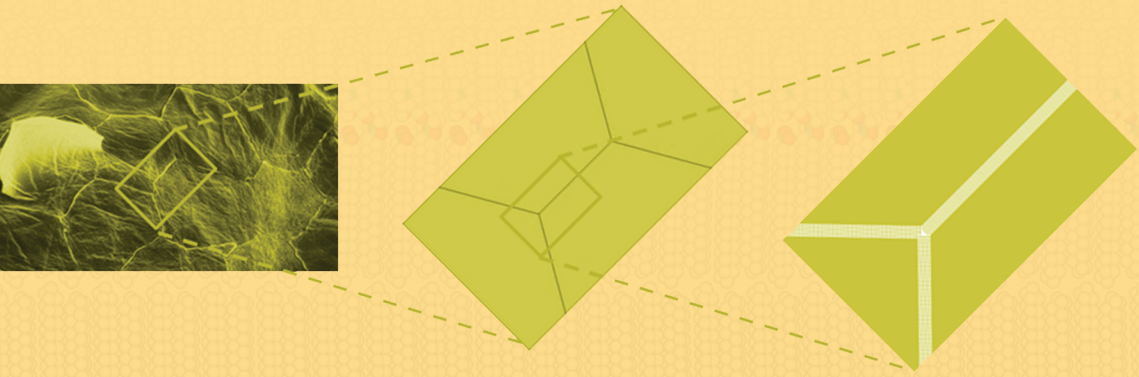
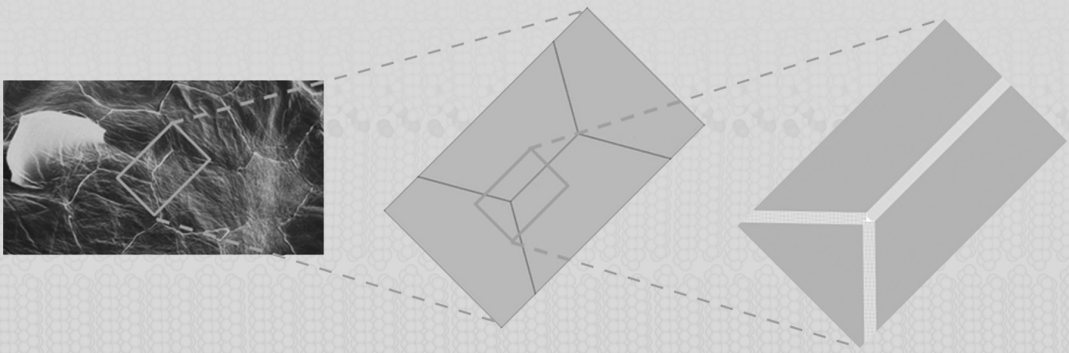
Computational Biophysics of the Skin



edited by
Bernard Querleux

Computational Biophysics of the Skin



Computational Biophysics of the Skin

edited by
Bernard Querleux

Pan Stanford Publishing

Published by

Pan Stanford Publishing Pte. Ltd.
Penthouse Level, Suntec Tower 3
8 Temasek Boulevard
Singapore 038988

Email: editorial@panstanford.com
Web: www.panstanford.com

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Computational Biophysics of the Skin

ISBN 978-981-4463-84-3 (Hardcover)
ISBN 978-981-4463-85-0 (eBook)

Printed in the USA

To my wife, Sylvie
To my sons, Simon, Samuel, and Elie

Look at the invisible skin to understand
the visible skin

—*Inspired by* The Picture of Dorian Gray*,*
Oscar Wilde, 1891
"The true mystery of the world is the visible,
not the invisible"

Contents

Foreword

We have learned much about skin. Starting in the 19th century, the observations can truly be described as enlightenment. Traditionally, this term is used for our basic knowledge in physics and chemistry; however, it represents what occurred in skin knowledge. The basics of anatomy, dissection, histology, cellular anatomy, the cell, and the power of special stains propelled us to what became possible in the 20th century.

The 20th century saw a rapid expansion, as the decades went along, from a handful of laboratories to dozens of strong basic and clinical science laboratories that took advantage of the start of the 19th century knowledge. Special stains rapidly gained prominence, followed by biochemistry, electron microscopy, and eventually molecular biology.

By the end of the 20th century, the critical mass had been reached that made this textbook possible.

The 21st century will see modeling become a main line part of cutaneous science and many other areas of investigation.

