science Congress was held at Panjab University.

Although I had faculty with diverse experience, I continually updated the program and knew each refinement added value. I recognized that diversity in the subject matter, as well as the personnel themselves, was crucial to an interdisciplinary field like biophysics. By investing in solid faculty, then creating and continually improving upon a cutting-edge curriculum, my new department was a win-win for both students and faculty. Teaching and research were intertwined; developments for each were made in tandem, which proved to be a recipe for success. After all, we were a teaching institution and imparting education

was our prime goal. Our department was one of the first in the country to offer undergraduate courses in biophysics. Today, it is the only department in India, which offers both undergraduate and postgraduate courses in the discipline of biophysics under the framework of the prestigious Honors School System. Based on a competitive national entrance exam, it draws students from both pre-medical and pre-engineering streams, blends them for four years, and ultimately graduates them as energetic biophysicists. I believe I managed to raise the Biophysics Department to an international status, in which research is accomplished on several major projects. I pressed my colleagues and students to publish their research in high-impact[76] international journals for it is important to measure oneself on a global stage.

I also encouraged a work-life balance. Social gatherings, celebration of various festivals, picnicking, and departmental variety programs were all to be enthusiastically enjoyed. We even participated in students' weddings (Photo 38). I was taught to rejoice in people's happy moments but lend a helping hand or shoulder to ease the burden of those in grief. Every year a new batch of students would graduate…we all would feel their departure. To this day, many of them keep in touch with me. I encouraged feedback, novel ideas, and criticisms in an open forum (Photo 39). This was an efficient way to implement reasonable adjustments and resolve critical issues early on before they spiraled out of hand.

Movies were entertainment that the students, faculty, and staff particularly relished. I tapped into this commonality. Rani and I used to watch every new Indian (Hindustani) movie before we left for New York in 1958. Even as a bachelor during my college years, I made every effort to see each new movie screened. It did not matter to me if it was in Hindi, Punjabi, Urdu, or English. Our favorite Indian movie stars were the super talented and handsome actors of the 1950s, 1960s, 1970s, and 1980s: the Kapoor family (Raj Kapoor, Shammi Kapoor, Prithvi Raj Kapoor, Shashi Kapoor, Randhir Kapoor, Rishi Kapoor), Shabana Azmi, Raj Babbar, Simi Grewal, Dev Anand, Pran, Bindu, Sunil Dutt, Madhu Bala, Meena Kumari, Dharmendra, Suraya, Om Prakash, Rajesh Khanna, Waheeda Rehman, Balraj Sahni, Rajendra Kumar, Raaj Kumar, Mumtaz, Mala Sinha, Prem Chopra, Prem Nath, Zeenat Aman, Guru Dutt, Anupam Kher, Amrish Puri, Nargis, Dilip Kumar, Kulbhushan Kharbanda, Om Puri, Rekha, Rakhi, Manoj Kumar, Bharat Bhushan, Nutan, Vyjayanthimala, and many more. In their energetic screen presence, superb performances, dialogues, and acting, we found the full spectrum of our own emotions—our joys, our sorrows, our prayers, and our love. Newer arrivals like Sanjay Dutt, Shahrukh Khan, Rani Mukerji, Ranbir Kapoor, Salman Khan, Sridevi, Hrithik Roshan, Priyanka Chopra Jonas, Akshay Kumar, Aamir Khan, Deepika Padukone, and others may have a great online presence and following,

[76]Impact factor (IF), or Journal Impact Factor, is a measure of the frequency with which the "average article" published in a given journal has been cited in a particular year or period. IF originally was developed by Eugene Garfield, the founder of the Institute for Scientific Information (ISI), which is now a part of Clarivate Analytics. The calculation is based on a two-year period and involves dividing the number of times articles were cited by the number of articles that are citable. The higher the IF, the more highly ranked the journal. It is one tool used to compare journals in a subject category. In general, the IF of 10 or higher is considered remarkable, while 3 is good. As an example, *Nature* had an impact factor of 69.504 in 2021. CiteScore is similar to IF but is based instead on a 4-year period.

Photo 38. Photograph taken at the wedding of my student, Dr. M. R. Bansal. I am seated second from the left while my wife is seated first on the right. The bride and the groom are seated in between us. My young son is leaning on me. I attended the weddings of many of my students unless it was logistically not possible. It was critical for me to participate in this special day as it was a major milestone in their development. My presence simply validated it. Over the years, I played matchmaker to a few of my students. I relished all my roles, some designated, some adopted—teacher, guide, research mentor, faculty advisor, matchmaker, motivator, leader, organizer, and host.

but they lack that screen presence and talent of the trailblazers of the 1950s–1980s who put their unforgettable mark on the entertainment industry. These new actors clearly have much to learn from the great masters. We rarely missed any English movie while in New York and later in Chandigarh, especially those starring Marilyn Monroe, Katharine Hepburn, Humphrey Bogart, Marlene Dietrich, Clint Eastwood, Judy Garland, Elizabeth Taylor, Bette Davis, Cary Grant, Marx Brothers, Bob Hope, Grace Kelly, Greta Garbo, Audrey Hepburn, Clark Gable, Robert Mitchum, James Stewart, Henry Fonda, Fred Astaire, Ingrid Bergman, Ava Gardner, Rita Hayworth, Burt Lancaster, Gene Kelly, Laurence Olivier, John Wayne, Gary Cooper, Lauren Bacall, Charlie Chaplin, Spencer Tracy, Kirk Douglas, James Cagney, William Holden, Marlon Brando, Sophia Loren, Frank Sinatra, or Gregory Peck. These Bollywood and Hollywood stars of yesteryear left behind an unforgettable legacy of artistry at its finest peak. Nowadays, it is disheartening to see mediocrity at the Oscars and the Indian Filmfare movie awards. Show-business and talent cannot be equated (*"Never confuse the size of your paycheck with the size of your talent."*—Marlon Brando).

Photo 39. For decades, the "Tea Room" has served as a common meeting place for all faculty members of the department. In the early days, since the staff came from different scientific disciplines of biophysics, these afternoon teas played a critical role in cross-disciplinary exchange of ideas. I am told that this tradition, along with the massive solid Burmese teak table I got constructed in the mid-1960s, survives to this day. The Tea Room continues to be an intellectual meeting ground for the department where free flow of ideas, reflection, criticisms, and discussions is still welcome ("*You can never get a cup of tea large enough or a book long enough to suit me.*"—C. S. Lewis).

In 1969, the department hosted the *1st International Symposium on Electron Microscopy in Biophysics and Molecular Biology*. The three-day symposium was organized to mark the inauguration of the department's Electron Microscope Facility. It was sponsored by the University Grants Commission, Panjab University, Deutsche Export-und Importgesellscehaft Feinmechanik-Optik, the German Democratic Republic, and Mr. K. Lal Bhakri, New Delhi. More than 100 biophysicists, molecular biologists, cell biologists, and biochemists participated. The distinguished speaker list included a galaxy of eminent international stars (Photo 40). The abstracts of the papers presented in the symposium were published in the *Journal of Ultrastructure Research* (1971) **37**:243–257. In 1984, the *Second International Symposium in Biophysics and Electron Microscopy* was held at the department and a proceedings volume was produced. I am proud to note that, since its inception, thousands of high-caliber research papers have emanated from my department—one of the youngest science departments of the university.

Photo 40. Group photo of the international and national speakers at the *1st International Symposium on Electron Microscopy in Biophysics and Molecular Biology* held at the department in 1969. Mr. Suraj Bhan, the Vice-Chancellor of Panjab University, is seated 5th from the left, next to the Governor of Haryana state. I am seated 7th from the left. *First row*: Mr. I. D. Paul, Prof. Jean André (France), Prof. F. S. Sjöstrand (USA), Mrs. Briggita Sjöstrand (USA), Mr. Suraj Bhan (Vice-Chancellor), Mr. B. N. Chakravarty (Governor of Haryana), Prof. S. R. Bawa (Convener), Prof. Noboru Higashi (Japan), Prof. P. N. Mehra, Prof. William Bernhard (France), Prof. G. F. Meyer (West Germany), Dr. Mrs. S. M. Sirsat, Prof. S. K. Malhotra (Canada). *Second row*: Dr. S. K. Sharma, Dr. R. P. Agarwala, Mr. B. K. Puri, Dr. Kanwar Bahadur, Prof. P. N. Srivastava, Dr. S. P. Sharma, Dr. K. G. Srivastava, Dr. Mrs. U. Kanwar, Miss Shimla Goyal, Dr. N. Chatterjee, Miss U. Saha, Miss S. Choudhury, Dr. Asha Khanna, Mrs. P. Bidwai, Miss Jasbir Cheema, Mrs. K. Sundaram, Dr. Kamal Bhasin, Mr. Kuldip Singh Rahil, Mr. P. K. Sharma, Dr. K. C. Kanwar, Dr. D. P. Dubey. *Third row*: Mr. Bhajan Singh, Dr. R. P. Kushwaha, Dr. N. R. Kalla, Dr. A. C. Shipstone, Dr. K. S. Korgaonkar, Dr. M. P. Yadav, Mr. G. S. Gupta, Dr. A. N. Namboodiri, Mr. U. C. Chaudhri, Mr. D. K. Chattoraj, Dr. G. P. Dutta. Dr. Baccio Baccetti (Italy) is not in the photo as he had to return to Siena as he received a telegram that his son was ill.

Since 1951, I have devoted an increasing share of my research efforts to the male reproductive tract in humans and animals, primarily because of the unique challenges it presents to the microscopist. Subsequently, to study the dynamics of the mammalian testis, I directed particular attention to the effects of hyperthermia, electromagnetic radiation (55 MHz), vasectomy, and anti-fertility drugs on testicular cells as well as developing spermatozoa. Light microscopy (bright field, phase contrast, and fluorescent), electron microscopy (transmission, scanning, and high voltage), histochemical techniques, spectroscopy (ESR, NMR), and cryo-techniques (freeze-fracture and fracture label) were also successfully used in these studies. Furthermore, microscopy was used to study (i) catecholamine-induced and Adriamycin-induced cardiomyopathies in rats, (ii) normal and dark-adapted reptilian retina, and (iii) autonomic innervation and hormonal status in the female pregnant rat. I also embarked on various studies involving (i) the biochemical mechanisms involved in cadmium-induced renal

hypertension, (ii) the biophysics of the snake spleen, (iii) the biophysics of hearing, (iv) cerebellar synapses and neurotransmitters during protein-malnourishment, and (v) the mammalian olfactory bulb. Recent years have witnessed the rapid evolution of a host of novel tools and techniques pertaining to biomedical research with respect to microscopy, cell biology, and molecular biology. Most of them involve a great deal of what is conventionally described as biophysics. As a young microscopist (Photo 41), stumbling through chemistry, physics, and math, I failed to appreciate how essential other sciences are for understanding biology. Modern cell biology is inextricably linked to chemistry, physics, and math—almost as if no boundaries between them exist. In fact, as the lines between various areas of biomedical research blurred, I engaged even more in interdisciplinary collaboration, as reflected in my publications from the mid-1980s onwards (list provided at the end of the chapter).

Photo 41. In the Electron Microscope Laboratory on an ultramicrotome, sectioning embedded biological tissue in preparation for microscopic examination.

Over the years, I have extensively studied the ultrastructure of the Sertoli cell[77] of the human and mammalian testis and the role of microtubules in these cells. Spermatogenesis is supported by intricate crosstalk between Sertoli cells and germ cells, which takes place in the epithelium of seminiferous tubules. Sertoli cells, also known as mother or nurse cells, provide nutrients, paracrine factors, cytokines, and other biomolecules to support germ cell development.

[77]Sertoli cells (SerC) are essential for testicular development, spermatogenesis, and formation of the blood-testis barrier. Named after the Italian physiologist, Enrico Sertoli (1842–1910), SerC limit the passage of substances such as hormones and nutrients to the adluminal compartment of the seminiferous tubules. In addition to forming the blood-testis barrier, SerC also provide the main structural support for the seminiferous tubules and protect the germ cells from the immune system.

When I was a visiting professor in the Anatomy Department at Downstate Medical Center (now SUNY Downstate Health Sciences University) in New York City from 1979 until 1980, my research focused on the fine structure of rat Sertoli cells cultured on monolayers. As a side note, I am proud to point out that the Professor and Chair of the department was Dr. Donald Fishman, a former medical student of mine from the early 1960s while I was an instructor at Cornell University Medical College. I continued this research with Dr. Hans Ris at the High Voltage Electron Microscope (HVEM) Facility at the University of Wisconsin-Madison in 1980 (Photo 42). There, we examined intact, untreated whole-mounts of cultured Sertoli cells to understand the complex three-dimensional configurations of cytoskeletal proteins. We also attempted to study the existence of the "microtrabecular lattice" (MTL), which the distinguished Dr. Keith Porter had described in the 1970s and 1980s. At that time, employing the HVEM, the cytoplasm or ground substance of eukaryotic cells had been shown to be divided into two major phases: the microtrabecular lattice and the intertrabecular spaces. It was believed that the lattice was not apparent in electron-micrographs of conventional thin TEM sections because the sections lacked the depth necessary to reveal the network. In fact, Dr. Porter, whom I had known since the late 1950s when he was at the Rockefeller Institute for Medical Research (now Rockefeller University) and I was at Cornell, considered the microtrabecular lattice seen in electron micrographs to closely represent the non-random structure of the cytoplasmic ground substance of living cultured cells.[78] However, I was unable to visualize this microtrabecular lattice via HVEM in cultured Sertoli cells.[79] I considered it to be an artifact of fixation and/or processing. In this regard, I cite an elegant analysis by another luminary of cell biology, Dr. John Heuser.[80] It is an instructive one for both the budding researcher as well as the seasoned one: Avoid being clouded by the flashy methods and tools of your time ("*Do not judge a book by its cover.*"—Lester Fuller and Edwin Rolfe):

> *Keith Porter culminated his stellar career as the founding father of biological electron microscopy by acquiring, in the late 1970s, a high-voltage electron microscope (HVEM). With this magnificent instrument he examined whole-mounts of cultured cells, and perceived within them a structured cytoplasmic matrix he named the "microtrabecular lattice". Over the next decade Porter published a series of studies, together with a team of outstanding young colleagues, which elaborated his broader "microtrabecular concept." This concept posited that microtrabeculae were real physical entities that represented the fundamental organization of the cytoplasm, and that they were the physical basis of cytoplasmic motility and of cell-shape*

[78]Wolosewick, J. J., and K. R. Porter. (1979). Microtrabecular lattice of the cytoplasmic ground substance. Artifact or reality. *Journal of Cell Biology* **82**(1):114–139.

