Preface

Welcome to the study of the *photonics of life*. As you venture into this exciting field, you will discover many wonderful things.

Photonics is an all-encompassing light-based optical technology that is being hailed as one of the dominant technologies for this new millennium. Photonics utilizes photons instead of electrons to transmit, process, and store information and thus provides a tremendous gain in speed in information technology. *Biophotonics* is an extension of photonics dealing with the interaction between light and biological matter. In nature, one recognizes beautiful examples of biophotonics at work in basic principles of life such as harnessing photons in photosynthesis and conversion of photons in molecular structures.

Conversely, biology is also dealing with the endogenous production of *ultra-weak photon emission* (also indicated as *biophotons*) in and from cells, organs and organisms. This light emission is endogenously formed and characteristic for alive organisms. Its sources, interactions with biological matter, and its temporal/spatial emission are increasingly investigated with the use of highly sensitive photomultiplier tubes (PMT) and charge-coupled device (CCD) imaging systems.

The connection between endogenous photon emission and free radical reactions has been known by biologists and clinicians for many years. However, such interest has been amplified by recent discoveries of a.) the importance of free radical reactions in normal body chemistry as well as b.) novel developments in whole (human and animal) body photon counting and imaging technology.

Unfortunately, any expanding field attracts the charlatan (i.e., those who make money out of proposing that endogenous photon fields are effectively changed by their "therapeutic" methods and "will make you live forever" or, at least, will enhance your health). In evaluating these and other less obviously silly claims, it is useful to understand that the basics of ultra-weak biophoton emission need to be scientifically discussed.

Although several books and journals exist that cover selective aspects of biophotonics, there is a void that could provide a space for a unified synthesis of biophoton research. This book provides such an overview which is intended for multi-disciplinary readership that aids research integrating endogenous light and the shaping of biological systems. It focuses on historical biological background of the biophoton (field) concept and its

recent progress plus potential benefits to medicine. It encompasses the fundamentals of light, photonics, biophotons, and biology. In short, you'll begin a journey of discovery about how ultra-weak light makes life possible.

This book is aimed to lead the reader as painlessly as possible into an understanding of what biophotons are, how they are generated, and how they are involved in life. Having established this basis, the role of biophotons in health and disease is critically evaluated in the hope that their importance will become more widely utilized. I have tried to maintain a relaxed and conversational prose in the book without being excessively colloquial. This style makes it easier to convey to the reader my own excitement and enthusiasm for the beauty, intellectual challenge, and fundamental unity of biophotons within biophotonics. I hope that I have succeeded.

Before beginning, I would like to offer a few words of advice:
—Be prepared to learn a multi-disciplinary vocabulary. An understanding of biophoton facts requires that you learn a little biological, biochemical, physics, photonics and biomedical vocabulary. As with any newly studied discipline, the more familiar you are with the vocabulary, the more easily you can learn and appreciate the discipline's potential. To help the student from getting lost in what may seem like a blizzard of detail, I have introduced *Boxed Essays* to aid in the understanding of particular important, intriguing, or basic aspects of biology and physics.
—Each chapter begins with an introduction describing what a reader will discover. Each chapter ends with a take home message. The book emphasizes referencing. Specific referencing is more difficult than it seems because many of the statements made are distilled from several published papers and interpreted through the scientific experiences (or prejudices) of the author. Each major statement in the text is now provided with some references placed at the end of each chapter under the corresponding header. We hope that experts will forgive us if they find their pet paper not cited.
—Please tell me what you think! I welcome communications from anyone, especially concerning errors or deficiencies. I have spent much time and effort writing the book. In turn, you can help me by letting me know (by email or regular mail) what still needs to be improved! Your comments will be greatly appreciated.

In order to author a book such as this covering a very broad range of topics, I received help from a large number of professors, associated professors and senior scientists, cooperating scientifically vis-à-vis the International Institute for Biophysics (and Biophotons). Such assistance consisted of gathering technical content and illustrations kindly shared at the Summer schools (2000-2010) of the Institute. I owe a special debt of gratitude to: Rajendra P. Bajpai (North Eastern Hill University, Shillong,

India), Lev. V. Beloussov (Moscow State University, Moscow, Russia), Larissa Brizhik (Ukrainian National Academy of Sciences, Kyiv, Ukraine), Marco Bischof (Viadrina University, Frankfurt an der Oder, Germany), Jiin-Ju Chang (Chinese Academy of Sciences, Beijing, P.R. China), Barbara W. Chwirot (Nicholas Copernicus University, Torun, Poland), Mitsuo Hiramatsu (Hamamatsu Photonics K.K., Hamamatsu, Japan), G.J. Hyland (University of Warwick, Coventry, England), Masaki Kobayashi (Tohoku Technical University, Sendai, Japan), Michael Lipkind (Kimron Veterinary Institute, Beit Dagan, Israel), Takahiro Makino (Shizuoka Agricultural Experiment Station, Tomigaoka, Japan), Franco Musumeci (University of Catania, Catania, Italy), Hugo Niggli (University Hospital, Lausanne, Switzerland), J. Pokorny (Academy of Sciences of Czech Republic, Prague, Czech Republic), Fritz-Albert Popp (International Institute of Biophysics, Neuss, Germany), Xun Shen (Chinese Academy of Sciences, Beijing, P.R. China), Janusz Slawinski (Poznan University of Technology, Poznan, Poland), Kwang-Sup Soh (Seoul National University, Seoul, South Korea), John Swain (Northeastern University, Boston, U.S.A.), Vladimir L. Voeikov (Lomonosov Moscow State University, Moscow, Russia), and Yu Yan (International Institute of Biophysics, Neuss, Germany).

