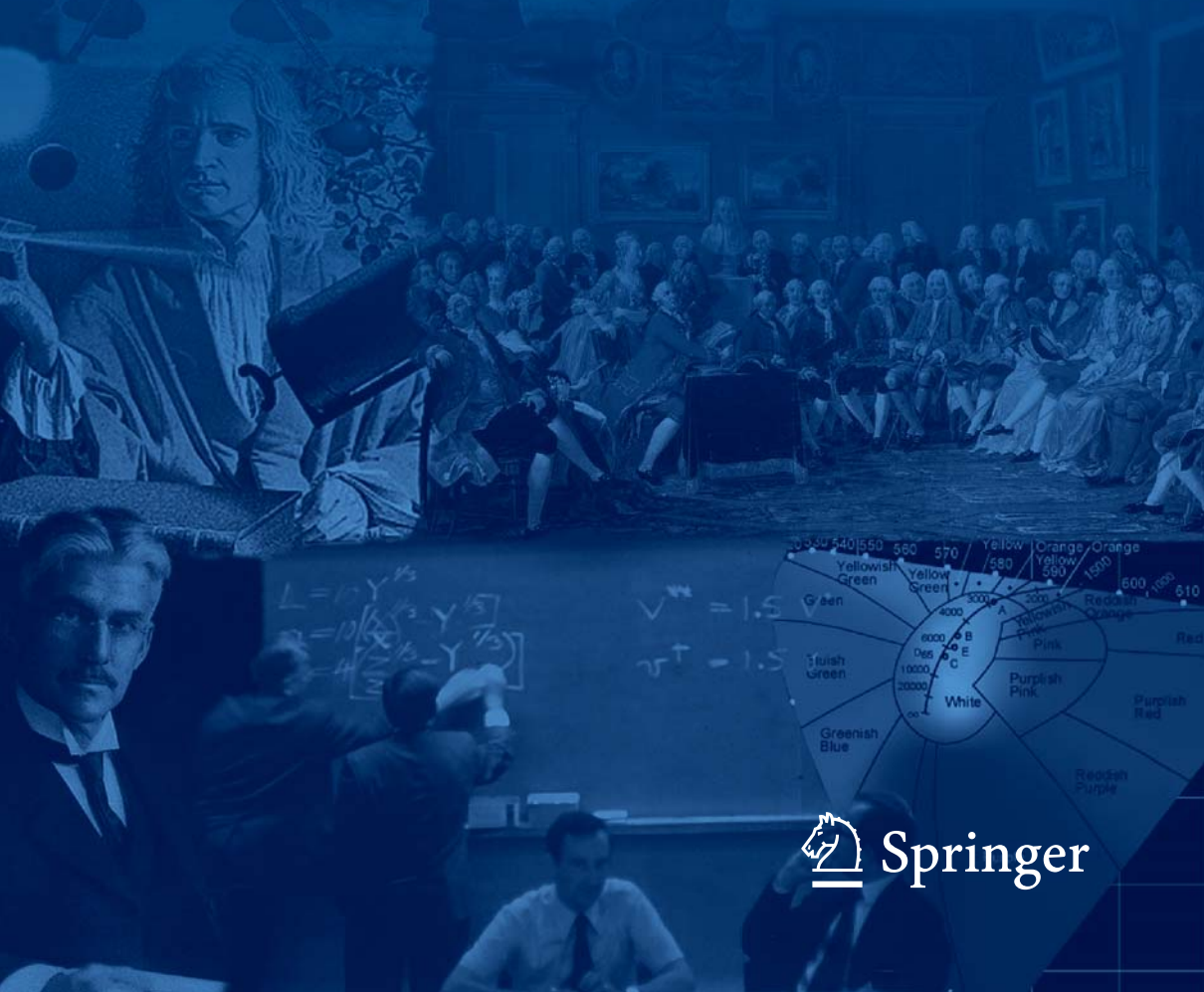
Renzo Shamey
Rolf G. Kuehni

Pioneers of Color Science



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◄ Cover Page Collage

The cover collage (by R. Shamey) depicts historical progress in the general domain of science including some of the important pioneers in the field of color science. The majority of images are available in the public domain. A brief description of the images from top left to bottom right is given below.