[79]Bawa, S. R., D. Fischman, R. R. Weihing, and H. Ris. (1982). Cultured Sertoli cells examined with TEM/HVEM and fluorescent microscopy. *In*: *Proceedings of the II European Workshop on the Molecular and Cellular Endocrinology of the Testis*, Boekelo, The Netherlands.

[80]Heuser, J. (2002). Whatever happened to the 'microtrabecular concept'? *Biology of the Cell* **94**(9): 561–596.

determination. The present review presents Porter's original images of microtrabeculae, after conversion to a more interpretable "digital-anaglyph" form, and discusses the rise and fall of the microtrabecular concept. Further, it explains how the HVEM images of microtrabeculae finally came to be considered as an artifact of the preparative methods Porter used to prepare whole cells for HVEM. Still, Keith's "microtrabecular concept" foretold of our current appreciation of the complexity and pervasiveness of the cytoskeleton, which has now been found by more modern methods of EM to actually be the fundamental organizing principle of the cytoplasmic matrix. During the impending eclipse of Porter's microtrabecular concept in the late 1980s, many of Keith's colleagues fondly described the cell as being filled, not with protoplasm, but with "Porterplasm." Despite the fact that Keith's view was clouded by the methods of his time, it would be fitting and apt to retain this name, still today, for the ordered matrix of cytoskeletal macromolecules that exists in the living cell. In the end, the story of what happened to Porter's microtrabecular concept should be an object lesson in scientific hubris that should humble and inform all of us in cell biology, even today—particularly when we begin to think that our most recent methods and observations are achieving "the last word."

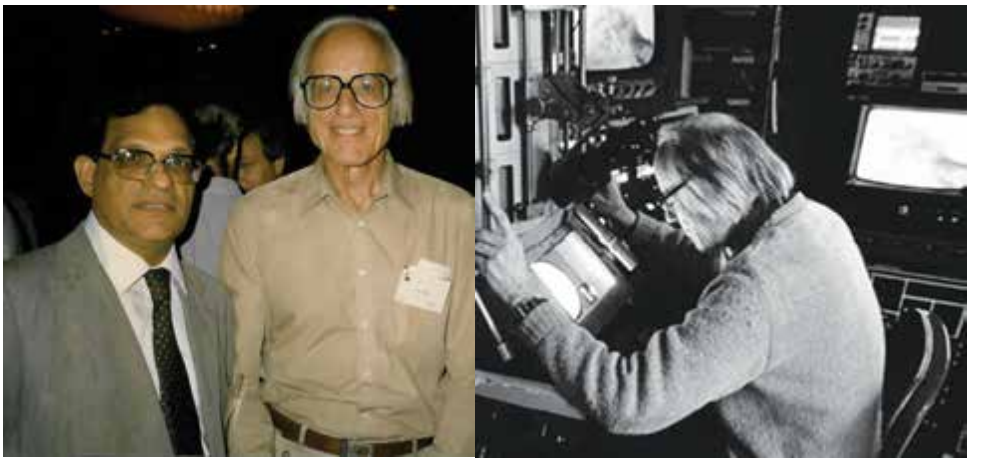


Photo 42. I met Dr. Hans Ris, one of the seminal minds of cell biology, in 1961 at Columbia University. I was a Fulbright Fellow, and he was an Associate Professor in the Zoology Department (now the Department of Biological Sciences). In the mid-1980s, I spent time in his lab at the University of Wisconsin-Madison. The photograph on the right shows Dr. Ris together with a one-million volt electron microscope at the University of Wisconsin-Madison. It was part of the High Voltage Electron Microscope (HVEM) Facility. This NIH-funded facility worked with interpreting the chemistry of chromosomes and later the nuclear pore complex. In his biographical memoir published in 2011 by the National Academies, Drs. Michael Dolan and Lynn Margulis describe his monumental contributions to science and his remarkable career: *Hans Ris occupied a unique historical position*: *he was a cytologist* (*student of the cell*) *at the beginning of the molecular biological revolution and a superb electron microscopist when* "*biochemical and biophysical cytology*" *was renamed "cell biology.*" *... he influenced the careers of scores of scientists as he generously collaborated to produce a massive collection of remarkably informative micrographs. He was a naturalist on a mission of investigation, an observer-researcher his entire life.*

Dr. Porter himself best described the microtrabecular lattice conundrum[81]:

> *In the strictest sense, of course, the content of the images is all artifact where the usual procedures are employed. The question is one of equivalence. To what extent do the images represent what was in the [cytoplasm] when the fixative was applied, and to what extent may these images be used to investigate the form and function of this part of the cell?*

Male contraception has been a challenge due to the high rate of sperm production (condoms or vasectomies being the most effective approaches). Nevertheless, attempts have been made to design chemical agents as contraceptives. Sertoli cells present attractive targets for anti-fertility agents. With this background and my extensive experience with Sertoli cells, I was interested in drugs that could have selective yet reversible effects on Sertoli cells, thereby leading to safe and effective male contraceptives. In this context, while I was a Visiting Scientist at the Worcester Foundation for Experimental Biology (WFEB)[82] in Shrewsbury, Massachusetts, from 1980 until 1981, I studied the relationship of cytoskeletal proteins vis-à-vis shape changes in the cultured Sertoli cells in both treated and untreated environments. Specifically, I studied the microtubule distribution pattern in non-stimulated and FSH-dibutyryl cAMP-stimulated cultured rat Sertoli cells by labeling them via anti-tubulin (see footnote 79). WFEB was best known for the development of the combined oral contraceptive/birth control pill by Gregory Goodwin Pincus (1903–1967) and Min Chueh Chang (1908–1991) and for pioneering research on *in vitro* fertilization (IVF) by Chang.

Today, electron microscopy continues along a rapid trajectory with ancillary techniques like freeze-fracturing and freeze-labeling (Image 24). These methods, to some extent, free the microscopist from limitations of two-dimensional images by revealing cell components in bas-relief. They also provide information that previously has been inaccessible via ultrathin sections. I have used freeze-fracture to supplement ^{13}C Nuclear Magnetic Resonance (NMR) and ^{31}P Electron Spin Resonance (ESR) data on the plasma membrane of the goat (*Capra indicus*), buffalo bull (*Bubalus bubalis*), and various bird spermatozoa. The distribution of the intramembranous particles (IMPs) in various regions of the spermatozoa also has been investigated; their disposition believed to correlate with sperm motility (Image 25). TEM of freeze-fractured replicas of the sperm-forming cells of the goat, buffalo bull, and dog provided further insight into the organizational variation of the plasma membrane of spermatozoa during their journey into the epididymis. Similarly, by employing numerous microscopic and biochemical techniques, I studied how microtubules function in the morphogenesis and development of the spermatozoon head in a variety of animals, such as the red slender loris (*Lori tardigradus*), palm squirrel (*Funambulus pennantii*), Indian hedgehog (*Paraechinus micropus*), and house crow (*Corvus splendens*).

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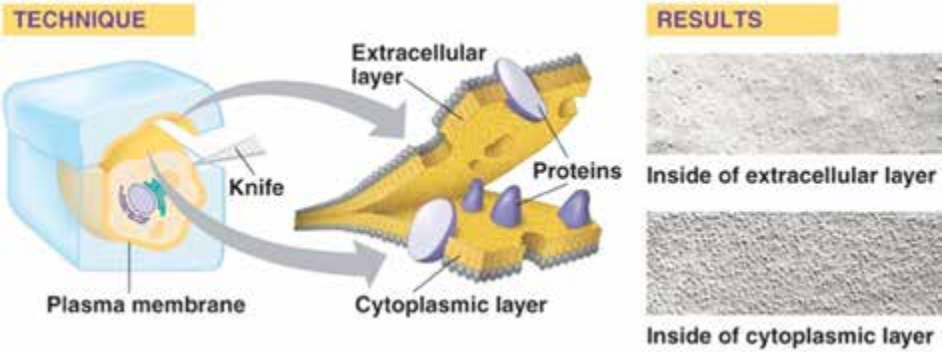
[81]Powell, K. (2005). "Porterplasm" and the microtrabecular lattice. *Journal of Cell Biology* **170**(6): 864–865.

[82]In 1995, the WFEB's name was changed to the Worcester Foundation for Biomedical Research. In 1997, it was taken over by the University of Massachusetts Medical School (UMMS). Also see: Chang, M. C. (1985). Recollections of 40 years at the Worcester Foundation for Experimental Biology. *Physiologist* **28**(5):400–401.



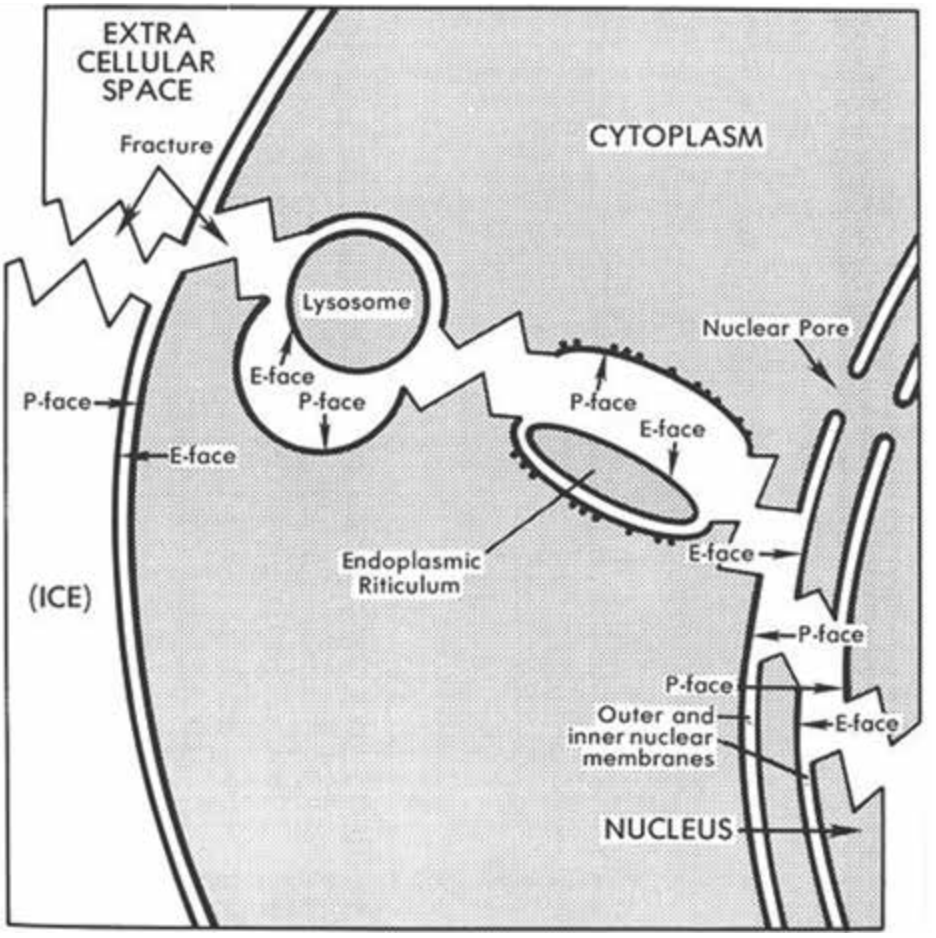


Image 24. Freeze-fracture electron microscopy is a technique for examining the ultrastructure of rapidly frozen biological samples via transmission electron microscopy. The technique involves breaking a frozen biological specimen to reveal internal structures, such as membrane structure and protein distribution (Image 25). On the other hand, freeze etching is the sublimation of surface ice under vacuum to reveal details of the fractured face that were originally hidden. Freeze replica immunolabelling (FRIL) is another related technique that can provide new insights into the roles of membrane proteins in dynamic cellular processes.

