

Preface

Osteoporosis (OP) is a major health problem in society. OP is characterised by low bone mass and deterioration of bone strength, resulting in fragile bones which are more prone to fracture. Osteoporosis is often called the “silent disease” because bone loss occurs without symptoms. New drugs are continually being developed and trialled in animals, and the most promising ones tested on humans. However, many bone diseases including OP do not have a proven means of prevention or effective treatment.

On the one hand, precision medicine is an emerging field for disease treatment and prevention that takes into account the variability in genes, environment, and lifestyle factors for each individual. Any comprehensive approach for understanding bone disease progression and effective drug interventions requires integration of experimental findings and computational modelling. Particularly, over the last few decades, a large number of regulatory factors in bone homeostasis and pathology have been identified together with interactions of bone tissue with other tissues such as muscles, blood vessels, and the nervous system which all have been shown to regulate bone responses. Furthermore, links between bone quality and environmental factors such as nutrition and mechanical loading have been established.

On the other hand, material engineering has made significant progress in characterising and modelling of biomaterials such as bone with high accuracy at various scales of observation. In particular, micromechanical approaches have proven to be very powerful in integrating different experimental information from different scales. A long-standing missing link between the mechanical aspects of bone and the biochemical and mechanobiological regulations has recently been established by developing cell-based models of bone remodeling and adaptation. These models allow to integrate subject-specific data and can be used to predict changes in bone mass and the respective mechanical properties. The ultimate goal of any of these models is to predict the fracture risk of a patient in order to start an intervention of either drug or physiological exercise in a timely manner.

The present book is a summary of the course notes of the 20th CISM-IUTAM International Summer School on *Multiscale Mechanobiology of Bone Remodeling*

and Adaptation. This course gathered experts from the fields of applied mechanics and biomedical engineering, complex systems modelling, bone biology, mechanobiology, and materials science, in order to give, in an unprecedented interdisciplinary fashion, the cutting-edge view on bone mechanobiology with emphasis on disease progression analysis in osteoporosis and assessment of changes in material properties. These include disease systems analysis of osteoporosis (P. Pivonka) in order to predict disease progression and drug interventions; musculoskeletal modelling (J. Fernandez) in order to accurately estimate muscle forces acting on bone; bone biology (D. Findlay) including interactions of bone tissue with other tissues such as muscle, cartilage, vascularisation, and central nervous system (CNS); bone mechanobiology (T. Skerry) including Frost's mechanostat theory, animal models of bone mechanical loading, and osteocytes and their role as mechanosensing cells; multiscale bone adaptation algorithms (T. Adachi); and bone quality assessment at different scales using experimental and computational approaches (Ch. Hellmich), including fundamentals of continuum micromechanics with application to bone and merging quantitative computed tomography (qCT) with micromechanics as a new clinical tool.

The individual chapters of this book were prepared by the respective lecturers and their collaborators with the exception of Prof. Tim Skerry who was not able to contribute due to many other commitments at that time. Fortunately, Prof. Mark Forwood with the assistance of myself was able to summarise the content of the *Bone Mechanobiology* chapter.

It is a pleasure to thank the six lecturers and the 25 attendees who came from 12 different countries and actively participated in the numerous discussions throughout the course. I would like to also extend my thanks and appreciation to the administrative staff of CISM for their help. Last but not least, support by the International Union for Theoretical and Applied Mechanics (IUTAM) is also gratefully acknowledged.

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