Top Row

1. The famous "School of Athens" by Raphael, painted between 1510–1511 CE, depicting all of the major philosophers of antiquity with Plato and Aristotle at the center (Vatican Museums, Rome).
2. Abd al-Rahman III and his court receiving the ambassador in Medina Alzahara, by Dionisio Baixeras Verdaguer (1862–1943)—University of Barcelona Virtual Museum.
3. Dar Al-Hikmah, The Museum of Science and Technology in Islam, Istanbul. Picture from Nikos Niotis.
4. The color order system according to Nasir al-din Tusi (1201–1274), Persian scientist.
5. Portrait of Ibn Sina (Avicenna) circa 980–1037, Persian polymath.

Middle Row

1. Galileo Galilei showing the Doge of Venice how to use the telescope, by Giuseppe Bertini (1825–1898).
2. Landscape with clerks studying astronomy and geometry, showing an armillary sphere, square, compasses, etc., La Vraye Histoire du Bon Roy Alixandre (The Alexander Romance in Old French prose) by Pseudo-Callisthenes, early fifteenth century.
3. Portrait of Sir Isaac Newton (1643–1727), English polymath, by Jean-Leon Huens (1921–1984).
4. Reading of Voltaire's L'Orphelin de la Chine (a tragedy about Ghengis Khan and his sons, published in 1755), in the salon of Madame Geoffrin (Malmaison, 1812), by Anicet Charles Gabriel Lemonnier (1743–1824).

Bottom Row

1. Portrait of Thomas Young (1773–1829), English physicist, From Life of Thomas Young (1855), George Peacock—frontispiece.
2. Michel-Eugène Chevreul (1786–1889), French chemist, taken in 1889.
3. James Clerk Maxwell (1831–1879), Scottish physicist. Circa 1875, Photograph by Stefano Bianchetti/Corbis Historical (1900).
4. Hermann Ludwig von Helmholtz (1821–1894), German physiologist.
5. Karl Ewald Konstantin Hering (1834–1918), German physiologist.
6. Albert Henry Munsell (1858–1918), American artist.
7. Photograph of a CIE Meeting (from left to right: Ernst Ganz, David MacAdam, Alan Robertson, Gunter Wyszecki), by Fred Billmeyer.
8. CIE chromaticity diagram.

Nanos gigantum humeris insidentes

Dedicated to my son Sean Araz Luca Shamey

Preface

Color plays an important role in our daily lives. Among our sensory qualities, color has historically attracted the greatest level of interest. The idea behind this book was conceived several years ago based on experiences gained from teaching color science and technology to undergraduate and graduate students. In the course of teaching, it was increasingly felt important to provide students with an opportunity to relate to the individuals behind discoveries. Thus, whenever a discovery or invention was mentioned, a brief description of the achievements together with a depiction (whenever possible) of the individual(s) was shown to introduce the scientist and signify their contribution in the field. The idea to generate a list of pioneers in the field was thus formed. Through conversations and consultations with colleagues, an initial list was created. A survey was then placed on social media sites to collect opinions from those interested in the domain, and a "final" list was generated.

In the meantime, the authors were placed in charge of the "People" section of the *Encyclopedia of Color Science and Technology* (Luo, 2016). There seemed to be a strong synergy between the two activities, and it became evident that many of the pioneers selected for the book could also be included in the reference encyclopedia. A number of expert individuals were invited to contribute manuscripts to the encyclopedia. When appropriate, the authors were asked for permission to incorporate their modified manuscripts in this book. These contributions enriched the book and enhanced the quality of this project. This work provided the authors with an opportunity to (re)discover some facts and interesting information about many of the pioneers listed which are now shared with the reader. The lives and works of pioneers generally reflect the ambition of man to discover unknowns and address the challenges associated with visual perception in general and color specifically. As might be expected, the journey included controversies and heated debates.

