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Skin Biophysics

From Experimental Characterisation to Advanced Modelling

Springer

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To Theo, Eva and Grace for making my life a happy, beautiful, fun, exciting and learning adventure.

Preface

> What spirit is so empty and blind, that it cannot recognise the fact that the foot is more noble than the shoe, and skin more beautiful than the garment with which it is clothed? [Michelangelo di Lodovico Buonarroti Simoni (1475–1564)]

From the soothing feeling of the sun warming one's face on a beach, through the perception of sand texture when walking towards the ocean, to the abrupt sense of cold one experiences when jumping into its waters, we all have an intuitive understanding of how our skin mediates our interactions with the outside world. Of course, these interactions extend beyond thermal and haptic sensing, contact mechanics and hydrodynamics. Skin, our largest organ, is the primary line of defence shielding our internal body structures from insults of the external environment. Interfacial and bulk exchanges take the form of mechanical, thermal, biological, chemical and electromagnetic processes which typically operate in concert and feature complex coupling effects. At the biophysical level, the skin is also an essential plant that synthesises vital compounds like vitamin D, hosts necessary immunologic biochemical and cellular processes and contains a rich sensory biophysical network that informs us in real time of any haptic cues or potentially threatening physical insults and noxious agents.

The more one studies skin physiology and biophysics the more one realises that there are multiple nested dimensions waiting to be unravelled, where psychology, human behaviour, health, well-being and biophysics are intrinsically connected, more often than not, in complex and mysterious ways. For example, the psychosocial role of the skin is multifaceted and strongly dependent upon the biophysical properties of this complex organ whose visual appearance continuously evolves across the life course, from birth to death. The skin tells a story about our health status, age, past traumas, emotions, ethnicity and our social and physical environments. These cues—mostly perceived at a subconscious level—are fundamental in human social interactions.

In the last few decades, we have witnessed a significant drive in efforts to move skin science research forward through engineering approaches, and more particularly within the biomechanics and biophysics communities, at both experimental and modelling levels. This is hardly surprising considering the special

place of the skin in human life and the multiple applications of skin science from cosmetics, pharmaceutics, surgery and medical devices, through consumer goods and automotive safety, to wearable electronics and biomimetics. The systemic complexity of skin biophysics can only be unravelled by adopting inter- and multidisciplinary research methods which integrate physical experiments, imaging and modelling. As a consequence, researchers must be trained in a wide range of topics from experimental physics, skin biology, continuum mechanics, soft matter physics, mathematical modelling and data analysis, through multiscale imaging protocols and image processing, to finite element methods and computational procedures.

A unified, structured and up-to-date review of cutting-edge research in experimental characterisation, imaging and modelling aspects of skin biophysics was long overdue. Despite a recent excellent book focused on computational skin biophysics, edited by Bernard Querleux of L'Oréal Research, a treatise simultaneously covering the three aforementioned topics was missing.

The frontier in skin biophysics research is presented in this volume through contributions of internationally leading groups in the field, from France, Ireland, New Zealand, South Africa, Switzerland, the UK and the USA. The aim of this book is to present the current state of the art and perspectives on future research directions, with a strong bias towards mechanics, structural and mechanical properties and constitutive models based on theories and concepts rooted in continuum mechanics. I take full responsibility and, cheekily, make no apologies for letting my personal research interests steer the coverage of skin biophysics in this particular direction. My experience in working in academia, and with industry, has consistently demonstrated that the methods and theories described in the book are not only critical research tools that are used for fundamental research or as part of the product life cycle but can also deliver practical engineering solutions that are used daily by hundreds of million people across the globe.

This book is addressed to postgraduate students in biomedical/mechanical/civil engineering, (bio)physics and applied mathematics, postdoctoral researchers as well as scientists and engineers working in academia and industry engaged in skin research, particularly, if at the cross-roads of physical experiments, imaging and modelling. The book will also be of interest to clinicians/biologists who wish to learn about the possibilities offered by modern engineering techniques for skin science research and, by so doing, provide them with an incentive to broaden their outlook, engage more widely with the non-clinical research communities and, ultimately, help cross-fertilising new ideas that will lead to better treatment plans and engineering solutions.

The book is divided into three main parts that covers Part I—Human skin structure and composition (Chapter 1), Part II—Mathematical and computational modelling (Chapters 2–5) and Part III—Experimental characterisation techniques (Chapters 6–10).

In the chapter entitled "Human Skin: Composition, Structure and Visualisation Methods", Graham, Eckersley, Ozols, Mellody and Sherratt discuss the molecular

composition and structure of the skin and associated invasive/non-invasive imaging techniques.

In the chapter entitled "Constitutive Modelling of Skin Mechanics", Limbert provides an expose of the current state-of-the-art constitutive theories and models for describing the passive mechanics of the skin.

Buganza-Tepole and Gosain present a constitutive modelling framework for skin growth in the chapter entitled "Constitutive Modelling of Skin Growth", while Bunganza-Tepole reviews frontier research in the constitutive description of skin wound healing in the chapter entitled "Constitutive Modelling of Wound Healing".

In the chapter entitled "Constitutive Modelling of Skin Ageing", Limbert, Pond and McBride examine the mechanical and structural aspects of both intrinsic and extrinsic ageing and present a multiphysics modelling framework to capture the chemo-mechanobiology of ageing.

State-of-the-art inverse characterisation methods which combine experimental characterisation and numerical techniques are presented by Weickenmeier and Mazza in the chapter entitled "Inverse Methods" and Flynn in the chapter entitled "Experimental Characterisation: Rich Deformations".

In the chapter entitled "Multiscale Characterization of Skin Mechanics Through in situ Imaging", Allain, Lynch and Schanne-Klein provide a review of multiscale characterisation techniques of skin mechanics through in situ imaging.

In the chapter entitled "Tension Lines of the Skin", Ní Annaidh and Destrade discuss experimental approaches to characterise skin tension lines which are proven to be essential in describing in vivo skin mechanics.

Finally, in the chapter entitled "Experimental Tribology of Human Skin", Masen, Veijgen and Klaassen review the current state of the art of experimental methods to characterise the tribological properties of the skin.

Southampton, UK Georges Limbert
December 2018

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