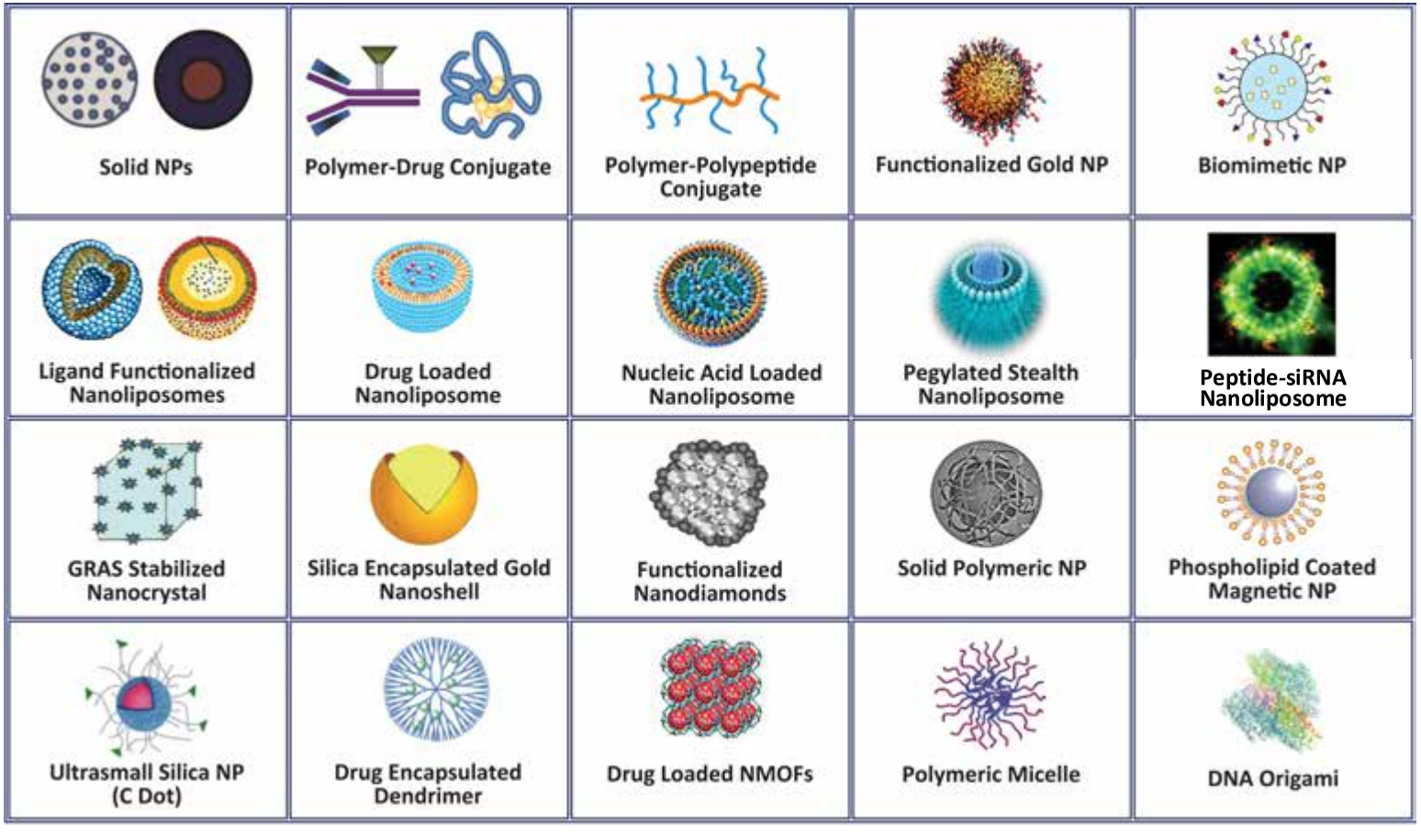
Image 25. The micrograph represents a freeze-fracture replica of water buffalo sperm. Intramembrane particles (IMPs) are present on the major portion of the acrosome (A). The post acrosome (PA) is densely populated with IMPs. "Cords" demarcating the posterior boundary of the sperm head are visible (arrowheads). 31,000X. Further details: Bains, H. K., M. A. Pabst, G. Werner, and S. R. Bawa. (1993). *Journal of Submicroscopic Cytology and Pathology* **25**(4):465–470.

After retiring from Panjab University in 1992, I relocated back to the US and joined the David Axelrod Institute of the New York State Department of Health in Albany, New York. I worked in the laboratory of Dr. Kathleen A. McDonough, now Deputy Director of the Division of Infectious Disease Bacterial Pathogenesis and Professor of Public Health at SUNY in Albany, New York. I relished the opportunity to join her team and impressive laboratory. I will always be grateful to her for her kindness, flexibility, and patience with me, given that my best research years were behind me. There, I focused on electron microscopy in conjunction with immuno-cytochemical methods to elucidate the mechanism of infection and pathogenesis of tuberculosis by (a) localizing surface antigens of *Mycobacterium tuberculosis* and (b) studying the mechanism of entry, growth, and elimination of *Mycobacteria* in lung epithelial cultures and macrophage cultures. I also examined the virulence of bacteria from the genus *Ehrlichia* by employing canine macrophage cultures. In a separate collaboration with Dr. M. H. Miller, Professor of Microbiology at Albany Medical College, we studied the effects of β-lactams with affinities for different penicillin-binding proteins on the cell envelope of *P. aeruginosa* as determined by differential contrast microscopy (DIC), TEM, and uptake of ^{3}H-Gentamicin. Following seven wonderful years in the McDonough lab, I retired from the David Axelrod Institute in 1999. Dr. McDonough's note to me dated July 1999 reflects our mutual respect and relationship:

> *Dear Dr. Bawa, With deep gratitude for all your years of hard work, boundless good nature, and terrific generosity of spirit, your gentle wisdom has been a daily gift that will always be remembered and treasured. Wishing you the best of luck in your new adventures, and looking forward to continued fruitful collaborations in our common endeavors against infectious disease.*

Since 2002, I have been a scientific advisor at my son's firm, Bawa Biotech LLC, in Ashburn, Virginia. Founded in 2002, Bawa Biotech LLC is a medical, biotechnology and pharmaceutical consultancy as well as a patent law firm. As scientific advisor, I have also co-authored several publications pertaining to patent law issues and FDA regulation of nanomedicine.[83] Nowadays, if my health permits, I am more involved in scientific/biomedical editing and e-lecturing via Zoom and other platforms. I have also started to dedicate an ever-increasing share of my day to the *Sudesh Bawa Medical Foundation*, a non-profit medical organization formed by my son.

[83]American Society for Nanomedicine, Resource Center: Available at: https://www.nanomedus.org/resource-center (accessed on May 25, 2023).


Solid NPs
Polymer-Drug Conjugate
Polymer-Polypeptide Conjugate
Functionalized Gold NP
Biomimetic NP
Ligand Functionalized Nanoliposomes
Drug Loaded Nanoliposome
Nucleic Acid Loaded Nanoliposome
Pegylated Stealth Nanoliposome
Peptide-siRNA Nanoliposome
GRAS Stabilized Nanocrystal
Silica Encapsulated Gold Nanoshell
Functionalized Nanodiamonds
Solid Polymeric NP
Phospholipid Coated Magnetic NP
Ultrasmall Silica NP (C Dot)
Drug Encapsulated Dendrimer
Drug Loaded NMOFs
Polymeric Micelle
DNA Origami

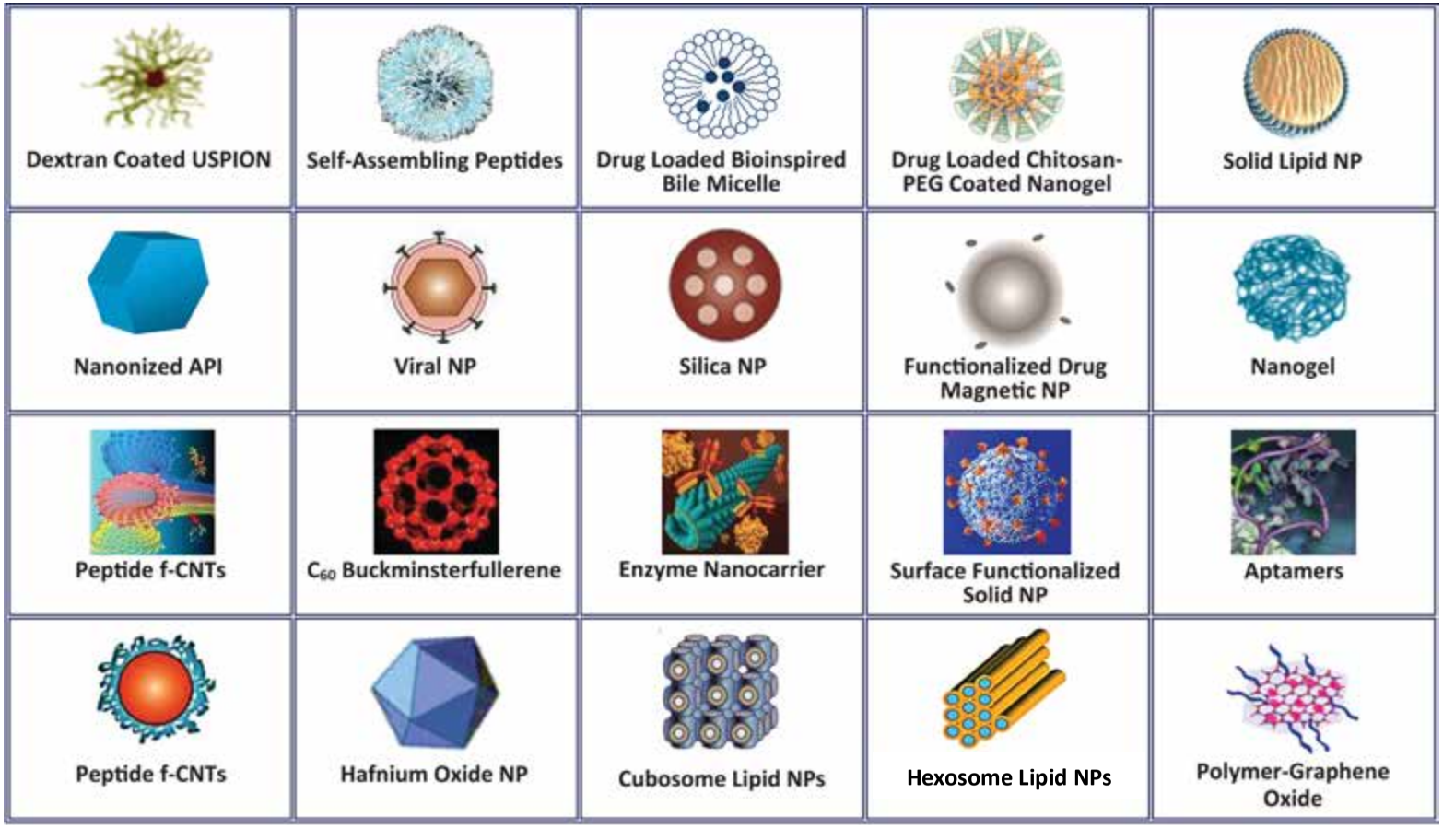


Image 26. Nanoscale Drug Delivery Systems (Nanodrugs or Drug Nanoparticles) (*Continued*).

Image 26. (*Continued*)

Schematic representation of selected engineered nanoparticles (NPs) used in drug delivery that are either approved by global regulatory bodies, are in preclinical development or are in various phases of clinical trials. They are considered as first or second generation, some are multifunctional in their mode of action, most ranging in an average diameter from one nanometer (1 nm) to a micron (1,000 nm). Active bio-targeting of a NP is often achieved via conjugating ligands or functional groups (e.g., antibodies, peptides, aptamers, folate, hyaluronic acid). These molecules are tagged to the NP surface with or without spacers/linkers such as PEG. Many nanodrugs depicted above (e.g., metal-based NPs, functionalized carbon nanotubes [f-CNTs], nanoscale metal organic frameworks [NMOFs]), although extensively advertised for drug delivery, will pose enormous regulatory approval and commercialization challenges. They will not appear in the clinic this century. Non-engineered antibodies, natural biological motors (e.g., sperms), engineered nanomotors, and naturally occurring NPs (e.g., natural protein nanotubes), although potential drug delivery candidates, are specifically excluded here. Note that antibody–drug conjugates (ADCs) are also encompassed by the cartoon labeled "Polymer-Polypeptide Conjugate." Therapeutic monoclonal antibodies (TMAbs), polymer-polypeptide conjugates, and aptamers shown are classic biologics, but they are also nanodrugs as they fall within the widely accepted standard definition of nanodrugs. The list of NPs depicted here is not exhaustive, the illustrations do not reflect precise three-dimensional shape or configuration and the NPs are not drawn to scale.

Abbreviations: NP, nanoparticle; PEG, polyethylene glycol; GRAS, Generally Recognized As Safe; C dot, Cornell dot; API, active pharmaceutical ingredient; ADCs, antibody–drug conjugates; NMOFs, nanoscale metal organic frameworks; f-CNTs, functionalized carbon nanotubes; siRNA, small interfering ribonucleic acid; USPION, ultrasmall superparamagnetic iron oxide nanoparticle; TMAbs, therapeutic monoclonal antibodies.

10.14 A Glimpse of Home Life at the University

After living in my personal villa (House No. 169, Sector 11-A) from 1964 to 1974, I was offered one of the three largest residences on the 550-acre campus of Panjab University. The residence came with a full-time gardener, servant quarters, massive lawns for afternoon teas, a vegetable garden, and an impressive orchard. The offer was too tempting to refuse. We moved into our charming new home (House No. G-2, Sector 14) in 1974 (Photo 43). It was two doors down from the Vice-Chancellor's official university residence. I was now the fifth most senior person in the university hierarchy, given that my appointment as Reader/Department Head was at the young age of 33. Subsequently, I became Full Professor at 39. It was a remarkable achievement for a refugee! Most proud was my father, by then in his 70s. Although he did not openly express it, his calm demeanor could not hide his apparent joy at my professional accomplishments. We were a humble family that shunned showiness and never bragged about anything. Moreover, all achievements

Photo 43. Our charming home (House No. G-2, Sector 14) on the Panjab University campus. Each summer, we stayed in Chandigarh until June-end prior to the annual monsoon season so that we could relish the summer fruit and the wonderful produce that our massive garden offered. In addition to the vegetables and herbs, the orchard had a variety of fruit trees: mangos (nine varieties), bananas, figs, peaches, grapefruits, pomegranates, and grapes. We even grew sugarcane, peanuts, and corn. Our neighbor, the Dean of Panjab University, had planted wheat. The fertile alluvial soil of Punjab is a gift of nature.[84]

[84] *Aisa des hai mera* song from the Bollywood classic, *Veer-Zaara*: Available at: https://www.youtube.com/watch?v=wDheWYmNEhQ (accessed on June 1, 2023).

in life are relative. My father used to bike to campus for visits with my family, or to attend special departmental functions and picnics. I cherished the time spent with my elderly parents. They were my heroes, having endured colonialism and the loss of their way of life. I visited their home every Sunday evening unless I was out of town. I never lost sight of the fact that my parents and family were most important to me in life. Although I was professionally successful at a young age, life had taught me that material wealth and high positions can evaporate in a flash. After all, I was the child of The Partition, having witnessed this firsthand. In addition to my family, I viewed the students and faculty of my biophysics department as my extended family, whose members deserved appreciation and nurturing.