The book contains a brief description of lives and scientific discoveries of 93 pioneers in the field of color science. It is arranged in five parts according to the following plan.

Part I covers ancient Greece which in the Western World was the source of thinking about color. Essays include discussions and views from Plato, Aristotle, and Ptolemy.

Part II involves scientific contributions in the field during the Islamic Golden Age which extended from Spain to the Far East through Persia. Major discoveries included advances in optics, vision, and categorization of color by scientists such as Alhazen, al-Tusi, Avicenna, al-Farisi, among others.

Part III is a short essay on discussions pertaining to color in the Middle Ages leading to the Renaissance. Only two notable individuals, Bacon and Dietrich von Freiberg, are recorded to have made significant contributions to this domain over the period.

Part IV covers a significant period of advancement in science including color formation and visual perception, a time period from about the sixteenth to the eighteenth centuries which provided a significant range of discoveries encompassing many domains that may fall under the general umbrella of color science. In "The age of enlightenment," many scientists laid the foundations for important discoveries in the nineteenth and twentieth centuries. This chapter addresses the works of nineteen pioneers including Newton, Goethe, Young, and Chevreul.

Part V is the largest section of the book and covers the most recent discoveries and contributions from pioneers born after 1800 and includes over 60 essays. Among them are Nobel laureates, renowned vision scientists including Helmholtz and Hering, and many other notable color pioneers such as Munsell and Land.

With respect to the academic disciplines and the fields of activity, the majority of pioneers were physicists or psychologists, but the group also includes chemists, mathematicians, optical engineers, physiologists, entrepreneurs, and a few artists, demonstrating the truly multi-disciplinary nature of activity in the field.

We have strived to incorporate, in this first edition, the most notable individuals from as many different disciplines as possible. Without a doubt, the story of lives and labors of the pioneers is one of inspirations. Their trials and tribulations is a reflection of humanity's desire to comprehend the world. The story of color is largely the story of humans, and it will continue to inspire, awe, and fascinate us. We found this journey captivating and hope the reader will find it of interest.

Raleigh, USA

Renzo Shamey
Rolf G. Kuehni

Acknowledging Contributions

This book includes several modified articles that were included in the first edition of the *Encyclopedia of Color Science and Technology* as well as a few articles which are planned to appear in the second edition of the encyclopedia. We have listed contributions from authors or co-authors of these articles in the following section. It has been an honor and a privilege to collaborate with these colleagues who dedicated time to contribute articles to the encyclopedia and graciously agreed to have them incorporated in this book. The biographies in the following section are shown in an alphabetical order.

In addition to those listed below, two other colleagues helped with the preparation of the material, who are duly acknowledged. Hugh Fairman assisted Michael Brill in writing the article for Hugh Davidson, and David Briggs assisted Stephen Westland in the preparation of the entry for Johannes Itten. A brief summary of their biographies is given below.

Hugh S. Fairman is a 1958 graduate of Princeton University, majoring in analytical chemistry. Currently, he is engaged in the development of third-party software for spectrophotometric analysis and computer color matching. He is a past President (1990–1992) of the Inter-Society Color Council and an active member of ASTM International Committee E-12 on Appearance.

David J.C. Briggs obtained a Ph.D. in Science at the University of Queensland in 1990. He has been teaching drawing and color theory at Sydney's Julian Ashton Art School since 1996 and has been a lecturer and instructor at the National Art School, Sydney, since 2009. Since April 2015, he has been Chairperson of the New South Wales Division of the Colour Society of Australia.

Finally, we are also grateful to Robert Hirschler for providing several photographs, from his personal collection, of some of the Pioneers who appear in this book.

