Authors

Steven Bradley Lowen received the B.S. degree in electrical engineering from Yale University in 1984, *Magna cum Laude* and with distinction in the major. He was elected to Tau Beta Pi that same year. Following two years with the Hewlett–Packard Company he entered Columbia University, from which he received the M.S. and Ph.D. degrees in 1988 and 1992, respectively, both in electrical engineering. Lowen was awarded the Columbia University Armstrong Memorial Prize in 1988 and in 1990 he was the recipient of a Joint Services Electronics Program Fellowship in the Columbia Radiation Laboratory.

He began his research career by examining fractal patterns in the sequences of action potentials traveling along auditory nerve fibers. Recognizing that efforts to understand these fractal processes were hampered by the lack of a solid theoretical framework, he set out to develop the relevant mathematical models. This effort led to the development of alternating fractal renewal processes and fractal shot noise, as well as point-process versions thereof. In connection with this effort he also investigated fractal renewal point processes and several other fractal-based processes. This body of work served as the foundation for his Ph.D. thesis, entitled *Fractal Point Processes* (Lowen, 1992), as well as the basis of a number of journal articles and the core of several chapters in this book.

After receiving the Ph.D. degree, Dr. Lowen continued his research at Columbia as an Associate Research Scientist. He then joined Boston University as a Senior Research Associate in the Department of Electrical and Computer Engineering in 1996. He was elected to Sigma Xi in 1994.

With a collection of models for fractal-based point processes in hand, Lowen focused on establishing appropriate methods for their analysis and synthesis. This work quantified the performance of fractal estimators for point processes and highlighted the practical realities of generating realizations for these processes. He also studied the interaction between dead time (refractoriness) and fractal behavior in point processes.

Concurrently, working with various collaborators, he returned to examining applications for point processes with fractal characteristics by adapting the mathematical framework he developed to a number of biomedical point processes. He demonstrated that suitably modified fractal-based point processes serve to properly characterize action-potential sequences on auditory nerve fibers. He then turned his attention to signaling in the visual system by identifying fractal models that could describe the neural firing patterns of individual cells in this system, as well as collections of such cells, and detailing how the fractal patterns affect information transmission in this network. Using a similar approach, he also examined human heartbeat patterns and investigated how different measures of these fractal data sets could serve as markers of the cardiovascular health of the subject. Finally, he explored neurotransmitter secretion at the neuromuscular junction, and developed a suitable model showing that it, too, exhibits fractal characteristics.

Dr. Lowen also applied his fractal models to physical phenomena. These included charge transport in amorphous semiconductors and noise in infrared CCD cameras; he developed multidimensional versions of his fractal-based point processes for the latter. He also devoted substantial efforts to the modeling, synthesis, and analysis of computer network traffic.

In 1999 Dr. Lowen joined McLean Hospital and the Harvard Medical School, where he is currently Assistant Professor of Psychiatry. He has brought his fractal expertise to bear on attention-deficit and hyperactivity disorder, and the analysis of data collected with functional magnetic resonance imaging (fMRI). He is currently investigating fractal and other aspects of these applications, as well as carrying out research on drug abuse.

Dr. Lowen has authored or co-authored some 30 refereed journal articles as well as a collection of book chapters and proceedings papers. He holds a number of patents, and serves as a reviewer for several technical journals and funding agencies. Over the course of his career, he has supervised three graduate students.

Malvin Carl Teich received the S.B. degree in physics from MIT in 1961, the M.S. degree in electrical engineering from Stanford University in 1962, and the Ph.D. degree from Cornell University in 1966. His bachelor's thesis comprised a determination of the total neutron cross-section of palladium metal while his doctoral dissertation reported the first observation of the two-photon photoelectric effect in metallic sodium. His first professional affiliation was with MIT's Lincoln Laboratory in Lexington, Massachusetts, where he demonstrated that heterodyne detection could be achieved in the middle-infrared region of the electromagnetic spectrum.

Teich joined the faculty at Columbia University in 1967, where he served as a member of the Electrical Engineering Department (as Chairman from 1978 to 1980), the Applied Physics Department, the Columbia Radiation Laboratory, and the Fowler Memorial Laboratory for Auditory Biophysics. Extending his work on heterodyning, he recognized that the interaction could be understood in terms of the absorption of individual polychromatic photons, and demonstrated the possibility of implementing the process in a multiphoton configuration. He developed the concept of nonlinear heterodyne detection — useful for canceling phase or frequency noise in an optical system.