To live and work in Chandigarh was a delight. Summer vacations often were spent in the hill stations of the majestic *Himalayas* (Sanskrit, "abode of the snow"). For centuries, the stark beauty of the Himalayas has been a source of inspiration and awe to poets, travelers, and adventurers.[85] Our favorite trip to the Himalayas used to be a month-long stay in the Kashmir valley, especially the lush green meadows and pristine waters of *Pahalgom* (Kashmiri, "village of shepherds"). Nature has endowed Kashmir with unfathomable beauty; it is rightly called the "Switzerland of the East" ("*All my life through, the new sights of Nature made me rejoice like a child."*—Marie Curie). Our summer trips to Kashmir ended when the Himalayas claimed our younger son, Mickey. He was not even four, innocent and helpless. I often think of his gentle and sweet demeanor. Mickey's days were spent following and playing with his best friend, his older brother Pinky. Life has its natural order and children are supposed to outlive their parents. Rani and I were both still in our 30s and tried our best to comfort each other. But we had a hard time finding strength to go through the dark days up ahead, or to fill the emptiness in our hearts. The sorrow of this loss almost half a century ago has stayed with me to this day ("*Memories saturate my heart and the story of you spills from my eyes."*—Grace Andren).

Chandigarh was and will always be a paradise in India. In this regard, I refer to the marvelous—though somewhat dated—description of this wonderful city by Barbara Crossette, a *New York Times* Reporter, who spent six months in India teaching at Panjab University on a Fulbright Fellowship[86]:

> *To see Chandigarh is to see India in a new way…The city of Chandigarh, on the edge of the Punjab plain near the foothills of the Himalayas, was built to replace the*

[85]*Deewana hua badal* song from the Bollywood classic, *Kashmir ki Kali:* Available at: https://www.youtube.com/watch?v=O0I61W2pMss (accessed on June 1, 2023).

[86]Crossette, B. (1982). Le Corbusier's Chandigarh. *The New York Times.* April 25th Issue, Section 10, p. 21.

Punjabi capital of Lahore, lost to Pakistan in 1947. Today it is an urban showpiece—a clean and open "garden" city with an annual rose festival, a cool lakeside park, a captivating folk-sculpture Rock Garden—and a collection of Le Corbusier buildings that attracts architects from all over the world. Chandigarh is a city, rare in India, where walking—except under the punishing summer sun—is a pleasure. Le Corbusier envisioned a city divided strictly by function. There were to be residential sectors, an industrial area, a sector for colleges—the university is worth a detour; its attractive campus contains Le Corbusier's Gandhi Bhavan, a center for the study of the works and legacy of Mohandas K. Gandhi—and a research institution, a central commercial and office area, a spacious capitol complex against a mountain backdrop. A lush green valley running through the center of it all, gives the city "lungs." Each residential area was allotted its own shops, schools and other essential services. Roads were designed to channel traffic away from homes. Sector 16 has the Zakir Hussain Rose Garden, which is at its most colorful in winter months, especially January and February when the whole city, cool at night, is brightened by the "European" flower season. During the annual February Rose Festival, blooms of every color are matched by the bright silk of saris worn by women who come to stroll around the fountains or sit on the grassy lawns. Walking through the "leisure valley" toward the mountains from the Rose Garden, brings a visitor to the Chandigarh Museum and Art Gallery. This small museum contains a good permanent collection of Gandhara sculptural art, which flourished in the Indus River valley, in what is now Pakistan, in the last few centuries B.C. and the early part of the Christian era. Gandhara art is distinguished by its Hellenistic rather than Oriental style, from the drape of the clothing to the Mediterranean faces of the Buddha. Across the park drive from the museum is a meadow where colorful tents called shamianas are erected for concerts from time to time. At the edge of the parkland is a very popular exhibit of another kind: a captured Pakistani [US Patton] tank. The Secretariat is a Le Corbusier building in his European style: massive, 10 stories tall and given to unexpected angles. The High Court building, which can be reached by a walk more or less east along an access road, was designed specifically for the Indian climate: it has Le Corbusier's "parasol" roof—an overhanging but rolled-up lid of concrete to fend off rain and sun. From the High Court, one can walk across a stretch of scrub land to the Rock Garden. As in all planned cities not inhabited by robots, people have wrought their own modifications, and probably nowhere in India is there anything as happily whimsical as this fantasy created by an untutored sculptor, Nek Chand. Mr. Chand produced a collection of captivating creatures fashioned of discarded construction materials, old pots, and broken crockery. After the Rock Garden, the hardy walker can strike out along Uttar Marg (which translates roughly as Northern Boulevard) to Sukhna Lake, an artificially created body of water that is at almost any time of day arguably the most pleasant place in Chandigarh. On a clear morning one can catch a glimpse of the snowy high Himalayas, and by afternoon, the lakeside park provides a perfect place for reading or just sitting on the retaining wall or along a grassy bank. At night the place has a special magic, with the stars of the immense Punjabi sky vying with the lights of Kasauli, the first of the Himalayan hill stations, sparkling in the distance. A long lakeside walkway seems to disappear into the distant Shivalik Hills.

10.15 International Travel and Research Collaborations

Alone we can do so little; together we can do so much.

—Helen Keller (1880–1968)

I always have believed deeply in the importance of both national and international cooperation for the progress of science. Teamwork is critical to success. It is not the team with the best players that wins but it is the players with the best team that wins ("*[Teamwork] is the fuel that allows common people to attain uncommon results.*"—Andrew Carnegie). Science, like music and food, brings people, cultures, and even enemies together. Biomedical sciences have a rich tradition of collaboration. Today, biomedical research is even more interdisciplinary and technologically based than in years past. In fact, this collaborative spirit is reflected in my own research publications. They were mostly single author in the 1950s and 1960s; however, just three decades later, they involved collaboration with immunologists, chemists, and physicists. In fact, the percentage of the Nobel Prizes in medicine, chemistry, and physics awarded to two or three individuals for one project has increased over the past 30–40 years. This emphasizes the value and frequency of collaborative work in these fields. Furthermore, a look at the recent issues of any major biomedical journal reveals the high frequency of collaborative research today. Scientific collaboration also has economic benefits: When scientists work together, they not only share ideas, lab facilities, and resources but also form innovative and interdisciplinary solutions for existing problems.

Over the decades, I visited many laboratories in multiple countries, made numerous friends, and learned more than I possibly could have imagined ("*There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy.*"—William Shakespeare's *Hamlet*). A nonagenarian's life is full of stories and experiences, too numerous to be recited here. As mentioned previously, these will be the subject of my autobiography that currently is under preparation.

I was lucky to travel the world for collaborative research, presentations at international conferences, as a member of governmental advisory boards, and even for vacations. Many of my trips were memorable—some not only for the professional activities but also for the bizarre stories related to them. My short trips generally were made solo. On those occasions, when I was a visiting professor for a longer stay, the entire family would either accompany me or follow me a few months later. Some of these best long stays during the late 1980s and 1990s were in Germany, where I was a Humboldt Fellow on five separate occasions. I spent a few summers in the lab of Dr. Gerhard Werner at Saarland University in Saarbrücken, Germany. It was a long and productive association that resulted in outstanding research work. Each time a manuscript was accepted for publication, it was an excuse to celebrate with a party at his home. He died a few years ago; my last collaborator was gone. His intellect, warmth, and graciousness are dearly missed.

Japan was a particularly favorite country for me to visit—not only for its unique cuisine and culture but also for its well-equipped research facilities. Whenever I was shopping for a transmission electron microscope (TEM) or scanning electron microscope (SEM), Japan was my destination in addition to Germany and the US. I purchased one JEOL TEM and one SEM for the university from Japan in the late 1980s for the newly established, Regional Sophisticated Instrumental Center (RSIC). Two of my favorite scientists whom I visited frequently in Japan were Dr. Noboru Higashi, Professor and Director of the Institute for Virus Research at Kyoto University, and Dr. G. Yasuzumi, Professor of Anatomy at Nara Medical College in Kashiwara, Japan. Dr. Higashi made significant contributions to microbiology. His research on the ultrastructure of rickettsia, chlamydia, poxviruses, and togaviruses as well as their mode of replication is considered world-class. Also, he was one of the first to introduce the well-controlled *in vitro* culture system into electron microscopic studies of viruses and established the foundation of chlamydia organisms as obligate intercellular parasites. On the other hand, Dr. G. Yasuzumi did seminal work elucidating the role of various cellular structural elements in mammalian fertilization. I was in awe of his prowess to work continuously in the lab for 10–12 hours straight. Electron microscopy is a laborious endeavor, requiring hours in the dark with limited breaks. One must have enormous patience, a surgeon's steady hand, and exceptional skills at preparing samples involving multiple processing steps. In short, it requires skill, perseverance, laser concentration, and long hours with a low probability of success. I caution the budding microscopist to be prepared for the usual final result: the developed print or micrograph following immense labor will generally be of limited value, replete with artifacts, and unpublishable. However, it is important not to be frustrated or be overwhelmed by disappointment. Repeated failures and incremental success are part of this area of research. Patience and perseverance will eventually yield a beautiful micrograph that has all the desired structural elements worthy of publication in a respectable journal ("*A bend in the road is not the end of the road…Unless you fail to make the turn*."—Helen Keller).

In the mid-1990s, I had a productive research partnership with Dr. Maria Anna Pabst, Professor at the Medical University of Graz in Austria. I frequented her laboratory for research activities, often working in the Electron Microscope Facility into the wee hours. Our joint publications pertaining to surface mapping of spermatozoa via a variety of cutting-edge tools and techniques, including TEM, lectin binding, and freeze-fracture replica immunolabeling, were very well received. Dr. Pabst, who retired a few years ago, is a multitalented scientist and artist. Her artistic flair involves transforming canvas-printed electron microscopic images by rendering them with colored Indian ink. Previously, her work on a 1,000-year-old mummy from Chiribaya Alta in Southern Peru and a 5,300-year-old Tyrolean Iceman garnered worldwide scientific accolades.

Some of my most memorable trips were to the lab of Dr. Baccio Baccetti (1931–2010), Professor and Director of the Institute of Zoology at the University of Siena, when I was a visiting professor there in the 1970s. His interests were many, but insects were the common denominator of all his research. He collected many insect specimens and put together a large collection that was transferred

to the Museo Civico di Storia Naturale of Genoa. Dr. Baccetti, who was the editor of the *Journal of Submicroscopic Cytology*, set an example as an exceptional scientist, with an enormous capacity for work and limitless erudition. He possessed a rare combination of qualities, being both a deep thinker and virtuoso experimenter. He was an equally good man, displaying inexhaustible optimism, vitality, and love of life. Dr. Baccetti hosted us at Pontignano Monastery outside Siena (Photo 44). These were probably the most memorable summers for my family—we enjoyed the deluxe accommodations, surrounding farms, and stunning vineyards of Lombardy. We had a first-class chef, Beppe, who prepared delicious Italian and European meals for us (Photo 45). A car was provided to me for my daily drive to the university and for weekend sightseeing trips. Since it was summer, we enjoyed *The Palio* horse race, Italy's most famous annual sporting event. Upon our return to Chandigarh, Dr. Baccetti sent a massive container that contained fine Italian China, upon which he served dinners for us at his home (I happened to compliment the exquisite beauty of the dinner set!). On another occasion, he sent us an enormous shipment of the finest Italian mozzarella and tomato sauce by airmail, a real treat for anyone in the mid-1970s. My wife, who was a master in the kitchen, used the mozzarella over a period of months to craft amazing pizzas for the family.

Photo 44. The Certosa di Pontignano (Pontignano Charterhouse), also known as the Certosa di San Pietro, is a magnificent Carthusian monastery and church in the neighborhood of Pontignano, a few kilometers north of Siena, in Tuscany, Italy. It was founded in the 14th century. It retains all the elements of Carthusian architecture with large cloisters, individual monk's cells, each with a small garden, and a large church that still preserves 14th century features. The former monastery of Pontignano (now part of the University of Sienna) is set amongst olive groves and has three cloister gardens. Two are traditional grass rectangles and one is now a renaissance parterre garden.

Photo 45. My son with head cook Beppe and his staff in the kitchen at Pontignano Charterhouse, north of Siena, Italy. Not only were they exceptional chefts who prepared gourmet Italian meals for the family during our stays, but they were patient and generous with their time. Some of our favorite foods included Ribollita, Sardinian stuffed eggplant, Ragù alla bolognese, woven lasagna, Sfogliatella, Crostini Toscani, Panzanella, Bistecca alla Fiorentina, Fagioli con salsiccia, Tagliatelle al tartufo, and Pecorino Toscana—all lovingly served by Beppe and his team.

During one of my trips to East Berlin in the 1960s, an army colonel demanded that he personally review each of my 45 slides used for my scientific talk. He had a perplexed look as he examined each slide by holding it against the sunlight. I do not blame him for his confusion, as they were 35 mm Kodak film slides of various electron micrographs and stained histological tissue. Did he consider me a spy and believe that my slides carried encrypted information? Did he think this information could have been a threat to German democratic socialism? He wanted me to explain what each slide represented, a task that I found both amusing and exhausting. Soon we both moved on: He had fulfilled his bureaucratic duty and I complied with his unreasonable request. Obviously, he never had heard of an electron microscope, although the "magnificent machine" had been invented by the German Nobel Laureate, Dr. Ernst Ruska in the 1930s (Photo 19). Anyway, I finally was allowed to enter East Berlin. During my week-long stay there, my hosts showed me around. One image is still fresh in my mind: people standing in a long queue to purchase bread and bananas at a grocery store. It reminded me of my refugee days when we would eat our meals sitting on the ground. There, small containers would be thrust into our face by those who parsimoniously dispensed lentil soup from ladles. I was told that the

reparations owed by the Germans to the Soviets after the Second World War (*Deutsche Reparationen*) had impoverished the Soviet Zone of Occupation and severely weakened the economy of East Germany. Between 1945 and 1946 alone, the Soviets had confiscated and transported approximately 33% of industrial plant resources to the USSR. By the early 1950s, they had extracted nearly $10 billion worth of agricultural and industrial products from reparations.[87]

Another visit to an Iron Curtain country is worth mentioning briefly. During a trip to Communist Warsaw in the late 1960s, I faced challenges similar to those encountered in the German Democratic Republic. I was tailed by a secret service police officer for most of my ten-day stay. He even followed me to the Grand Theatre-National Opera. Although nerve-racking, I do not believe that my life was ever in danger. Nevertheless, it was a unique experience.