Seyed Hossein Amirshahi was born in Qazvin, Iran, on June 22, 1957. He received a Bachelor of Science degree in Textile Engineering from Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran, in 1983, and a Master of Science in Textile Engineering from the same university, in 1987. He was awarded a Ph.D. in 1994, from the University of New South Wales, Sydney, Australia.

In 1987, he joined the Department of Textile Engineering of Isfahan University of Technology, Isfahan, Iran, as a lecturer and was promoted to assistant professor (1995) and associate professor (1999). Since September 2001, he has been with the Department of Textile Engineering, Amirkabir University of Technology (Tehran Polytechnic), where he became a professor of color science in 2006. His current research interests include computational color science, spectral and colorimetric data processing, analysis of near to one-dimensional colorimetric data (such as blacks and whites), and metamerism. He has supervised several masters and Ph.D. students in the field of color science and taught graduate courses in this area. He was an invited guest professor at Gjovik University College, Norway. He is the co-author of the following articles:

- Al-Tusi, Nasir al-Din
- Al- Farisi, Kamal al-Din
- Inb Sina
- Ibn Sahl

Michael Henry Brill is the Director of Research at Datacolor in Lawrenceville, NJ, where he has been Principal Color Scientist since 2003. He was born in Bay Shore, NY, on January 26, 1949, graduated from Case Western Reserve University in June 1969, and was granted an MS and a Ph.D. in physics in Syracuse University in January 1971 and June 1976, respectively. Via research positions at M.I.T., Jaycor, Science Applications International Corporation, Sarnoff Corporation, and (most recently) Datacolor, he has carried out extensive theoretical research in color in human and computer vision, in geometric/photometric invariance, in underwater acoustics, and in physics-based vision. He is co-inventor of the Emmy-Award-Winning

Sarnoff vision model. Dr. Brill is also a Past President of the Inter-Society Color Council, and author of more than 80 refereed technical publications, 16 US patents, numerous national standards, and a SID test pattern. He has acted as a referee for more than 40 technical journals. He chaired or co-chaired six conferences on color technology, vision, and digital display. In addition, he obtained the 1996 ISCC Macbeth Award for his work on color constancy, and the 2010 ISCC Nickerson Service Award. Dr. Brill is an associate editor of *Color Research and Application*, chairs ASTM Subcommittee E12.04 (Color and Appearance Analysis), and edits and writes for the *ISCC News* column, "Hue Angles."

Michael H. Brill is the author (or co-author) of the entries for the following Pioneers of Color Science:

- Hemmendinger, Henry
- Davidson, Hugh
- Kubelka, Paul
- Judd, Deane Brewster
- MacAdam, David
- McCamy, Calvin
- Schrödinger, Erwin
- Stanziola, Ralph

Ellen Campbell Carter is the editor of the journal Color Research and Application and a color science consultant. She received a B.A. in chemistry from Manhattanville College in Purchase, NY, and a Ph.D. in chemistry from Rensselaer Polytechnic Institute in Troy, NY. Her doctoral thesis, "The Application of Turbid Medium Theory to Metallic Paint Systems," was supervised by Prof. Fred W. Billmeyer, Jr. After graduation, she worked in industry and education. She was a Senior Color Scientist for the Sherwin-Williams Company and later Minolta (now Konica Minolta) Corporation. Currently, Dr. Carter is the Associate Director for Color in Division 1 (Vision and Color) of the International Commission on Illumination (CIE). She is also a member of ASTM International—currently serving as Vice-Chair of Committee E12 on Color and Appearance, the Inter-Society Color Council (ISCC)—where she served on the Board of Directors and as President, the Committee for Graphic Arts Technology Standards (CGATS), the Detroit Colour

Council (DCC), the Society for Imaging Science and Technology (IS&T), the Illuminating Engineering Society (IES), US National Committee of the CIE (CIE/USA), Sigma Xi: The Scientific Research Society, and a Senior member the Optical Society of America (OSA) and the American Association of Textile Chemists and Colorists (AATCC). She received the ISCC Nickerson Service Award in 2003 and the ASTM E-12 Fred W. Billmeyer, Jr. Award in 2009.