During his tenure at Columbia, he also carried out extensive work in point processes, with particular application to photon statistics, the generation of squeezed light, and noise in fiber-optic amplifiers and avalanche photodiodes. Among his achievements is a description of luminescence light in terms of a photon cluster point process. This perspective led him to suggest that detector dead time could be used advantageously to reduce the variability of this process and thereby luminescence noise. This approach was incorporated in the design of the star-scanner guidance system for the Galileo spacecraft, which was subjected to high radio- and beta-luminescence background noise as a result of bombardment by copious Jovian gamma- and beta-ray emissions. In the domain of quantum optics he developed the concept of pump-fluctuation control in which the variability of a pump point process comprising a beam of electrons is reduced by making use of self-excitation in the form of Coulomb repulsion. Using a space-charge-limited version of the Franck–Hertz experiment in mercury vapor he demonstrated the validity of this concept by generating the first source of unconditionally sub-Poisson light. His work on fiber-optic amplifiers led to an understanding of the properties of the photon point process that emerges from the laser amplifier and thereby of the performance characteristics of these devices.

Teich's interest in point processes in the neurosciences was fostered by a chance encounter in 1974 with William J. McGill, then Professor of Psychology and President of Columbia University. This, in turn, led to a long-standing collaboration with Shyam M. Khanna, Director of the Fowler Memorial Laboratory for Auditory Biophysics and Professor in the Department of Otolaryngology at the Columbia College of Physicians & Surgeons. Together, Teich and Khanna carried out animal experi-

ments over many years in which spike trains in the peripheral auditory system were recorded. Analysis of these data led to the discovery that, without exception, action-potential sequences in the auditory system exhibited fractal features. Teich and his students, including Lowen, developed suitable point-process models to accommodate these data and to offer a fresh mathematical perspective of sensory neural coding. In a collaboration with researchers at the Karolinska Institute in Stockholm, they also conducted heterodyne velocity measurements of the vibratory motion of individual sensory cells in the cochlea, discovering that these cells can vibrate spontaneously, even in the absence of a stimulus.

In 1995 Teich was appointed Professor Emeritus of Engineering Science and Applied Physics at Columbia. He joined Boston University, where he is currently teaching and pursuing his research interests as a faculty member with joint appointments in the Departments of Electrical and Computer Engineering, Physics, Cognitive and Neural Systems, and Biomedical Engineering. He is Co-Director of the Quantum Imaging Laboratory and a Member of the Photonics Center, the Hearing Research Center, the Program in Neuroscience, and the Center for Adaptive Systems. He also serves as a consultant to government and private industry.

His current efforts in the domain of quantum optics are directed toward developing imaging systems that make use of entangled photon pairs generated in the nonlinear optical process of parametric down-conversion. His work in fractals and wavelets is directed toward understanding biological phenomena such as the statistical properties of neurotransmitter exocytosis at the synapse, action-potential patterns in auditory- and visual-system neurons, and heart-rate-variability analysis of patients who suffer from cardiovascular-system dysfunction.

Teich is a Fellow of the Acoustical Society of America, the American Association for the Advancement of Science, the American Physical Society, the Institute of Electrical and Electronics Engineers, and the Optical Society of America. He is a member of Sigma Xi and Tau Beta Pi. In 1969 he received the IEEE Browder J. Thompson Memorial Prize for his paper "Infrared Heterodyne Detection." He was awarded a Guggenheim Fellowship in 1973. In 1992 he was honored with the Memorial Gold Medal of Palacký University in the Czech Republic, and in 1997 he received the IEEE Morris E. Leeds Award.

He has authored or coauthored some 300 journal articles and holds a number of patents. He is the coauthor, with Bahaa Saleh, of *Fundamentals of Photonics* (Wiley, 1991).

Among his professional activities, he served as a member of the Editorial Advisory Panel for the journal *Optics Letters* from 1977 to 1979, as a Member of the Editorial Board of the *Journal of Visual Communication and Image Representation* from 1989 to 1992, and as Deputy Editor of *Quantum Optics* from 1988 to 1994. He is currently a Member of the Editorial Board of the journal *Jemná Mechanika a Optika* and a Distinguished Lecturer of the IEEE *Engineering in Medicine and Biology Society*.