Some of the conferences and symposia, which I presented or attended, had awkward moments or humorous twists. During a major international conference held in Europe during the late 1960s (the Charles de Gaulle era), a French speaker started his presentation in English only to suddenly switch over to French. The audience was stunned; he refused to switch back to English and eventually was asked to leave. Another similar bizarre incident occurred in 2002 at Rensselaer Polytechnic Institute at a biotechnology symposium chaired by my son. The opening keynote was a 45-minute presentation by the editor of *Nature Biotechnology.* After his presentation ran over by 15 minutes, my son politely asked to him close out. However, he continued for another 30 minutes, yet kept assuring the audience that he was near the end of his talk. This was yet another case of a distinguished speaker who had too much to showcase for the available time allotted ("*The greatest virtue of a speaker is not only to say what is necessary, but also not to say what is not necessary.*"—Cicero). Eventually, the Dean of Science, Dr. Joseph Eckert, stood next to him and literally gently nudged him off the podium.

Procuring samples of both human and non-human tissue was critical to my research endeavors. During my Cornell days in the early 1960s, for my research work on the Sertoli cells of the human testes, I flew to Birmingham, Alabama. There I had arranged to obtain testes from a volunteer prisoner on death row. A prison doctor castrated the death-row inmate and provided me with the necessary tissue. It was a strange sight indeed: a surgeon operating on the inmate; I serving as the surgical assistant; and a dozen prisoners surrounding us observing the procedure at close range. There were two guards nearby, certainly not enough in case something went awry. Obviously, it was a different era without informed consent, approval forms, and institutional review boards (IRBs). I was in the segregated South. It was prior to Dr. Martin Luther King, Jr.'s (1929–1968) famous speech or the Civil Rights movement. Birmingham in the early 1960s was the most segregated city in the US where Jim Crow laws separated black and white people in parks, pools, elevators, drinking fountains, and lunch counters. Black Americans even were barred from working at the same downtown businesses where they

[87]Naimark, N. M. (1995). *The Russians in Germany: A History of the Soviet Zone of Occupation, 1945–1949.* Harvard University Press, Cambridge.

shopped. It reminded me of British India and my youth in Lahore only a decade earlier where brutal, racially motivated prejudice, segregation, and violence were the norm. Being in New York City and at the rarefied ivory towers of academia, I was isolated from the news pertaining to the ills perpetrated against Black Americans of the South. I realized that there were two Americas ("*And we must face the hard fact that many Americans would like to have a nation which is a democracy for white Americans but simultaneously a dictatorship over black Americans.*"—Martin Luther King, Jr.). The evils and legacy of slavery persisted. My adopted country—the one that I viewed as the shining star on the hill—was, in fact, rotten at the core.

During my Panjab University days, I would venture on sample expeditions into the Himalayas or to the Indian Ocean. One memorable trip involved being on a day-long trip on a yacht with a crew of fishermen, who helped me procure a variety of sea-animals deep in the Indian Ocean near the Andaman and Nicobar Islands. I later realized that, in my excitement, I had forgotten to wear a lifejacket—an oversight that I did not repeat. Upon my return flight, I went home and temporarily stored the containers with the live sea life in my refrigerator. The neighborhood children visited the house all day to peer into the strange world. In fact, they were always excited to see me following a trip because it involved something unique and exciting for them (chocolates from Switzerland, toys from the US, live sea animals from the Indian ocean, exotic birds from the Himalayas, etc.).

My life in biomedicine often involved traveling with tissue samples (normal or pathological) that had been polymer-embedded and were ready for sectioning, staining, and microscopic examination. These were hard to procure for my collaborators in Europe or the US. It was a wonderful joint endeavor: I provided samples that were then processed in the world-class research facilities of my collaborators. Such efforts resulted in stellar publications. For human pathological or autopsy/biopsy tissue, I had my collaborators worldwide. For non-human tissue, I generally relied upon the excellent animal facility located adjacent to our Basic Medical Sciences building. This facility housed a variety of animals, birds, and fish. Additionally, I had access to numerous research stations throughout India. Over the years, I conducted research on monkey, goat, squirrel, cobra, mouse, rat, rabbit, hedgehog, turtle, rose-ringed parakeet, common hornet, honeybee, lizard, parrot, chicken, Indian crow, sparrow, pigeon, and so on.

Besides procuring samples from the most unusual places, like a US prison in the segregated South or the Indian Ocean, I was frequently forced to navigate complex logistics or devise creative ways to transport them. Carrying biological samples would prove especially arduous when I travelled abroad. It often caused commotion at airports and transit points. If I declared what I was carrying, my "material" would almost always be confiscated or trashed, thereby defeating the purpose of my scientific trip. On the other hand, if I did not disclose the biological samples, they could be considered contraband resulting in a stiff fine or worse. I was stuck between a rock and a hard place. In case the custom officer decided to photograph or X-ray the sample, it caused further confusion. Although the tissue samples were embedded in polymer, I nevertheless was always wary of

X-rays; I wondered if that could somehow introduce artifacts. I started to carry my faculty ID badge, business cards, and invitation letters from my hosts—all in hopes of pleading my innocence, if necessary. I would have to do even more explaining if I carried with me medicinal pills, plant extracts, or protein samples. Once, to my amusement, an airport police officer in Europe smashed open an ampule and tasted its contents; the bitter white powder was lyophilized protein.

10.16 Future of the Research Enterprise

As I have stated, extensive research and pedagogy have been powerful catalysts for my personal and professional development. My professional journey has allowed me to bear witness to incredible intellectual feats. In contrast to the phenomenal advances in biomedicine, I have also observed the evolution of unacceptable trends in the scientific community, including increased plagiarism, fraud, and irreproducibility of preclinical research. Other threats to the future of scientific research include the rise of predatory journals, compromised confidentiality of the peer-review process, and financial influence of large pharmaceutical companies. One trend with unknown consequences is open access research—or, rather, sharing early results of studies and experiments online. This gained momentum during the COVID-19 crisis. Hopefully, this online availability of research outputs incorporates rigorous quality checks, the lifeblood of authentic scientific progress.[88]

(a) Scientific Misconduct

Science depends on complete trust. The vast majority of researchers report the facts as per the results of experiments. Many errors that occur can be attributed to mistakes in preparing figures or interpreting data. Mistakes also can be introduced by being too trusting of commercial reagents and antibodies.[89] This said, I am most concerned with a minority of studies in which data are fabricated deliberately. This pollutes scientific literature, drains finite resources, and misdirects future research endeavors.

Dr. Vishwa J. Gupta, an internationally renowned paleontologist from my own Panjab University, conducted large-scale scientific fraud. His two decades of scientific research work, during which he generated more than 400 research papers, came under scrutiny. Many had fabricated data and/or images. For example, he purchased fossils from shops, museums, or academic collections and then falsely claimed to have found them in the Himalayas. According to the *New York Times* (1989), it was "the most serious case of its kind since the Piltdown hoax more than half a century ago." Sadly, as a result, the paleontological literature on the Himalayas has become shot through with disinformation.[90] I find it equally

[88]I will leave these important issues out of my brief discussion here, as they will be dealt with in an editorial piece that I currently am working on for Volume 5 of this series.

[89]Shortcuts taken by antibody manufacturers and researchers alike have resulted in a crisis of reproducibility in antibody performance. Obviously, this greatly affects the identification of drug targets, thereby contributing to the reproducibility crisis in biomedical research.

[90]Talent, J. (1989). The case of the peripatetic fossils. *Nature* **338**:613–615.

appalling that despite overwhelming published evidence of multiple acts of research misconduct and despite being found guilty of misconduct by our university, Dr. Gupta remained a tenured professor until his retirement in 2002.

Based on my experience reviewing grant applications and serving on journal editorial boards, I believe that the number of fraudulent papers is increasing rapidly. This is due, in part, to authors purchasing papers through "paper mills," which generate literature by recycling text and figures. This illustrates the need for vigilance against deliberate fraud, which should be arbitrated with the gravity of other criminal investigations. Journals should require contributing authors to provide rigorous data to support their conclusions; standards should be implemented consistently prior to publication. Fraud should be unacceptable now and always. To guard against falsified publications, it is critical to employ a variety of safeguards including anti-plagiarism software, and image integrity analytics.

(b) Irreproducibility of Basic Research

Apart from fraud (i.e., scientific misconduct discussed in (a) above), there is another major issue regarding biomedical research—the elephant in the room. It is the irreproducibility of preclinical research and/or data due to sloppy science. In this regard, I refer to an excellent review[91]:

> *We are in the midst of a widening research crisis. The current pervasive culture of science focuses on rewarding flashy, eye-catching, and positive findings. There is an increased emphasis on making provocative statements rather than presenting technical details or reporting basic elements of experimental design. These are some of the factors that have resulted in irreproducible preclinical research in biomedicine, mainly from academia. There are reports that less than one-third of biomedical papers can be reproduced; this is due to sloppy science blamed in part on scientific culture, training, and incentives. A survey of nearly 900 members by the American Society for Cell Biology in 2015 found that more than two-thirds of respondents had been on at least one occasion unable to reproduce published results. These results are strikingly similar to another online survey of 1,576 researchers by Nature conducted in 2016 that reported that 70% of researchers have tried and failed to reproduce another scientist's experiments, and more than half have failed to reproduce their own experiments. Irreproducible research delays treatments, wastes time, and squanders research dollars. It is clearly widespread. In fact, it is seen in all disciplines of biomedical research, with the area most susceptible being research work that employs animal models. Research institution administrators, faculty members, and trainees all share blame here. They must do far more for reproducibility of biomedical research data. Most institutions will, however, not make the necessary moves unless forced by a regulatory or funding body. However, note that there is no evidence to suggest that irreproducibility is caused by scientific misconduct […] Obviously, human clinical trials are less at risk from irreproducibility*

[91]Bawa, R. (2017). A practical guide to translating nanomedical products. *In:* J. Cornier, et al. (eds.). *Pharmaceutical Nanotechnology: Innovation and Production.* 1st edition. Wiley-VCH Verlag, Chapter 28, pp. 663–695.

because they are already governed by various regulations that stipulate rigorous design and independent oversight [...] the American Statistical Association (ASA) issued principles to guide use of the P-value and warned that P-values cannot be used to determine whether a hypothesis is true or whether the results are important. According to the ASA, misuse of P-values is also contributing to this irreproducibility crisis.

10.17 Concluding Remarks: Moving toward the Future while Reflecting on the Past

Yesterday is but a dream, tomorrow but a vision.

—Indian Proverb

Life is short. Break the rules, forgive quickly, kiss slowly, love truly, laugh uncontrollably, and never regret anything that makes you smile.

—Mark Twain (1835–1910), American Writer

We do not learn from experience... we learn from reflecting on experience.

—John Dewey (1859–1952), American Psychologist

Don't judge your greatness by your shadow at sunset.

—Pythagoras (570 BC–495 BC),
Greek Philosopher and Mathematician

Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning.

—Albert Einstein (1879–1955),
American Physicist and Nobel Laureate

I have been fortunate enough to be an active participant in the development of the most interesting and exciting areas of cell biology and biomedicine, and in the elucidation of essential concepts for both fields. My career has been a journey, whose destination never was clear along the way. Through my research and during my travels, opportunities continually presented themselves though I had little more than a guess as to where they might lead. In broad brushstrokes, I have made strides in the fields of spermatology, microscopy, reproductive medicine, cardiology, and cell biology. Yet, when I reflect on my publications and curriculum vitae, I realize they are the product of an uncharted walk along the paths of opportunity; they are not the purposeful pursuit of prowess in a specific area. I hope that my ability to navigate uncertain, and sometimes dire circumstances might provide encouragement to students. My personal and professional life proves a simple point: In the face of uncertainty and extreme odds, one can not only survive but thrive. The message is clear: Never give up, look forward, and put your best with honest intentions.

Whatever may have shaped my meandering, the rewards have been many and regrets few ("*Tell me, what is it you plan to do with your one wild and precious life?"*—Mary Oliver). I fan the embers of fading memories to understand how and why such meandering has been so fruitful. One ember, which still is glowing in the ashes of my memories, is a passion for science and biomedical research. It is important to have passion for whichever path one chooses. I chose benchwork over patient care. Money and fame should be secondary considerations. With training and inspirational education that began in my childhood home, my life's journey led to scientific satisfaction and travels to exotic lands. Following retirement, I have served as both consultant and scientific advisor, which has been stimulating and pleasant. I still am invited to give lectures, participate in workshops, and write articles for journals and books. Obviously, now I cannot undertake or participate in such events, at least not with the same vigor. Age does have its limitations. I look back and feel that I have led a very full and productive life and have created something for future generations. I hope that I have spawned generations of scientific offspring, who continue my scientific legacy and make crucial contributions to the development of basic sciences and applied biomedicine. This would symbolize the continuity of science and the passing of the torch to the next generation.

Over the later years of my academic life, teaching became a passion equal to—if not more important than—research. Initially, my teaching was limited to a few courses: microscopic anatomy and microscopy. Later, I became involved in giving guest lectures in at least seven more courses, including some outside of my department. Over the past 65 years, I have taught more than a dozen different courses, and thousands of students have passed through my classes. Additionally, I have served as thesis advisor to around 37 master's and PhD students. Both the students who passed through my classrooms and the graduate students in my laboratory have gone on to successful careers in academia, government, and industry around the globe. In short, it has been a tremendous joy and privilege to conduct research and to teach. It has been an exciting experience to observe and participate in the growth of the Department of Biophysics at Panjab University in Chandigarh: from one employee when I took charge in 1964 to approximately 70 when I retired three decades later. The years since have been full, challenging, and gratifying. Several of my students, classmates, collaborators, staff members, and colleagues from around the world have maintained contact with me. I make a point of calling as many of them as I can on New Year—a process that generally takes most of the day.