Ellen C. Carter is the author of the entries for the following Pioneers of Color Science:

- Billmeyer, Jr., Fred Wallace
- Saltzmann, Max

Mark D. Fairchild is a Professor and Associate Dean of Research and Graduate Education of RIT's College of Science and Director of the Program of Color Science and Munsell Color Science Laboratory. He received his B.S. and M.S. degrees in Imaging Science from RIT and Ph.D. in Vision Science from the University of Rochester. Mark was presented with the 1995 Bartleson Award by the Colour Group (Great Britain) and the 2002 Macbeth Award by the Inter-Society Color Council for his research work in color appearance and other areas of color science. He is author of over 300 technical publications and the book, Color Appearance Models, 3rd Ed., which serves as a reference to the fundamentals of color appearance and the formulation of specific models. He served as Color Imaging Editor for IS&T's Journal of Imaging Science and Technology for 3 years and was named a Fellow of IS&T (the Society for Imaging Science and Technology) in 2003 for his contributions to digital color imaging. In 2007, Mark was presented with the Davies Medal by the Royal Photographic Society for his contributions to photography in the digital field of imaging science. He received the 2008 IS&T Raymond C. Bowman award for excellence in education and was named a Fellow of the Optical Society of America in 2012 for his contributions to research and education in color and imaging sciences. He was chair of CIE Technical Committee 1–34 on color appearance models and is currently a member of several other CIE

technical committees dealing with color appearance and image technology issues. Mark is an active member of IS&T, ISCC, CORM, CIE-USNC, OSA, SID, AAAS, and ACM-SIGGRAPH.

Mark Fairchild is the author or co-author of the following entries:

- Fechner, Gustav
- Lippmann, Gabriel
- Stevens, Stanley
- von Kries, Johannes
- Lovibond, Joseph

Robert William Gainer Hunt was born at Sidcup, Kent, England, on July 28, 1923, and passed away on October 23, 2018, in Salisbury, England, before the completion of this project. He was awarded a B.Sc. (Bachelor of Science) with first-class honors, an ARCS (Associate of the Royal College of Science), in physics, 1940–1943, and a DIC (Diploma of Imperial College) in Technical Optics, 1946–47, all from the Imperial College of Science and Technology, University of London. He was also awarded a Ph.D. (Doctor of Philosophy), 1953, and a D.Sc. (Doctor of Science), 1968, from the University of London. He worked as an Experimental Officer at the Ministry of Supply on optical sighting devices for tanks, 1943–46. He was a research scientist at the Kodak Research Laboratories, Harrow, 1946–82, where he worked on factors affecting the quality of color images, and devices for making reflection prints from both negative and positive images on film; he was finally Assistant Director of Research. Since 1982, he worked as an independent color consultant and took a leading role in the development of color appearance models. He was a Visiting Professor of Physiological Optics at the City University, London, 1967–1998, a Visiting Professor of color science at the Colour & Imaging Institute at the University of Derby, England, 1994–2004, and a Visiting professor of color science at the Department of Colour Science at the University of Leeds, 2004–2009. He was Chairman of the Colour Group of Great Britain, 1961–63; Chairman of the Colorimetry Committee of the