In this textbook, Bernard Querleux has amassed a monumental amount of information that had been widely dispersed and not previously readily available to the passive and active scholar.

By dividing the book in broad sweeps, it becomes readily absorbed. Scientists interested in color, mechanics, the inordinate complexity of the many skin barriers, the numerous fluids, and that all-encompassing area known as homeostasis will find well-disciplined packages that make for easy reading.

The limitation of this book's scholar relates not to the power of the computer or the programming but to the limitations of high-quality biological observations that are currently available.

Whether at the subcellular, cellular, anatomic, functional (physiology), pathologic, or pathology levels, the human brain, programming, and the computer can do more than what is available in terms of hard high-quality scientific observations.

Much of this is in the realm of so-called big science obtaining cooperative study groups to provide the data that is necessary to predict with the power of the computer.

This volume will serve as the standard textbook for undergraduates, masters, and PhD students wishing to utilize the computer and programs to understand the complexity of human cutaneous biology.

It will likely be the source of dozens of masters and PhD theses in the decades to come.

Because we are now at the critical mass and we have this superb concise overview, we predict that the next decades will be highly fruitful and will benefit many areas of science, in addition to skin.

Howard I. Maibach, M.D.
The University of California School of Medicine
Department of Dermatology
San Francisco, California 94143-0989, USA
May 2014

Preface

For a long time, skin properties have been considered easy to explore, as the skin is accessible to palpation and visual control. If clinical exam remains the reference approach for individual diagnosis, it has also shown its limits in reproducibility and accuracy for quantifying skin properties, for instance, in clinical studies aiming at characterizing chronological and photoaging, skin specificity related to ethnic origins, and the evaluation of the efficacy and safety of dermatological and cosmetic products.

Taking advantage of the accessibility of the skin in vivo, non-invasive methods were developed for about 40 years, which nowadays offer accurate measurements of the skin color through optical methods, firmness and elasticity measurements through biomechanical devices, and even direct measurements of some skin functions such as excretion, transepidermal water loss, perfusion, and the barrier function. In vivo skin imaging has also appeared in the past decades and gives us much information on the skin structures from the microscopic to macroscopic levels.

However, we should admit that at the dawn of the 21st century, the mechanisms involved in these properties are still partly understood owing to the multidomain (biological, biochemical, and biophysical domains) and multiscale dimension (cellular and below to tissular and beyond) of the mechanisms. In many domains, including biomedical engineering, numerical modeling is nowadays recognized as a complementary key actor for improving our knowledge.

This book presents for the first time the contributions that focus on scientific computing and numerical modeling and simulations to offer a deeper understanding of mechanisms involved in some skin functions. The book is structured around some skin properties and functions, with—for each of them—several chapters describing either biological or physical models at different scales.

Part 1 is dedicated to skin optics. From skin color simulation to the biology of skin pigmentation, these three chapters offer key issues to modulate skin appearance.

Part 2 deals with the biomechanical properties of the skin, which are analyzed from the tissular scale toward the cellular scale. These chapters bring new insights on the relative impact of the main skin components on its non-linear biomechanical properties.

One major function of the skin is to work as a protective barrier against the penetration of external substances, allergens, and microorganisms. Part 3 considers this function at different scales and represents the state of the art in the understanding of skin permeation.

Part 4 is focused on skin fluids, whose impact on the skin physiology is very important but surprisingly have not been studied much. Water behavior and state in the different skin layers and a deeper description about skin microcirculation through numerical simulation allow a better knowledge of some dynamic properties of the skin physiology.

The last part of the book is more prospective and gathers two chapters that introduce new modeling approaches based on the "systems biology" approach. Aiming at integrating a large quantity of data, the chapters discuss mathematical and non-mathematical modeling of skin homeostasis.

I would like to thank all the authors for providing outstanding contribution to this book and also for their support to this idea that computational biophysics is a key approach to foster our understanding of the physiology of organs such as the skin.

I am personally deeply grateful to Stanford Chong, from Pan Stanford Publishing, who first suggested that I edit this book and helped me broaden the covered topics. I don't forget to thank Sarabjeet Garcha and Arvind Kanswal from Pan Stanford Publishing, not only for their great job concerning the publishing but also for their permanent kindness to solve all the problems.

I hope this book will help all the readers, from master students to confirmed researchers, coming from many disciplines such as dermatology, cosmetic science, biology, chemistry, physics, and computer science, in developing their own research of this fascinating but complex organ, which is the human skin.

Bernard Querleux
May 2014