The educational process of teaching and research is one of teamwork between students and teachers. The student's qualifications must include the ability and willingness to learn while the teacher's qualifications must include the ability and passion to teach, provide inspiration, imagination, and impart meaningful knowledge ("*Any man can learn anything he will, but no man can teach except to those who want to learn.*"—Henry Ford). Great teachers are not born; they are

built over time and through education, perseverance, practice, and guidance. In this context, there is one point that I cannot emphasize enough: *What* is taught is important but *how* it is taught is equally significant. The great Indian surgeon Sushruta ("father of plastic surgery"), who probably lived in the 6th century BC, touches on how to be a successful student and emphasizes the importance of good study habits: "*A pupil who is pure, obedient to his preceptor, applies himself steadily to his work, and abandons laziness and excessive sleep, will arrive at the end of the science he has been studying.*"

I hope people realize that my real legacy is not in material things: It is in the intangibles of academic excellence and devotion. Live your life through experiences, not materialism. I value the people whose lives and careers I have directly impacted. I equally value those that I influenced indirectly through those whom I taught and shepherded to success. I believe that there are only three professionals in this world who are entrusted with one's most intimate details—a physician, a priest, and a teacher. I am fortunate to be on this list.

I must vent about one issue that has damaged the international reputation of Indian universities. I lament the demise of the permanent headship system in Indian universities, including Panjab University. Permanent headship refers to life-long tenure at a university. As a rule, all central universities in India now follow the "headship rotation model." This ill-conceived injection of democracy into Indian academia involves rotating the department chair from one person to the next, generally after a mere three years—all based solely on seniority and with complete disregard for merit or talent. As a result, a junior lecturer could be the department head when there are numerous tenured full professors. This is exactly the current situation in my former Department of Biophysics. Obviously, this ridiculous set-up has eroded confidence in and quality of Indian universities. Contrary to the assertions of those pushing for the expansion of this outrageous system, it does little to ensure equality, accountability, shared responsibility, and a cooperative work culture. In my academic experience, the permanent headship system, where the appointed person occupied the post until his/her retirement, was always based on merit. It clearly represents a superior alternative to the current headship rotation model. As a compromise, maybe a hybrid rotation approach can be tested. According to this model, the senior-most professor would take over as the department head for a period of time, or upon the retirement of the incumbent; after expiry of the term, the next senior-most professor takes over as department head. In those rare circumstances where the departments have no professor or associate professor, the senior-most lecturer/assistant professor could serve as head. Things are not that rosy at US universities either. From my perspective, there has been a gradual loss of academic freedom, inflation of student grades, unjustified increase in tuition, rise of legacy admissions, financial influence to drive specific agendas, and a curriculum (at least in the sciences) that poorly prepares the student for the global economy. Not to sound cynical, but

maybe this is simply a reflection of our rotten societal forces that persist today, mediocrity at every level in academia, few inspirational educators, and lack of visionary administrators.

I still follow developments of my department from afar, which celebrated its Golden Jubilee in 2014 (Photos 46–48). In commemoration of this occasion, I took my immediate family from the US to Chandigarh to participate in the week-long festivities. My former MSc student, Dr. D. K. Dhawan, Professor and Chair of the department, not only organized a world-class program but ensured that we had a comfortable stay at the university guest house. Celebrations were filled with lectures, seminars, social events, parties, and variety programs. The Vice-Chancellor, Dr. A. K. Grover, inaugurated the opening session and gave a wonderful presentation highlighting noteworthy achievements of the university (Photo 46). He mentioned that he was an undergraduate at the university in 1969 and had attended the international symposium that I had organized then (Photo 40). He also made an interesting observation that I never previously thought of: A founder of an institute or department almost never is present for the Golden Jubilee celebrations. There was a poignancy in this observation because I knew in my heart that it would be the last time our immediate family would be together. I was right.

Photo 46. Inauguration ceremonies of the Golden Jubilee of the Biophysics Department in 2014. The Vice-Chancellor of Panjab University, Dr. A. K. Grover, is on the left, Dr. D. K. Dhawan, Professor and Chair, is in the middle, and I am on the right.

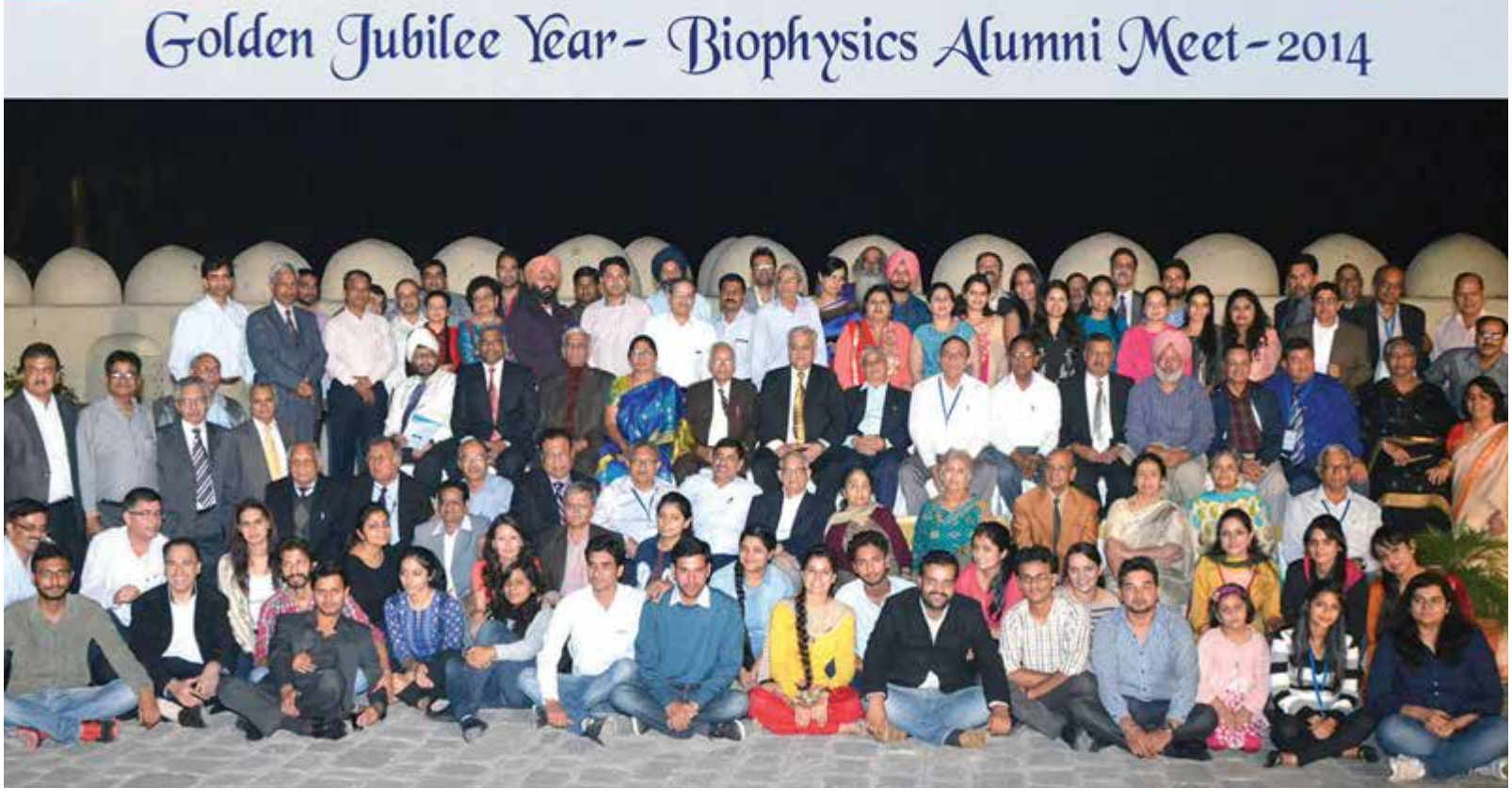


Photo 47. Group photograph taken at Pinjore Gardens during the Golden Jubilee celebrations of our Biophysics Department in 2014. As can be seen in the background, the Garden complex is beautifully illuminated at night. Pinjore Gardens, a historic 17th century Mughal Garden located in the foothills of the Himalayas, were one of summer retreats of the Mughal Emperor Aurangzeb (1658–1707), who then had his capital at Lahore. Pinjore Gardens have often been used as a setting for filming Bollywood movies.

Photo 48. Pinjore Gardens at night. This exquisite, historical garden is well-known for its fountains, lush greenery, and its various water bodies.

Nowadays, I live in Virginia (Photo 49) with my son and daughter-in-law (Photo 50). My son is my caregiver and I have no words for the daily sacrifices he makes tending to my myriad of ever-increasing needs. His world revolves around me. At times, I feel worthless: almost 94 years old, handicapped, with severe osteoarthritis, limited mobility, poor eyesight, urinary incontinence, and substantial hearing loss. I am more aware than ever that time is finite ("*Time obliterates the fictions of opinion and confirms the decisions of nature.*"—Cicero). I feel depressed, only to be quickly reminded that I am still mentally sharp and in a loving home. I do realize that I have never had any surgeries or cognitive issues. I still manage to venture out frequently and maintain a relatively active social network. As I analyze my life and look back, I have a better perspective of things, both good and bad ("*Getting old is like climbing a mountain; you get a little out of breath, but the view is much better!*"—Ingrid Bergman). I do appreciate everything and take things in stride, as I always have.

I lost my gentle Rani on September 21, 2020. I miss her because she was my whole world, my life, and the very reason for my existence. We were married for 66 years but knew each other for more than 80 years. I always could count on her valuable advice, support, and unconditional love. While returning home from a long day's work, I knew that she would be waiting for me with a lovely smile, a warm heart, and an amazing meal. ("*There is no greater happiness for a man than approaching a door at the end of a day knowing someone on the other side of that door is waiting for the sound of his footsteps.*"—*Ronald Reagan*). I miss the way Rani (Photo 51) talked, the way she walked. I miss the way she laughed at my jokes, especially on those occasions when she accompanied me to speaking engagements and had to listen to my old stories again. I miss her warmth, calm demeanor, and the sunshine of her smile. I miss her every second of every minute ("*It has been said, 'time heals all wounds.' I do not agree. The wounds remain. In time, the mind, protecting its sanity, covers them with scar tissue and the pain lessens. But it is never gone.*"—Rose Kennedy).

Photo 49. My residence in Ashburn, in picturesque Loudoun County, Virginia. Loudoun is the nation's wealthiest county with the highest median household income. It is also where 70% of the world's internet traffic flows through every second of every day.

Photo 50. Rani and I with our son and lovely daughter-in-law, Sangita, at Rensselaer Polytechnic Institute in Troy, New York, around 2006. The occasion was the annual international biotechnology conference organized and chaired by my son. The beautiful fall foliage of Upstate New York is visible in the background.

Photo 51. At home with Rani in Niskayuna, New York (c. 2002). Happier times!

(*रहें ना रहें हम महका करेंगे बनके कली, बनके सबा, बाग-ए-वफ़ा में* / *rahe na rahe hum mahakaa karenge, banke kali banke sabaa baagh-e-wafaa mei;* translation from Urdu: *Whether or not I am here, this fragrance will remain, as if a flower, as if a breeze in our devoted garden.*—Majrooh Sultanpuri)

(*नाम गुम जाएगा चेहरा ये बदल जाएगा मेरी आवाज़ ही पहचान है गर याद रहे* / *naam gum jaayegaa chaharaa yeh badal jaayegaa merii aavaaz hii pahchaan hai gar yaad rahe*; translation from Hindi: *My name will disappear; my face will change with time; only my memory will remain as my identity, just remember this.*—Gulzar and R. D. Burman).

Disclosures and Conflict of Interest

This chapter is based, in part, on my autobiography that is currently under preparation. The stories penned here spun out at speed because at my age there is hardly anything to live on except nostalgia and recreating the past. They have benefited from my conversations with countless individuals over time. I have especially enjoyed summoning my dear friends, siblings, classmates, colleagues, students, employees, and family to sessions of sweet memory. Many of them now sleep their last sleep, I have wept at the separation.

In 2010, I started penning my autobiography. Prior to this, I had collected reference materials, photographs, notes, letters, and my previous short articles—all serving as the basis for a decent start for this chapter. There were days when I would handwrite or type 5–25 pages, spanned by weeks when I was idle, busy with other things, or tending to my ailing wife. All our lives, whether in Europe,

India, or US, Rani and I lived in a single-family home, blessed to have each other's company and support. When Rani was gone, my precious security blanket and pillar of strength were lost; there was little motivation to continue on with my autobiography or this chapter. It is only because of the kind encouragement and support of the publisher and the editors of this volume that I concluded this chapter.

Sometimes my handwriting was legible, while other times, I had a hard time deciphering it. Although I tried to be chronological in my approach, often I could not make sense of the sequence of events that I had recorded. Eventually, I got a large amount of my writings typed. Then, I meticulously edited it, cross-checking for accuracy and timelines. Finally, I was further able to piece together events, travels, visits, lectures, incidents, and conferences. The editors and publisher meticulously read many iterations of the manuscript and insisted on further reflection and clarification. They also made several helpful suggestions and saved me from many errors. My deep gratitude to them.

The views expressed in this chapter are solely mine. No writing assistance was utilized to produce this chapter and no payment was received for its preparation.

Acknowledgements

I would be remiss not to acknowledge my many collaborators, mentors, teachers, students, staff, and colleagues, without whom I never could have accomplished what has been done over the past 75 years. They were some of the smartest people I've had the privilege to work with. My departmental faculty and staff at Panjab University, while I was department head and later dean, provided superb support, advice, and undertook all assignments with honesty and dedication. Many colleagues and, especially, my many teachers have contributed much to my scientific work and personal growth. I truly appreciate the confidence they had in me. They lit up my career path, so I could achieve my goals. Their doors were always open to me, and they were extremely generous with their time and advice. I have tried my best to follow their example and reciprocate the favor. Finally, I also would like to thank the editors for soliciting this chapter and the publishers for their patience in receiving it. Although, they have been subjected to multiple versions of the various parts of this chapter, they have provided outstanding advice and criticism throughout the process.