I also acknowledge the individuals whose broad-based support has been of paramount value in completing the book. I am much indebted to John M. Ackerman, M.D. (Santa Barbara, CA, U.S.A.) for sacrificing so much of his quality time with me to discuss and edit each chapter. It was a pleasure that such cooperation received its final form in our co-authorship of the chapter on "Perspectives". It was also a joy and a privilege to express my gratitude to my son, colleague and researcher, Eduard for his support during writing as well our joint many years of common research addressing human photon emission. I would further like to thank my colleagues Wim Berendsen, Fred A. C. Wiegant, and Jan Souren at Utrecht University (Utrecht, The Netherlands) and Jan van der Greef, Herman van Wietmarschen, and Everine van de Kraats at Leiden University (Leiden, The Netherlands) for their wholehearted support during many helpful discussions. I wish to also express my thanks to Jan Eikelenboom for his careful literature data work. In addition, I am deeply indebted to the publishing professionals who made this venture a reality. Special recognition goes to Kirsten Stekelenburg and Rens Wezelman.

Last but certainly not least, I wish to express my thanks to my wife, who has been a constant source of inspiration, providing support and encouragement for this project, in spite of her own busy schedule. Hey Mar, the book is finished, let us start a new one ☺.

Contents

1

Prelude

During the transition from the twentieth into the twenty-first century, the first amazing images of human body light emission were eventually captured. A Japanese team of researchers were able to develop a novel and sensitive imaging technology that facilitated the recording of photon emission spatial patterns emanating in a completely dark room from anatomical sites of the human body. The emission of the body's light intensity was extremely weak. In order to record the light emission, the recording device (based on photon energy multiplication principles) was positioned very close to (but not touching) the body. Therefore, only light emission from very small body surfaces (such as fingers or a spot on the hand) were targeted. The utilization both of lenses as well as effective data handling improved the detection of signals, facilitating the recording from further distances. Larger surfaces could then be imaged. The light intensity was so weak that it was expressed in single photons per unit of time. It was calculated per square cm of body surface. No more than ten photons or multiples of ten escaped from the body. The energy of such photons was high enough to result in a blueish-green color.

The attention to the phenomenon of light-emitting humans was very limited for several decades both in biology and other sciences because only a small number of researchers and few biological laboratories world-wide had the technology to detect ultra-weak photon emission. However, those who were interested hypothesized that the emission was actually emitted by all living organisms. In the field of biochemistry, attention had been focused on chemiluminescence only as a byproduct of specific enzyme reactions in cells without any special function. In biology then, it was only known that several living organisms do, in fact, emit light (bioluminescence) with an intensity that we, as humans, can visually detect. Although rare in nature, bioluminescence can be observed in some simple as well as complex organisms. It varies from bacteria to more organized multicellular animals (both invertebrates and vertebrates) living terrestrially or in the ocean. Bioluminescence is at least 1000 times more intense than ultra-weak photon emission. Biologists eventually discovered that bioluminescence can play a role in communication such as mating or attracting prey. The communicative role of ultra-weak photon emission was then not easily accepted without clear evidence.

However, one discovery within ultra-weak photon emission research was the fact that emission intensity was not a constant property. It seemed to be related to life style, health and disease. Its presence had been previously published in *Nature* in 1988 under the title, "Body light points to health". Subsequently, it was largely forgotten until more pronounced ultra-weak photon emission was scientifically documented both when tumors begin to grow and during the beginning stage of rheumatoid arthritis. It was also increased under the influence of stress. Although the awareness of enhanced ultra-weak photon did not explain its functional role, it did stimulate the possibility that such data might be useful for early diagnostic purposes.

Ultra-weak photon emission had not yet been a subject taught in general biology nor in the field of biomedicine. That made it difficult to discuss and understand not only how it could be measured but also how it is related to the state of the organism. Its potential use in diagnosis could not be based on the presence (increase or decrease) of specific molecular substances. Rather, it had to be related to another development in the field of biological system diagnostics that included substance/field dualism and its interpretation. Substance/field dualism had often been illustrated when iron filings are scattered on a card held over a magnet. The iron filings arrange themselves vis-à-vis the pattern of lines of force of the magnetic field. If the filings are thrown away and fresh ones are scattered, the new filings will assume the same pattern as the old. Something analogous may happen in the cell or the body. Molecules and cells are constantly being torn apart and rebuilt with fresh materials. The combined pattern of molecular structure and a magnetic field is a very simple example of the substance/field dualism.

The basics of systems biology include how a system develops, how it is maintained, how its maintenance can fail, and how repair is possible in that system. They are the core questions utilized in the disciplines of embryology, pathology (tumor biology), and regeneration. It is the "program" that determines the outer and the inner forms of biological organisms. The term "program" will be defined later in the book. The most intriguing aspect of the "program" determines the exact "positioning" of the many differentiated cell types of tissues and organs as well as the thousands of different proteins and other large molecules that restore the overall pattern of molecular aggregates inside an injured cell (Figure 1.1). Cancer is directly related to this mysterious "program" reflecting disturbances of the most fundamental rules of behavior of "normal" cells.

The substance/field dualism in a biological system is based on its associated radiant (electromagnetic) structure, a stationary field obtained by superimposition of all fields associated with its sub-systems. Under such