Commission Internationale de l'Éclairage (CIE), 1975–83; and President of the International Colour Association (AIC), 1981–85. He had over a hundred papers on color vision, color reproduction, and color measurement, and two books "The Reproduction of Colour" which had six editions, and "Measuring Colour" with four editions co-authored with Michael Pointer. His research included modeling the human system of color vision to predict colors appearance in different viewing conditions, and applying color science to practical problems in industry and in the environment. He was an Honorary Fellow of the Royal Photographic Society, Fellow of the Royal Society of Arts, Fellow of the Royal Television Society, Honorary Fellow of the British Kinematograph, Sound and Television Society, Honorary Member of the Society for Imaging Science and Technology, and Honorary Fellow of the Society of Dyers and Colourists. He was a member of the Royal Institution and served as one of its Vice-Presidents, 1985–87. He was awarded the Newton Medal of the Colour Group (Great Britain), 1974, the Progress Medal of the Royal Photographic Society, 1984, the Judd-AIC Medal of the International Colour Association, 1987, the Gold Medal of the Institute of Printing, 1989, the Johann Gutenberg Prize of the Society for Information Display, 2002, the Godlove Award of the Inter-Society Color Council (USA), 2007, and Honorary Fellowship of the Society of Dyers and Colourists, 2009. For services to the field of color science and to young people through Crusaders bible classes, he was presented by the Queen of Britain with the medal of an Officer of the British Empire (OBE) in 2009.

Robert Hunt was the author (or co-author) of the following entries:

- Bartleson, James
- Crawford, Brian Hewson
- Guild, John
- Stiles, Walter Stanley
- Wright, W. David

Eric Jacob Jan Kirchner was born on June 26, 1966. He received an M.Sc in Theoretical Physics from the University of Utrecht, the Netherlands. He was awarded a Ph.D. in 1993 in Theoretical Chemistry, at the Free University of Amsterdam. His Ph.D. thesis was focused on quantum mechanical calculations in chemistry. He worked as a researcher at the environmental state agency of the Netherlands until 1996, before starting to work as a quantum chemist at Akzo Nobel.

Since 2000, he has worked in the area of colorimetry, initially as research physicist for the Car Refinishes business unit. He became project leader and team leader of color innovation and is currently Principal Color Scientist for Performance Coatings where he investigated texture measurement and appearance. He has published several articles on the methodology for developing color difference equations, the best type of gray scales for such analysis, and the optimum design of the visual tests underlying those studies.

His current research interests include accurate representation of colors on electronic displays and their color calibration, and the history of color science in the Islamic world. Besides authoring dozens of scientific articles, he is also co-inventor in eight patent applications, and sole developer of five android apps related to color.

Eric Kirchner is the author (or co-author) of the following entries:

- Al-Biruni, Abu Rayhan
- Al-Farisi, Kamal al-Din
- Ibn al-Haytham
- Al-Tusi, Nasir al-Din
- Ibn Sina
- Ibn Sahl
- Ibn Rushd

Michal Vik is currently a Professor of Material Science at the Technical University of Liberec in Czech Republic and a research consultant for VUTS a.s.

His scientific activities are mainly in the areas of color science (color and appearance measurement, color difference formula development, quality control, development and design of instruments), textile material science (smart materials, advanced microscopy), and textile finishing (surface modification-plasma, photo-polymerization).

He has been a member of the Optical Society of America since 1999, board member of the Czech Society of Textile Chemists and Colorists (1994–2000), board member of ČNK CIE, Czech National Committee which is a national society of International Commission on Illumination, since 1999, a member of Division 1 of International Commission on Illumination (CIE) since 2003, and a member of CIE Technical Committees (TC1-55, TC1-63, TC1-72, TC2-61). Since 2010, he has been an expert member of the European Technology Platform—Textile.

Currently, he is the head of the Colorimetry Group of Czech Republic as well as leading the Color and Appearance Measurement Laboratory of the Department of Material Engineering of Technical University of Liberec. He is author or co-author of six books, five patents, about 20 scientific papers, as well as more than 150 scientific contributions on international conferences.

Michal Vik is the author or co-author of the following entries:

- Kubelka, Paul
- Purkinje, Jan Evangelista
- Mach, Ernst

Stephen Westland joined the University of Leeds in 2003 to take up a Chair in Color Science and Technology following academic posts at a School of Neuroscience (Keeled University) and a School of Engineering (Derby University). He was Head of School of Design (2006–2013) and Acting Dean of the Faculty for a semester in 2012.