Included among my collaborators are all the graduate students and postdoctoral fellows, who "worked in the trenches" and made much of the progress possible. Their dedication, fresh perspectives, passion, novel insights, challenging questions, and honest hard work were critical to the research endeavors in my laboratory. It made the discovery process productive and exciting. They ended up teaching me new skills, techniques, and inspired me. They are (in alphabetical order): Avtar K. Attri, P. Bahl, S. Bahl, Harminder K. Bains, Madhu Bhasin, P. P. Bidwai, N. C. Bissonauth, Reena Darbari, Ranjana Deo, D. K. Dhawan, P. Gill, G. S. Gupta, S. Hussanmal, M. S. Jabbal, R. Kachroo, S. C. Kapur, R. Kaul, Rajinder Kaur, Rashwinder Kaur, Neelam Mahajan, Ricky Malhotra, Raj K. Marwaha, Meena Mehra, Balraj Mittal,

Ashok Moza, R. Pannu, P. Prakash, C. M. Pathak, Adarsh Pratibha, C. P. Puri, R. K. Rai, N. K. Relan, Rupinder K. Sandhu, P. Sharma, S. K. Sharma, Ishwar Singh, S. Singh, and Rakesh C. YashRoy.

Since 1951, my research has been funded by fellowships and grants from numerous sources: Fulbright Program, US Department of State; Cornell University Medical College, New York City; Columbia University, New York City; The Population Council, Inc., New York City; University of Wisconsin-Madison, USA; UCLA, USA; University of Manitoba, Canada; Panjab University, India; Alexander von Humboldt Foundation, Germany; University Grants Commission, India; Indian Council of Medical Research; PL 480 Funds, US Department of Agriculture; Bawa Biotech, LLC, USA; Worcester Foundation for Experimental Biology, USA; University of Hamburg, Germany; Downstate Medical Center, New York City; Tata Institute of Fundamental Research, India; Albany Medical Center, USA; New York State Department of Health, USA; Saarland University, Germany; Medical University of Graz, Austria; and University of Siena, Italy.

I fondly acknowledge the faculty, technicians, clerks, and non-teaching staff members of my Biophysics Department at Panjab University from 1964 until my retirement in 1992. These are (in no particular order): Dr. G. S. Gupta, Dr. Ashwani Koul, Dr. K. C. Kanwar, the late Dr. F. S. Nandel, the late Dr. S. N. Sanyal, Dr. M. L. Garg, Dr. M. R. Bansal, Dr. N. R. Kalla, Dr. D. K. Dhawan, Dr. Bimla Nehru, Dr. P. P. Bidwai, Dr. V. K. Shukla, Dr. N. K. Relan, Dr. D. V. Rai, P. K. Sharma, Dr. Rajesh Mehra, the late Dr. Shimla Bansal, the late Dr. P. C. Mangal, Dr. M. P. Bansal, Dharam Singh, Kishori Lal (department photographer), Krishan Lal (department librarian), Pal Singh (first employee in 1964), Kashmiri Lal, Pritam Chand, K. S. Verma, Roshan Lal, the late Gurbachan Singh, Charan Singh, Asutaty Mehta, Kuldip Singh, Dharma Singh Dogra, the late Ram Avadh, Ram Chander, Neelam Batra, Sham Lal, the late Som Dutt, the late Barsati Ram, Chaman Lal, Balaur Chand, Bharat Bhushan, Karam Singh Thakur, Manohar Lal Chug, Ram Samujh, Amarjit Singh, Yash Pal, Ajmer Singh Kang, Damodar Dass, and Sewai Singh.

Over the years, I have collaborated with numerous investigators and researchers, including the late Dr. Vishwa Nath (Panjab University); the late Dr. Gerhard Werner (Saarland University, Germany); Dr. Toshio Nagano (University of Chiba, Japan); the late Dr. Jean Andre (University of Paris, France); Dr. Marianne A. Pabst (University of Graz, Austria); the late Dr. E. Horstmann (University of Hamburg, Germany); the late Dr. Baccio Baccetti and the late Dr. Romano Dallai (both of the University of Siena, Italy); the late Dr. Pawan K. Singal (University of Manitoba, Canada); the late Dr. Brij L. Gupta (University of Cambridge, UK); the late Dr. F. S. Sjöstrand (UCLA, USA); the late Dr. Hans Ris (University of Wisconsin-Madison, USA); Dr. Raj Bawa (Bawa Biotech LLC, USA, Guanine Inc., USA, and Teva Pharmaceutical Industries Ltd., Israel); Dr. Garish Govil (Tata Institute of Fundamental Research, India); the late Dr. D. V. S. Jain (Chemistry Department, Panjab University); Dr. Donald Fishman, (Anatomy Department, Downstate Medical Center, New York City); Dr. S. P. Anand (National Dairy Research Institute, India); Dr. Kathleen McDonough (New York State Department

of Health, Albany, NY, USA); Dr. G. S. Gupta, Dr. P. P. Bidwai, Dr. N. R. Kalla, Dr. U. Kanwar, Dr. K. C. Kanwar, Dr. N. K. Relan, and Dr. M. R. Bansal (all of the Biophysics Department, Panjab University); Dr. C. P. Puri (Institute of Research in Reproduction, India); and Dr. Shoba Sehgal (Postgraduate Institute of Medical Education and Research, India). Over the years, technical support of Madan Lal Sharma and Kishori Lal (Panjab University); E. Maatz (Saarland University); Betty Wallace and Robert Ward (Columbia University); and Brigitta Sjöstrand (UCLA) is gratefully acknowledged.

I would also like to acknowledge various individuals who have helped me along my journey by offering counsel or providing support: the late Dr. George N. Papanicolaou; the late Dr. Leonard L. Ross, the late Dr. George B. Chapman (all former Professors of Anatomy, Cornell University Medical College, New York City); Dr. Shaker A. Mousa (Endowed Professor, Albany College of Pharmacy, Albany, NY); Dr. S. Sirsat (former Professor, Cancer Research Institute, Bombay, India); the late Des Raj Kapur (Catering Business Owner, Hoshiarpur, India); the late Dr. R. K. Misra (former Professor and Head, All India Institute of Medical Sciences, Delhi, India); Kamal Doshi (Certified Public Accountant, McLean, VA); Dr. P. N. Srivastava (former Vice Chancellor, Allahabad University, India); Dr. Vinod Shah (former Vice Chancellor, Ahmedabad University, India); Dr. Ashok SenGupta (formerly of Harvard Medical School and BU School of Medicine, Boston, MA); Theresa B. Marangas (Attorney, Meier Law Firm PLLC, Latham, NY); Lata Maheshwari (Certified Public Accountant, Herndon, VA); the late Dr. R. E. Beamish and Dr. N. S. Dhalla (both former Professors at the University of Manitoba, Canada), Dr. Charles W. Boylen (Professor Emeritus, Rensselaer Polytechnic Institute, Troy, NY); the late Dr. Shanti Swarup (former Professor and Head, Political Science, Panjab University, Chandigarh, India); Dr. Charles A. Trout (Primary Care Physician, Albany, NY); Bryan M. Clenahan, (Attorney and former Albany County Legislator, Albany, NY); the late Mr. K. S. Bedi (*Everyday Science*, Biophysics Department, Panjab University, Chandigarh, India); the late Dr. Noboru Higashi (former Professor, University of Kyoto, Japan); Stephanie Martino-Kilmartin (Licensed Real Estate Salesperson, Clancy, Albany, NY); the late Dr. G. F. Meyer (former Professor, Germany); Lilit Ghazaryan (Artist and Poet, Rockville, MD); Kishor Doshi and Kalpana Doshi (Richmond, TX); the late Dr. Neuman (former Professor, Saarland University, Germany); Dr. Mabel M. P. Cheng (Eye Surgeon, Niskayuna, NY); the late Dr. H. S. Vashisht, Dr. Ram Parshad, the late Dr. G. L. Arora, Dr. O. P. Dhingra, the late Dr. Romesh Satija, the late Dr. Deshraj Kapoor, Dr. Shakti Kapoor, Dr. B. N. Sud, the late Dr. Usha Kanwar, the late Dr. G. P. Sharma (all former Professors of Zoology, Panjab University, India); the late Dr. Rajender Pal (Director of Fisheries, Himachal Pradesh); the late Dr. Saroj Mehta (Professor of Pediatric Gastroenterology, Postgraduate Institute of Medical Education and Research, India); the late Dr. Rastogi (former Professor of Endocrinology, Post Graduate Institute of Medical Research, India); Dr. Cheema (former Professor of Botany, Panjab University, India); Elizabeth A. Pacheco (Purcellville, VA); the late Dewan Anand Kumar, the late Dr. A. C.

Joshi, the late Lala Suraj Bhan and Dr. A. K. Grover (all former Vice-Chancellors of Panjab University, India); the late Dr. Roop C. Sawhney (former Professor, New York University, New York City); the late Dr. Keith Porter (former Professor, Rockefeller Institute for Medical Research, New York City); the late Dr. Arthur Pollister (former Professor and Chair of Zoology, Columbia University, New York City); the late Dr. Marion Hines (former Professor of Zoology, Columbia University, New York City); the late Dr. Donald Fawcett, (former Professor and Chair of Anatomy, Cornell University Medical College, New York City); the late Dr. Roy C. Swan, Jr. (former Professor and Chair of Anatomy, Cornell University Medical College, New York City); the late Dr. M. S. Randhawa (former first Commissioner of Chandigarh, India); Nilima Mehra (Journalist and TV Producer, MHz Networks, Fairfax Station, VA); Florence Montgomery (Nurse, Schenectady, NY); Jayne Thrane (Caregiver, Melrose, NY); Arvind Kanswal (Associate Publisher, Jenny Stanford Publishing, Singapore); Paula Dalotto-Lippitt (Entrepreneur, Altamont, NY); Maxwell W. Lippitt (Software Engineer, Altamont, NY); Dr. Pathak (Professor of Biophysics, Postgraduate Institute of Medical Education and Research, India), Dr. Rajesh N. Mehra (Primary Care Physician, Fairfax Station, VA); the late Sam Coleman, Jr. (Handman, Albany, NY); Dr. Ajaib Singh (Professor, Panjab University, India); Dr. Ambrish K. Gupta and Dr. Jyotsna Gupta (Primary Care Physicians, McLean, VA); Dr. Ken Belle and Terry Belle (Authors and Poets, Richmond, TX); Michelle C. Rost, Jennifer S. Rudolph and Prem Jaddu (Managers, 1st National Bank of Scotia, Niskayuna, NY); Dr. Albert N. Huho (Dermatologist, Schenectady, NY); Dr. Robert Busch (Endocrinology Department, Albany Medical Center, Albany, NY); Dr. Richard Holub (Physician, Albany, NY); Dr. Jay K. Doshi (Dentist, Spring, TX); Dr. Sulagna Mookherjee (Associate Professor, Cardiology Department, Albany Medical Center, Albany, NY); Dr. Aisha Awais Sarwar (Pharmacist, St. Peter's Hospital, Albany, NY); Dr. Alok Rustogi (Primary Care Physician, Potomac Falls, VA); Dr. Paul J. Davis (Co-Founder, NanoPharmaceuticals LLC, Rensselaer, NY); Tony Rossler (Caregiver, Scotia, NY); and Dr. Darrell Reisner (Ophthalmologist, Reston, VA).

Brief Biography

S. R. Bawa, MSc, PhD, is currently scientific advisor at Bawa Biotech LLC, a biotechnology and patent law firm founded in 2002 and based in Ashburn, Virginia. Previously, he was Founding Chairman and Professor of Biophysics at Panjab University, Chandigarh, India (1964–1992). At Panjab University, he also served as Dean of Foreign Students (1986–1988) and Coordinator of the Biotechnology Center (1986–1988). He was president of the Electron Microscopy Society of India (1986–1992), Secretary of the Indian Biophysical Society (1986–1988), and Founding Secretary of the Northern India Science Association (1966–1992). Dr. Bawa received his BSc (University Gold Medal), MSc (University Gold Medal), and PhD degrees in 1949, 1951, and 1954, respectively, from Panjab University. He was a Fulbright Fellow and Instructor (1958–1960) and a Boese Postdoctoral Research Fellow

(1959–1960), both at Columbia University. He was an Instructor (1961–1963) in the Department of Anatomy at Cornell University Medical College. In 1964, at the age of 34, he assumed the position of Founding Head and Reader of the newly established Biophysics Department at Panjab University, Chandigarh, India. He was promoted to Professor and Head in 1969. After retiring from Panjab University in 1992, Dr. Bawa joined the David Axelrod Institute of the New York State Department of Health in Albany, New York, from where he retired in 1999. Dr. Bawa has published over 150 scientific papers in peer-reviewed journals, books, and conference proceedings. His numerous accolades include Alexander von Humboldt Fellowship, Germany (five times); Fulbright Fellowship, US; US Alumni Research Travel Grant, US; Boese Postdoctoral Fellowship, Columbia University, US; British Council Invitee, UK; Diatome Award of the Electron Microscope Society of America; PL-480 Research Project and Appreciation Award, US Department of Agriculture; Kazato Research Award, Japan; and National Lectureship, India. He is an elected member or life member of various professional societies and organizations. He has served on various international scientific committees, advisory boards, government expert panels, and held visiting professorships in the US, Canada, and Europe. He has been a member of various peer-reviewed international journal editorial boards, including *Ultramicroscopy* (1986–1995, Elsevier), *Andrologia* (1993–1995, Blackwell/Wiley), *Acta Anatomica* (1974–1977, Karger), *Journal of Ultrastructure Research* (1969–1985, Elsevier) and *Journal of Submicroscopic Cytology* (1970–1977, Università di Bologna). Since 2004, the *Dr. S. R. Bawa Merit Scholarship* is awarded by Panjab University to a student standing first in the BSc (Honors School) class in biophysics. In 2022, Panjab University presented Dr. Bawa the *Distinguished Alumnus Award*.

Graduate Students' Thesis Advisor

Below is the list of graduate students for the PhD and MSc (Honors School) degrees whom I supervised at Panjab University, Chandigarh, from 1970 to 1993.

Candidate	Thesis Title	Year Degree Awarded
R. Kaur	Spermiogenesis and molecular characterization of spermatozoon plasma membrane	1993
H. K. Bains	Regional heterogeneity of the sperm plasma membrane—a biophysical study	1992
S. Bahl	Human spermatozoa: Ultrastructural and magnetic resonance studies	1987
R. Kaul	Ultrastructure study of cardiac muscle of lizard, parrot and squirrel	1986
R. Darbari	Adriamycin treated rat myocardium—light and electron microscope study	1985

Candidate	Thesis Title	Year Degree Awarded
R. Kaur	Surface topography of ejaculate spermatozoon of buffalo and maturing spermatozoa of goat—an electron microscope and spin-label study	1984
I. Singh	Autonomic innervation of the female rat genital tract in relation to hormonal status and pregnancy—light and electron microscopic studies	1983
R. Malhotra	Light and electron microscopic studies of gossypol acetic acid treated rat testis and buffalo bull spermatozoa	1983
S. C. Kapur	Physiochemical and biochemical mechanisms involved in cadmium-induced renal hypertension in rats	1982
R. Kachroo	Effect of gossypol on lactic dehydrogenase *in vivo*	1982
M. S. Jabbal	Effect of electromagnetic radiations (55MHz) on human spermatozoa and seminal variations	1979
N. C. Bissonauth	Pituitary-testicular studies in the Indian palm squirrel, *Funambulus pennantii*: seasonal plasma	1979
P. P. Bidwai	Light and electron microscopic studies of the testes and associated sex glands of the Indian hedgehog, *Paraechinus micropus*	1977
P. Prakash	Biochemical and histological studies on developing cerebellum of rat stressed by maternal protein-calorie malnutrition	1977
S. Hussanmal	Changes in the epididymis of rat after vasectomy	1977
Rajinder Kaur	Effect of maternal protein calorie malnutrition of the young rat	1977
D. K. Dhawan	Immunological and biochemical studies on fractionated bull spermatozoa	1977
P. Sharma	Cytomorphological and biochemical studies of the Leydig cells in the seasonally breeding palm squirrel, *Funambulus pennantii* Wroughton	1976
R. K. Rai	Cerebellar synapses and neurotransmitter in the protein-malnourished rats	1976
S. K. Sharma	Cerebellar cortex myelinogenesis in the malnourished rat	1976
Ranjana Deo	Hyperthermia and impaired male fertility in rats	1975
A. K. Attri	Quantitative enumeration of spermatogenesis in male ground squirrel, *Funambulus pennantii*	1975
P. Bahl	Seasonal fluctuations in testicular interstitial tissue in the Indian palm squirrel, *Funambulus pennantii*	1975
G. S. Gupta	Physiochemical studies on normal and irradiated mammalian testes	1974

Candidate	Thesis Title	Year Degree Awarded
P. Gill	Testicular and epididymal study of male ground squirrel *Funambulus pennantii*	1974
N. K. Relan	Experimental studies on pineal, pituitary, testis and adrenal of the chicken	1974
B. Mittal	Experimental studies on chicken brain with special reference to the optic tectum	1974
Adarsh Pratibha	Biophysical studies on hedgehog and snake spleen	1971
R. Pannu	Visual apparatus of the common hornet, *Polistes hebreus Fab*	1971
S. Singh	Biophysics of hearing: Architectonics of hedgehog cochlea	1971
R. K. Sandhu	Histophysiology of the ovary and uterus of hedgehog, *Hemiechinus auritis collaris*	1970
R. C. YashRoy	Visual mechanism, cytochemical architecture and radiation effects of bird retina and pecten	1970
A. Moza	Mammalian olfactory bulb: Experimental studies	1970
C. M. Pathak	Normal and dark adapted reptilian retina—histochemical and biochemical analysis	1970
C. P. Puri	Pituitary-testicular interaction in the rose-ringed parakeet, *Psittacula Krameri scopoli*	1970
R. K. Marwaha	Studies on the testis and associated glands of the honey bee, *Apis indica*	1970
Neelam Mahajan	Comparative studies on the mammalian retina	1970

Principal Scientific Publications

Nath, V., S. R. Bawa, R. K. Bhardwaj, and B. L. Gupta. (1951). Sperm formation in certain Coleoptera with particular reference to chromosome number, acrosome and mitochondrial nebenkern. *Research Bulletin of the East Panjab University* **16**:39–50.

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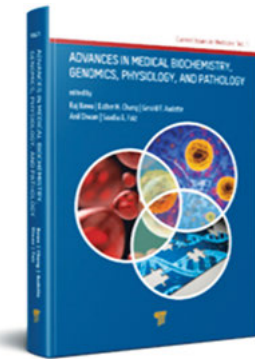
978-981-4877-44-2 (Hardcover), 978-1-003-18044-9 (eBook)
696 pages



The pace and sophistication of advances in medicine in the past two decades have necessitated a growing need for a comprehensive reference that highlights current issues in medicine. Each volume in the Current Issues in Medicine series is a stand-alone text that provides a broad survey of various critical topics—all accomplished in a user-friendly yet interconnected format. The series not only highlights current advances but also explores related topics such as translational medicine, regulatory science, neglected diseases, global pandemics, patent law, immunotoxicology, theranostics, big data, artificial intelligence, novel imaging tools, combination drug products, and novel therapies. While bridging the gap between basic research and clinical medicine, this series provides a thorough understanding of medicine's potential to address health problems from both the patient's and the provider's perspectives in a healthcare setting. The range of topics covered, and the expertise of the contributing authors accurately reflect the rapidly evolving areas within medicine—from basic medical sciences to clinical specialties.

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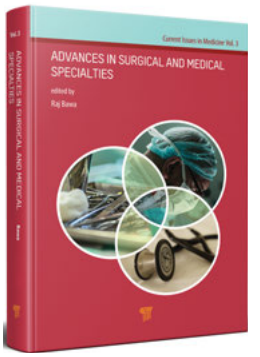

The pace and sophistication of advances in medicine in the past two decades have been truly breathtaking. This has necessitated a growing need for comprehensive references that highlight current issues in specific sectors of medicine. Keeping this in mind, each volume in the *Current Issues in Medicine* series is a stand-alone text that provides a broad survey of various critical topics in a focused area of medicine—all accomplished in a user-friendly yet interconnected format. However, unlike other series on medicine or medical texts, this series focuses on current trends, perspectives, and issues in medicine that are central to healthcare delivery in the 21st century. Medical practitioners today continue to improve upon techniques and technologies to provide procedures for patients that are safer, faster, less invasive, and more accurate—a direct consequence of advances in technological breakthroughs from a variety of medical and engineering fields. In order to render modern patient care, it is imperative that surgeons and medical practitioners stay current with these latest advances in their respective specialties. Given this backdrop, the specific topics covered in this volume and the expertise of the contributing authors accurately reflect the rapidly evolving areas within surgical and medical specialties. While recognizing how expansive and multifaceted medicine is, *Advances in Surgical and Medical Specialties* addresses crucial recent advances in surgical and medical specialties, integrating the knowledge and experience of experts from academia and practicing surgeons. The multidisciplinary approach reflected here makes this volume a valuable reference resource for medical practitioners, medical students, nurses, fellows, residents, undergraduate and graduate students, educators, venture capitalists, policymakers, and biomedical researchers. A wide audience will benefit from having this volume on their bookshelf: health care systems, the pharmaceutical industry, academia, and government.

Handbook of Clinical Nanomedicine – Volume 1

Nanoparticles, Imaging, Therapy, and Clinical Applications

Raj Bawa, PhD, MD, Gerald F. Audette, PhD, and Israel Rubinstein, MD (Editors)

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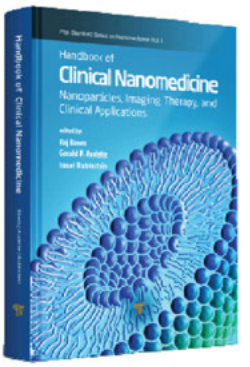

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Handbook of Clinical Nanomedicine – Volume 2

Law, Business, Regulation, Safety, and Risk

Raj Bawa, PhD, MD, (Editor), Gerald F. Audette, PhD, and Brian E. Reese, PhD, MBA, JD (Assistant Editors)

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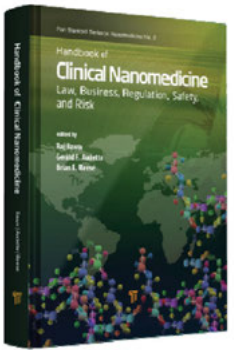

This unique handbook (60 chapters) examines the entire "product life cycle," from the creation of nanomedical products to their final market introduction. While focusing on critical issues relevant to nanoproduct development and translational activities, it tackles topics such as regulatory science, patent law, FDA law, ethics, personalized medicine, risk analysis, toxicology, nano-characterization and commercialization activities. A separate section provides fascinating perspectives and editorials from leading experts in this complex interdisciplinary field.

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Immune Aspects of Biopharmaceuticals and Nanomedicines

Raj Bawa, PhD, MD, János Szebeni, MD, PhD, DSc, Thomas J. Webster, MS, PhD, and Gerald F. Audette, PhD (Editors)

978-981-4774-52-9 (Hardcover), 978-0-203-73153-6 (eBook)
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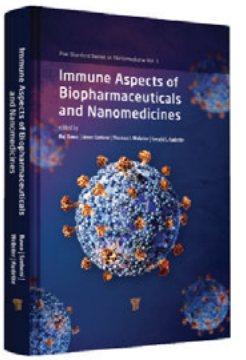

The enormous advances in the immunologic aspects of biotherapeutics and nanomedicines in the past two decades has necessitated an authoritative and comprehensive reference source that can be relied upon by immunologists, biomedical researchers, clinicians, pharmaceutical companies, regulators, venture capitalists, and policy makers alike. This text provides a thorough understanding of immunology, therapeutic potential, clinical applications, adverse reactions, and approaches to overcoming immunotoxicity of biotherapeutics and nanomedicines. It also tackles critical, yet often overlooked topics such as immune aspects of nano-bio interactions, current FDA regulatory guidances, complement activation-related pseudoallergy (CARPA), advances in nanovaccines, and immunogenicity testing of protein therapeutics.

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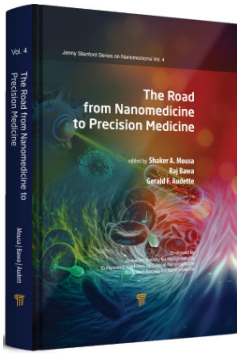
The Road from Nanomedicine to Precision Medicine



Shaker A. Mousa, PhD, MBA, Raj Bawa, PhD, MD, and Gerald F. Audette, PhD (Editors)

978-981-4800-59-4 (Hardcover), 978-0-429-29501-0 (eBook)
1208 pages

The enormous advances in nanomedicine and precision medicine in the past two decades has necessitated a growing need for an authoritative and comprehensive reference source that can be relied upon by biomedical researchers, clinicians, pharmaceutical scientists, regulators, and lawyers alike. This stand-alone, full-color book provides a broad survey of various interconnected topics, all accomplished in a user-friendly format. Each chapter contains key words, tables, and figures in color, future projections, and an extensive list of references. It is intended to be a standalone reference volume that broadly surveys and highlights innovative technologies and advances pertaining to nanomedicine and precision medicine. In addition, it also addresses often-neglected yet key issues such as translational medicine, intellectual property law, FDA regulatory issues, nanomedicine nomenclature, and artificial nanomachines—all accomplished in a user-friendly, broad yet interconnected format. The book is essential reading for the novice and expert alike in diverse fields such as medicine, law, genomics, pharmaceutical sciences, biomedical sciences, ethics, and regulatory science. The book's multidisciplinary approach will attract a global audience. It will serve as a valuable reference resource for the industry, academia, and government.

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Medical care is the most critical issue of our time and will be so for the foreseeable future. In this regard, the pace and sophistication of advances in medicine in the past two decades have been truly breathtaking. This has necessitated a growing need for comprehensive reference resources that highlight current issues in specific sectors of medicine. Keeping this in mind, each volume in the *Current Issues in Medicine* series is a stand-alone text that provides a broad survey of various important topics in a focused area of medicine—all accomplished in a user-friendly yet interconnected format. This volume addresses advances in medical imaging, detection, and diagnostic technologies. Technological innovations in these sectors of medicine continue to provide for safer, more accurate, and faster diagnosis for patients. This translates into superior prognosis and better patient compliance, while reducing morbidity and mortality. Hence, it is imperative that practitioners stay current with these latest advances to provide the best care for nursing and clinical practices. While recognizing how expansive and multifaceted these areas of medicine are, *Advances in Medical Imaging, Detection, and Diagnosis* addresses crucial recent progress, integrating the knowledge and experience of experts from academia and the clinic. The multidisciplinary approach reflected makes this volume a valuable reference resource for medical practitioners, medical students, nurses, fellows, residents, undergraduate and graduate students, educators, venture capitalists, policymakers, and biomedical researchers. A wide audience will benefit from having this volume on their bookshelf: health care systems, the pharmaceutical industry, academia, and government.

About the Series Editor

Raj Bawa, PhD, MD, is president of Bawa Biotech LLC (founded 2002), a biotech/pharma consultancy and patent law firm based in Ashburn, Virginia. Trained as a microbiologist and biochemist, he is an inventor, author, entrepreneur, professor, and registered patent agent licensed to practice before the US Patent & Trademark Office. He is currently scientific advisor to Teva Pharmaceutical Industries, Israel; visiting research scholar at Pharmaceutical Research Institute of Albany Pharmacy, Albany, New York; and full professor (adjunct) at NOVA in Annandale, Virginia. He is VP/chief IP officer at Guanine, Inc., in Rensselaer, New York, a company focused on rapid, accurate detection of infectious pathogens. Dr. Bawa has served as a principal investigator of various NCI research grants, and most recently as a principal investigator of a CDC grant to develop an assay for *Klebsiella pneumoniae* carbapenemase (KPC)-producing bacteria. Previously, he was an adjunct professor at Rensselaer Polytechnic Institute, Troy, New York, from 1998 to 2018. He held various positions at the US Patent Office, including primary examiner from 1996 to 2002. He earned a BSc (Honors School) in microbiology, MS in cancer biology, PhD in biophysics/biochemistry, and MD. Currently, he is a life member of Sigma Xi, cochair of the nanotech and precision medicine committees of the American Bar Association and founding director of the American Society for Nanomedicine (established 2008). He has authored over 100 publications, edited 10 texts, and serves on the editorial boards of numerous peer-reviewed journals, including serving as an associate editor of *Nanomedicine* (Elsevier).

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ISBN 978-981-4877-46-6
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