He has published over 100 peer-reviewed papers, chapters, and books in the areas of color science, color imaging, and color design. In 2008, he was awarded a

Fellowship of the Society of Dyers and Colourists (SDC) and is currently the President of SDC. He was awarded the Royal Photographic Society's Davies Medal for work on color imaging.

He is also an Adjunct Senior Scientist at the Dental School of the University of Texas (USA). Since 2009, he has been a member of the International Advisory Board at the Colour and Imaging Institute at Tsinghua University (China). Since 1998, he has been a member of the International Editorial Board of the Journal of Coloration Technology and in 2006 helped to launch a new journal (as editor) Colour: Design and Creativity that was renamed in 2012 as the Journal of the International Colour Association. He is also a member of the editorial boards of Journal of Textile Science and Engineering (2011-) and the Slovene Journal for Textile Clothing Technology, Design and Marketing (2009-). He is the author of Computational Colour Science using MATLAB (published by Wiley in 2004) with a second edition published in 2012.

Stephen Westland is the author (or co-author) of the following entries:

- Rushton, William
- Dalton, John
- Itten, Johannes

Contents

About the Authors

Renzo Shamey was born in 1967 and completed his basic and higher education in multiple locations. After receiving a Bachelor of Engineering degree in Textile & Fiber Chemistry in 1989, and a short stint in the coloration industry he obtained a Master of Science and a Ph.D. from the Colour Chemistry Department of Leeds University in England. After working on an industrial project for about a year, he joined Heriot-Watt University in Scotland as a faculty member for six years where he conducted research on color science and technology including the development of diagnostic expert systems. He then joined North Carolina State University (NCSU) in 2003, where he eventually became a professor in 2012. In 2018, he was named the CIBA Professor. He directed the Polymer and Color Chemistry (B.S.) and Textile Chemistry (M.S.) programs at NCSU for about nine years and is currently the head of the Color Science and Imaging Laboratory. He was awarded a Fellowship of the Society of Dyers and Colourists in 2010, the AATCC, JW Weaver Award in 2011, and an honorary professorship from Tianjin University in China in 2012. He has authored over 100 peer-reviewed publications, including several chapters and two books. In 2017, he was elected President of the Inter-Society Color Council of America (ISCC). He served as Technical Committee Chair in AATCC (Color Measurement Test Methods; Textile Education), CIE (TC1-76, co-chair), and serves on the editorial board of multiple Journals including Color Research & Application, and Coloration Technology. He is the current Editor in

Chief of the Encyclopedia of Color Science and Technology.

He has authored (or co-authored) the following articles:

- Plato
- Ptolemy
- Biruni, Abu Rayhan
- Al-Farisi, Kamal al-Din
- Ibn al-Haytham
- Al-Tusi, Nasir al-Din
- Ibn Sina
- Descartes, Rene Du Perron
- Newton, Isaac
- Maxwell, James Clark
- Chevrerul, Michel-Eugene
- Young, Thomas
- Mach, Ernst
- Purkyně, Jan Evangelista,
- Rood, Ogden
- Abney, William
- Lovibond, Joseph
- Albers, Josef
- Birren, Faber
- Adams, Elliot
- Hardy, Arthur Cobb
- Helson, Harry
- Hunter, Richard
- Stiles, Walter Stanley
- Luckiesh, Mathew
- Macbeth, Norman
- Nayatani, Yoshinobu

Rolf G. Kuehni was born and basically educated in Switzerland. He earned a degree in textile chemistry at the Textilingenieurschule in Krefeld, Germany. Kuehni moved to the USA in 1963, where he eventually became a dual citizen. Being involved in color matching of textiles, he became interested in color technology. In 1965, he joined Verona Dyestuffs, owned by Bayer Corp., as Manager of Development and Color Physics and became a member of the Inter-Society Color Council in 1967. He advanced to Vice President, Marketing/Textile Products for Bayer Corp. in the USA, and also was a Vice President in the